CoSMiC

(Collegiate Space Mining Competition)

2024-2025

Guidebook

SECTION 1: APPLICATION AND ADMINISTRATION

1. CoSMiC Objective

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

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

CoSMiC encourages innovation in student designs and increases the potential of identifying clever solutions to the many challenges inherent within the CoSMiC competition. Advances for off-world construction offer new possibilities for the same activities here on Earth. The skills developed in CoSMiC apply to other high-technology industries that rely on systems engineering principles. These industries will create a workforce posed to lead a new space-based economy and add to the economic strength of our country.

2. CoSMiC Events

This is the website to the overall challenge. Apply using this link. You will receive an email letting you know the selection status of your application. Those teams selected will continue with the challenge consisting of the following events:

Event 1 – Project Development Challenge:

1. Project Management Plan
2. Systems Engineering Paper (optional)
3. Proof of Life Video

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

Event 2 – CoSMiC On-Site Challege at Iowa State University

1. This event is held at Iowa State University.
2. The team's Presentation will be On-site during the competition dates.
3. Compete in the ISU arena.

3. CoSMiC Regulations and Policies

Frequently Asked Questions / Ask for Help

1. There will be no response to requests for information already contained in the Guidebook, to change a deadline or a rubric.
2. The team is responsible for monitoring the CoSMiC Website, and the CoSMiC discord for notices, updates, feedback requests, and responses to FAQs. The Guidebook and the FAQs shall be read together as one document.
3. The faculty advisor and/or team leads shall submit the FAQs. Email shall use an ".edu" domain address. This applies to the application process and communications with CoSMiC. We can only respond to ".edu" addresses.
4. Provide your school's name, cite the relevant rule/paragraph number in the guidebook, your inquiry, and send it to csmc_isu@iastate.edu. There will be no response to inquiries from any other source.
5. We understand the on-site events may conflict with final exams and /or your commencement ceremony. We can assist with proctoring exams on-site; please don't ask us to change dates or deadlines.

5. Roles and Responsibilities

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

6. Code of Conduct

CoSMiC is a Cardinal Space Mining Club (CSMC) Student Challenge and is held in a positive and safe environment. Students and faculty shall conduct themselves with integrity as to the spirit and intent of the rules, rubrics, and regulations. Violation of the intent of a rule is a violation of the rule itself. A team found in violation of the rules and rubrics, exhibiting unprofessional behavior, or not following the directions of the CoSMiC staff may be assessed penalty points or may be disqualified from a competition run or the entire Challenge. The CoSMiC Staff have the authority to act in this manner.

7. Appeals

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

8. Participant Waiver

Participants hereby waive any claims against ISU, 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 ISU's related entities for any injury, death, or property damage/ loss arising from or related to ISU's CoSMiC, whether such injury, death, or property damage/loss arises through negligence or otherwise, except in the case of willful misconduct.

9. Social Media

The CoSMiC Discord allows us to post notifications to the teams and the teams to communicate with each other, post photos, etc.

Discord: https://discord.com/invite/xc9MTRb9Hs

Facebook: https://www.facebook.com/ISUSpaceMining

Follow the CSMC on X and Instagram as well! @ISUSpaceMining

10. Media Advisory

All participants and visitors to CoSMiC at ISU give permission to be photographed/videotaped by ISU or its representatives for potential use in future media products, unconditionally releasing ISU and its representatives from any claims and demands.

13. The CoSMiC Awards

1. **Construction** – 1st, 2nd, and 3rd place will be awarded for teams who score the most points during robotic operation (does not include autonomy points).
2. **Autonomy** – 1st, 2nd, and 3rd place will be awarded for teams who score the most points for autonomous operation.
3. **Innovation** – 1st, 2nd, and 3rd place will be awarded. Points will be awarded by judges during the presentation and application of innovation.
4. **Systems –** 1st 2nd 3rd place will be awarded.

14. Eligibility

1. The schools shall:
   Be an accredited Institution.
   Enroll one (1) team per school only.
   Be a post-high school, vocational/technical school, college, university, etc.
   Be in the United States, its Commonwealths, territories, and or possessions.

2. The students shall:
   Be 18 years old at registration.
   Be currently enrolled and in good standing with their school.
   Be from the same school as their team. Participate in one team.
   Have been enrolled in and a member of the team within the academic year.

   Note: Students who graduate during the fall semester are welcome to participate and compete with their team.

3. The Teams shall:
   Have its own working robot(s).
   Have at least two (2) undergraduate or graduate students.
   The number of students on the team is at the school's discretion.

4. The Faculty / Advisor (F/A) shall:
   Supervise the team as to the spirit and intent of the Guidebook.
   Be employed by the institution and authorized to represent it. Cannot be a part of the team.

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

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 CoSMiC. 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 be submitted to the submission link in the deliverables section of this document, and include the signature of the faculty advisor:

Faculty Advisor: ____

University / College: ____

Date: ____________

I concur with the concepts and methods by which the students plan to compete in "NASA CoSMiC". 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.

SECTION 2: TECHNICAL

1. RoboPits

The RoboPits are in the Student Innovation Center. This is where you will meet with competitors from across the country and prep your robots before heading to the Competiton arena. The RoboPits are equipped with emergency eyewash stations and disposal containers for used aerosol cans, batteries, degreasers, and wipes used as cleaners. Teams are encouraged to bring additional LED lighting, floor coverings/mats to facilitate cleaning, power strips, and a first-aid kit to the RoboPits.

2. Check-in and Set-up

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

3. Team Spirit

You are responsible for making your pit identification sign. Use common sense, and keep it fun; under 6’ tall, you can use LED light strings. Remember, ISU Fire/Safety may ask you to remove it if it is outside their policy.

4. Safety (robot) and Communication (comm) Inspection

1. The inspection stations will be identified.
2. The robot will have to pass the safety inspection first before moving forward.
3. The inspections are not scheduled and are on a first-come, first-served basis.
4. The Pit Boss will provide the team lead with the inspection card.
5. Return the card when you have passed the Safety and Comm checks and are ready to compete. The card is to ensure that all teams have had their robot(s) checked out prior to entering the arena.
6. Before each competition run, an escort will come to the RoboPit to retrieve the team; do not leave without the escort.

5. Preparing for the Competition Attempt

The teams will be brought to the safety inspection approximately 30-45 minutes before the scheduled start time to ensure a smooth flow. At this time up to four (4) students will go to the personal protective equipment (PPE) prep area to don the PPE gear they will be wearing in the CoSMiC Arena. Following the inspection, the escort will take the team to the arena, where arena escorts will take over. If the team is not ready or cannot be located, the competition run time will be given to another team that is ready.

6. Clean-up and Check-out

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

7. Stop Work Order (SWO)

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

8. The ISU Machine Workshop

The ISU machine shop” has grinding, sanding, mini-mill and mini-lathe, band saw, drill press, hand tools and welding. The Workshop can help repair broken robots but does not have the capability to finish a started robot. You have the privilege of using this resource to make repairs and/or modifications to your robots on a first-come, first-served basis. Protective eyewear shall be worn in the workshop.

9. Safety in the RoboPits and CoSMiC Arena (participants and other carbon-based life forms)

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

10. Personal Protective Equipment (PPE)

Teams will be provided goggles, N-95 masks, bunny suits, rubber gloves and booties for use in the CoSMiC Arena. The teams are responsible for providing all other OSHA, ANSI, etc., or equivalent required PPE (see SECTION 2: TECHNICAL, 14. Eye / Face Protection, 15. Hand Protection, 16. Hearing Protection, 17. Foot Protection).

11. Regolith Simulant

1. Is a crushed agricultural limestone mixture
2. It is alkaline and may cause skin and eye irritation.
3. If you are allergic to talcum powder, it is a good indication that you may be allergic to the Regolith simulant.
4. Participants are required to don Personal Protective Equipment (PPE) before coming into contact with the Regolith simulant.
5. The Regolith Simulant contains a small percentage of crystalline silica, which is a respiratory nuisance. Respiratory protection shall be used.
6. All PPE must be ANSI-approved, UL-Listed, CE EN166 rated, AS/NZS certified, or CSA rated, as applicable. The following describes the common PPE that you are required to wear.

12. Respirators

1. OSHA1926.1153 – Respirable Crystalline Silica, 29 CFR 1910.1053. Permissible exposure limit (PEL). The employer shall ensure that no employee is exposed to an airborne concentration of respirable crystalline silica in excess of 50 μg/m3, calculated as an 8-hour TWA.
2. The Respiratory Protection standard, paragraph 29 CFR 1910.134(g)(1)(i)(A), states that respirators shall not be worn when facial hair comes between the sealing surface of the facepiece and the face or that interferes with valve function. Facial hair is allowed as long as it does not protrude under the respirator seal or extend far enough to interfere with the device’s valve function.
3. OSHA – has not exempted any workers for religious reasons; however, we recognize that if such a situation should arise, there are respiratory protection alternatives, such as loose-fitting hoods or helmets that will accommodate facial hair.
4. OSHA – workers cannot sign a waiver to be exempted from the stated requirements. A release or waiver is not possible for employees. That being said, when an employer is looking to accommodate a religious practice, they may have to explore respiratory protection alternatives like helmets or loose-fitting hoods.
5. Most N95 respirators are manufactured for use in construction and other industrial-type jobs that expose workers to dust and small particles. They are regulated by the National Personal Protective Technology Laboratory (NPPTL) in the National Institute for Occupational Safety and Health (NIOSH), which is part of the Centers for Disease Control

and Prevention (CDC). NIOSH-approved N95 Particulate Filtering Facepiece Respirators are required in the CoSMiC Arena.

6. There are very few options, but the best choice would be for the individual to purchase a hooded-powered air purifying respirator (PAPR) – especially if they intend to stay in a career that requires the occasional use of PPE. These items shall be provided by the institutions for their participants if required.

13. Eye/Face Protection

1. Without exception, protective eyewear must be worn in the individual pits and CoSMiC Arena.
2. Teams must provide their own eye protection for team members and guests.
3. It is also a good practice and principle to wear eye protection in the following situations:
   - Any area posted with signs requiring the use of eye protection.
   - When performing any work on the robot, including grinding, drilling, soldering, cutting, welding, etc.
   - When there is a risk of flying particles or chemical exposure (such as splashes, splatters, and sprays).
   - Several forms of eye/face protection are available to provide protection from related hazards, including safety glasses with side shields, goggles, face shields, and face masks.
   - Safety Glasses and protective eyewear are designed to provide a shield around the entire eye to protect against hazards such as splashes of liquids, burns from steam, compressed air, and flying wood or metal debris. To prevent injury, all individuals in the pit area, the practice field area, and the arena must wear safety glasses or protective eyewear that is ANSI-approved,
   - Reflective lenses are prohibited; your eyes must be clearly visible to others. Accommodation will be made for participants that require tinted safety glasses.
   - Prescription Glasses: If you wear prescription glasses that do not have a marked safety rating, you must wear rated safety goggles over them to achieve adequate protection. If you wear marked safety-rated glasses, you may use ANSI-approved
   - Safety-rated glasses, side shields, and frames can be identified by markings stating the standard that they are rated to (ex. Z87.1).

14. Hand Protection

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

15. Hearing Protection

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

16. Foot Protection

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

17. Clothing Allowed

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

18. Clothing Not Allowed

Hair must not impede vision or come in contact with work. Hair must be kept away from the eyes. Long hair must be tied back. Hair longer than 6 inches from the nape of the neck must also be pinned up (use of hair nets or hats is acceptable). Flowing garments and neckwear such as ties and scarves that hang loose. Caps worn low over the eyes so as to impede vision. Cropped shirts, plunging necklines, spaghetti straps, or ripped shirts.

Ripped jeans, shorts, capris, or skirts. Loose or flowing tops with wide/bell sleeves, outerwear such as coats or shawls. Sandals, open-toe, open-back, or open weave shoes, and shoes with holes in the top or sides that will expose the skin to regolith or retain regolith.

19. Spectators

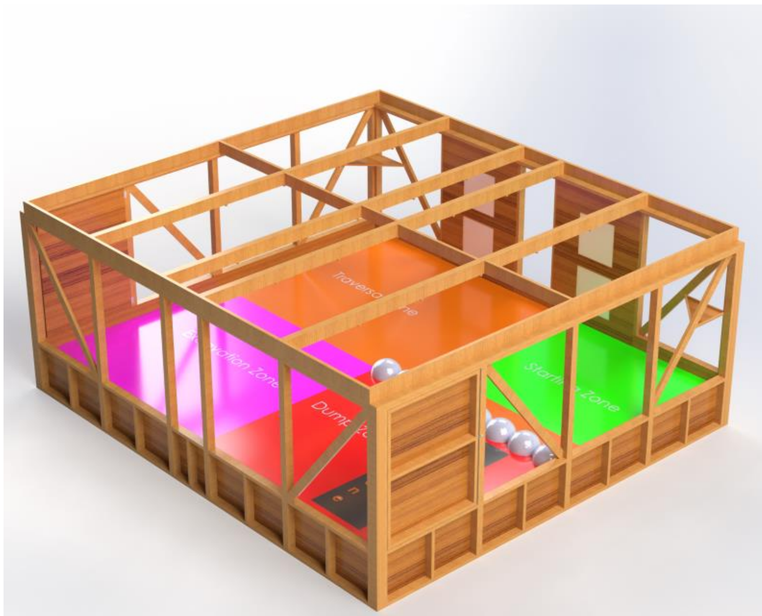
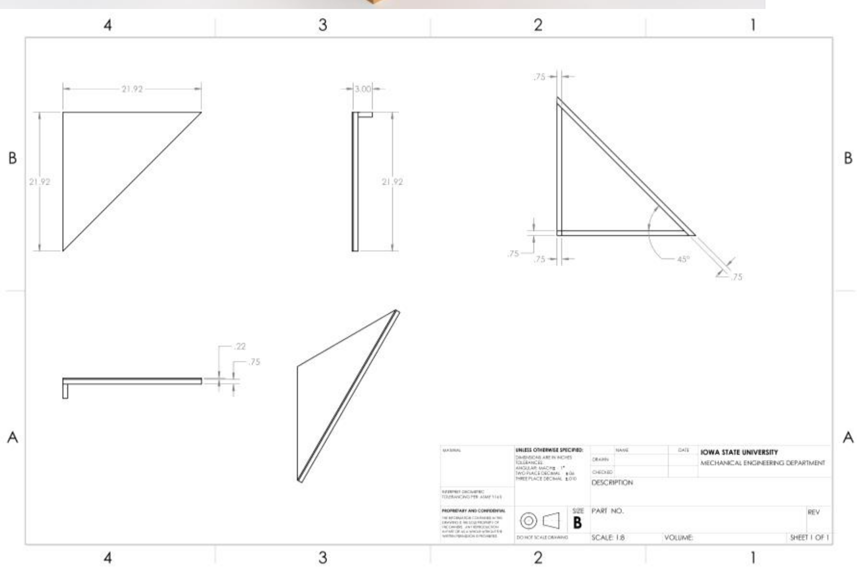
Should follow the same rules as participants. Spectators who do not meet the footwear requirement for participants, as described above, are not allowed inside individual team pits or in any locations where robots are being worked on.

There will be view locations on campus that will not require PPE. More information to come.

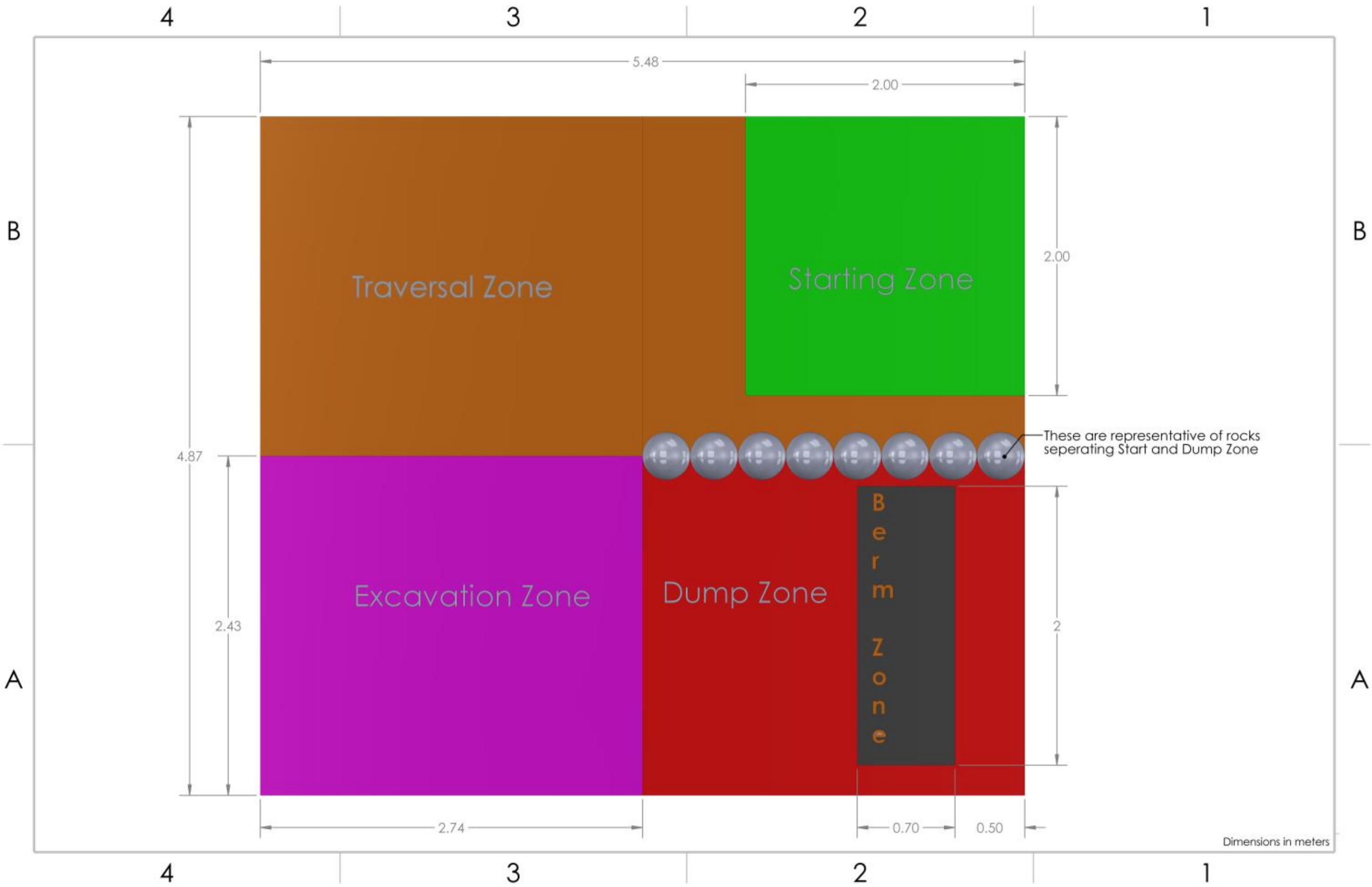
CoSMiC ARENA SPECIFICATIONS AND PROTOCOL

1. CoSMiC Arena Specifications

1. The CoSMiC arena is filled with Aglime Regolith Simulant
2. The arena area measures 5.48 meters long and 4.87 meters wide. The CoSMiC arena contains 45 cm depth of Regolith.
3. Larger rocks may also be mixed in with the Regolith Stimulant in a random manner

4. **Obstacle Zone** - the judges will attempt to construct the obstacle field in such a way as to require obstacle detection, mapping, and navigation planning to determine a “slalom” route to reach the excavation zone.
5. **Boulder Obstacles** - there will be at least three (3) obstacles placed on top of the arena surface within the obstacle zone area before each competition attempt is made. The placement of the obstacles will be randomly selected before the start of the competition. Each obstacle may have a diameter of approximately 30 cm to 40 cm and will have random heights. There may be boulders in the excavation zone, these will not exceed the dimensions of any in the obstacle zone.
6. **Crater Obstacles** - there will be at least three (3) craters of varying depth and width, being no wider or deeper than 40 - 50 cm in the obstacle zone.
7. 
8. 

9. Mounting of Beacons for Navigation: There is a shelf (Drawing Above) in the corner of the starting zone that will be used as a mounting point for any ground-based support equipment. The shelf may not be modified, e.g. screwing to it, but clamps and the like are encouraged.
10. Arena CAD can be found as 2024 SolidWorks files at https://github.com/Cardinal-Space-Mining/2025-Comp-Arena



2. CoSMiC Arena Protocol

1. Once competition runs begin, the CoSMiC 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 CoSMiC 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 CoSMiC Arena.
5. 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).
6. Photography and personal electronic devices (smart devices, tablets, cell phones, etc.) will be restricted in the CoSMiC Arena.
7. Team members placing the robot in the Competition Arena will don PPE in the RoboPits staging area.
8. When properly attired, they and Mission Control teammates will be escorted to the CoSMiC Arena entrance.
9. The Arena Chief will grant access to CoSMiC Arena staging area when ready.
10. Student cell phones, cameras, tablets, and other restricted electronics devices brought into the CoSMiC Arena shall be placed on the Arena Chief's station to be retrieved later. No exceptions.
11. Team members will be given a Pre-Task Briefing (PTB) containing specific information needed for the run.
12. 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.
13. 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.
14. Approaching the Competition Arena before instructed to do so by the Arena Chief or designated representative is not permitted.
15. The Arena Chief will inform the team members in the staging area when the Competition Arena is ready for the team.

16. At the direction of the Arena personnel, the team members will place their robot in the Arena and perform setup activities necessary to establish communication with Mission Control. The construction robot will be placed in the arena in a randomly selected starting position and direction. Assume there are positive and negative obstacles. Assume you cannot drive over the obstacles.
17. When completed or directed by Arena personnel, the team members will promptly exit the Arena.
18. 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.
19. 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 CoSMiC Arena. Violation of this rule may result in team disqualification.
20. 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.
21. At the HEPA station, team members shall:
    1. Vacuum excess Regolith from their robot.
    2. Doffing Protocol in the CoSMiC Arena After completion of the Robot Run
        - ❖ Remove hood then remove Tyvek coverall rolling down from inside of suit.
        - ❖ Remove gloves taped to suit. Place coveralls in designated waste container:
        - ❖ Participants: Remove eye protection and return to PPE attendant.
        - ❖ Remove N-95 filtering face piece and discard.
        - ❖ Judges: Shall maintain their PAPR equipment IAW the manufacturer's specifications.
        - ❖ Properly discard all used PPE.
        - ❖ Return goggles for cleaning and reuse.
        - ❖ Wait until directed to exit the CoSMiC Arena by the Arena Chief or designated personnel.

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 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

1. Volumetric dimensions - robot(s) shall be contained within a payload envelope measuring 1.50 m length x 0.75 m width x 0.75 m height. The orientation of these dimensions may be chosen by the team. It may deploy or expand beyond the envelope after the start of each attempt but shall not exceed 1.25 m in additional height (which is 2 m above the surface of the regolith). Multiple robot systems are allowed but the starting dimensions of the whole system (all the robots) shall comply with the volumetric dimensions given in this rule.
2. Robots will be inspected for the volumetric dimensions in the stowed configuration during the Safety Inspection. A "jig" frame will be placed over the rover for volume constraint verification. No modifications or team robot interaction is permitted during this verification.
    - Robot Mass - a maximum mass of 80kg. Subsystems/equipment on the robot that are used to transmit commands / data and video to the telerobotic operators are counted toward the mass limit.
    - The mass of the navigational aid system, including any beacons or targets not attached to the robot, is included in the maximum mining robot mass limit of and must be self-powered.
3. Equipment not on the robot used to receive data from and send commands to the robot for telerobotic operations is excluded from the mass limit. Multiple robot systems are allowed but the total mass of the whole system shall comply with the mass given in this rule.

4. External robot antennas are required to reduce potential interference problems.
5. Robots shall have a minimum of four (4) lifting points, safe for human hands and clearly marked (ISO 7000-1368) for students and staff to use. Teams are responsible for placement and removal of their construction robot onto the Regolith. There must be one person per 20 kg of mass of the construction robot, requiring a minimum of four people to carry the maximum allowed mass of 80 kg.
6. The robot can separate itself intentionally, if desired, but all parts of the robot must be under the team's control at all times. Unintentional breakage will not be counted against the team. The robot does not have to re-assemble prior to the end of the competition run.
7. The robot can run either by telerobotic (remote control) or in autonomous operations and cannot have any touch sensors to sense and avoid obstacles.
8. Reference Points / Reference Arrows - The launch volume dimensions of the robot may be oriented in any way (length, width, height can be defined along any of the X, Y, Z axes, dimensions correspond to the typical payload volume available on today's Lunar landers).
    - The team must declare the robot orientation by length (arrow 1) and width (arrow 2) to the inspection judge. Reference Point (arrow 3) - must mark the forward direction of the mining robot in the starting position configuration (the reference location and arrow pointing forward can point any direction of the team's choosing, except up or down). The arrow is used only to orientate the robot prior to starting the robot run to face the robot arrow either north, east, south, or west after spinning the direction wheel.
    - The judges will use this reference point and arrow to orient the mining robot in the randomly selected direction and position (you can use a permanent-type marker) indicating the team's choice of forward direction on any location on the robot is acceptable if multiple arrows do not conflict.

3. E-STOP Button

1. Also known more formally as an emergency brake, emergency stop (E-stop), emergency off (EMO), kill switch, or emergency power off (EPO), is a safety mechanism used to shut off machinery in an emergency, when it cannot be shut down in the usual manner.
2. OSHA and relevant standards such as IEC 60204-1 state that an e-stop must be readily accessible to the operator. Additionally, it should be unobstructed—no collars or actuation restrictions—and easily accessible without having to reach over, under or around to actuate. Machine-building standards such as ANSI B11, B11-19 and National Fire Protection Agency (NFPA) 79 also address specifics in regard to safety devices such as an e-stop.
3. OSHA and relevant standards such as IEC 60204-1 further state that resetting of the e-stop alone shall not resume operation. A second deliberate action is needed, such as the pressing of a reset button. This could include twisting the mushroom button and allowing it to spring back up or pulling the button back up to reset. It cannot automatically reset.
4. The robot shall be equipped with an E-STOP button. An unmodified "Commercial Off-The-Shelf" (COTS) red button is required. Use sound engineering practices and principles in placing and securing the E-STOP button on your robot(s), failure to do so may result in a safety disqualification. The E-STOP button shall have a minimum diameter of 40 mm and require no additional steps to access it.
5. The E-STOP button shall be placed on the highest practical location on the robot. There shall be only one E-STOP button per robot and in the case of multiple robots, each robot shall have its own E-STOP button
6. Disabling the E-STOP button without authorization from the Staff shall result in a safety disqualification.
7. The E-STOP button shall stop the construction robot's motion and disable power with one push motion on the button. It shall be reliable and instantaneous. A closed control signal to a mechanical relay is allowed as long as it stays open to disable the robot. This rule exists in order to have the capability to save the construction robot in the event of a fire or other mishap. The button shall disconnect the batteries from all controllers (high current, forklift type button) and it shall isolate the batteries from the rest of the active sub-systems as well.
8. Only onboard laptop computers may stay powered on if powered by its own, independent, internal computer battery. For example: it is acceptable to have a small battery onboard that only powers a Raspberry Pi control computer, and whose power does not flow through the main robot E-STOP button.

4. Power Meters / Data Loggers

1. The robot shall provide its own onboard power. No facility power will be provided to the robot during the attempt. There are no power limitations except that the robot must be self-powered and included in the maximum mass limit. Shall be schematically located between the battery and kill switch, so the readings are not erased if the E-STOP button is activated. The devices shall be placed on the highest practical location on the robot and be easily visible.

2. The energy consumed shall be recorded with a “Commercial Off-The-Shelf” (COTS) electronic data logger device. Actual energy consumed during each attempt shall be shown to the judges on the data logger immediately after the attempt (‘immediate’ includes time for the judge climbing into the arena, finding the logger, and recording the power reading). If the logger is independently powered, then the robot can be remotely powered off after the run. Although this is acceptable, it is not recommended in case the robot needs to be commanded to complete an operation so that it can be removed from the arena.

5. Battery Protocol

1. This is for the Lithium-Ion / Nic-Cad batteries used in your robots.
2. Batteries must be attended to while charging. Chargers shall be unplugged overnight.
3. Battery containers must be designed for safely storing, charging, and transporting lithium-ion batteries, or approved equivalent.
4. Batteries must be stored in upright containers; batteries cannot be in contact with each other.
5. Batteries that have been dropped must be inspected for damage and replaced as needed.
6. Do not store batteries that are hot to the touch after charging.
7. If a battery continues to feel hot after charging, if possible, remove it from the building and place outside and notify event staff.
8. To ensure the robot is usable for an actual mission, it cannot employ any fundamental physical processes, gases, fluids, or consumables that would not work in an off-world environment. For example, any dust removal from a lens or sensor must employ a physical process that would be suitable for the Lunar surface. Teams may use processes that require an Earth-like environment (e.g., oxygen, water) only if the system using the processes is designed to work in a Lunar environment and if such resources used by the robot are included in the mass of the robot. Closed pneumatic systems are allowed if the gas is supplied by the robot itself. Pneumatic systems are permitted if the gas is supplied by the robot and self-contained.
9. The rules are intended for robots to show an off-world plausible system functionality, but the components do not have to be traceable to an off-world qualified component version. Examples of allowable components are: Sealed Lead-Acid (SLA) or Nickel Metal Hydride (NiMH) batteries; composite materials; rubber or plastic parts; actively fan cooled electronics; motors with brushes; infrared sensors, inertial measurement units, and proximity detectors and/or Hall Effect sensors, but proceed at your own risk since limestone simulant is very dusty and abrasive
10. Teams may use honeycomb structures as long as they are strong enough to be safe and the edges sealed to prevent dust intrusion, a wheel with a large honeycomb 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.
11. Teams may not use GPS, rubber pneumatic tires; air/foam filled tires; open or closed cell foam, ultrasonic proximity sensors; or hydraulics

12. Robotic Operations:

❖ The robot cannot be anchored to the sand prior to the beginning of the proof of life demonstration.
❖ At the start of the competition run, the mining robot may not occupy any location outside the defined starting position in the regolith arena.
❖ The robot must operate within the regolith arena; it is not permitted to pass beyond the confines of the outside perimeter of the arena or hit the walls during the competition run.
❖ The robot may not use any process that causes the physical or chemical properties of the regolith simulant to be changed or otherwise endangers the uniformity between competition attempts. The mining robot may not penetrate the regolith simulant surface with more force than the weight of the mining robot before the start of each competition attempt.
❖ No ordnance, projectile, far-reaching mechanism, etc. may be used. The mining robot must move on the regolith simulant surface.
❖ 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.
❖ 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.

- ❖ 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 faculty member responsible for "eye-safe" lasers.

13. Communications:
    1. Each team is required to command and monitor their construction robot over the provided network infrastructure.
    2. This configuration must be used for teams to communicate with their robot.
    3. The "Lander" camera is staged in the Construction Arena. Lander Control Joystick and camera display will be located with the team in the Mission Control Center (MCC).
    4. The MCC will have an official timing display.
    5. Handheld radios will be provided to each team to link their Mission Control Center team members with their corresponding team members in the construction arena during setup.
    6. Each team will provide the wireless link (access point, bridge, or wireless device) to their construction robot, which means that each team will bring their own Wi-Fi equipment/router and any required power conversion devices. Teams must set their own network IP addresses to enable communication between their construction robot and their control computers, through their own wireless link hosted in the Construction arena.
    7. In the construction arena, CoSMiC will provide an elevated network drop (male RJ-45 Ethernet plug) that extends to the Mission Control Center, where CoSMiC will provide a network switch for the teams to plug in their laptops.
        a. The network drop in the Construction arena will be elevated high enough above the edge of the regolith bed wall to provide adequate radio frequency visibility of the Construction arena.
        b. A shelf will be set up next to the network drop at a height 0 to .5 meter above the floor of the arena and will be placed in a corner area. During robot system operations during the competition, there may be some dust accumulation in this area. This shelf is where teams will place their Wireless Access Point (WAP) to communicate with their construction robot.
        c. Teams are strongly encouraged to develop a dust protection cover for their wireless access point (WAP) that does not interfere with the radiofrequency signal performance.
    8. Power Interfaces
        a. CoSMiC will provide a standard US National Electrical Manufacturers Association (NEMA) 5-15 type, 110 VAC, 60 Hz electrical jack by the network drop. This will be no more than1.5 meters from the shelf.
        b. The team must provide any conversion devices needed to interface team access points or Mission Control Center computers or devices with the provided power sources.
    9. During the setup phase, the teams will set up their access point and verify communication with their construction robot from the Mission Control Center.
    10. The teams are required to use any combination of the USA IEEE 802.11 standards for their wireless connection (WAP and rover client) such as WIFI 7, WIFI 6e and WIFI 4 running on 2.4, 5 and 6GHZ frequencies respectively.
    11. Each team will be assigned an SSID that they must use for the wireless equipment.
        a. Teams SSID will be "Team_##."
        b. Teams are required to broadcast their SSID.
    12. The use of specific low power (these power consumers are not part of the total power consumed COTS meter) Bluetooth transmission equipment in the 2.4 GHz range is allowed for sensors and other robot communications. Bluetooth is allowed only at power levels of Classes 2, 3, and are limited to a maximum transmit power of 2.5 mW EIRP. Class 1 Bluetooth devices are not allowed.
    13. The use of 2.4 GHz ZigBee technology is prohibited because of the possibility of interference with the competition wireless transmissions.
    14. Interference avoidance will be the responsibility of the Team and will not be grounds for protest by any team.
    15. Radio Frequency Power:
        a. All Team-provided wireless equipment shall operate legally within the power requirements set by the FCC for Unlicensed Wireless equipment operating in the ISM radio 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.

    b. 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 this is NOT allowed in the competition.
    c. This radio frequency power requirement applies to all wireless transmission devices at any ISM frequency.
16. Use of the CoSMiC provided situational awareness camera in the control room will be scored. If the team elects to turn on the camera during the match, they will be charged as though they used the camera for the full run. Teams start with 120 points and are deducted 60 points per camera used to a maximum of two cameras.
17. Radio Frequencies and Communications Approval
    a. To successfully pass the communication judges' station, a team must drive their construction robot by commanding it from their construction robot driving/control laptop through their wireless access point. The judges will verify the course of travel and verify that the team is operating only on their assigned channel.
    b. The teams must identify and show to the judges all the wireless emission equipment on the robot, including amplifiers and antennas. If the team has added an amplifier, written documentation shall be submitted to the judges demonstrating that the limits as designated in these rules for power transmission levels are not being exceeded.
    c. If the team robot is transmitting low power Bluetooth, or is using any non-2.4 GHz frequency equipment, the following information must be provided to the judges during the communications checkout. Printed documentation from the manufacture with part numbers of all wireless transmission equipment. 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.
    d. If a team cannot demonstrate the above tasks in the allotted time, the team will be disqualified from the competition.
    e. The teams will be able to show the communication judges their compliance with the rules.
    f. The CoSMiC communications technical experts will be available to help teams make sure that they are ready for the communication judges' station.
    g. Once the team arrives at the communication judges' station, the team can no longer receive assistance from the CoSMiC communications technical experts.
18. Teams in the pit awaiting competition are expected to power down their wireless access points. Violation of this rule is grounds for disqualification. Teams are encouraged to have a wired method of communication for testing in the pits.

SCORING, CONSTRUCTION, NAVIGATION

1. Scoring

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

2. Construction Points:

1. **Pass All Inspections (Comm/Vehicle) -** each team is required to perform a mechanical inspection and communications check prior to the first competition run. This should be performed as early as possible after check-in to ensure compliance to all rules and communication functionality. Neither is optional, if one cannot pass, the robot will not be permitted in the Arena.
2. **Construction Berm Productivity – Normalized for Robot Mass (BP Mass) –**
   A volumetric scan before and after the run will be performed. Only the berm volume within the target berm location will be counted. The team will earn construction points for each cubic cm of berm constructed above grade per minute per each kg of the robot's mass. Only the portions of the constructed berm within the target area for berm placement will be counted. The target area has perimeter dimensions of 2.2 M x 0.9 M. There is no restriction on the shape, height, or number of berms constructed.
3. **Construction Berm Productivity – Normalized for Energy (BP Energy) -** A volumetric scan before and after the run will be performed. Only the berm volume within the target berm location will be counted. The team will earn construction points for each cubic cm of berm constructed above grade per minute per each w*hr of energy consumed. The electrical energy consumed must be displayed by an (commercial off the shelf or "COTS") electronic data logger and verified by a judge.
4. **Camera bandwidth Use -** During each competition attempt, the team will be scored on camera usage as follows: 0 cameras = 120, 1 camera = 60, 2 cameras = 0 points.

5. **Dust Penalty** - Teams must control dust distribution to a reasonable degree, excessive dust will result in a point penalty up to 60 points at the discretion of the judges.

Construction Points Calculator – CoSMiC Arena

Construction Category Elements	Units	Specific Points	Example Actuals	Example Points
1. ***Pass All Inspections (Comm/Vehicle)***.	Pass = Run / 0=Default		1	**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.	cm^3 berm / min /watthour	1.5	77551 cm^3 / 15 min run / 36 whr **143.6**	**215.4**
4. ***Camera Use*** – During each competition attempt, the team will be scored on camera usage as follows: 0 cameras = 120, 1 camera = 60, 2 cameras = 0 points.	# cameras	120, 60, 0	1	**60**
5**. Dust Penalty –** See description			Excessive dust during operation	**-60**
5. ***Autonomy*** – See Construction Points – Autonomy	task	150, 200, 350, 450, or 600	150.00	**150.00**
6. ***Total Points***				**710**

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. SLAM and other such like algorithms are acceptable.
    - use any process that causes the physical or chemical properties of the regolith simulant to be changed or otherwise compromises the uniformity between attempts.
15. Bulldozing (i.e. pushing a pile of dirt/rocks) with a bladed dozer-type of rover is considered an acceptable excavation and regolith simulant transfer technique for the CoSMiC challenge. In this case, the robot would push material from the excavation zone into the berm area to create the berm. All regolith simulant material must be pushed in a pile from the excavation zone into and through the construction zone to the berm. Regolith simulant may be skimmed from the construction zone, but only if it is part of the operation of pushing it from the excavation zone into the berm (it may not be intentionally collected in the construction zone). The bulldozing pushing operation shall not start inside the construction zone – each bulldozing attempt shall start in the excavation zone.
16. Obstacles that are moved from the excavation zone into the target area will count towards these dimensions.
17. The robot shall end operations immediately when the power-off command is sent and/or as instructed by the Construction Judge. After the official competition run ends, the regolith judge will determine if the robot needs to move prior to being removed. The judge will instruct the team members when they can enter to remove the robot after ensuring that the lidar scan of the berm has been completed.

5. 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.

6. Autonomy Rules:

1. Telemetry to monitor the health of the construction robot is allowed during the autonomous period. Teams will need to remain "hands free" during any attempts at autonomy points. Teams shall explain to the inspection/ attending judge before each competition run how they are interacting with the telemetry system, and the judge will observe to ensure compliance with all competition rules.
2. Teams shall not touch the controls during the autonomous period. Orientation data cannot be transmitted to the construction robot in the autonomous period. See complete details in the Mission Control Center (MCC) and Autonomous Operations.
3. Teams are responsible for notifying judges when in "hands free" operation vs "driver controlled" operation for each autonomy attempt. Teams are allowed to record video in the MCC for evidence of sufficient communication with judges and "hands free" operation.
4. 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.
5. 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.
6. 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.
7. Teams are not permitted to update or alter the autonomy program to account/detect or upload information about obstacle locations.

8. Failure to divulge the method of autonomy sensing shall result in disqualification from the competition.

MISSION CONTROL CENTER AND AUTONOMOUS OPERATIONS

1. Mission Control Center (MCC)

Teams will control or autonomously operate their robot from the MCC to simulate operations of a Lunar In-Situ Resource Utilization (ISRU) construction mission. CoSMiC Mission Control Judges (MCJs) will supervise team activities in the MCC and assess their performance during each competition run. A Mission Control Director (MCD) will serve as the Lead Judge for the MCC to maintain the integrity of the MCC rules in the CoSMiC guidebook and ensure they are interpreted and enforced equally 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 CoSMiC. 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 CoSMiC Arena teammates during the setup period, which is only permitted using equipment provided by CoSMiC.
   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 CoSMiC staff may be assessed penalty points, disqualified from a competition run, or disqualified from the entire CoSMiC 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 CoSMiC 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 CoSMiC Arena. This radio will be returned to the MCJ at the end of the setup period and may not be used during the competition run.
   4. Arena team members are prohibited from pointing out obstacles, craters, and other arena conditions to the MCC team members.
   5. Teams may use the situational awareness cameras during the setup period without penalty.

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 construction area in the CoSMiC Arena via monitors provided in the MCC. The use of these cameras will result in a point deduction.

The MCC monitors provided for situational awareness may not be utilized by the team for any other purpose.

3. Telerobotic operators are only allowed to use data and video originating from the robot and the competition video monitors.
4. It is the sole responsibility of team members in the MCC to communicate effectively with the MCJ to ensure every autonomy attempt is recognized and scored correctly. If the judge Is not notified of the attempt in advance of the team initiating its execution, the score will be zero points. Teams should:
   - Clearly announce and make eye contact with the MCJ when they are going to autonomous operations.
   - Clearly announce when autonomy has begun and has been completed each time they trigger an autonomy cycle.
5. All autonomy attempts must be "Hands-Free", meaning no team members are permitted to touch any components (e.g., laptops, game controllers) brought into the MCC until the team has declared autonomy completion or autonomy failure.
   - If a team member interacts with any equipment while the robot is still moving or before the team has declared the autonomy attempt complete, the team will receive zero points for the attempt.
   - In the event of an autonomy failure, the team shall announce that the attempt has failed before resuming manual control.
   - Manipulation of the arena situational awareness cameras, if in use, is permitted during autonomy attempts.

4. **Mission Anomolies**
   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 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 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 CoSMiC 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.

2. Autonomous Operations

During each competition attempt, the team will earn up to 500 Construction points for autonomous operation. As Mission Control Judges (MCJ) are not intimately familiar with each robot's concept of operations (ConOps) procedures, it is the sole responsibility of the team members in the control room to coordinate with and inform the

MCJ of each attempt for autonomy points to make sure their autonomous attempts are recognized and therefore scored correctly.

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 & Dump Automation: 150 pts

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

2. Excavation & Dump Automation - Full Run: 300 pts

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

3. Travel Automation: 200 pts

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

1. Localization across the entire competition arena
2. Object detection and location relative to the robot
3. Navigational planning based on location and obstacles/traversable area
4. The competition judges will attempt to construct the obstacle field in such a way as to require obstacle detection, mapping, and navigation planning to determine a “slalom” route to reach the excavation zone. The teams should not architect a “Point and traverse” approach for this automation step.
5. If the robot comes in contact with a rock or drives across a crater in the obstacle zone, as determined by the MCJ/Arena judges, a 35-point reduction will be applied.
6. For maximum points, the attempt must be made at the start of the run when first leaving the starting zone. In order to discourage the approach of “breadcrumbs”, a penalty of 50 points will be applied to any attempt that occurs after traversing the obstacle zone in remote control. If multiple attempts are made, this penalty will only be assessed one time to the successful attempt.
7. If attempting excavation and dump automation in coordination with travel automation, the robot must remain in “hands-free” control during travel and excavation.
    - Example: Robot crosses the obstacle course in remote control before the attempt, hits an obstacle, and drives across a crater during the attempt. 200 points – 50 – 35= 115 points.

4. Full Autonomy: 600 pts

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

5. Autonomous Operations Scoring

Allowable Combinations	Excavation & Dump	Travel	Excavation & Dump – Full Cycle	Full Autonomy	Total
Ext: 1	150	-	-	-	150
Ext: 2	-	200	-	-	200
Ext: 3	-	-	300	-	300

Ext: 4	150	200	-	-	350
Ext: 5	-	200	300	-	500
Ext: 6	-	-	-	600	600

Autonomous Score Sheet

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

SECTION 3: DELIVERABLES AND RUBRICS

If it is evident to the CoSMiC judges the team has not fulfilled the spirit and intent of the deliverable, then a score of zero shall be assigned and the team shall be removed from the challenge.

The team lead will be the responsible party for uploading the deliverables to the respective forms. The following deliverables are required to remain in the CoSMiC Challenge [use the following format to name your PDF files, Deliverable Name-School Name (NOT YOUR TEAM'S NAME)]:

1. Project Management Plan (PMP)

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.

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.

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.

Here are some Tips on the PMP previously provided:

Project Management Plan (PMP) Tip #1: 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).

Project Management Plan (PMP) Tip #2: 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 the name of the review that replaces each in the discussion.

Project Management Plan (PMP) Tip #3: 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 CoSMiC project planning process, and asks you to tell us what those specific decisions were.

Project Management Plan (PMP) Tip #4: 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. If 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.

Project Management Plan (PMP) Tip #5: 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 SE Video 2: 'The Central Elements of Project Management'. That video describes budget allocation; the approach is similar for mass and other TPM allocations. Don't forget to include the TPM allocations in your PMP.

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 five 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 ✪ Systems Requirements Review ✪ Preliminary Design Review ✪ Critical Design Review ✪ others may be identified as you find appropriate 4. Product delivery dates to the CoSMiC Engineering Challenge, including as a minimum ✪ delivery of Systems Engineering Paper, ✪ the planned date to submit "Proof of Life" 5. Dates for important milestones related to Project Cost Budget and Technical Performance Measurement budget as identified in the Initial Project Budget and Initial Technical Performance Measurement budget sections of your Project Management Plan. (Optionally, you may also identify any major Systems Engineering activities in your Initial Project Schedule.) 6. 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).	**There are 3 points total for 6 elements**

SCORING RUBRIC – PROJECT MANAGEMENT PLAN

Element	Points
Initial Project Cost Budget Provide an estimate of the total project cost, inclusive of all possible costs. 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.) ✪ 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. ❖ Labor costs, if any ❖ Material costs for challenge (for production and completion of CoSMiC deliverables) ✪ Travel costs: transportation and accommodations Identify any Critical scheduling milestones (and dates) for budget or cost related items. (These critical cost budget milestones should appear in item 5 for the Initial Project Schedule; for example, dates funds will be needed, 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).	**There are 3 points total for 3 elements**

Element	Points
Project Technical Objectives List and discuss the specific technical criteria or characteristics that your team intends to achieve (typically some technical parameter or measure you want to minimize or maximize, increase to some limit, or decrease to some limit) in your system design and operations 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 these (or any other criteria or combination of criteria) to produce a system that will win the competition.	**There is 1 point total for 1 element**

SCORING RUBRIC – PROJECT MANAGEMENT PLAN

Element	Points
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 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. Include the following in the table as a minimum. Discuss only as needed. 1. Identification of Technical Performance Measures 2. Initial Target Value for each Technical Performance Measure to be achieved by the challenge Provide the allocation of each Initial Target Technical Performance Measure value across the elements of the earliest System Hierarchy (should combine to the total at the highest level). 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 should be reflected in item 5 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).	**There is 1 point total for 1 element**

2. STEM Engagement Report Rubric)

This is not required. A session to review your report will be given.

Each team must participate in engagement activities with at least one Elementary, Middle, or High School (K-12) student group in their local community and submit a report detailing their engagements. This project is designed to engage K–12 students in STEM (Science, Technology, Engineering, and Math) through direct (hands-on) and indirect activities. Teams must include data regarding the students reached with the engagement activities. We suggest using a table like the one shown below. We encourage teams to engage with underrepresented and underserved local community students.

Activity Date	Activity	Outreach Recipient Group	K–3rd grand level participants	3rd–5th grade level participants	6–8th grade level participants	9–12th grade level participants

9/24/2024	Presentation about the Moon	Wissahickon Elementary School	5	5	0	0
9/24/2024	Hands on Moon Dust Activity	Wissahickon Elementary School	5	5	0	0

Teams will also be required to include a table recording the total hours dedicated to the engagement activities by each team member in their report.

The Engagement activities must include at least one Indirect Educational Engagement and one Direct Educational Engagement. Definitions and examples of Indirect and Direct Educational Engagements are outlined below.

Please read carefully, as this section has been updated since last year.

Indirect Educational Engagement (Student-centered)

The report must include at least one Indirect Educational Engagement centered around the Lunar surface or robotics. This Activity should connect to what you teach the K–12 Students in Direct Engagement. The teacher facilitates the activity without direct instruction.

Indirect Educational Engagement is an instructional, hands-on activity where participants engage in learning a STEM related concept by actively participating in an activity. This includes instructor-led facilitation or inquiry around an activity regardless of media (e.g., face-to-face, video, conference, etc.).

> **Example:** Students learn about lunar robotics by creating their own robotics experiment with the help of the team to go on an CoSMiC-themed “mission,” such as collecting resources, constructing a base, or surveying craters.

Direct Educational Engagement (Teacher-led)

The report must include at least one Direct Educational Engagement focused on teaching the K–12 Students about the team’s robot or the moon. This engagement should give context for the indirect activity.

Direct Educational Engagement is when participants are engaged in learning a STEM concept through instructor-led facilitation or presentation.

> **Example:** Students learn about why lunar regolith presents design challenges for robotics/space systems through a presentation or lecture.

The activities may be conducted at the same event and with the same student group, but both must be completed by the submission deadline. Additional completed engagement activities may be included in the body of the report but are not required. Plans for future engagement may be included in the appendix (not body of the report) but are not required. The Appendix has a 5-page limit, totaling a 10-page maximum (not including Cover Page or any references). If photographs make your appendix too large, consider sharing them as a link to a cloud folder containing the photographs to save space.

The STEM Engagement Report will be judged according to the following rubric. If there is a tie, the winner will be chosen at the judges’ discretion.

Element	Points
Structure, Content, and Formatting Section	

• Maximum of 5-page body. • Maximum 5-page appendix. • Cover page (not included in page count) must include team name, title of paper, full names of all team members, university name, and faculty advisor's full name. • The cover page must also include the faculty's signature and a statement that they have read and reviewed the paper prior to submission. • Formatted professionally, clearly organized, correct grammar, and spelling, size 12 font, single spaced.	1 point
The appendix includes a write up of the team's engagement activities using the 5E model of instruction.	1 point
Pictures or video clips must appropriately demonstrate the activities (provide a link in the document or include images in the report body or appendix).	1 point
The report must include a table describing how the CoSMiC Competition team participated, the number of team members present, and the number of hours each team member contributed.	1 point
The report identifies lessons learned and plans for improvement.	1 point
The report describes student outcomes and accomplishments. What did they learn? Provide evidence.	1 point
The report must show statistics on the participants and activities.	1 point
Structure, Content, and Formatting Section Subtotal	**7 points**
Indirect Educational Engagement Section	
The report describes a hands-on activity that teaches K–12 students about the moon or robotics.	1 point
The report identifies the materials used and the rationale behind these decisions (cost, userfriendliness, access, etc.).	1 point
The report identifies the level of familiarity students had with the activity topic pre and post activity. What new things did they learn?	1 point
Element	**Points**
The team makes connections to other uses for the skills the K–12 students learn in their indirect engagement. How could the younger students apply what they learned to something else?	1 point
Indirect Educational Engagement Section Subtotal	**4 points**

Direct Education Engagement Section	
The report describes a direct educational engagement that educated K–12 students about their robot or the moon.	1 point
The Report identifies how the team members shared their STEM journey with the K–12 Students. How did you get to a CoSMiC Team, and what do you do now?	1 point
The Report describes how the team inspired the K–12 students to get involved in STEM or STEM careers	1 point
The report describes how the team shared their robot with the K–12 students. What specifically did you teach them about your robot?	1 point
Direct Education Engagement Section Subtotal	**4 points**
Grand Total of Points	**15 points**

NASA Educator Resources

The following new resources contain hands-on Moon activities and videos that NASA has developed for the CoSMiC Mission that can be used for the STEM Engagement Report.

- Landing Humans on the Moon Educator Guide (nasa.gov) – This educator guide contains activities and pictures for your presentations and rubrics for the Engineering Design Process and Scientific Process. Activities and topics included are:
  - ➤ water filtration
  - ➤ lunar surface activities
  - ➤ choosing a landing site on the moon
  - ➤ sculpting lunar geology
  - ➤ priority packing
  - ➤ safe landing on the lunar surface
- 'First Woman' Graphic Novel and Camp Experience – The novel is available in English and Spanish. The Camp experience includes hands-on activities that are excellent examples of Moon-based STEM engagement activities. Activities and topics covered are:
  - ➤ The "CoSMiC" Mission
  - ➤ Electrostatic Moon Duster activity
  - ➤ Digging on the Moon activity
  - ➤ Printing a Lunar Habitat
  - ➤ Finding our Way on the Moon (robotic)

Student Activity Videos

These short videos introduce the hands-on activities for the First Woman Camp Experience.

- NASA's Deep Space Communications Game Instructions
- RoboTools Engineering Design Challenge
- Design a Spacecraft Drag System like NASA
- Filling Up in Space: NASA Engineering Design Challenge
- Digging on the Moon

CoSMiC-Related / Space Tire Engineer Videos

- Why the Moon? - Explains why returning to the Moon is the natural next step in human exploration and how the lessons learned from CoSMiC will pave the way to Mars. https://youtu.be/bmC-FwibsZg

- CoSMiC I mission highlights video – This is a short recap of our first step on the path back to the Moon. https://youtu.be/jrDv0OdMt5s
- CoSMiC II Crewed Mission Overview – Provides a short overview of the first crew test flight. https://www.nasa.gov/artemis/videos.
- Artemis II Meet the Astronauts Who will Fly Around the Moon (Official NASA Video).mp4
- Surprisingly STEM Space Tire Engineer video – Watch a NASA Engineer discuss her career path to developing tires for robots going to the Moon. https://plus.nasa.gov/video/surprisingly-stem-space-tire-engineer-2/
- Explore NASA's Electrostatic Moon Duster Activity – Use the first part of the video to help K-12 students understand the difficulties dust poses to operations on the Moon back in the Apollo era and for future Artemis missions.

Robotic Activities – Mars

STEM Lessons for Educators – NASA Jet Propulsion Laboratory

These lessons are from the NASA Jet Propulsion Laboratory with robotic activities for Mars. While these activities are Mars-based, university teams can modify the activity to make it Moon-themed. Activities covered are:

- Designing a Robotic Insect
- Robotics: Making a Self-Driving Robot
- Robotics: Creating a Roving Science Lab
- Robotic Arm Challenge

3. Presentation Rubric

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

A slideshow is not required but teams encouraged to make one. The presentation room will be equipped with AV equipment to show the slides via HDMI. Teams are responsible for ensuring the technology works and no extra time will be given for technical difficulties.

1. The Presentation will occur in-person during to the CoSMiC challenge week.

2. Each team is allotted 25 minutes before the judging panel and should be prepared to present their own slides. The presentation and demonstration are expected to last approximately 20 minutes, with the final 5 minutes available for questions and answers. To maintain the judging schedule, there is a hard cut-off at the 25-minute mark. Teams are responsible for managing their time accordingly.

3. A panel of judges will evaluate the presentations on content coverage, team performance, and overall slide quality (e.g., grammar and spelling, use of graphics, general aesthetics). Chart packages must be logically organized with proper supporting slides to augment the scored content. Teams should remember they are representing their university as well as their work for the competition and should strive to do so in a manner befitting both.

4. The team's robot can be used as a visual aid during the presentation, but it must be powered off for the duration. Videos or images can be used to demonstrate functionality.

SCORING RUBRIC – PRESENTATION

Element	Points

Scoring Element 1: Content Coverage 1. <u>Project Objectives:</u> Qualitative technical objectives and quantitative Technical Performance Measures 2. <u>Design Process:</u> Systems Engineering approach and execution 3. <u>Project Management:</u> Budget and schedule evolution, team management, risk mitigation 4. <u>Concept Development:</u> System trades, reuse decisions, and planned configuration 5. <u>Design Maturation</u>: Subsystem trades, reuse decisions, and final configuration (mechanical, electrical, and software) 6. <u>System Testing:</u> Test plan, test progress, test results relative to project objectives, etc. 7. <u>Safety:</u> Considerations in design, development, and test; implemented safety features, etc.	**There are 15 points for this element.**
Scoring Element 2: Presentation Execution 1. <u>Presentation Quality:</u> Organization, slide quality (if used): grammar and spelling, formatting, graphics usage, general aesthetics, etc. 2. <u>Preparedness:</u> 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. <u>Delivery:</u> Presenter body language, cadence, enthusiasm, comfort with the material, communication effectiveness, camera awareness, etc. 4. <u>Question and Answer Session:</u> Demonstrated understanding of questions and quality of responses	**There are 5 points for this element.**
Scoring Element 3: Demonstration *This will be determined by robot functionality during the competition run. A video can be used during the presentation to demonstrate functionality.* 1. <u>Functionality:</u> Does the robot meet the challenge, how well does the system work 2. <u>Innovation:</u> Innovative design, application of innovation, integration, etc.	**There are 5 points for this element.**

4. Systems Engineering Paper Rubric

Teams must participate in this event to qualify for the Systems Engineering prizes. It is otherwise optional, and teams will not be penalized for choosing not to participate.

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 Here.
2. A video of the Project Management and Systems Engineering Seminar presented at the Lunabotics competition at KSC can be viewed Here.
3. A video of the Seminar "How to Develop the Perfect Lunabotics SE Paper" presented at the 2024 Lunabotics competition at UCF can be viewed Here.
4. A video of the Seminar presented at the 2024 Lunabotics competition at UCF titled "System's design" can be viewed Here.
5. *As one example, undergraduate course materials in systems engineering are available* 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 robot.
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" note reminds authors to provide appropriate white space at the margins and between sections.

SCORING RUBRIC – SYSTEMS ENGINEERING PAPER

Element	Points

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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 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 within the 25-page count. Content in the appendices shall be addressed 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.

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There are 3 points for 3 elements, one point each

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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> The CoSMiC System Engineering Paper should only describe the systems engineering done 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 did 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 address this year is on 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. Provide the following: • Clearly state that the system is an entirely new system design, or that it is a substantial update to a design from a previous competition (minor tweaks to a previous design will not allow sufficient exercise of Systems Engineering practices to allow SE Paper scoring). • 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; and, 2. Explain how you arrived at your decisions to change (or add/delete) these hierarchy elements. • If you have an entirely new system design, only content specifically relative to that new system design in the SE Paper will be subject to judging. Any references to systems engineering performed on previous designs, and any discussions of previous designs, will not contribute to scoring any rubric elements in the paper. • If you have a substantially updated design, any content in the paper that addresses the previous system will not contribute to scoring, except how the modified system hierarchy elements interface with the previous system hierarchy elements and how the modified system is verified to satisfy its key driving requirements. *[3 points]* 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, and their comments which led to changes in the system design (requirements), the schedule, the cost budget, and/or TPM's.	**8 points for 4 elements.** **2 bonus points may be awarded for exceptional work on Project Management Merit elements**

Element	Points

Provide examples of changes that occurred specifically as the result of external reviewers' comments at each review to:

- The system design (provide examples of requirements before the comments and the changed requirements as a result of the comments).
- The schedule.
- The cost budget.
- Technical Performance Measurements values or allocation of values across a system hierarchy level.

[3 points]

3. <u>Schedule of work:</u>

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.
- Why it changed.
- When it changed.
- How these changes affected the cost budget and relevant 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. [1 point]

4. <u>Cost budget:</u>

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 CoSMiC Qualification Challenge and to KSC to participate in NASA's CoSMiC 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, 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.

Element	Points

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Provide examples of:

What changed between the provided cost budgets.
Why it changed.
When it changed.
How these changes affected the schedule and relevant 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 cost budget to change.
Demonstrate in the discussion that the cost budget was used to manage the project.
[1 point]
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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)

</td><td>
8 points for 8 elements, one for each element.

Up to 4 additional points for exceptional work and additional systems engineering methods used.
</td></tr>
</table>

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 (PoL) Video and Robot Data

There are no points for this, but these are required deliverables, and failure to submit them will result in disqualification from the challenge.

Proof of Life

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.
- Routers are required to be able to turn off.
- The video shall be of one complete cycle of operations or 15 minutes of continuous operations.

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 functioning robot to present to the CoSMiC judging staff.

ROBOT DATA

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.

Summary of Deliverables

Applying to the CoSMiC Challenge – Due February 28, 2024 – google forms submission link

Statement of Support SOS-School Name

Project Management Plan
PMP-School Name

Proof of Life – Due March 31, 2025 – google forms submission link

Proof of Life Video and Robot Survey (the POL is a pass / fail item)

Pre Competition Paperwork– Due May 1, 2025 – google forms submission link

Systems Engineering Paper

Stem Engagement Report

Signin Paperwork – Due on Sign In – Files and submissions are in person

ISU CoSMiC Regulated Waste Management Overview RWMO-School Name

Liability Waiver CoSMiC Arena
LIA-School Name

Selected Teams

You are now part of CoSMiC. Congratulations!

1. To remain in the challenge a team shall complete the following:
    1. Complete your student and faculty registration and Liability Waiver.
    2. Systems Engineering Paper (Optional)
    3. Proof of Life Video (this is a pass/fail requirement)
    4. Send the List of potential participants (students/faculty) who will be attending to the CoSMiC mailbox: csmc_isu@iastate.edu
    5. CoSMiC Regulated Waste Management Overview

2. .edu email addresses are not required but are preferred.

3. The timeline/deadlines for all CoSMiC items are posted above. Submissions shall take the form of a google forms submission. One submission per team. Duplicate submissions will not be considered. Dates Are Subject to extension.

4. The tentative competition dates are May 21st through May 24th. These are subject to change depending on facility availability. These dates may conflict with university exam dates. Unfortunately, we cannot accommodate every university schedule. Please do not ask to change the dates.

FIRST RESPONDERS

Calling First Responders

- Remain Calm. If you see something, say something.
- Notify the Pit Boss, Arena Chief, Mission Control Director, CoSMiC Staff.
- If in doubt, call 911.
- 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.

MISCELLANEOUS

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

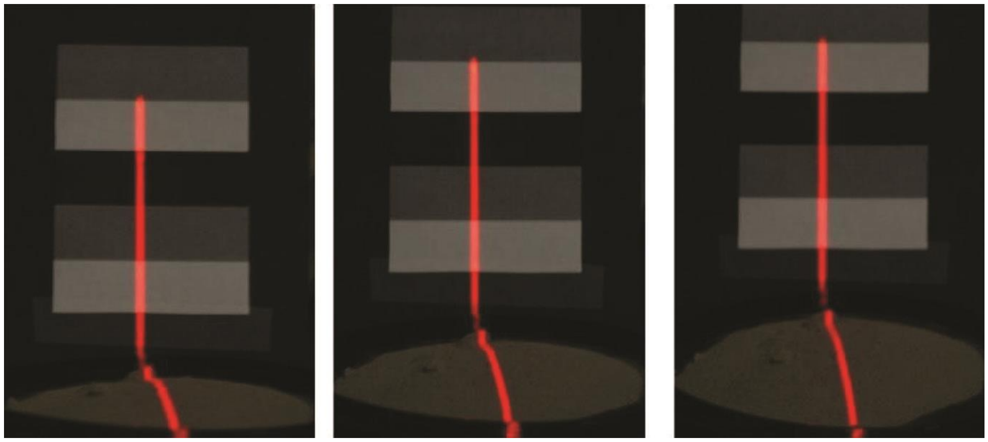
2. Military Containers (ammo cans)
Spray paint or cover up the former military content signage to avoid any extra security checks.

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 on the ISU campus. Please leave items secured off campus to expedite your entry. Violation is grounds for disqualification of the team.

GLOSSARY OF TERMS

1. **CoSMiC Arena**: Located in the Student Innovation Center where the robots will perform each competition attempt.
2. **Autonomous:** The operation of a robot with no human interaction.
3. **Limestone Regolith Properties:** [TBD]
4. Limestone Regolith: 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.
   - See “Soil Test Apparatus for Lunar Surfaces”
   - The density of the compacted Limestone regolith aggregate will be between 1.3 g/cm3 and 1.5 g/cm3.
   - Limestone Regolith simulant 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.
5. **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.



10 Degree, 16 Degree, 21 Degree
LIDAR/Laser Deflection

6. **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

7. **Regolith Construction Points:** Points earned from the competition attempt will be used to determine ranking in the on-site robotic operations category.

8. **Mission Control:** Mission Control is the operations area where teams will operate or autonomously control their robotic excavator to simulate a lunar In-Site Resource Utilization (ISRU) construction mission. It is located outside of the CoSMiC Arenas. Only students from the team are allowed into the Mission Control Rooms during the robot run. A team will be disqualified for having faculty / advisors or non-team members in the mission control room during the robot run.

9. **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.

10. **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 you will be working on your robots, meeting other competitors, and after spending months designing and building, this is where your robot gets inspected before it goes to work.

11. **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.

12. **Telerobotic:** 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.