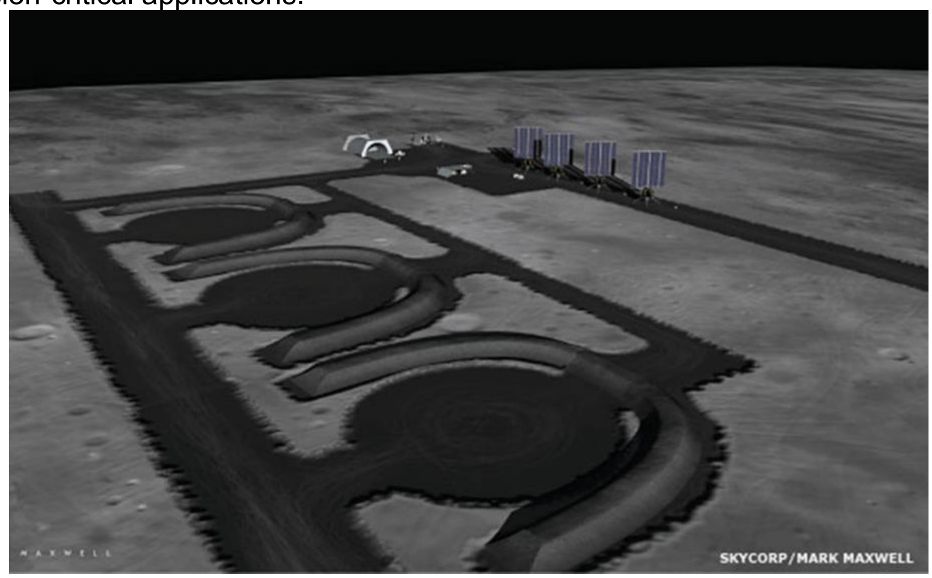
DRAFT Lunabotics 2025-2026 Guidebook

Section 1: APPLICATION AND ADMINISTRATION

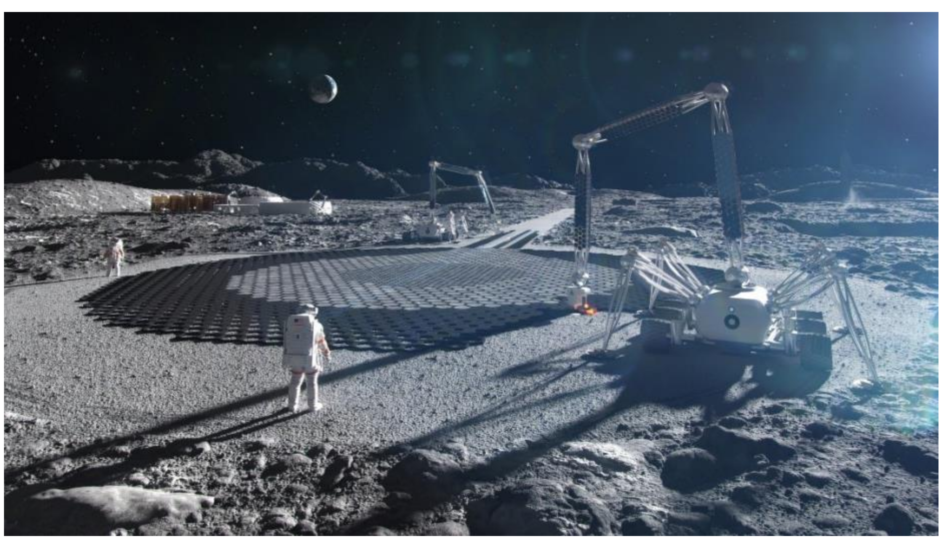
1. Lunabotics Objectives

   The primary objective of Lunabotics is for teams to apply the NASA systems engineering process to design, develop, build, and test a prototype lunar robot that supports simulated lunar construction operations. Teams must create a robot capable of traversing challenging lunar terrain while constructing regolith-based berms—gathering valuable data on lunar construction techniques in the process.

   These berm structures serve critical functions for the Artemis Mission, including blast and ejecta protection during lunar landings and launches, shading for cryogenic propellant tank farms, radiation shielding around nuclear power plants, and other mission-critical applications.



Drawing 1. - Typical concept of Lunar Landing Pads with Berms (Source: NASA/ SkyCorp)



Drawing 2. - Typical concept of Lunar Landing Pads (Source: NASA)

Lunabotics is a two-semester competition that challenges higher education students to design, build, and test prototype lunar construction robots using NASA's systems engineering principles. This innovative challenge engages participants in developing solutions for future off-world construction while providing practical, hands-on learning experiences that complement academic education.

Selected teams can earn points by successfully completing several key deliverables: the STEM Industry Plan, the Systems Engineering Paper, the Proof of Life Video, Robot Data Specifications Report, an optional Presentation and Demonstration, and developing robots that meet all challenge criteria.

The competition actively seeks participation from diverse educational institutions, including:
• Vocational, technical, and trade schools
• Community, state, and 2-year colleges
• Colleges and universities (Title IV degree-granting institutions)

Through this multidisciplinary challenge, students gain valuable real-world experience in computer coding, engineering, manufacturing, metrology, welding, fabricating, installing, and repairing sheet metal. Participants develop both technical expertise in space technology development and essential career skills that prepare them for future professional opportunities.

Challenge Objectives
Teams will submit deliverables for evaluation by NASA subject matter experts. Successful prototype robots should demonstrate capabilities for constructing off-world structures that serve critical functions such as:

- Blast and rocket engine plume ejecta protection during spacecraft landings and launches
- Radiation shielding for habitation modules and propellant storage
- Thermal shading for cryogenic propellant storage
- Environmental and radiation protection for power generation facilities
- Other mission-critical infrastructure in extraterrestrial environments

Student Benefits
Participants gain valuable career and technical skills through hands-on experience:
• Creating computer code for autonomous construction operations.
• Engineering and designing robot frames, mobility, sensors and electronic systems.
• Using various types of manufacturing processes to create the robot systems.
• Stress-testing of mechanical components.
• Troubleshooting, prototyping and iterative design improvement.
• Applying professional engineering principles to real-world challenges.

2. Background

NASA is developing foundational technologies and approaches needed to fulfill Artemis missions on the Moon in preparation for human exploration of Mars. Lunabotics plays a vital role in this development process. By working in partnership with other government agencies in the U.S. and abroad, academia, the private sector, and non-profit institutions, NASA can expand technology and maintenance activities initially designed for the lunar surface. These collaborative efforts will allow us to explore more of the solar system in profound new ways.

Lunabotics is a critical asset to NASA, spurring innovation and providing risk reduction for lunar surface system development. It was established to cultivate new ideas, drive solutions, and enhance cohesive development of capabilities for productive exploration of the extreme lunar environment while developing 21st century workforce skills for the next generation of explorers. Through collaboration across public and private sectors, NASA and our partners maximize efforts and leverage resources to design and test new approaches, technologies, and systems in parallel. This strengthens our ability to achieve successful long-duration missions while increasing access to space, providing economic benefits to our nation, and creating pathways of discovery for future generations.

As NASA embarks on revolutionary exploration in our solar system, initiatives like Lunabotics bridge the technological capabilities needed for sustained human exploration missions on the Moon that can evolve for other challenging environments in deep space, including Mars. From a technology development perspective, the Moon serves as an ideal proving ground for complex Red Planet missions while supporting current and future lunar science missions. As we enhance our understanding of the challenging lunar environment, new knowledge from these pursuits advances technology development that informs our plans for Mars exploration and other celestial bodies, while transferring applications that can improve everyday life on Earth.

Technologies that enable affordable, advanced manufacturing and autonomous construction are critical for NASA missions. These same technologies must also support long-term system maintenance, allowing NASA and its partners to carry out a variety of missions.

Key technical challenges include excavation of hard regolith and ice materials, as well as the ability to travel long distances across uneven terrain with obstacles and other hazards. Both capabilities are essential for establishing sustainable operations in off-world environments where autonomous systems must function reliably without direct human intervention.

A concrete example of progress in excavation technology is the NASA Swamp Works ISRU Pilot Excavator (IPEx). This system is designed to reliably excavate and deliver a total of 10 metric tons of lunar regolith for pilot-scale in-situ resource utilization demonstration over the course of 100 meters and 11 days—representing 200 times more operational capacity than the current state of the art.

NASA's Return on Investment

This competition multiplies NASA's research capacity by evaluating numerous design approaches simultaneously. By assessing student innovations using the same rigorous standards applied to internal prototypes, NASA gains exposer to creative solutions for complex off-world construction challenges.

The challenge helps develop a skilled workforce ready to lead in the emerging space economy, strengthening America's technological leadership. Technologies developed for lunar construction often yield innovations applicable to terrestrial construction and manufacturing, creating broader economic benefits. These advances support space exploration goals that benefit NASA, America, and humanity's future.

3. Lunabotics Events

Event 1 – Project Development Challenge

Required Deliverables:

To qualify for the Lunabotics onsite competitions the following deliverables will be part of the Lunabotics 2026 program development challenge. Teams must submit all required deliverables to remain in the challenge.

STEM Industry Plan Report -Due **Thursday, February 26, 2026**
Systems Engineering Paper Due- **Thursday, April 2, 2026**
Robot Data Specifications Report Due- **Thursday, April 30, 2026**
Proof of Life Video Due- **Thursday, April 30, 2026**

Optional Deliverable: Presentation and Demonstration Due- **Friday, March 20, 2026**

Event 2 – University of Central Florida Space Institutes Exolith Lab® Challenge - May 12-17. 2026 (Event dates subject to change)

This event is held at UCF's Florida Space Institute's Exolith Lab® in Orlando, Florida. During this event, teams will conduct field tests of their robots. The ten highest-scoring teams will advance to the Lunabotics Challenge finals at NASA's Kennedy Space Center.

Event 3- NASA’s Lunabotics On-Site Challenge -May 19-21, 2026 (Event dates subject to change)

The Lunabotics on-site challenge, hosted at Kennedy Space Center, brings together the top 10 teams from the UCF Florida Space Institute’s event. Teams will conduct field tests of their robots in NASA's Artemis Arena. Please be advised the Kennedy Space Center is an active launch range. NASA mission requirements may change deadlines and deliverables and/or cancel the event itself without prior notice.

The NASA Chief Judge and Project Manager are responsible for ensuring challenge integrity through fair and consistent interpretation, application, and enforcement of the Guidebook. The goal is to apply all guidelines equally and objectively to all participants. Lead Judges are responsible for creating rules and rubrics for individual events and evaluating team deliverables. For matters affecting the overall Lunabotics Challenge, the Chief Judge and Project Manager will render the final decision.

Scoring decisions are considered final. If warranted, appeals must be submitted in writing by the team advisor or student leader within 30 minutes of score posting. The Chief Judge / Project Manager will render a final decision.

Teams should begin by thoroughly reviewing the Lunabotics Guidebook and the Challenges Frequently asked Questions (FAQ).

Lunabotic Communication Protocols and FAQ’s

Email Requirements

- Use only email addresses with ".edu" domains—NASA cannot respond to non-.edu domains
- Only faculty advisors and team leads may submit FAQs

FAQ Submission Process:

- Use the format: School Name, Rule/Paragraph Number & Question
- Send FAQs to: ksc-lunabotics@mail.nasa.gov

Important Guidelines:

- The Guidebook and FAQs are complementary documents—review both
- Teams are responsible for monitoring the Lunabotics website for updates
- Conflicts with exams, commencements, etc. may occur—prioritize deadlines based on the team's needs.

Available Support:

- Proctoring assistance is available at UCF and KSC

NASA will NOT Respond to:

- Requests to change deadlines

- Questions sent from unauthorized email addresses
- Questions about information already covered in the Guidebook
- Questions specifically about the UCF onsite challenge

Updating your school /team information

Each team is responsible for updating the application database with changes to personnel, email addresses, and/or phone numbers. Maintaining current contact information is the only way the Lunabotics team can reach the team if there are issues affecting the team's participation in Lunabotics.

Code of Conduct

Lunabotics operates within NASA's commitment to maintaining a positive and safe environment. All participants must demonstrate integrity in following rules and maintaining professional behavior. Violations of rules or attempts to circumvent their intent, unprofessional conduct, or failure to follow staff directions may result in penalty points or disqualification from an event or the entire challenge

Liability Wavier

Participants hereby waive any claims against NASA, its employees, its related entities (including, but not limited to, contractors and subcontractors at any tier, grantees, investigators, volunteers, customers, users, and their contractors and subcontractors at any tier), and employees of NASA's related entities for any injury, death, or property damage/loss arising from or related to the NASA Lunabotics Challenge, whether such injury, death, or property damage/loss arises through negligence or otherwise, except in the case of willful misconduct.

Media Authorization

All participants and visitors to Lunabotics events at Kennedy Space Center or the UCF Exolith Lab® Laboratory grant permission to be photographed/videotaped by NASA or its representatives for potential use in media products, unconditionally releasing NASA from related claims.

NASA Media Release for Adults
(Do Not Use for Minors)

I, ____ do hereby give permission to be
(Please print name your name)

interviewed, photographed, and/or videotaped by NASA or its representatives in connection with a NASA production.

I understand and agree that the text, photographs, and/or videotapes thereof containing my name, likeness, and voice, including transcripts thereof, may be used in the production of instructional, promotional materials, and for other purposes that NASA deems appropriate and that such materials may be distributed to the public and displayed publicly one or more times and in different formats, including but not limited to, websites, cablecasting, broadcasting, and other forms of transmission to the public. I also understand that this permission to use the text, photographs, videotapes, and name in such material is not limited in time and that I will not receive any compensation for granting this permission.

I understand that NASA has no obligation to use my name, likeness, or voice in the materials it produces, but if NASA so decides to use them, I acknowledge that it may edit such materials. I hereby waive the right to inspect or approve any such use, either in advance or following distribution or display.

I hereby unconditionally release NASA and its representatives from any and all claims and demands arising out of the activities authorized under the terms of this agreement.

By signing below, I represent that I am of legal age, have full legal capacity, and agree that I will not revoke or deny this agreement at any time.

I have read the foregoing and fully understand its contents.

Accepted by:

____

Signature: ____

Date: ____________________

Name and Location of Event:

____

Address:

____

Telephone:

Email Address:

Lunabotics Awards

1. Presentation and Demonstration (1st - $2000, 2nd - $1000, 3rd - $500) – Awarded to teams who best present the objectives, execution, and technical outcome of their design project.

   Presentation and Demonstration First Steps Award – Best Presentation by a First-Year Team – Judge's recognition for standout performance by teams whose college/university has not previously participated in P&D.

2. Systems Engineering Paper (1st - $2000, 2nd - $1000, 3rd - $500) – Awarded to teams who demonstrate the best application of the NASA Systems Engineering process to design, build, test, and evaluate their robot.

   Systems Engineering Nova Award for Stellar Systems Engineering by a First Year Team – Judge's recognition of teams 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 - Judge's recognition for significant improvement over the previous year(s) in the team's application of systems engineering to develop their robot system.

3. Lunabotics Innovation Award – ($250) – Awarded to the team with the best design based on creative construction, innovative technology, and overall architecture.

4. Lunabotics Efficient Use of Communications Power Award- ($250)

5. The Caterpillar Autonomy Award (1st - $2,000, 2nd - $1,250, 3rd - $750, 4th -500, 5th - $250, 6th - $250) - Awarded by Caterpillar for the most successful autonomy implementation.

6. The Lunabotics Construction Award (1st - $2000, 2nd - $1000, 3rd - $500) - Awarded to the teams that score the most points during berm building operations in the Artemis Arena.

7. The Off World Grand Prize ($5000) – Awarded to the team that submits the required items, completes all the events, and score the most points, a cumulative of the scores.

Point Breakdown:

1. STEM Industry Plan	10 Points
2. Systems Engineering Paper	25 Points
3. Presentations and Demonstrations	25 Points
4. Robotic Construction	25 Points

Note: The Awards list is not all-inclusive; and is subject to change without notice.

Eligibility

Team Composition Requirements:

- All team members must be currently enrolled students from accredited institutions of higher learning, career/technical education programs, trade schools, community colleges, or universities located in the United States, its Commonwealths, territories, or possessions.
- Students may be registered in either fall or spring semester to qualify
- Multi-institutional teams are permitted (two schools may collaborate to form one challenge team).
- Teams from accredited institutions of higher learning (2-year or 4-year colleges/universities) must include a minimum of two (2) undergraduate students. There is no restriction on the number of graduate students.
- All students must be 18 years or older prior to attending on-site events.
- Each team must be accompanied by an adult advisor age 21 or older who is employed by the registered institution and will remain on-site for the duration of the challenge.

Participation Standards:

- All team members must be actively engaged in the robot's design and construction, with clearly defined roles to be communicated during Presentation and Demonstration (P&D).
- Students must complete 100% of the project work, including design, robot construction, written reports, presentations, and competition preparation. Professional assistance is permitted only for training or safety purposes under student supervision.
- Excessive re-use of materials from previous Lunabotics Challenge years (vehicles, reports, presentations, etc.) will result in disqualification.

Disqualification Criteria:

- Unsportsmanlike conduct by any team member or advisor may result in individual or team disqualification.
- NASA reserves the right to exclude individuals or teams for unauthorized behavior, including:
    - Impersonating NASA officials
    - Misusing NASA, sponsoring organization, or commercial logos/trademarks
    - Failing to follow competition rules or staff instructions
    - Falsely claiming NASA affiliation or sponsorship
- Teams not meeting all stated requirements may be disqualified.

Administrative Notes:

- All requirements for participation are outlined in this guidebook.
- All times listed are USA Eastern Time.
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Applying on the STEM Gateway Website- Applications Open Monday, September 8, 2025

STEM Gateway is the application portal for this challenge. Teams can submit applications here: Engagement Opening: Lunabotics 2026. Selected teams will receive an email notification regarding their application status to begin participation in the Event 1 of the Challenge.

The number of applications accepted is not pre-determined but based on the quality of the applications received and other factors. The entire application process has three steps:

Step 1 - Team Application in Gateway

Application Process:

- Apply through the NASA Gateway Application Website -**Open Monday, September 8, 2025, and the entire Applications Due Monday, September 29, 2025**
- Only faculty advisors or team leads may initiate the application process—no other team members or students can apply for the team

Technical Support:

- For website issues, contact the Gateway Help Desk directly
- Response time may be 2-3 business days
- Do not contact Lunabotics staff for website technical issues

Step 2 – Submitting Team Application Deliverables.

Submit completed deliverable package via email to: ksc-lunabotics@mail.nasa.gov

Required Deliverables

- Statement of Support & Statement of Rights Use file name: SOS-School Name
- Project Management Plan file name: PMP-School Name
- Systems Requirements Report -ONLY If more teams qualify for the Lunabotics Challenge through their PMP submission than can be accommodated at the Qualifying Event(s), then the PMP-qualified teams will be required to submit a System Requirements Review (SRR) Report.

Formatting Requirements:

- Submit all documents as PDF files
- Use the following naming convention (deliverables not following this format will be rejected): Deliverable Name-School Name (use official school name, not team name)
  Examples:
  - SOS-Harrison University
  - PMP-Adams College

Step 3 - Team Application Evaluation and Selection

This completes your application process. Note: Submitting an application does not guarantee acceptance into the Lunabotics Challenge.

Applications will be scored and ranked, and all deliverables will be evaluated for compliance.

- REMINDER if more teams qualify for the Lunabotics Challenge through their PMP submission than can be accommodated at the Qualifying Event(s), then the PMP-qualified teams will be required to submit a System Requirements Review (SRR) Report.

You will be notified of your application status via email.

The following items are required in your application package:

Statement of Support

A statement of support from a faculty/advisor indicating a willingness to supervise and work with the team during all stages of NASA's Lunabotics. There will be no consideration for teams working without a faculty advisor. The faculty advisor must also sign off on the cover of all deliverables as evidence they have seen the application and approves of the submission.

The following statement shall appear on an institution letterhead and include the signature of the faculty advisor:

Faculty Advisor:

University / College:

I concur with the concepts and methods by which the students plan to compete in “NASA Lunabotics”. I will ensure the student team members complete all project requirements and meet deadlines in a timely manner. I understand any default by this team concerning any project requirements (including submission of final report materials) could adversely affect selection opportunities of future teams from their institution.

Signature and Date:

	Name (Print)	Signature	Advisor/ Faculty/Student
1			

Statement of Rights of Use

Statements of Rights of Use - 1

These two statements grant NASA, acting on behalf of the U.S. Government, rights to use the team’s technical data and design concept, in part or in entirety, for government purposes. This statement is not required. However, teams with a Statement of Rights of Use may receive greater consideration in the application selection. If choosing to include these statements, all team members and faculty advisors must sign. The statements read as follows:

Statement of Rights of Use - Agreement 1

As a team member for a(n) application entitled “NASA Lunabotics” proposed by a team of students the undersigned will and hereby do grant the U.S. Government a royalty-free, nonexclusive and irrevocable license to use, reproduce, distribute (including distribution by transmission) to the public, perform publicly, prepare derivative works, and display publicly, any data contained in this application in whole or in part and in any manner for Federal purposes and to have or permit others to do so for Federal purposes only.

~OR~

Statement of Rights of Use

Statements of Rights of Use - 2

These two statements grant NASA, acting on behalf of the U.S. Government, rights to use the team’s technical data and design concept, in part or in entirety, for government purposes. This statement is not required. However, teams with a Statement of Rights of Use may receive greater consideration in the application selection. If choosing to include these statements, all team members and faculty advisors must sign. The statements read as follows:

Statement of Rights of Use - Agreement 2

As a team member for a(n) application entitled "NASA Lunabotics" proposed by a team of students, the undersigned will and hereby do grant the U.S. Government a nonexclusive, nontransferable, irrevocable, paid-up license to practice or have practiced for or on behalf of the United States an invention described or made part of this application throughout the world.

Use the following Sign-In Sheet for either **Agreement 1 or Agreement 2 -**

University/College:

____

	Name (Print)	Signature/Date	Faculty/Student
1			

<u>PROJECT MANAGEMENT PLAN (PMP)</u> - Due Monday, September 29, 2025

Each team shall submit a complete Project Management Plan (PMP) electronically in one PDF file. This is an initial plan. As you execute your project, things will change and your project will evolve, which is okay and expected. In your Systems Engineering Paper you can discuss the changes to your plan and how your project adapted.

Include your school's name on the PMP.

The maximum length of the plan is 5 pages. If you include a cover page, it will not count towards the page limit.

Any content over 5 pages will not be judged and will not be scored.

Format: The Project Management Plan shall be formatted professionally, organized clearly so that each required rubric element is easy to find, with correct spelling and grammar, with text no smaller than size 12-point font in the main body, with text no smaller than size 9-point font in graphics and tables, and using professional margins.

Scoring Rubric - Project Management Plan	
Element	Points

Initial Project Schedule Provide a Gantt Chart or equivalent that shows the project's major due dates and events to include at least the items listed below. Discuss these only as needed. 1. Start Date 2. Completion Date: after project decommissioning; this is the date when you have disposed of your robot system after the challenge; for example, you hand the system over to next year's team, dispose of it, or other) 3. Dates for the Major Review milestones: as a minimum, these must include o Systems Requirements Review o Preliminary Design Review o Critical Design Review o others may be identified as you find appropriate 4. Product delivery dates to the Lunabotics Engineering Challenge, including as a minimum o delivery of Systems Engineering Paper, o the planned date to submit "Proof of Life" 5. If you identified any critical milestones in your discussion of the Initial Project Cost Budget, show the dates for these milestones related to your Project Cost Budget. 6. If you identified any critical milestones in your discussion of Initial Technical Performance Measures (Technical Budgets), show the dates for these milestones related to your Technical Performance Measurement budget	There are 3 points total for 6 elements

7. Optionally, you may also identify any major Systems Engineering activities in your Initial Project Schedule. Discuss how you will manage the evolution of the schedule during the life of the project (how often and when you plan to review the project schedule, and how you plan to adapt to schedule slips or schedule advance opportunities).	
Initial Project Cost Budget Provide an estimate of the Total Project Cost, inclusive of all possible costs throughout the project life cycle, independent of any funding sources. Provide a Table of Major Budget Categories and Items including the following list items as a minimum. Discuss only as needed. 1. Breakdown of total project cost estimate for at least the following major items. (Total should add up to the estimate of the Total Project Cost.) a. Cost estimates for elements in the earliest level System Hierarchy (provide this earliest level System Hierarchy, which may only be two levels at this early point in the project). Break these estimates down as follows. 1. Labor costs, if any 2. Material costs (for production and completion of Lunabotics deliverables) b. Travel costs including costs to travel to UCF and KSC if you intend to accept a proffered invitation to UCF to participate in UCF's Lunabotics Qualification Challenge and to KSC to participate in NASA's Lunabotics On-Site Challenge Identify any Critical scheduling milestones (and dates) for budget or cost related items. These critical cost budget milestones must be included in item 5 for the Initial Project Schedule. (For example,	There are 3 points total for 3 elements

dates funds will be needed, dates of planned activities to raise funds, or others). Discuss how you will manage the evolution of the budget during the life of the project (how often you plan to review your project budget and when, and how you plan to adapt to budget shortfalls or possible cost savings should they occur).	
Project Technical Objectives List and discuss the specific technical criteria or characteristics that your team intends to achieve (typically some measurable technical parameter you want to minimize or maximize, increase to some limit, or decrease to some limit) in your system design and operations for you to win the competition. These provide the technical direction and focus for the entire team in design and operations. For example: you might choose to minimize mass, or maximize automation, or minimize bandwidth, or some combination of minima or maxima of these or any other criteria, to produce a system that will win the competition.	There is 1 point for 1 element
Initial Technical Performance Measures (Technical Budgets) Provide a Table of Technical Performance Measures that you deem are important for your design to accomplish the mission. [A Technical Performance Measure is any quantifiable technical characteristic or parameter that you may consider important, difficult to achieve, or particularly risky to project success. These may derive from your Project Technical Objectives. For example, it may be that total mass (high or low) is important to you, or that a low bandwidth is difficult to achieve, or that high speed is risky for your project, or any number of other quantifiable and measurable technical quantities.]	There are 3 total points for 5 elements

Include the following in the table as a minimum. Discuss only as needed. 1. Identification of the Technical Performance Measures you chose to monitor and manage 2. Initial Target Value for each Technical Performance Measure to be achieved in the system by the challenge Provide the allocation of each Initial Target Technical Performance Measure value across the elements of the earliest System Hierarchy at each level (may only be two levels at this early point in the project; should combine at lower levels to the total Target at the highest level in the hierarchy). Discuss any critical schedule milestones (and dates) for achieving critical technical performance levels (for example, decision points in the design process where if you are unable to achieve the desired level you would change the design). These must be included in item 6 for the Initial Project Schedule.) Discuss how you will manage the evolution of the Technical Performance Measurement budgets during the life of the project (how often you plan to review current Technical Performance Measure values, and how you plan to adapt to performance shortfalls or exceedances should they occur).	

Resources available:

Project Management and Systems Engineering educational videos can be viewed at (clickable link) **NASA Lunabotics Videos**.

These videos include a series titled ***Systems Engineering for University Level Engineering Competitions Videos*** that introduces key project management and systems engineering concepts and methods useful for the Lunabotics Challenge.

Also included are **five** different project management and systems engineering **seminars** that were recorded live at Lunabotics Challenges at Kennedy Space Center. The most immediately relevant of these for the Project Management Plan is the seminar titled ***How to Develop the Perfect Lunabotics Systems Engineering Paper: And Win the Whole Competition***. We recommend viewing this video at the very start of your project.

<u>Tips on the PMP </u>previously provided:

<u>Project Management Plan (PMP) Tip #1 - </u>Make sure your Gantt Chart (if using) and tables are readable if you are providing them to satisfy a rubric element. If we can't read it, we can't give you points. If you provide graphics with unreadable (less than 9-point text as viewed in the pdf) text, make sure the information to satisfy the rubric elements are discussed in the main body (at least 12-point font).

<u>Project Management Plan (PMP) Tip #2 - </u>Initial Project Schedule: Major Reviews. Make sure at least 3 show up on your schedule: SRR, PDR, and CDR. If you are using an alternate review instead of SRR, PDR, and CDR, then identify in the discussion the name of the review that replaces each.

<u>Project Management Plan (PMP) Tip #3 - </u>Developing any management plan boils down to two things: making decisions and writing them down. It's important to document those decisions at the beginning of the project and share with your team. Update your plan as you learn more and your project progresses. The Project Management Plan rubric identifies an important subset of the decisions you will have to make in your Lunabotics project planning process, and simply asks you to tell us what those specific decisions were.

<u>Project Management Plan (PMP) Tip #4 - </u>Initial Project Budget: Budget evolution. As your design matures, you will learn more about how much your project is to actually going to end up costing. To be sure you don't run out of money before the end of the project, set up periodic reviews of your cost budget. In case your costs are much greater (or much less) than you expect, decide at the beginning of the project how you will address budget shortfalls, and what you will do with budget excesses. Don't forget to make these decisions and discuss them in your PMP.

<u>Project Management Plan (PMP) Tip #5 - </u>Initial Technical Performance Measures (TPM): Allocation to System Hierarchy. The system hierarchy is the backbone of your project. At the very start of a project, it may only consist of two levels. That early decomposition allows you to allocate how much time you plan to spend on each sub-element in the hierarchy, how much money you plan to spend on each sub-element, and how much of the technical performance measure's values each sub-element will have to provide so the system can accomplish the

mission. As your design matures, these early allocations of TPM values across the system hierarchy levels will guide you through the design process to deeper levels in the system hierarchy and enable sub-allocations of TPM values across these new levels. And of course, you may learn things in the design process that might change even those earliest allocations of TPM values. There is an example of allocations down through the system hierarchy in (clickable link) ***SE Video 2: 'The Central Elements of Project Management***. That video describes budget allocation across the system hierarchy; the approach is similar for mass and other TPM allocations. Don't forget to include the TPM allocations in your PMP.

Rubric for System Requirements Review (SRR) Report

If more teams qualify for the Lunabotics Challenge through their PMP submission than can be accommodated at the Qualifying Event(s), then the PMP-qualified teams will be required to submit a System Requirements Review (SRR) Report within a week of notification.

The SRR Report will be judged to enable a final down-select to the number of teams that can be accepted at the competition. **It is advised to conduct your SRR and prepare this SRR Report for delivery before the announcement of PMP-qualified teams** and the requirement to deliver it. (The SRR Report also provides a good start for the Systems Engineering Paper).

SRR Report Requirements

1) Include your School Name and Team Name on the Systems Requirements Review Report.

2) The maximum length of the Systems Requirements Review Report is 4 pages. If you include a cover page, it will not count towards the page limit.

   Any content over 4 pages will not be judged and will not be scored.

3) The rubric for the Systems Requirements Review Report is very prescriptive. Pay very close attention to the precise required content, the precise required format, and the precise required location of content in the report. Non-compliance all but assures a low score on the SRR Report and elimination from the competition. This prescriptiveness allows a team to demonstrate the requisite Systems Engineering skill of assurance of technical communications despite technical complexity.

4) Format: The System Requirements Review Report shall be formatted professionally, organized clearly so that each required rubric element is easy to find, with correct

spelling and grammar, with text no smaller than size 12 point font in the main body, with text no smaller than size 9 point font in graphics and tables, and using professional margins of at least 0.75 inches on all sides (headers, footers, and page numbering may be in the margins).

Scoring Rubric – Systems Requirements Review Report	
Element	Points
<u>Page 1</u> <u>Content</u>: **Mission Analysis** 1) Provide a functional Mission Statement for the System; discuss as necessary. *[1 point]* 2) Identify All Stakeholders and Customers for the System, and clearly denote them as internal or external stakeholders and any role they have in system development and accomplishing the mission. *[1 point]* 3) Provide a System Boundary Sketch (a Functional Block Diagram) identifying all top-level functional elements in the system (should mirror the Systems Hierarchy in the PMP) and elements external to the system that will be involved in accomplishing the Mission. *[3 points]*	**5 points**
<u>Page 2</u> <u>Content</u>: **Integrated Operational Scenario** 1) Explain and discuss how the elements of the System Boundary Sketch (both internal and external) will be *operated* to accomplish the mission, including the involvement of all Stakeholders and Customers. This Integrated Operational Scenario should begin when the system is formally baselined as ready for operation to accomplish the mission (typically at a final Operational Readiness or System Integration and Operation Test Review, at your site), continuing through transport of the	**5 points**

system to the competition and competition operations, ending with final disposal of the system. *[5 points]*	
<u>Page 3</u> <u>Content</u>: **Systems Requirements Baselined** at the **SRR** 1) Present a table that includes: a. Key requirements (functional and performance) derived from customer documentation baselined at the SRR. Customer documentation may include the Lunabotics Guidebook and any answers to questions in the competition FAQs. These key requirements shall be stated in proper "shall" requirements language. *[2 points]* b. All additional requirements (functional and performance), that are necessary to execute the Integrated Operational Scenario to accomplish the Mission. These key requirements shall be stated in proper "shall" requirements language. *[2 points]* (These requirements, combined with the key requirements derived from customer documentation, provide a valid, complete, consistent, and coherent description of the problem space.) c. Planned Verifications for each SRR baselined requirement including: [*0.5 point]* i. When verification will occur ii. How verification will be executed iii. The success criteria for the verification. 2) **Also**, identify in this table the requirements related to system reliability, maintainability, logistics, transportation, human factors/operations, training, and safety. *[0.5 point*	**5 points**
<u>Page 4</u> <u>Content</u>: **Systems Requirements Review** 1) Explain how the SRR was conducted:	**5 points for 10 elements, one half**

a. Identify the reviewers, identifying them as either internal and external reviewers. b. Explain how the proposed problem space baseline was presented to reviewers. c. Explain how reviewer comments were collected. d. Explain how responses to reviewer comments were developed and presented to the reviewers. e. Explain how consensus between the team and the reviewers was achieved on the responses. f. Explain how baseline approval was obtained. 2) Provide explicit and preferably quantitative examples of Changes resulting from reviewer comments received during the SRR process (any good control gate almost always produces changes to a proposed baseline) to: a. The Schedule as presented in the PMP. b. The Cost Budget and Allocations to system hierarchy elements as presented in the PMP. c. TPMs and Allocations to system hierarchy elements as presented in the PMP. d. System Requirements as proposed (added, deleted, modified) and verifications.	**point for each element.**

Requirements for Teams that make it through the Application process:

For Teams who receive an email notification they have been accepted into the Lunabotics Challenge, to maintain your participation in the Lunabotics Challenge, teams must complete the following deliverables:

- Complete student and faculty registration in Gateway and Liability Waiver
- STEM Industry Engagement Plan
- Team Photos and NASA Media Release for each photo submitted
- Presentations and Demonstrations (optional but required for Lunabotics Off-World Grand Prize eligibility)
- Systems Engineering Paper
- Proof of Life Video (pass/fail requirement)
- Robot Data Files
- Updated Student/Faculty Registration in Gateway for KSC on-site attendance
- List of potential participants (students/faculty) attending UCF and KSC sent to: ksc-lunabotics@mail.nasa.gov
- KSC Lunabotics Regulated Waste Management Overview (bring to KSC)

Timeline and Deadlines: All Lunabotics deadlines are posted at: https://www.nasa.gov/learning-resources/lunabotics-challenge/timeline/

- Deliverables are accepted via the Lunabotics email up to seven (7) days prior to each deadline
- All deadlines are 5:00 PM Eastern Time
- Dates are subject to change

Submission Guidelines:

- Lunabotics will review the most recent file received prior to the deadline
- NASA reserves the right to question or reject any item submitted by unauthorized representatives.
- Team leads are responsible for sending all deliverables to: ksc-lunabotics@mail.nasa.gov

Section 2: TECHNICAL

RoboPits

The RoboPits are located in the Astronauts Memorial Foundation's (AMF) Center for Space Education (CSE) Building, room M6-306. This is where teams will meet with competitors from across the country and prepare robots before competing in the Artemis

Arena. Robots will be inspected before each competition attempt, and teams are permitted to repair or modify their robots while the RoboPits are open.

The RoboPits are equipped with emergency eyewash stations and disposal containers for used aerosol cans, batteries, degreasers, and cleaning wipes. Teams are encouraged to bring additional LED lighting, floor coverings or mats to facilitate cleaning, power strips, and a first-aid kit to enhance their workspace.

Teams are responsible for creating team pit identification sign. Use common sense and keep it fun—signs must be under 6 feet tall and may include LED light strings. Remember that KSC Fire/Safety personnel may require modifications or removal if a sign is deemed unsafe.

The RoboPits

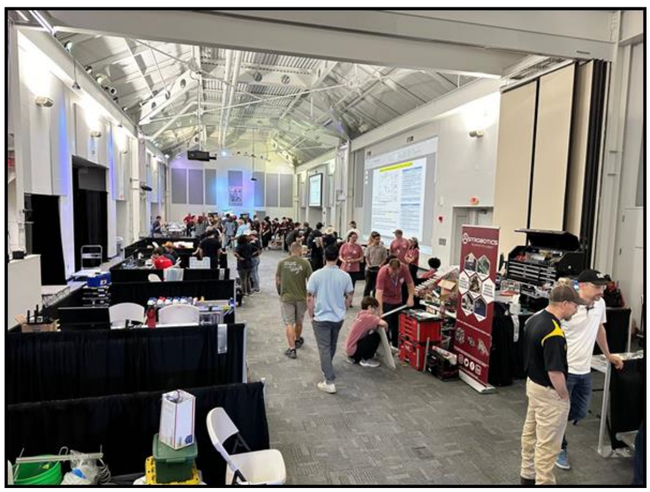


Image of RoboPits

RoboPits Check-in Procedures

Spectators must follow the same rules as participants.

Step 1: Check-in and Setup

Upon arrival, the Pit Boss will assign teams pit location and explain the inspection process, run sign-up procedures, and other competition protocols. Please remain professional and patient during busy periods.

Contact Information:

Teams must provide two contact phone numbers for emergency communication during the competition. These numbers will remain confidential and be deleted at the competition's conclusion.

Pit Specifications, Guidelines & Shared Equipment:

Teams assigned 10' x 10' pit includes two chairs, one table, and two power outlets with provided power strips. Do not daisy-chain power strips. Keep all team members and equipment within assigned pit boundaries, ensuring walkways and hallways remain clear and unobstructed.

Vacuums are provided for shared use by all teams. Return vacuums to the designated area after use and notify the Pit Boss of any safety concerns or vacuums requiring cleaning.

KSC Prototype Development Laboratory (PDL) Bot Shop:

The PDL is staffed by KSC engineering technicians who specialize in designing, fabricating, and testing prototypes and test equipment. This mobile machine shop is equipped with grinding, sanding, mini-mill and mini-lathe, band saw, drill press, and hand tools (welding is not available). The Bot Shop can assist with robot repairs but cannot complete unfinished robots. Only PDL mechanics are authorized to operate the equipment. Teams may use this resource for repairs and modifications on a first-come, first-served basis. **Protective eyewear is required in the Bot Shop at all times.**

Step 2: Clean-up and Check-out

The RoboPit must be kept neat each night with nothing outside the pit boundaries. Unplug all equipment before leaving. Maintain cleanliness in the pits and the surrounding area using the provided vacuums as necessary. Teams are encouraged to bring floor coverings or mats to facilitate cleaning. Each team must leave their RoboPit in the same condition as found and request a final inspection from the Pit Boss.

Industrial Waste Protocol

Teams must comply with Federal and Kennedy Space Center hazardous and controlled waste program requirements. Coordinate with the RoboPit Chief before disposing of any of the following items (specially marked containers will be provided):

- Batteries (Alkaline, Lithium, Ni-Cd)
- Spray paint, spray foam, spray adhesives
- Oily wipes, IPA solvent wipes, acetone wipes
- Solder waste
- PVC cement/primer (brushes, wipes, cans)

- Lubricants (WD40, PB Blaster, 3-in-1 oil)
- Adhesives (super glue, epoxy tubes)
- Aerosol cans
- Any other items as required by regulations

Regolith Simulant- Black Point-1 (BP-1)

BP-1 is a crushed lava basalt aggregate with particle size distribution similar to lunar soil. Important safety considerations:

- BP-1 is alkaline and may cause skin and eye irritation
- Contains a small percentage of crystalline silica, which is a respiratory irritant
- If a person is allergic to talcum powder, they may be allergic to BP-1
- All participants must wear ANSI-approved, UL-Listed, CE EN166 rated, AS/NZS certified, or CSA rated PPE when in contact with BP-1
- Respiratory protection is required

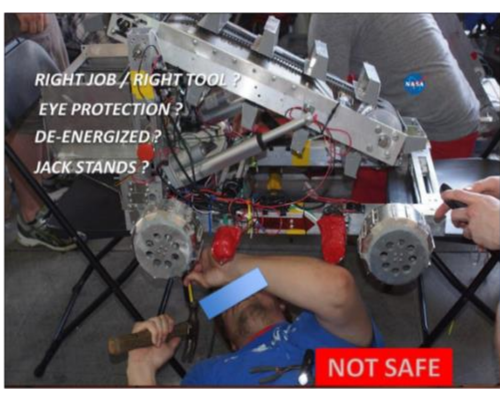
Stop Work Order (SWO)

Lunabotics staff may issue an SWO for any suspected safety issue. Teams must immediately stop all activity. The Faculty Advisor must meet with the Pit Boss to resolve the issue. The SWO remains in effect until the Pit Boss makes a final ruling.

Robot Inspections- Safety and Communications

- Inspection stations will be clearly identified
- Inspections operate on a first-come, first-served basis (no scheduling)
- Return to the Pit Boss after passing both Safety and Communications inspections
- An escort will retrieve teams before each competition run—do not leave without the escort

IMPORTANT: ROBOTS MUST PASS BOTH SAFETY AND COMMUNICATIONS INSPECTIONS BEFORE ENTERING THE ARTEMIS ARENA.



Images of examples of unsafe scenarios

NOTICE TO TEAMS

Teams must resolve all questions and rule clarifications pertinent to a competition run before entering the Artemis Arena and Mission Control Center. The competition schedule will not be delayed to accommodate last-minute requests of this nature.

Pre-Competition Personal Protective Equipment (PPE) Preparation Notification and Setup

Teams will receive notification approximately 45 minutes before their scheduled start time to ensure smooth operations. During this preparation period, up to four (4) students will proceed to the PPE preparation area to don the required protective equipment for the Artemis Arena. An escort will then accompany the PPE-equipped students and Mission Control students to the Artemis Arena and Mission Control Center. Important: Teams that are not ready or cannot be located at the designated time will forfeit their competition opportunity, and their slot will be given to another ready team.

PPE Provision and Team Responsibilities

NASA will provide the following standard PPE for use in the Artemis Arena:

- Safety goggles
- N-95 masks
- Protective coverall suits (bunny suits)
- Rubber gloves
- Protective booties

Teams and schools are responsible for providing any additional PPE required by OSHA, ANSI, or equivalent standards to accommodate participants in this event.

Respiratory Protection Requirements

OSHA 1910.134 - Occupational Safety and Health Standards, Subpart I: Personal Protective Equipment, Standard Number: 1910.134, Title: Respiratory Protection (Appendices A, B-1, B-2, C, D, GPO Source: e-CFR).

Facial Hair Restrictions

Per OSHA Standard 1910.13, respirators cannot be worn when facial hair interferes with the sealing surface of the facepiece or valve function. While OSHA 1910.134 does not provide religious exemptions; loose-fitting hoods or helmets that accommodate facial hair are acceptable alternatives. Schools/teams are responsible for providing any specialized respiratory equipment required by regulation.

Under OSHA 1910.134(a)(2), respirators must be provided when necessary to protect a person's health. The employer must provide suitable respirators and establish a comprehensive respiratory protection program covering all required users as outlined in paragraph (c).

Eye/Face Protection

Mandatory Requirement: ANSI-approved protective eyewear must be worn without exception in individual pits, the Bot Shop, and Artemis Arena.

Additional Protection Recommended for:

- Robot work including grinding, drilling, soldering, cutting, and welding
- Activities with risk of flying particles or chemical exposure (splashes, splatters, sprays)

Available Protection Options: Safety glasses with side shields, goggles, face shields, and face masks.

Important Restrictions:

- Reflective lenses are prohibited; eyes must be clearly visible
- Accommodations available for prescription tinted safety glasses

Prescription Glasses: Non-safety-rated prescription glasses require ANSI-approved safety goggles worn over them. Safety-rated prescription glasses marked with standards (e.g., Z87.1) may be used with appropriate side shields and frames.

Additional PPE Requirements

Hand Protection

Use appropriate gloves and mechanical tool guards to protect against heat, electrical, chemical, laceration, and mechanical hazards. Select proper protection for each specific activity.

Hearing Protection

Provide and use hearing protection devices (such as earplugs) in areas with objectionable or questionable sound levels.

Foot Protection

Wear completely enclosed shoes covering the instep, preferably leather that can be wiped clean.

Clothing Requirements

Required Clothing:

- Shirts/tops covering the upper torso
- Long pants covering to the ankle
- Completely enclosed shoes covering the instep (preferably leather, wipeable)

- Baseball caps and headgear (positioned to avoid vision impairment and interference with protective eyewear)

Prohibited Clothing:

- Flowing garments and loose neckwear (ties, scarves)
- Caps worn low over eyes that impede vision
- Cropped shirts, plunging necklines, spaghetti straps, or damaged shirts
- Damaged jeans, shorts, capris, or skirts
- Loose or wide/bell-sleeved tops, coats, or shawls
- Open-toe, open-back, open-weave shoes, or shoes with holes that could expose skin to regolith

Hair Requirements:

Hair must not impede vision or contact work surfaces. Long hair must be tied back, and hair longer than 6 inches from the neck must be pinned up (hair nets or hats acceptable).

Artemis Arena PPE Requirements

PPE is mandatory when placing robots in the Artemis Arena (Room 9010) and during robot operation involving regolith material disturbance.

Participant PPE (entering Artemis Arena):

- N-95 filtering facepiece
- Full-body protective suit with hood and booties
- Nitrile gloves

Judges/Regolith Assistants PPE (during robot operation):

- Full-face respirator with P100 filters OR full-face powered air purifying respirator (PAPR)
- Full-body protective suit with hood and booties
- Rubber boots
- Nitrile gloves

Donning Protocol

Participants:

- Select appropriately sized Tyvek coverall and put on over shoes
- Don appropriate gloves, overlapping the Tyvek suit
- Tape gloves to coverall overlap to prevent skin exposure
- Apply tape above ankles and waist as needed to secure excess material
- Place N-95 filtering facepiece over nose and mouth, adjusting nose bridge for comfort and to prevent fogging

- Note: Clean-shaven face required for proper mask/respirator use as determined by Competition Staff
- Place dust goggles over eyes and cover head with Tyvek hood

Judges/Assistants:

- Don full-face negative pressure respirator with P-100 filters OR full-face PAPR
- Cover head with Tyvek suit hood
- Don rubber boots over Tyvek booties when working in regolith pit

Doffing Protocol (After Robot Run Completion)

- Remove hood, then remove Tyvek coverall by rolling down from inside
- Remove gloves taped to suit and place coveralls in designated waste container
- **Participants:** Remove eye protection and return to PPE attendant; remove and discard N-95 facepiece
- **Judges:** Maintain PAPR equipment in accordance with manufacturer's specifications

Arena Specifications at the Kennedy Space Center

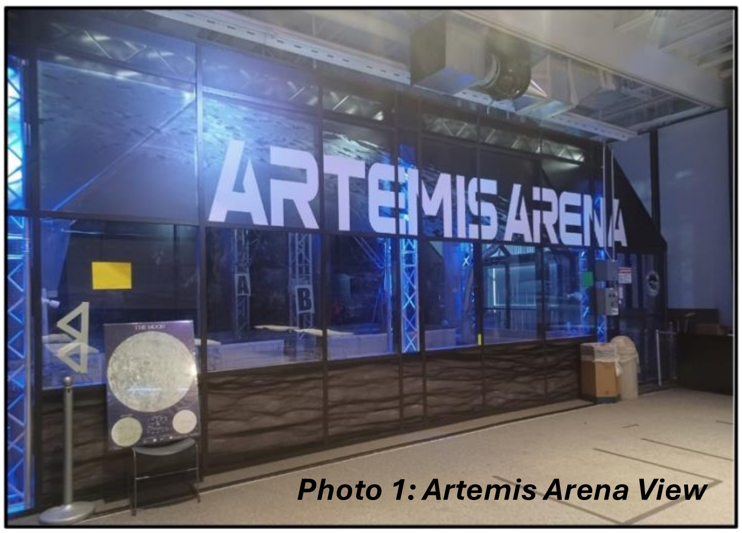


Photo 1: Artemis Arena View

1. <u>Arena Composition and Dimensions</u>
   1.The interior dimensions are approximately 6.8 m long × 5.0 m wide (measured between the interior ducts).
   2.The arena contains Black Point-1 (BP-1), a crushed basalt lunar regolith simulant to a depth of approximately 45 cm
   3.Additional material: Random distribution of gravel (approximately 2 cm diameter) may be mixed with the BP-1

Photo 2: Artemis Arena Layout

2. Obstacle Zone

The obstacle zone is designed to test:

1. Obstacle detection capabilities
2. Mapping functions
3. Navigation planning abilities

3. Obstacle Types

Boulder Obstacles –

1. Quantity: Minimum of three (3)
2. Placement: Randomly positioned before each competition round
3. Size: Approximately 30-40 cm in diameter with varying heights
4. Note: Boulders may also appear in the excavation zone but will not exceed the dimensions of those in the obstacle zone

Crater Obstacles -

1. Quantity: Minimum of three (3)
2. Dimensions: Varying depths and widths, not exceeding ~ 40-50 cm in either measurement
3. Fixed Infrastructure
4. Central support column: Permanent obstacle that must be avoided

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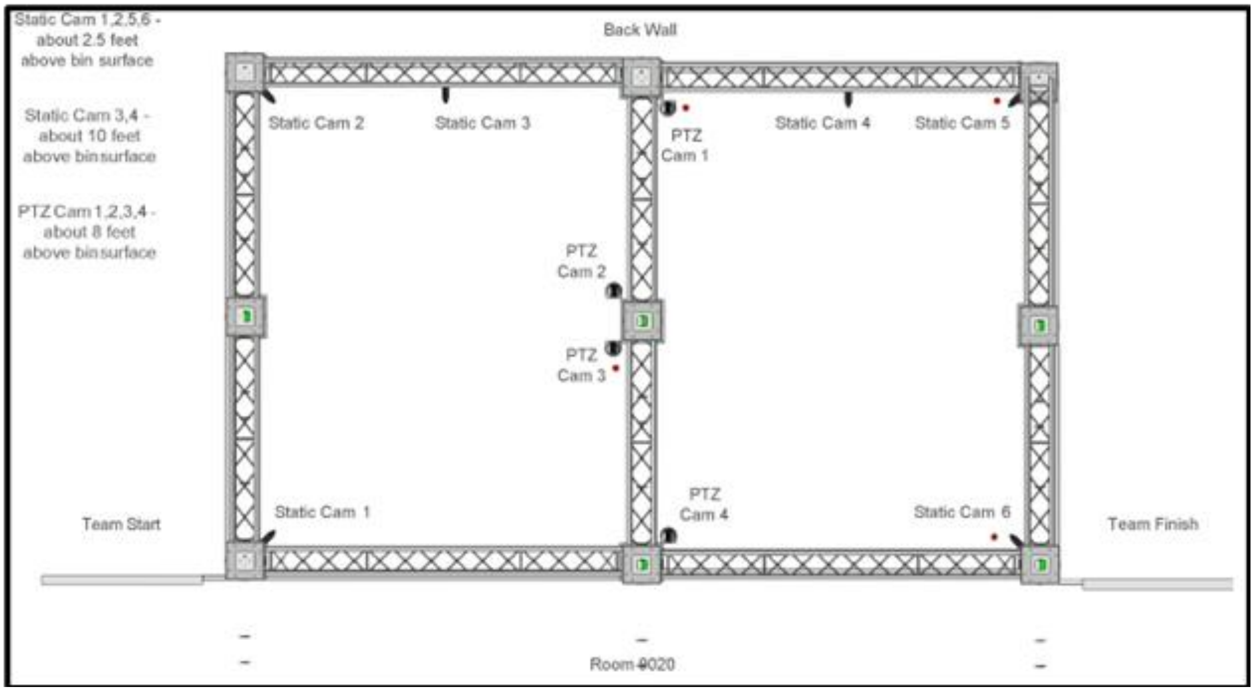
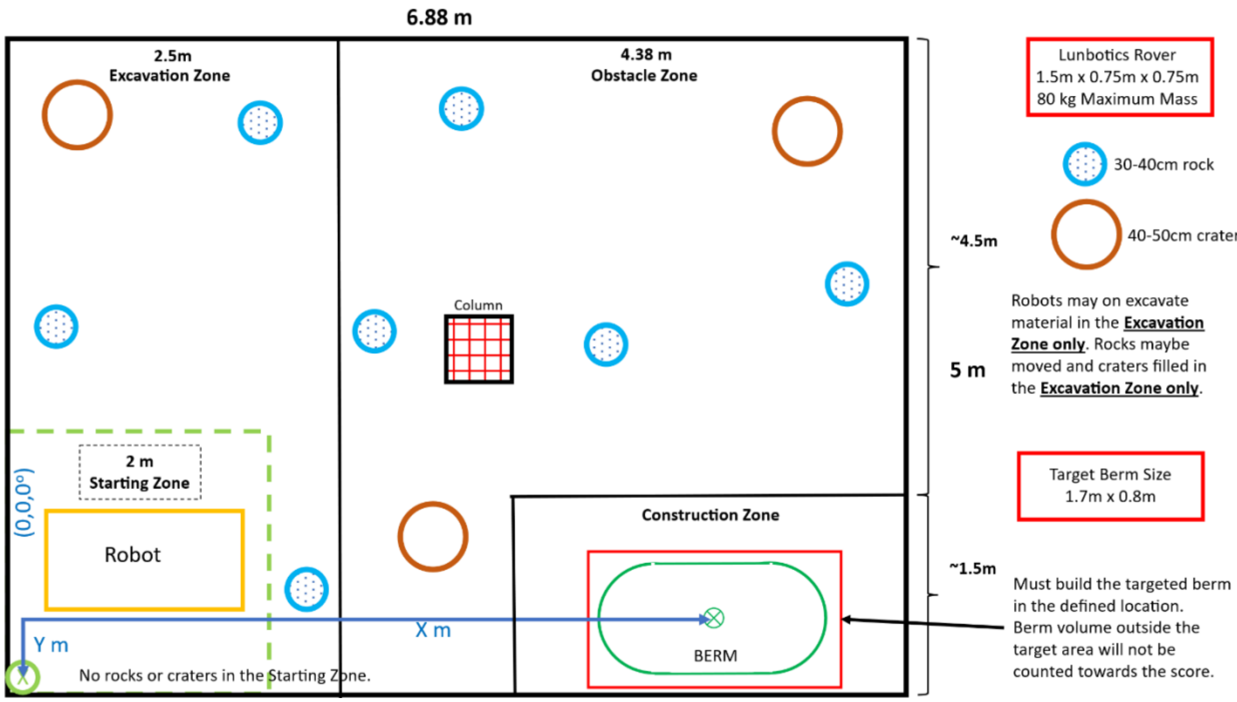


Artemis Arena, camera layout

Mounting of Beacons for Navigation – information to be posted as an FAQ



X: 5.38 m   Y: 0.6 m

Figure 1: Artemis Arena Layout

Artemis Arena Protocol

1. Once competition runs begin, the Artemis 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 Artemis Arena.
5. The Artemis Arena is defined as all areas within room 9010/9020 of building M6-306 (Center for Space Education) at Kennedy Space Center Visitor Complex. The Arena staging area, Competition Arena, HEPA station, and Arena Chief's station are located within the Artemis Arena.
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 Artemis Arena.

8. Team members placing the robot in the Competition Arena will don PPE in the RoboPits staging area.
9. When properly attired, they and Mission Control teammates will be escorted to the Artemis Arena entrance.
10. The Arena Chief will grant access to Artemis Arena staging area when ready.
11. Student cell phones, cameras, tablets, and other restricted electronics devices brought into the Artemis 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 robots 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 Artemis 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:
    a. Vacuum excess BP-1 from their robot.
    b. Doffing Protocol in the Artemis Arena After completion of the Robot Run
        i. Remove hood then remove Tyvek coverall rolling down from inside of suit.
        ii. Remove gloves taped to suit. Place coveralls in designated waste container:

iii. Participants: Remove eye protection and return to PPE attendant.
iv. Remove N-95 filtering face piece and discard.
v. Judges: Shall maintain their PAPR equipment IAW the manufacturer's specifications.
vi. Properly discard all used PPE.
vii. Return goggles for cleaning and reuse.
viii. Remain in the HEPA area until directed to exit the Artemis Arena by the Arena Chief or designated personnel.

23. Remember, the Artemis 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.

Figure: Artemis Arena, crew observing robots

ROBOTS AND ROBOTIC OPERATIONS

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 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). Components (i.e. electronic, mechanical, etc.) are not required to be space qualified for atmospheric, electromagnetic, thermal, or Lunar environments.

2. Robot Requirements

Students on the team shall perform 100% of this project (including design, construction, and task components of their vehicle and deliverables, 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 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 dust 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 NASA does not anticipate the use of these on an off-world mission. 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 BP-1 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.

3. <u>E-STOP Button</u>

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. 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.
6. 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.

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.

4. 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 robot 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 has to 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.

5. Battery Protocol
    1. Lithium-Ion / Nic-Cad 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 NASA Fire as a non-emergency issue.
    7. No one will fault you if in your opinion you need to call NASA Fire at 321.867.7911.
    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.

    a. 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.

9. Closed loop 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. 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.
10. 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-1 & BP-1 regolith simulant is very dusty and abrasive.

6. Robotic Operations

1. The robot cannot be anchored to the regolith simulant 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 Artemis Arena.
3. The robot must operate within the Artemis 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.
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. The designated area is anywhere on the bin frame structure along the perimeter of the starting zone (2 sides). 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.

Figure 1: Beacon or Fiducial Target Mounting locations

(note: the ducts along the sides of the Arena walls are 17cm diameter).

SCORING, CONSTRUCTION, NAVAGATION

1.Scoring

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.

1.UCF & KSC-

a. 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 scores will NOT be added across the venues.
b. 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.

2.KSC Only-

Team scores for construction will be normalized to the maximum construction points achieved by all teams to a scale between 0 and 25 points for the grand prize.

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 of 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 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 bandwidth usage as follows: (# arena cameras used *0.2 + wifi bandwidth Mbps = Total Bandwidth Mbps.
If Total Mbps > 4 = 0, else Total Mbps *-.30 + 120.

    a. Example: (1) arena camera used, 0.5 Mbps wifi bandwidth. (1*0.2) + 0.5 = 0.7 Total Mbps
    b. 0.7 * -0.3 = 120 = 119.79 points

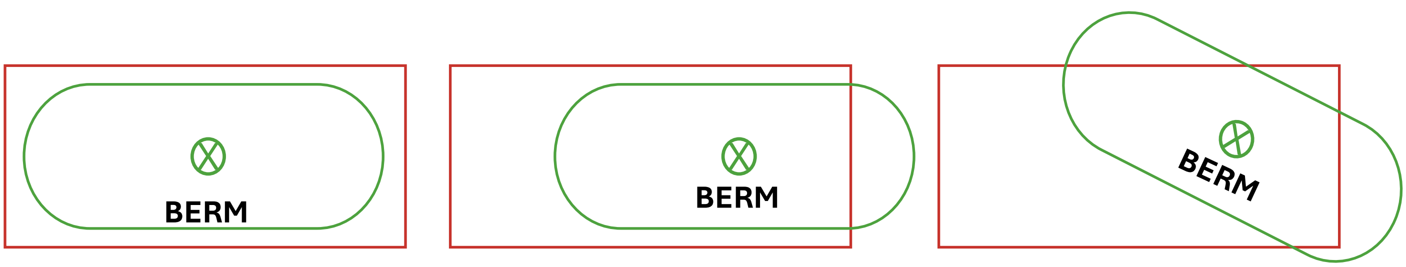
5**. Dust Tolerant Design** - During each competition attempt a team can earn up to 30 points for dust tolerant design features on the construction robot. Teams are encouraged to point out dust tolerant and dust free features to the judges during setup. The judges will allocate these points based on an inspection and performance during the competition run. The points for dust-tolerant design are as follows:

a. Drive train and components enclosed/protected: 15 points
b. Active dust control (brushing, electrostatics, etc.): 5 points
c. Custom dust sealing features (bellows, seals, etc.): 10 points

6. **Dust Free Operation** - During each competition attempt, a team can earn up to 30 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 (5 points)
- Digging without dusting up regolith (20 points)
- Transferring regolith without dumping the regolith on your own robot (5 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)

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 – Artemis Arena

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)*** – 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^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)*** - 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. **NOTE: A 30 point penalty will be accessed if your robot energy data logger is not wired in accordance to ROBOTS AND ROBOTIC OPERATIONS section 4**	cm^3 berm / min /watthour	1.5	77551 cm^3 / 15 min run / 36 whr **143.6**	**215.4**
4. ***Bandwidth Use*** – During each competition attempt, the team will be scored on bandwidth use as follows: Total average bandwidth (TAB) = ((# arena cameras * 0.5) + avg bandwidth in Mbps). If TAB is greater than 4 then 0, else, (TAB * -30) + 120 = score.	# cameras Avg bandwidth Mbps	1 camera 0.7 avg bandwidth Mbps	TAB = (1*0.5)+0.7 = 1.2 (1.2*-30) + 120 =84	**84**
5. ***Dust Tolerant Design*** – see description				**30**
6. ***Dust Free Operation*** – see description				**25**

7. ***Autonomy*** – See Construction Points – Autonomy	task	50, 75, 125, 250, 300, 375, 450, or 600	75.00	**75.00**
8. ***Total Points***				**774**

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 simulant 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 not considered an acceptable excavation and regolith simulant transfer technique for the Lunabotics challenge. All regolith simulant must be carried through the obstacle zone.

16. Obstacles may not be moved into the excavation zone.

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.

4. 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. <u>Autonomy Rules:</u>

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.

MISSION CONTROL CENTER AND AUTONOMOUS OPERATIONS

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. 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 Lunabotics guidebook and ensure consistent interpretation and enforcement for all teams.

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 Artemis 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, may be disqualified from a competition run, or disqualified from the entire Lunabotics Challenge.

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 Artemis 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 Artemis 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.

3. Mission Operations

1. Teams are allowed 30 minutes per competition run under nominal conditions.
2. Telerobotic operators will have access to two situational awareness cameras in the Artemis 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.

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.

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 Artemis 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.

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 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 Artemis 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.

KSC Communications Operations:

1. KSC Finals General Communication System Requirements

1. All teams shall use IEEE 802.11 wireless protocol standards for their wireless connection (Wireless Access Point (WAP) router and rover client).
2. Routers are required to support both the 2.4 and 5 GHz bands.
3. Routers are required to have the ability to turn off the 2.4 GHz band.
4. Each team will be assigned an SSID upon checking in for the competition that must be used for their wireless equipment. Team's SSID will be written as "Team_##."
5. Teams are required to broadcast their SSID.
6. Robots and access points are ONLY allowed to transmit using their designated SSID.
7. Hidden networks are not allowed.
8. Wireless encryption is required.
9. Teams cannot use channel bonding for 2.4 GHz data transmission. Meeting this rule will require a spectral mask or "maximum spectral bandwidth setting" of 20MHz for all wireless transmission equipment.
10. All team-provided wireless equipment shall operate legally within the power requirements set by the Federal Communications Commission (FCC) for unlicensed wireless equipment operating in the Industrial, Scientific, and Medical (ISM) radio frequency band. The FCC Federal Regulations are specified in the Electronic Code of Federal Regulations, Title 47, Telecommunication, Part 15, and must be followed if any commercial equipment is modified. All unmodified commercial off the shelf access point equipment and computers already meet this requirement.
11. If a team inserts any type of power amplification device into the wireless transmission system, this will likely create a violation of FCC rules and is NOT allowed in the competition.

12. The radio frequency power requirements apply to all wireless transmission devices at any ISM frequency.
13. 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.
14. 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.
15. 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.
16. 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.
17. All robots should have an external WiFi antenna for the rover wireless client or demonstrate that the rover antennas are not obstructed by conductive or metal structure on the robot.
18. Use of the NASA-provided situational awareness camera in the control room will add 500 Kbps (Kilobits Per Second) of data use for each camera. If the team elects to turn on the camera during the match, they will be charged for the full 500 Kbps of data use.
19. 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.

2. KSC Finals General Radio Frequency and Communications Approval (Comm Check)

1. All teams are required to successfully pass a Comm Check prior to entering competition in the UCF qualification or the KSC final competition.
2. Compliance with all rules specified in Section 1 General Communication System Requirements listed previously will be verified during the Comm Check.
3. Each team must demonstrate to the communication judges that their robot and access point are operating only on the assigned channel. Each team will have a maximum of 15 minutes at the communication judges' station.
4. Comm checks are to be performed on Channel 1.
5. Teams that are in the queue for a comm check are allowed to quickly

configure to Channel 1, then turn their wireless off until they are at the comm test station for checkout.

6. The teams must identify and show to the judges all the wireless emission equipment on the robot.
7. If the team robot is transmitting low power Bluetooth or any non-2.4 or 5 GHz frequency equipment, printed documentation from the manufacturer with part numbers of all wireless transmission equipment must be provided to the judges. This printout must be from the manufacturer's data sheet or manual, and will designate the technology, frequency, and power levels in use by this type of equipment.
8. If teams are using Bluetooth on their robot, printed documentation of the hardware in use must be provided to the judges. Teams must show that the equipment in use is not using Bluetooth Class 1 and can be verified within the provided documentation.
9. The team must also verify that they are connected to the robot by remote wireless control and are able to control the robot.
10. The team must show that they can turn off 2.4 GHz after demonstrating control of the robot.
11. If a team cannot demonstrate the above tasks ~~in the allotted time,~~ the team will be disqualified from the competition.

3. KSC Comm Rule Qualifications

Each team is required to command and monitor their robot over the NASA provided Artemis network infrastructure. This configuration must be used for teams to communicate with their robot

4. KSC 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.
4. Teams that are in the queue for a comm check are allowed to quickly

configure to Channel 1, then turn their wireless router off until they are at the comm test station for checkout.

5. The RoboPits communication environment will be monitored. If you team is found to be transmitting on Channel 1 while in the RoboPits the following will occur:
   a. 1st time a warning and announcement to all teams in the RoboPits that your team was in violation.
   b. 2nd time a 500 point deduction from your final score (sum of the two runs) will be accessed.
   c. 3rd time will result in disqualification from the competition.

5. The KSC Artemis Arena Comm Rules

1. Robot operations will be performed only on Channel 1.
2. Teams must be able to configure to Channel 1 for the competition within 15 minutes of being notified to accommodate real-time scheduling changes.
3. If a team is on the wrong channel during their competition attempts, the team will be disqualified and required to power down.
4. Channels 1 will be monitored during competition to assure there are no other teams transmitting on the assigned frequencies.
5. Situational cameras are staged in the Artemis Arena. The camera joystick and camera display will be located with the team in the MCC.

6. KSC Communications [(Artemis Arena – Mission Control Center (MCC)]

1. Handheld radios will be provided to each team in the Artemis Arena to link with their Mission Control Center team during the setup period.
2. Each team will provide the wireless link (access point, bridge, or wireless device) to their robot, which means that each team will bring their own Wi-Fi equipment/router and any required power conversion devices.
3. Teams must set their own network IP addresses to enable communication between their robot and their MCC control computers, through their own wireless link hosted in the Artemis Arena.
4. In the arena, Artemis will provide an elevated network drop (male RJ-45 Ethernet plug) that extends to the Mission Control Center, where Artemis will provide a network switch for the teams to plug in their laptops. The network drop in the Artemis Arena will be elevated high enough above the edge of the regolith bed wall to provide adequate radio frequency visibility of the entire arena.
5. Network connections to the robot are ONLY allowed via the WAP router and the cable going to the MCC. Any backchannel wireless connections

via laptop or cellphone to the WAP router or robot during setup or competition are expressly forbidden and will result in disqualification.

6. A shelf will be set up next to the network drop at a height 0 to .5 meter above the walls of the arena and will be placed in a corner area. This shelf is where you will place the Wireless Access Point (WAP) to communicate with your robot. During robot system operations during the competition there will be dust accumulation in this area.
7. KSC Artemis will provide a standard US National Electrical Manufacturers Association (NEMA) 5-15 type, 110 VAC, 60 Hz electrical jack by the network drop. This power connection will be used for the WAP router used for robot WiFi communications. This will be located no more than 1.5 meters from the shelf. The team must provide any conversion devices needed to interface team access points or Mission Control Center computers or devices with the provided power source.
8. Teams are strongly encouraged to develop a dust protection cover for their wireless access point (WAP) that does not interfere with the radio frequency signal performance.
9. During the setup phase, the teams will set up their access point and verify communication with their robot from the Mission Control Center.

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 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. A tie in autonomy points relative to the Caterpillar Autonomy Award will be broken based on the total berm construction from UCF and KSC.

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

1. The Excavation Zone now overlaps with the Starting Zone. Teams may excavate material anywhere in the Excavation Zone.
2. Within the Excavation zone, the team 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 and collect for regolith for transport. A discernable amount of regolith 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 regolith to begin the excavation process.
5. Excavation mechanisms must be completely removed from contact with the regolith before returning to remote control operation.
6. Once excavation is complete the team must indicate they are going to remote control before taking control of their robot.
7. 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 past 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
    1. Teams are allowed to traverse the Obstacle Zone via remote control.
    2. Prior to crossing into the Construction zone, they must indicate to the MCJ that they are going hands-free for the dump attempt.
    3. The robot must execute machine control commands itself during the dump task.
    4. 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.
    5. Once dumping is complete the team must indicate they are going to remote control before taking control of their robot.
    6. 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

The teams must indicate to the MCJ that they are going into hands-free mode while still in the excavation zone. The robot must remain in hands-free mode while crossing the obstacle field and crossing into the construction 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 construction zone. The teams shall not architect a "Point and traverse" approach for this automation step.
5. 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.
6. For maximum points, the attempt must be made at the start of the run on the first time leaving the excavation 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. 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

1. The robot must be in hands free control for one entire cycle.
2. Attempt must be made at the beginning of the competition run.
3. 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 excavating, crossing the obstacle field, crossing into the construction zone, dumping the regolith for the berm, and crossing the obstacle field and returning to the excavation zone. Once successfully crossing into the excavation zone the team may return to remote control. A discernable amount of regolith must be placed at the berm location as determined by the MCJ.
4. 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.
5. 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

1. The attempt must be made from the beginning of the competition run..
2. The robot must be in hands free control for the entire competition run.
3. 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 excavating, crossing the obstacle field, crossing into the construction zone, dumping the regolith for the berm, and crossing the obstacle field and returning to the excavation zone must be completed during the competition run. Berm construction points, as determined by the volumetric scan, must be achieved for this level of autonomy.

4. 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.

5. 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
Et: 3	-	-	250	-	-	250
Ex: 4	75	50	-	-	-	125
Et: 5	-	50	250	-	-	300
Ex. 6	75	50	250	-	-	375
Ex: 7	-	-	-	450	-	450
Ex: 8	-	-	-	-	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, Travel automation points will not be combined with Full Autonomy (one Cycle) or Full Autonomy.

SECTION 3: DELIVERABLES AND RUBRICS

Deliverable due dates are posted on the Timeline located on the Lunabotics website at https://www.nasa.gov/learning-resources/lunabotics-challenge/.

You must score a minimum of 70% on each deliverable. Teams failing to meet this requirement will be removed from the challenge.

Submit your Deliverables

- Submit your deliverables to the KSC-Lunabotics mailbox at ksc-lunabotics@mail.nasa.gov.
- Submit as a PDF (portable document format) file and use the following naming format, deliverables that do not follow this format will not be accepted by the program
- Deliverable Name-School Name (not your team's name)
  Ex: SEP-Harrison University

List of Deliverables

- Team Photos and NASA Media Release for each photo submitted **(Due- Wednesday, February 4, 2026)**
  PHOTOS-School Name
- STEM Industry Plan
- (**Due- Thursday, February 26, 2026)**
  STEM -School Name
- Presentations and Demonstrations ((optional but required to be eligible for the Lunabotics Grand Prize, The Off- World Grand Prize Award))
- (**Due- Friday, March 20, 2026)**
  PD-School Name
- Systems Engineering Paper
- **(Due Thursday, April 2, 2026)**
  SEP-School Name
- Proof of Life Video Link **(Due Thursday, April 30, 2026)**
  POL-School Name
- Robot Data Specifications Report (your robot) **(Due Thursday, April 30, 2026)**
  RDF-School Name
- List of Students / Faculty attending the Challenge at KSC
- **(Due- Wednesday, May 6, 2026)**
  KSC-School Name
- Liability Waiver – Artemis Arena **(Due prior to KSC Challenge)**

LIA-School Name

- Regulated Waste Management Overview **(Due prior to KSC Challenge)**
  RWM-School Name (bring a hard copy with you to KSC).

2.STEM Industry Plan (Due- Thursday, February 26, 2026

Provide a plan for how your team will engage with industry professionals and community leaders to enhance your project's impact and educational value while developing meaningful connections that could lead to future workforce opportunities for your team members. Your plan should be no more than 1 page maximum.

1. Audit local community and create a list of potential partners and alignment with project goals. Consider technical expertise, mentorship, skills development, certifications or resources sought to advance project goals.

2. Your plan should assess the team's Professional Development Strategy (choose at least one from this category)

   a. Summarize mentorship arrangements your team plans to target with industry experts/partners

   b. Identify skills development and certification opportunities your team members plan to seek with industry partners (e.g. welding, safety training, electrical, software)

   c. Explain how your team's industry connections would support team members' career goals

   d. Identify potential internship, fellowship, apprenticeship, or career opportunities your team members plan to seek

3. Your plan should assess the team's Community Leadership Outreach (choose at least one from this category)

   a. Describe how your team engage with local civic and community leaders.

   b. Summarize the method your team will use to raise awareness about your NASA challenge participation.

   c. Identify and outline connections your team has and/or will seek with community leaders and industry partners.

2. Presentation and Demonstration (P&D) Rubric (Due- Friday, March 20, 2026)

Teams must participate in this event to qualify for the Lunabotics grand prize. It is otherwise optional, and teams will not be penalized for choosing not to participate.

1. NASA will request an Intent to Present from all teams approximately one month before P&D submissions are due. Only teams that provide a “yes” response to NASA by the Participation Intent deadline will be guaranteed a presentation time slot. Teams that do not respond will be recorded as a “no”.

2. Competing teams shall deliver a completed Presentation and Demonstration slideshow in one PDF file in accordance with Lunabotics submission guidelines. Teams are not permitted to modify their slides between submission to NASA and presentation to the P&D Judges Panel. Penalty points may be assessed for non-compliance. In the event a Team has updated progress they want to share with the judges, they may verbally address it in the appropriate section of their presentation. Teams that submit slides but do not present will not receive a score for this event.

3. P&D will occur virtually prior to the UCF Qualifiers. NASA will establish the judging schedule with a place holder window after the presentation deadline closes and allow teams to select their time slots on a first come, first served basis. NASA will provide the virtual meeting location and include setup time in each slot prior to the judging panel’s arrival.

4. Each team is allotted 25 minutes in front of the judging panel and should be prepared to present their own slides. AI recording and transcription is not permitted. It is recommended that the presentation and demonstration last approximately 20 minutes with the final 5 minutes available for questions and answers. There is a hard cut-off at the 25-minute mark to maintain the judging schedule. Teams are responsible for managing their time accordingly.

5. A panel of engineering professionals will judge the presentations on content coverage, team performance, and overall slide quality (e.g., grammar and spelling, use of graphics, general aesthetics). Chart packages are expected to be logically organized with proper supporting slides to augment the scored content and appropriately sized for the time allowed. Content included in appendices will not be scored. Teams should remember they are representing their university to the panel as well as their work for the competition and should strive to do so in a manner befitting of both.

6. While a live demonstration of all functions via the control system is preferred, the judges recognize that it is not always possible. If parts or the entire robot cannot be controlled at the time of demonstration, it is acceptable to move them by hand (with the robot powered off), show video from practice runs, etc. to communicate the functionality and attributes of the system and/or subsystems. Links to any videos used for demonstration should be included within the PDF slideshow submitted to NASA. Teams planning to demonstrate robot functionality within or alongside their charts instead of at the end of them are advised to notify the judges before they begin presenting.

7. Each team must provide a safety plan immediately prior to their demonstration. Teams unable to perform a live demonstration are not exempt from this requirement. Safety plans for videos of robot operations should indicate what safe practices the team followed when they recorded it, and adherence to those practices should be evident in the video. Safety plans for demonstration via software, simulation, display of components awaiting assembly,

or unpowered systems should identify the safe practices the team will follow when their robot is operational.

8. Teams who do not present an acceptable safety plan to the judging panel will not be allowed to demonstrate. Teams who fail to adhere to their safety plan may have their demonstration cut short. In both cases, teams will receive a score of zero for the demonstration portion of the rubric.

SCORING RUBRIC – PRESENTATION AND DEMONSTRATION

Element	**Points**
Scoring Element 1: Content Coverage 1. Project Objectives: Qualitative technical objectives and quantitative Technical Performance Measures 2. Design Process: Systems Engineering approach and execution 3. Project Management: Budget and schedule evolution, team management, risk mitigation 4. Concept Development: System trades, reuse decisions, and planned configuration 5. Design Maturation: Subsystem trades, reuse decisions, and final configuration (mechanical, electrical, and software) 6. System Testing: Test plan, test progress, test results relative to project objectives, etc. 7. Safety: Considerations in design, development, and test; implemented safety features, etc.	**There are 15 points for this element.**

Scoring Element 2: Presentation Execution 1. Slide Quality: Organization, grammar and spelling, formatting, graphics usage, general aesthetics, etc. 2. Preparedness: Team cohesion, time management, proper consideration of the virtual format (e.g., slide visibility, audio quality, participant mic/camera awareness), sufficient mitigation of external distractions and technical issues, etc. 3. Delivery: Presenter body language, cadence, enthusiasm, comfort with the material, communication effectiveness, camera awareness, etc. 4. Question and Answer Session: Demonstrated understanding of questions and quality of responses	**There are 5 points for this element.**
Scoring Element 3: Demonstration *Reminder: Teams who do not present an acceptable safety plan to the judging panel will not be allowed to demonstrate. Teams who fail to adhere to their safety plan may have their demonstration cut short. In both cases, teams will receive a score of zero for the demonstration portion of the rubric.* 1. Demonstration Safety Plan: Safety plan is clearly communicated, suitable for the type of demonstration to be performed, and followed. 2. Preparedness: Organization and flow, consideration of the virtual format (e.g., suitability of demo location, robot visibility, presenter audio quality, participant mic/camera awareness), explanation quality, time management, etc. 3. Scope: Systems demonstrated and their associated depth of coverage	**There are 5 points for this element.**

4. Systems Engineering Paper Rubric (Due Thursday, April 2, 2026)

Resources available:

1. A video series introducing the key products and techniques of systems engineering and how to apply them to your project can be viewed (clickable link) Here.
2. Additional Project Management and Systems Engineering educational videos can be viewed at (clickable link) NASA Lunabotics Videos
3. These videos include the series titled ***Systems Engineering for University Level Engineering Competitions Videos*** that introduces key project management and systems engineering concepts and methods useful for the Lunabotics Challenge.
4. Also included are **five** different project management and systems engineering **seminars** that were recorded live at Lunabotics Challenges. The most immediately relevant of these seminars for the Systems Engineering Paper is the one titled

(clickable link) *How to Develop the Perfect Lunabotics Systems Engineering Paper: And Win the Whole Competition*. We recommend viewing this seminar video at the very start of your project, or before.

5. Undergraduate course materials in systems engineering (one example) are available (clickable link) Here.

Directions:

1. Each team shall submit a complete Systems Engineering Paper electronically in one PDF file.
2. The purpose of the Systems Engineering Paper is for the team to demonstrate how they used the systems engineering process in designing, building, and testing their system. At least one explicit, clear, and preferably numerical example should be provided for every assertion related to elements of the Systems Engineering Paper Rubric.
3. A minimum score of 20 out of 25 possible points must be achieved to qualify to win in this category. In the case of a tie, the judges will choose the winning Systems Engineering Paper.
4. Either one-column or two-column formatting is acceptable. The “professional journal margins” requirement reminds authors to provide appropriate white space at the margins and between sections.
5. Deliverables such as the Systems Engineering Paper (SEP) must comply with expectations of academic honesty at your host university. Plagiarism concerns are taken seriously and are grounds for disqualification.
6. Teams are reminded that plagiarism of a team’s previous Systems Engineering Paper is still plagiarism. The content for this SEP may be inspired by SEPs from previous years’ competitions, but the exact content must be developed specifically for this delivery.

SCORING RUBRIC – SYSTEMS ENGINEERING PAPER

Element	Points

Content 1. <u>Format:</u> **Provide a cover page.** The cover page shall include team name, title of paper, full names of all team members, university name, and faculty advisor's full name. The Systems Engineering Paper shall consist of a maximum of 25 pages (letter size) not including the cover page, title page, table of contents, and a list of references pages. If a team chooses to use appendices, they shall be included in the 25-page count. Content in the appendices shall be referenced and discussed in the main body of the paper. ***Only the first 25 pages of the paper will be judged.*** The Systems Engineering Paper shall be formatted professionally as if for submission to a professional journal: • Organized clearly so that each required rubric element is easy to find • Correct grammar and spelling • Text no smaller than size 12-point font in the main body and appendices • Text no smaller than size 9-point font in graphics and tables • Using professional journal margins and single spaced 2. <u>Faculty Signature:</u> The cover or title page shall include the signature of the sponsoring faculty advisor and a statement that he/she has read and reviewed the paper prior to submission to NASA.	**There are 3 points for 3 elements, one point each**

Element	**Points**
3. <u>Reason for using Systems Engineering:</u> A statement shall be included early in the main body explaining the reason the team used systems engineering in this Engineering Competition (beyond that it is required). (For example: What benefit did it provide? How was systems engineering valuable to your project? You may have other reasons.)	
Project Management Merit 1. <u>Is your system a New Design or Design Update?</u> Clearly state that the system is an entirely new *clean-sheet-of-paper* system design, or that it is a substantial update to a design from a previous year or competition (minor tweaks to a previous design, i.e., simple part replacement at the CDR level of the System Hierarchy, will not allow sufficient exercise of Systems Engineering practices to allow SE Paper scoring).	**9 points for 4 elements.** **1 bonus points may be awarded for exceptional work on Project Management**

The Lunabotics System Engineering Paper should only describe the systems engineering activities performed during this competition year. If your system design is a new clean-sheet-of-paper design, then by default the paper would address the systems engineering you performed to develop all of this new design, implement it, and field it for the competition. If your system design this year is a substantial modification of some previous system, the only systems engineering you should describe in your SE Paper this year is the development of the modified or added system hierarchy elements (subsystems/assemblies/components), how you interfaced the modified or added hierarchy elements with the previous system's hierarchy elements, and how you verified that the key driving requirements are satisfied in the modified system. If you have a substantially updated design, specifically address the following: 1. Provide the system hierarchy for the previous system and ***clearly identify*** on it which hierarchy elements were changed or added/deleted for this year's competition. 2. Explain how you arrived at your decisions why you decided to change (or add/delete) these hierarchy elements and how they should affect the mission. *[3 points]* 1. 2. <u>Major Reviews:</u> At a minimum, describe how you conducted the System Requirements Review (SRR), Preliminary Design Review (PDR), and Critical Design Review (CDR). Clearly demonstrate that these reviews served as control gates. Identify the external reviewers. Provide examples of comments at each Major Review received from external reviewers (and identify the reviewer who made the comment) that led to changes to: • The system design (provide explicit, and preferably numerical, examples of requirements before the comments and the changed requirements as a result of the comments). • The schedule (provide explicit, and preferably numerical, examples of schedule changes as a result of the comments). • The cost budget (provide explicit, and preferably numerical, examples of cost budget changes as a result of the comments). • Technical Performance Measurements values or allocation of values across a system hierarchy level (provide explicit, and preferably numerical, examples of TPM changes as a result of the comments). *[4 points] ß Note increase from last year* .	**Merit elements**

Element	Points
Schedule of work: Discuss the project schedule and how it evolved from inception to disposal of robot system. Provide the original planned schedule before project start (the one you submitted as part of the PMP). Provide as a minimum the actual final schedule (or schedule at the time the paper is delivered). You may provide other interim schedules at relevant milestones as well. Provide examples of: • What changed between the original and subsequent schedules (explicit, and preferably numerical, examples). • Why it changed. • When it changed. • How these schedule changes produced any changes to the cost budget and/or any changes to technical requirements (i.e., requirements before the schedule change and the changed requirements as a result of the schedule change). {When you go through a major review, it's not unusual for the schedule to change.} Demonstrate in the discussion that the schedule was used to manage the project (and not just an after the fact result of the project). *[1 point]* 3. 4. Cost budget: Discuss the cost budget for total project costs (including travel, especially the travel costs if you intend to accept an invitation to UCF to participate in UCF's Lunabotics Qualification Challenge and to KSC to participate in NASA's Lunabotics On-Site Challenge if proffered) and how it evolved from inception to disposal of robot system. Provide the original Total Estimated Project Cost and budget before project start (from your Project Management Plan), and as a minimum the actual final project cost and budget (or at the time the paper is delivered). You may provide other interim cost budgets at relevant milestones as well. Provide examples of: • What changed between the provided cost budgets (explicit, preferably numerical, examples). • Why it changed. • When it changed. • How these cost budget changes produced any changes to the schedule and/or any changes to technical requirements (i.e., requirements before the budget change and the changed requirements as a result of the	

budget change). {When you go through a major review, it's not unusual for the cost budget to change.} Demonstrate in the discussion that the cost budget was used to manage the project. *[1 point]*	

Element	**Points**

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Systems Engineering Merit

1. <u>System Hierarchy:</u>

Provide top-down breakdowns of the system design at each control gate or major review (SRR, PDR, CDR). If you have a substantially updated system design this year, indicate clearly for all Systems Engineering Merit elements in the paper which hierarchy elements are from the previous design, and which are modified or new.

2. <u>Requirements</u>:

Identify the key driving requirements for robot system design, operations, interfaces, testing, safety, reliability, etc., stated in proper “shall” language. (Key driving requirements will include system and lower-level derived requirements.)

Each of these requirements should specifically be addressed when you discuss verification – see Systems Engineering Merit element 8 “Verification of system meeting requirements.”

3. <u>Interfaces:</u>

Identify the key important interfaces between elements in the system hierarchy at each system hierarchy level.

Identify the type (e.g., mechanical, electrical, human, signal, data, communication, etc.) of each key important interface.

Identify which key important interfaces are interfaces to elements external to the system.

Demonstrate how consideration of the interfaces affected system design.

Indicate which of the key driving requirements are interface requirements.

4. <u>Engineering Specialties:</u>

Identify the engineering specialties that you deem important in your system for accomplishing the mission.

Discuss how considerations of these engineering specialties affected design and operations. Identify key driving requirements for design and operations that resulted from the considerations of these specialties in the design process.

Indicate which of these engineering specialties played a role as evaluation criteria in trade studies.

The following are examples of a few engineering specialties that may or may not be important for your system design. There may be several others not listed here that you deem important to your system. Only discuss those that you deem important to your system.

- **Reliability** (what did you have to design into your system to assure that the system will operate properly until the end of the competition)

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8 points for 8 elements, one for each element.

Up to 4 additional points for exceptional work and additional systems engineering methods used.

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Element	**Points**

• **Maintainability** (what did you have to design into your system to assure that you can maintain and repair your system if it fails at the competition, and what tools you might need for repairs and maintenance), • **Logistics** (what did you have to design into your system to assure that if you have a failure at the competition that you have on hand parts for repairs and maintenance, possibly bringing spare parts with you or finding parts sources local to the competition), • **Transportability** (what did you have to design into your system to be able to transport your system to and from the competition in a working condition, including possibly design features and tools needed for easy disassembly for packing/transport/shipping and reassembly at the competition), • **Safety** (what did you have to design into your system to assure that it cannot cause injury or damage during the mission from pack up to leave until return home and disposal)]. 5. <u>Concept of Operations (ConOps):</u> Describe how the team will operate the elements of the system hierarchy, at each system hierarchy level, under the environmental conditions of the competition, to accomplish the robot system mission. Indicate which of the key driving requirements are operations requirements. 6. <u>Technical Performance Measurement:</u> Identify and discuss technical measures that you deem to be important to accomplishing the mission and that you used to manage the project. A Technical Performance Measure is any quantifiable and measurable technical characteristic that you may consider important, difficult to achieve, or particularly risky to project success, and may derive from your Project Technical Objectives. For example, it may be that total mass (high or low) is important to you, or that a low bandwidth is difficult to achieve, or that high speed is risky for your project, or any number of other quantifiable and measurable technical quantities. Provide the allocation of TPM values to elements of the system hierarchy across each level of the system hierarchy. Discuss how that allocation of TPM values changed as the system design evolves through final verification. Demonstrate that the budgeting and management of these important technical quantities was used in management of the design process. 7. <u>Trade Studies:</u> Discuss how important system decisions were made using trade studies, i.e., using weighted evaluation criteria scorings of alternatives. Indicate which of the key driving requirements resulted from trade studies. (The result of any decision important enough to need a trade should by definition be captured as a key driving requirement.) 8. <u>Verification of system meeting requirements:</u> Discuss how you assured or intend to assure that the as-built system satisfies, in the context of the concept of operations and under the environmental conditions of the	

competition, each of the key driving requirements that you identified in the section addressing Systems Engineering Merit element 2 “Requirements.” Provide the success criterion for each verification. Discuss how the key important interfaces were verified or are planned to be verified in the system build processes.	

5. Proof of Life Video (Thursday, April 30, 2026)

Maximum Points – N/A – This is required, failure to submit will result in the team being removed from the challenge.

A video recording of the faculty advisor verifying the following:

- The robot being weighed on a scale.
- The dimensions being verified using a measuring tape.
- The “Commercial Off-The-Shelf” (COTS) E-STOP button red button with a minimum diameter of 40 mm.
- Demonstrate the router(s) are required to be able to turn on/off the 2.4 GHz band.
- The video shall be of one complete cycle of operations
- A safe, functional robot.

Your operations area can use the beach, play, construction, or outdoor volleyball sand as an acceptable granular material. If weather or other issues prevent operations on a granular surface, use your best judgment to record operations.

Submit a YouTube link to your video recording. Present what you can by the due date. The spirit and intent are that you have a safe robot to present to the NASA judging staff and to bring to the on-site events and to prove that your team has a functioning robot.

6. Robot Data Specifications Report (Thursday, April 30, 2026)

The purpose of this form is to collect data about your team's robot. One for each robot.

Information on this deliverable will be provided prior to the on-site events.

The following deliverables are required for Selected Teams to attend the On-Site Finals at KSC

- KSC Lunabotics Regulated Waste Management Overview
  RWMO-School Name
- Liability Waiver Artemis Arena
  LIA-School Name

7. KSC Regulated Waste Management Overview and Liability Waiver Artemis Arena (Due prior to KSC Challenge)

- Students and faculty advisors attending the on-site must read the following and sign the RWMO Acknowledgement and LIA wavier document at the end of this section and submit to ksc-lunabotics@mail.nasa.gov

NASA Environmental Protection Specialist Environmental Assurance Branch (SI-E2)

This is not formal/official RCRA training. This is a basic overview of KSC waste management policy.

TOPICS

KSC Hazardous Waste Subject Matter Expert Background and Regulatory Requirements
Examples of Waste Site and Locations Waste Generators

KSC Hazardous Waste Subject Matter Expert – **Al Gibson**

➤ Will be in the pit area throughout the event

➤ Visiting each team

➤ If you have a question or concern, please contact:

- albert.e.gibson@nasa.gov
- 321-861-0863

Background & Regulatory Requirements

➤ Hazardous Waste Laws, Regulations, & Agencies

- Federal Law: Resource Conservation & Recovery Act (RCRA)
- Regulations: Code of Federal Regulations, Title 40, Parts 240- 299 United States Environmental Protection Agency (EPA)
- Regulations: Florida Administrative Code Chapter 62-730 Florida Department of Environmental Protection (FDEP)
- EPA delegated its authority to enforce RCRA regulations to FDEP
- FDEP performs inspections, permitting, & enforcement at KSC

➤ Hazardous Waste Types

- Characteristic (flammable, corrosive, toxic, or reactive)
- Listed (from a specific source)

➤ Hazardous Waste Violations

- In 2021, Florida's hazardous waste program completed 34 formal enforcement actions (consent orders) for a total of $821,851.75 in civil penalties.
- Criminal penalties – fines and/or jail time

➤ KSC "Large Quantity Generator" of Hazardous Waste

- Stricter management and reporting requirements and must comply with 40 CFR 262.15 and 40 CFR 262.17

➤ Increased oversight by regulatory agencies ➤ Hazardous Waste Cradle-to-Grave Liability

- Listed EPA Waste
- Hazardous waste sites are either Satellite Accumulation Area (SAA) or Central Accumulation Area (CAA)

➤ Controlled Waste

- Non-hazardous wastes not regulated by other laws i.e., used oil dry.

➤ Universal Waste

- Certain wastes that are exempt from being managed as hazardous waste as long as they are recycled, reused, or reclaimed in a certain manner.
- If not managed as universal waste, it falls under the hazardous waste rules

Examples of Waste

➤ Hazardous Waste Examples

- PVC primer, cleaner and cement
- Hypergolic scrubber liquor
- Spent isopropyl alcohol & cleaning solvents
- Solvent wipes

- Paint thinners & unused paint
- Acetone
- Super glue

➤ Examples of Controlled Waste

- Used oil & oily wipes
- Petroleum contaminated material

➤ Examples of Universal Waste

- Aerosol cans
- Batteries

Waste Site and Locations

➤ There will be a SAA waste site in the “Pit Area” and one in the “Bot Shop”.

➤ Place your waste in the appropriate container. If you are not sure, see the Pit Boss.

Waste Generators

Lunabotics waste generators training requirements are to:

- Know hazardous waste has been generated (hazardous material = hazardous waste)
- Know the waste must be managed in accordance with the RCRA regulations (i.e., ensure proper handling, it does not go in the trash or poured/flushed into the sewer.)
- If you are not sure about your waste let the Pit Boss know.

If you see an issue report it to the Pit Boss.

Always follow proper safety protocol and use material as defined by the manufacture.

If you don’t know the KSC way, ask – we are here to help you.

9

Acknowledgement- and Liability Waiver Artemis Arena

Signature Sheet for Faculty Advisor and Students Attending. By signing this sheet, you affirm you have read this document. You will abide by KSC policy and procures for handling hazardous waste while attending Lunabotics.

Any questions or concerns about KSC Hazardous & Controlled Waste Management should be address to Al Gibson, albert.e.gibson@nasa.gov, 321-861-086

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WAIVER OF LIABILITY AND HOLD HARMLESS AGREEMENT FOR ACCESS TO THE ARTEMIS ARENA

1. In consideration of the permission granted by the National Aeronautics and Space Administration (NASA), Kennedy Space Center (KSC), to enter the Artemis Arena, I hereby release NASA, KSC, their officers and personnel, agents, servants, employees, representatives, successors, assigns, (hereinafter referred to as RELEASEES), from liability for any loss, damage, injury, or death, that may be sustained by me, or any of the property belonging to me, while participating in such activity and caused or alleged to be caused in whole or in part by the negligence of the RELEASEES. I have been informed of all the activities in which I will engage as a participant in the Artemis Arena and understand that these activities carry risk of injury, death, and property damage.

2. I also waive all claims, demands, damages, actions and suits against the United States of America and
RELEASEES, arising out of or related to any loss, damage, injury, or death, that may be sustained by me, or any of the property belonging to me, while participating in such activity, or that occurs incident to my entering in, on, or upon KSC premises.

3. I am fully aware of the risks involved and the hazards connected with activities associated with the Artemis Arena, and I am fully aware that there may be risks and hazards unknown to me connected with being on the premises and participating such activities, and I hereby elect to voluntarily participate in said activities with full knowledge that said activities may be hazardous to me and my property. I voluntarily assume full responsibility for any risks of loss, property damage, personal injury, or death, which I may sustain as a result of engaging in such activities.

4. It is my express intent that this Waiver of Liability and Hold Harmless Agreement shall bind the members of my family and spouse, if I am alive, and my heirs, assigns, executors, administrators and personal representative, if I am deceased. In addition, I agree to abide by all safety and security regulations of NASA KSC and the State of Florida. I agree to comply with all directions from security and safety personnel.

5. I certify that I have not been advised against participation in these types of activities by a health professional and that I am physically able to participate in this type of activity. I hereby authorize emergency medical treatment in the event of injury or illness. I also authorize trained health care providers to administer routine and/or emergency medicines and treatments, as needed.

6. In signing this release, I acknowledge and represent that I have read the foregoing Waiver of Liability and Hold Harmless Agreement, that I understand it and that I sign it voluntarily as my own free act and deed. I execute this Release for full, adequate and complete consideration fully intending to be bound by same.

Signed on this _______ day of ____________________________ , 20 ____ .

______________________________ ______________________________

Participant's Name (printed) Participant's Signature

If Participant named above is under the age of 18, I, as Participant's Parent/Guardian consent to the minor's participation in the event, give consent for NASA KSC to seek reasonable and necessary medical treatment for Participant during such event or associated activities, and agree to be responsible for any cost of such treatment.

______________________________ ______________________________

Parent/Guardian Signature Date

WAIVER OF LIABILITY AND HOLD HARMLESS AGREEMENT FOR ACCESS TO THE ARTEMIS ARENA			
Participant’s Name		Participant’s Signature	Date Signed
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Section 4: Lunabotics Week at The Kennedy Space Center (KSC)

CONSTRUCTION – TWO ON-SITE EVENTS

The task is to gather data on Lunar construction by designing and building a robot that will traverse the chaotic Lunar terrain and construct a regolith-based berm. The goal is to build a berm structure which would be useful to the Artemis Mission for blast and ejecta protection during lunar landings and launches, shading cryogenic propellant tank farms, providing radiation protection around a nuclear power plant and other mission critical uses.

Event 1 – Construction Challenge at the University of Central Florida Qualification Challenge

Selected teams will first attend this challenge located at the University of Central Florida, held at UCF's Florida Space Institute's Exolith Lab® in Orlando, Florida (532 S. Econ Cir, Oviedo, FL 32765). You can find current and complete information about UCF's Lunabotics Qualifying Challenge here.

Event 2 – Construction Challenge at the Kennedy Space Center

The 10 highest-scoring teams from the UCF Qualifying Event will be invited to bring their robot and finish the competition here. All other participants are invited to attend the final robot runs, participate in lectures, seminars, and workshops which will be provided with passes to the Kennedy Space Center Visitors Complex (KSCVC). KSCVC information on attractions, parking, and restaurants can be found Here.

ON-SITE SAFETY

Calling First Responders

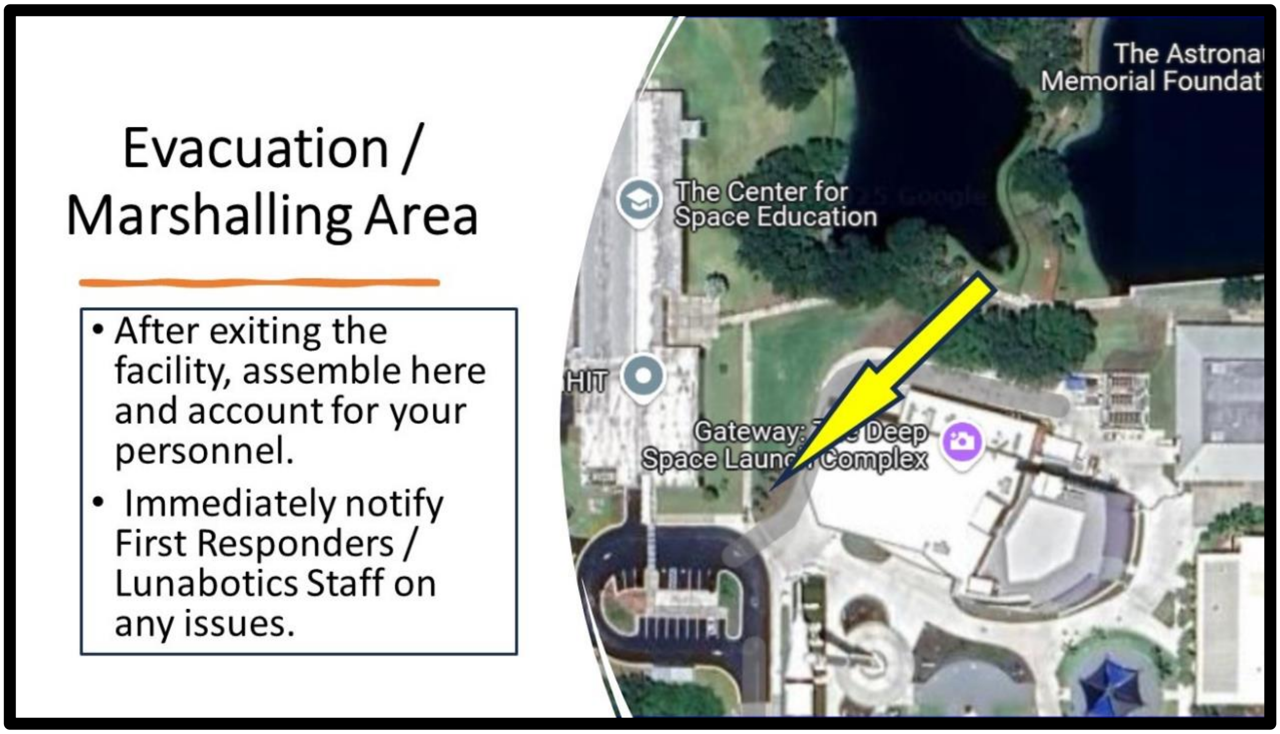
- Remain Calm. If you see something, say something.
- Notify the Pit Boss, Arena Chief, Mission Control Director, Lunabotics Staff.
- If in doubt, call KSC First Responders (fire, paramedics, etc.) at 321.867.7911.
- Tell them why you are calling, answer their questions, and tell them you are located in the Astronauts Memorial Foundation's Center for Space Education, Building M6-306, located on the west side of the Kennedy Space Center Visitor Complex.
- Get people to meet and guide the First Responders to where you are located. There is no judgment on calling for First Responders. Remain Calm.

Marshalling Area

If you are directed to leave the facility for whatever reason, do not hesitate, do not delay, exit the facility, and head over to the east side of the facility designated as the Marshalling

Area. Advisors and Team Leads account for your participants. If there is an issue, immediately notify the Lunabotics Staff and or the KSC First Responders.

Report to the Marshalling Area under the Apollo-Saturn 1B



MISCELLANEOUS

1. **Fire Exits / Eyewash Stations**
   Know where the fire exits, fire extinguishers, and eyewash stations are located.

2. **Kennedy Space Center Visitor Complex Accessibility Information Page**
   This page is available for students / faculty / guests with special needs that may be joining us for the challenge. You are under no obligation to self-identify, but if you want to discuss accessibility issues, please send your inquiries to ksc-lunabotics@mail.nasa.gov

3. **Military Containers (ammo cans)**
   Spray paint or cover up the former military content signage to avoid any extra security checks.

4. Controlled Substances

The consumption of alcoholic beverages or use of any controlled substances by a participant during the event is prohibited. Violation is grounds for disqualification.

5. Weapons

No weapons of any kind are permitted inside Kennedy Space Center Visitor Complex. (contact John Stubbe, KSC Protective Services at john.w.stubbe@nasa.gov) for more information.) Please leave items secured within your vehicle to expedite your entry into the Visitor Complex. Violation is grounds for disqualification of the team. For example, COTS wire strippers should be utilized instead of knives.

6. Unmanned Aerial Vehicles (UAV), Unmanned Aerial Systems

The use of Unmanned Aircraft Systems (Drones) is prohibited at the Kennedy Space Center Visitor Complex and the Astronauts Memorial Foundation Center for Space Education. The UAV/UAS will be confiscated and not returned. Violation is grounds for disqualification of the team.

7. Wildlife

There are alligators, ants, armadillos, mosquitoes, raccoons, snakes, and wild hogs. Do not attempt to feed or interact with the wildlife in any manner.

8. Florida Weather

Stay hydrated, drink plenty of water. You and your off-world mining robots will be exposed to the Florida weather, so be prepared for heat, humidity, wind, and rain. You are responsible for protecting your robot from the elements while outdoors. Remember to have hats, sunglasses, insect repellent, sunscreen (SPF 50 or better), and a raincoat/poncho on hand for the competition. Giant Voice will issue weather alerts for the following lightning conditions:

- Phase I Lightning Condition - prepare to seek shelter.
- Phase II Lightning Condition - seek shelter NOW in any building.

DAILY SCHEDULE

Lunabotics Daily Schedule (Subject to Change)				
Time		May 20	May 21	May 22
0630	AM	Staff Check-In	Staff Check-In	Staff Check-In

0700	AM	Check-In	Pits Open	Pits Open
0800	AM	Judges Meeting	Judges Meeting	Judges Meeting
0900	AM	Opening Ceremony	Construction Run 6	Construction Run 4
1000	AM	Robot Inspections	Construction 7	Construction 5
1100	AM	Robot Inspections	Construction 8	Construction 6
1200	PM	Lunch	Lunch	Lunch
1300	PM	Construction Run 1	Construction Run 9	Construction Run 7
1400	PM	Construction Run 2	Construction Run 10	Construction Run 8
1500	PM	Construction Run 3	Construction Run 1	Construction Run 9
1600	PM	Construction Run 4	Construction Run 2	Construction Run 10
1700	PM	Construction Run 5	Construction Run 3	
1800	PM	Pits Close	Pits Close	Award Ceremony

ON-SITE WEEK

Day 1, 0700 – 0800 Tuesday, May 19, 2026

College Team Check-In, opening ceremony, seminars, run construction robots. 10 teams and 120 students and faculty will check in from 0700 – 0800. An additional 200 students and faculty members are expected to attend this event and will check in during normal KSCVC hours.

Day 2, 0700 – 0800 Wednesday, May 20, 2026

Seminars, run construction robots.

Day 3, 0700 – 1800 Thursday, May 21, 2026

Seminars, run construction robots, award ceremony. The award ceremony may be held in the Central Conference Room. The location of the award ceremony may change based on mission and other factors.

Lunabotics participants who want to attend the on-site event at KSC must do the following (this applies to all teams): have your faculty advisor/team lead of record send one list of names (last, first, middle Initial) to ksc-lunabotics@mail. nasa.gov by Wednesday, May 06, 2025. Tickets and passes will be reserved based on this information. Each team will be allocated 15 tickets. If more are needed, we can have a discussion.

Kennedy Space Center Visitor Complex, Florida

Day 1 – Check-In

Enter the KSCVC entrance, show your parking pass, and proceed to Parking Lot 4. Go to the check-in tent, located on the left side of the main entrance, next to the picnic benches. The faculty advisor and team members shall check in together at the same time, with no exceptions.

Remember, we move spaceflight hardware and launch rockets. The Kennedy Space Center is an operational range with mission and security having priority. Please be patient during delays.

1. Photo Identification
   The following are acceptable:

   - Foreign passport.

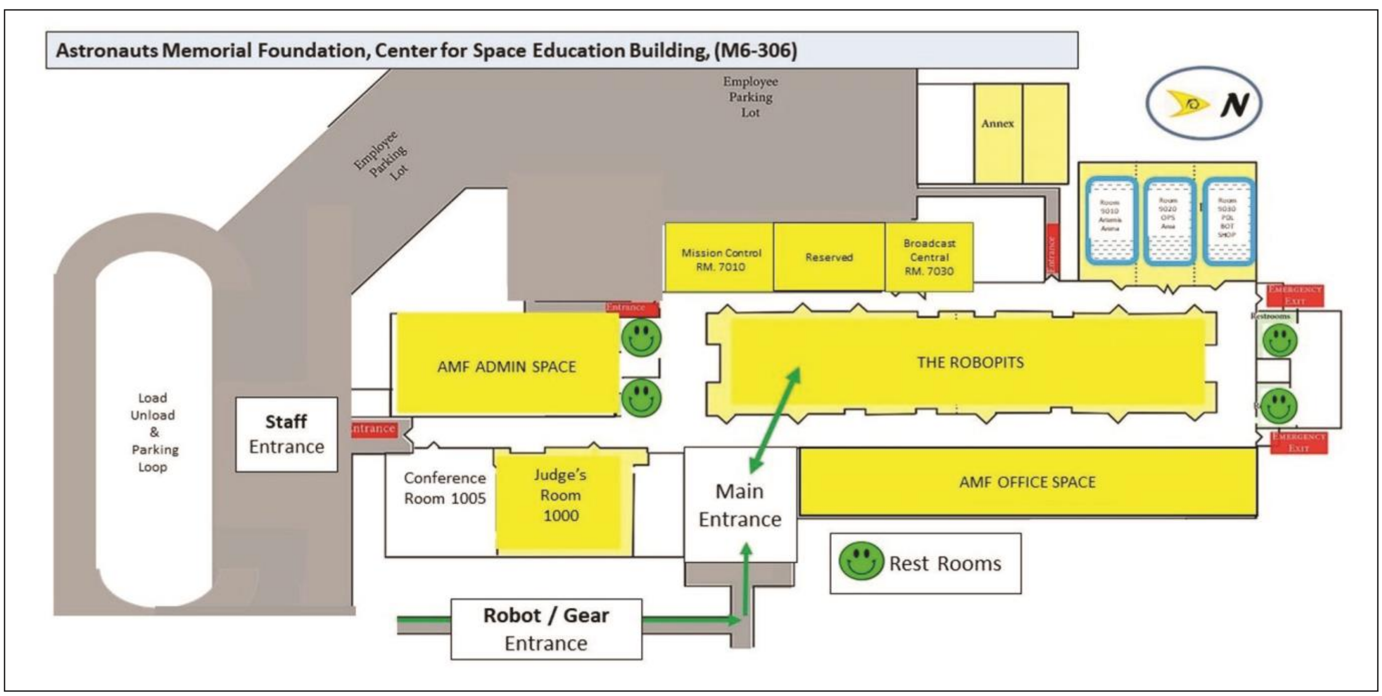
- Permanent resident card or alien registration receipt card (Form I-551).
- PIV card.
- State-issued driver’s license or ID card.
- Tribal ID card.
- U.S. military dependent’s ID card.
- U.S. military ID card.
- U.S. passport.

2. School ID cards cannot be accepted. Damaged ID cards and blurred images cannot be accepted. For students walking into the Complex through security and the magnetometers, leave your equipment tools, wire cutters, nibblers, moopsies, etc., in your vehicle.

3. Check-in staff will direct the students to proceed to the KSCVC Main Entrance and then on to the CSE unloading area.

4. Check-in staff will direct the robots/gear / etc., and one driver will remain with the vehicle. Please comply with the directions from security.

5. Meet your vehicle(s), unload gear, and proceed to the CSE main entrance located on the east side of the building. Proceed to the RoboPits and have the faculty advisor/team lead meet with the Pit Boss for further directions.



Map of the CSE, RoboPits and Artemis Arena

Days 2 and 3 – Competition Days

On these days, show the parking pass to the parking attendant and proceed to the KSCVC Main Entrance. Team members shall show their tickets to enter the Complex's main entrance and proceed to the CSE.

1. Check-Out Robots and Equipment
   There is only one check-in. Robots can check-out at any time but will not be allowed back into the challenge.

2. Tours/Groups
   There may be press, elected officials, NASA HQ representatives, families, STEM 8-12 students, and others touring the CSE during the challenge. Remember, when things go south, and they will, remain professional.

ADDITIONAL ACTIVITIES

There will be various seminars/workshops throughout the week that may include the following topics:

Systems Engineering Seminar

How to Produce a Perfect Lunabotics SE Paper (and How to Win the Whole Competition)

Systems 'd'esign - How All the Systems Engineering Tools Work Together

IPEX Overview

- KSC Swamp Works lunar rover designed for excavation)
- Overview of the ISRU Pilot Excavator (IPEx)
- Design of the IPEx
- Mission Concept of Operations
- Simulation work of IPEx in lunar environment collaboration with Caterpillar
- Demonstration of IPEx's predecessor RASSOR in the Competition Arena
- IPEx on display (possible)
- Announcement of new student competition involving IPEx

Autonomy Seminars

- Q&A with Caterpillar Autonomy Technologists
- 30-minute segments
- 15 mins - students present their autonomy system/questions
- 15 mins - Q&A exchange with CAT Autonomy Technologists
- First come first serve signup
- Open venue
- Learn from each other

UCF - Bootstrapping of the Solar System Economy through the use of Space Resources.

KSC - Tech Transfer University

KSC - NASA Internships

… and many more!

GLOSSARY OF TERMS

1. **Arena: Located in the Astronaut Memorial Foundation's Center for Space Education (CSE) where the robots will perform each competition attempt.**
2. **Astronaut Memorial Foundation's Center for Space Education (CSE)** (https://www.amfcse.org/about-cse): Located adjacent to the northwest end of the Kennedy Space Center Visitor Complex (KSCVC), at the Eastern terminus of Florida S.R. 405 in building M6-306.
3. **Autonomous:** The operation of a robot with no human interaction.
4. **Basaltic Regolith Properties:** Since the properties of regolith vary and are not well known, this competition will assume that basaltic regolith properties are similar to the Lunar regolith as stated in the "Lunar Sourcebook: A User's Guide to the Moon", edited by G. H. Heiken, D. T. Vaniman, and B. M. French, copyright 1991, Cambridge University Press (https://www.lpi.usra.edu/lunar_sourcebook/) .
5. **Black Point-1 (BP-1)** (https://ares.jsc.nasa.gov/projects/simulants/bp-1.html): both parameters (coefficient of friction and cohesion) are highly dependent on the humidity and compaction (bulk density, porosity) of the Lunar soil. Note the following:
   - It does not behave like sand.
     The coefficient of friction has not been measured.
   - There are naturally occurring rocks in the aggregate.
   - BP-1 is made from crushed basalt fines and not commercially available.
   - See "Soil Test Apparatus for Lunar Surfaces"
   - The density of the compacted BP-1 aggregate will be between 1.5 g/cm3 and 1.8 g/cm3.
   - BP-1 behaves like a silty powder soil with most particles under 100 microns in diameter.

- Will be compacted and the top layer will be raked to a fluffy condition of approximately 0.75 g/cm3, similar to the Lunar surface.
- Teams are encouraged to develop or procure simulants based on basaltic minerals and lunar surface regolith particle size, shape, and distribution.

6. **Black Point-1 (BP-1) Reflectivity:** NASA performed tests to answer questions about BP-1 reflectivity for LIDAR (or other LASER-based) navigation systems. The laser is not a beam – it is spread out as a sheet that is oriented in the vertical direction, so it is draped across the BP-1 and across a white/gray/black target that is standing up behind the BP-1 in the images. The BP-1 is the mound at the bottom of each image. Teams can get the reflectivity of the BP-1 by comparing the brightness of the laser sheet seen reflected from the BP-1 with the brightness of the same sheet reflected from the white and black portions of the target. The three images are for the three angles of the laser.

- Note the BP-1 is mounded so they need to account for the fact that it is not a flat surface if they choose to analyze the brightness in the images. The three pictures below were shot with the camera at 10, 16, and 21 degrees relative to the surface.
- The laser was at an angle of 15 degrees. The camera speed and aperture were set to (manual mode): 1/8 s, f/4.5.

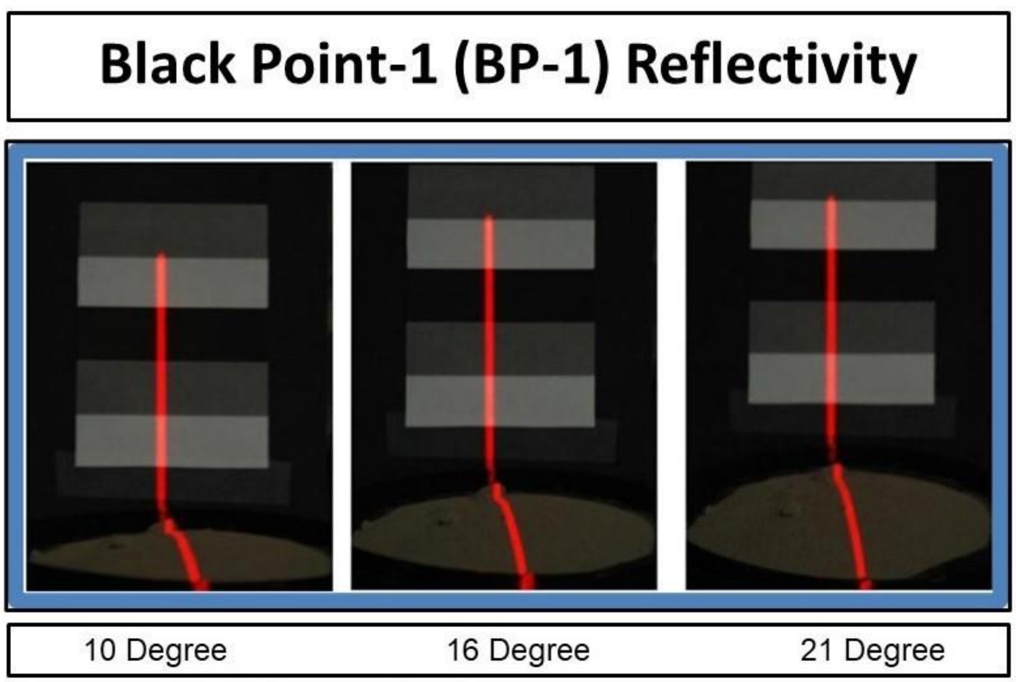


Diagram – LIDAR / Laser Deflection

7. **Bot Shop** (https://public.ksc.nasa.gov/partnerships/capabilities-and-testing/testing-and-labs/prototypedevelopment-laboratory/): the Prototype Development Laboratory's (PDL) Bot Shop is a "mobile machine shop" with grinding, sanding, mini-mill and mini-lathe, band saw, drill press and hand tools. There is no welding capability. Help teams in repairing broken robots but do not have the capability to finish a started robot. The Bot Shop is busy throughout the competition.

8. Center for Lunar & Asteroid Surface Science (CLASS) https://sciences.ucf.edu/class/ **-** is at the intersection of NASA science and exploration for rocky, atmospherel-ess bodies.

9. **Exolith Lab®** (https://exolithsimulants.com/): enable space development and growth by providing high-fidelity analogs to researchers and educators globally. "

10. **In-Situ Resource Utilization (ISRU)** (https://beta.nasa.gov/mission/in-situ-resource-utilization-isru/): To live and work in deep space for months or years may mean crew members have less immediate access to the life-sustaining elements and critical supplies readily available on Earth. However, the farther humans go into deep space, the more important it will be to generate products with local materials

11. **Kennedy Space Center Visitor Complex (KSCVC)** (https://www.kennedyspacecenter.com/): As a Smithsonian Affiliate, we offer the chance to view artifacts of NASA's Mercury, Gemini, Apollo and Space Shuttle Programs in the context of exhibits and attractions that tell the NASA story.

12. **Lunar Highlands Simulant (LHS-1)** **(**https://sciences.ucf.edu/class/simulant_lunarhighlands/) - the LHS-1 Lunar Highlands Simulant has been developed by the CLASS Exolith Lab. It is a high-fidelity, mineral-based simulant appropriate for a generic or average highlands location on the Moon.

13. **Lunar Regolith Density:** The density of regolith at the Apollo 15 landing site averages approximately 1.35 g/cm3 for the top 30 cm, and it is approximately 1.85g/cm3 at a depth of 60 cm. The regolith also includes breccia and rock fragments from the local bedrock. About half the weight of lunar soil is less than 60 to 80 microns in size.

14. **Mission Control:** Mission Control is the operations area where teams will operate or autonomously control their robotic excavator to simulation a lunar In-Situ Resource Utilization (ISRU) construction mission. It is located outside of the Artemis Arenas.

15. **NASA Application Website** (https://stemgateway.nasa.gov/s/course-offering/a0BSJ000003pitJ/lunabotics-2026): The Team Lead starts the team application process and then invites students and faculty advisor(s) to apply within the website. When you run into an issue on the NASA Gateway OSTEM application website, send your inquiries to the website Help Desk.
16. **Regolith Construction Robot:** An autonomous or tele-operated robotic excavator including mechanical and electrical equipment, batteries, gases, fluids, and consumables delivered by a team to compete in the competition
17. **Regolith Construction Points:** Points earned from the competition attempt will be used to determine ranking in the on-site robotic operations category.
18. **Reference Point:** A fixed location signified by an arrow showing the forward direction on the mining robot that will serve to verify the starting orientation of the mining robot within the mining arena.
19. **RoboPits:** The RoboPits are equipped with emergency eyewash stations and disposal containers for industrial waste. Teams are advised to bring additional LED lighting, power strips, and first-aid kits to the RoboPits. This is where teams will work on their robots, meet other competitors, and have their robot inspected before it goes to work.
20. **Rock/Gravel:** The gravel is #57 limestone gravel (~2 cm in diameter) and is intended to simulate the icy-regolith buried in the South Polar region of the Moon. It will have random particle sizes larger than that also mixed into the gravel. The rock/gravel may be mixed in with the BP-1 in small quantities.
21. **Swamp Works**: The Swamp Works is a lean-development, rapid innovation environment at NASA's Kennedy Space Center. It was founded in 2012, when four laboratories in the Surface Systems Office were merged into an enlarged facility with a modified philosophy for rapid technology development. https://public.ksc.nasa.gov/partnerships/capabilities-and-testing/technical-capabilities/swamp-works/
22. **Telerobotic:** the area of robotics concerned with the control of semi-autonomous robots from a distance, chiefly using television, wireless networks (like Wi-Fi, Bluetooth and the Deep Space Network) or tethered connections. Communication with and control of the mining robot during each competition attempt must be performed solely through the provided communications link which is required to have a total average bandwidth of no more than 5.0 megabits/second on all data and video sent to and received from the mining robot.

23. **University of Central Florida (UCF)** (https://www.ucf.edu/): The University of Central Florida is a public research university with its main campus in unincorporated Orange County, Florida. It is part of the State University System of Florida.

READINGS

1. NASA's Plan for Sustained Lunar Exploration and Development https://www.nasa.gov/sites/default/files/atoms/files/a_sustained_lunar_presence_nspc_report4220final.pdf

2. Nasa Lunabotics Robotic Mining Competition 10th Anniversary (2010-2019): Taxonomy Technology Review https://ntrs.nasa.gov/citations/20200003009

3. Novel Approaches to Drilling and Excavation on the Moon https://arc.aiaa.org/doi/pdf/10.2514/6.2009-6431

4. Preparing for Mars: Evolvable Mars Campaign "Proving Ground" approach https://ieeexplore.ieee.org/abstract/document/7119274

5. NASA Human Spaceflight Architecture Team: Lunar Surface Exploration Strategies https://ntrs.nasa.gov/citations/20120008182

6. NASA Centennial Challenge: 3D-Printed Habitat https://ntrs.nasa.gov/api/citations/20170009010/downloads/20170009010.pdf

7. Lunar Spaceport: Construction of Lunar Landing & Launch Pads https://commons.erau.edu/cgi/viewcontent.cgi?article=1017&context=spaceport-summit

8. Towards In-Situ Manufacture of Magnetic Devices from Rare Earth Materials Mined from Asteroids https://robotics.estec.esa.int/i-SAIRAS/isairas2018/Papers/Session%2010c/1_iSAIRAS_Ellery_2018_final-11-40Ellery-Alex.pdf

9. NASA Centennial Challenge: 3D Printed Habitat, Phase 3 Final Results https://ntrs.nasa.gov/citations/20190032473

10. A Process Plant for Producing Rocket Fuel from Lunar Ice https://asmedigitalcollection.asme.org/IMECE/proceedings-abstract/IMECE2019/V006T06A108/1073266

11. Robotic Construction on the Moon https://ntrs.nasa.gov/api/citations/20210018912/downloads/Design%20for%20Robotic%20Construction%20 on%20the%20Moon%20ISU%20SSP%2021%20STRIVES.pdf

12. ISRU: The Basalt Economy.

https://www.researchgate.net/profile/Rodrigo-Romo-2/publication/322567782_ISRU_The_Basalt_Economy/links/5a5fff9c458515b4377b89cb/ISRU-The-Basalt-Economy.pdf

13.RASSOR - Regolith Advanced Surface Systems Operations Robot
https://ntrs.nasa.gov/citations/20150022134

14.Building a Vertical Take Off and Landing Pad Using in situ Materials.

http://ssi.org/2010/SM14-proceedings/Building-a-Vertical-Take-Off-and-Landing-Pad-using-in-situ-MaterialsHintze.pdf

15.Mars Water In-Situ Resource Utilization (ISRU) Planning (M-WIP) Study
https://mepag.jpl.nasa.gov/reports/Mars_Water_ISRU_Study.pdf

16.Affordable, Rapid Bootstrapping of the Space Industry and Solar System Civilization
https://arxiv.org/abs/1612.03238

17.Additive Construction with Mobile Emplacement (ACME)
https://www.researchgate.net/profile/Rodrigo-Romo-2/publication/322567924_Additive_Construction_with_Mobile_Emplacement_ACME/links/5a5ffe7faca2727352458863/Additive-Construction-with-Mobile-EmplacementACME.pdf

18.A Review of Extra-Terrestrial Mining Concepts
https://ntrs.nasa.gov/citations/20120008777