National Aeronautics and Space Administration

HERC HUMAN EXPLORATION ROVER CHALLENGE

2024 HANDBOOK

ALIGNMENT WITH NATIONAL STANDARDS IN ENGINEERING AND SCIENCE

The NASA Human Exploration Rover Challenge (HERC) is a rigorous and continuously evolving activity which engages students in hands-on engineering design related to NASA's missions. HERC aims to meet established educational objectives and provide continuous program improvement that satisfy the needs of its participants.

Through participating in HERC, students will develop a deeper understanding of content and enhance their communication, collaboration, inquiry, problem-solving, and flexibility skills that will benefit them throughout their academic and professional lives.

HERC aligns with the Next Generation Science Standards and Accreditation Board for Engineering and Technology (ABET) criteria outlined below:

Next Generation Science Standards (NGSS); High School (9–12)

HS-PS2-1 Motion and Stability: Forces and Interactions

Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.

HS-PS2-2 Motion and Stability: Forces and Interactions

Use mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system.

HS-PS2-3 Motion and Stability: Forces and Interactions

Apply scientific and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision.

HS-PS2-6 Motion and Stability: Forces and Interactions

Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.

HS-PS3-1 Energy

Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.

HS-PS3-3 Energy

Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.

HS-ETS1-1 Engineering Design

Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.

HS-ETS1-3 Engineering Design

Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.

HS-ETS1-4 Engineering Design

Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.

Accredidation Board for Engineering and Technology (ABET); Criteria 3. Student Outcomes

- an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics
- an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors
- an ability to communicate effectively with a range of audiences
- an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts
- an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives
- an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions
- an ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

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1. BACKGROUND: THE NASA HUMAN EXPLORATION ROVER CHALLENGE

Each year the NASA Human Exploration Rover Challenge (HERC) features an engineering design challenge to engage students worldwide in the next phase of human space exploration. As an Artemis Student Challenge, HERC draws inspiration from both the Apollo and Artemis missions, emphasizing designing, constructing and testing technologies, and traversing in unique environmental terrains.

During Apollo 15, astronauts utilized the first automotive vehicle on the moon, the Lunar Roving Vehicle (LRV). With this rover, astronauts were able to collect more lunar samples than the previous two Moon-landing missions combined and spent twice the time on Moon than Apollo 14. Taking inspiration from the LRV, HERC aligns with NASA's mission to further scientific exploration and experiments on the Moon with the use of a roving vehicle.

NASA's 21st century lunar exploration program is called Artemis. Artemis missions will turn science fiction into science fact as we make new discoveries, advance technologies, and learn to live and work on another world.

NASA's goal with the Artemis mission is to send the first woman and first person of color for exploration at the Moon's South Pole and to develop a sustained human presence on the Moon. On the Moon we will learn what resources are available and abundant enough that we don't need to send them from Earth. Using resources, including water, found in space will help reduce our dependency on Earth as we move farther into the solar system.

With human exploration of Mars on the horizon, NASA is developing many of the technologies needed to send humanity farther into the solar system today. Our work on the Moon under the Artemis program will prepare us for that next giant leap sending astronauts to Mars.

Lunar science on the surface of the Moon will be conducted with polar and non-polar landers and rovers which will explore areas not investigated during Apollo missions. This student design challenge encourages the next generation of scientists and engineers to engage in the design process by providing innovative concepts and unique perspectives. HERC also continues the Agency's legacy of providing valuable experience to students who may be responsible for planning future space missions including crewed missions to other worlds.

The Artemis Generation will inspire diverse scientists, engineers, explorers, and other STEM professionals just as we did with the previous human spaceflight programs.

To learn more about the Artemis missions, including specific plans for how to achieve these goals, visit: https://www.nasa.gov/specials/artemis/

2. HERC OBJECTIVE

The primary objective of HERC is for teams of students to design, develop, build, and test human-powered rovers capable of traversing challenging terrain and a task tool for completion of various mission tasks.

Teams earn points by successful completion of design reviews, designing and assembling a rover that meets all challenge criteria, and successfully completing course obstacles and mission tasks. The team with the highest number of points accumulated throughout the project year will be the winner of their respective division (high school and college/university).

The competition course requires two students, at least one female, to use the student-designed vehicle to traverse a course of approximately one half-mile that includes a simulated field of asteroid debris, boulders, erosion ruts, crevasses, and an ancient streambed. The challenge's weight and size requirements encourage the rover's compactness and stowage efficiency. Just as in the Apollo 14 surface mission, teams must make real-time decisions about which mission objectives to attempt and which to leave behind—all driven by a limited, virtual eight-minute supply of oxygen. Like in the Apollo 15 mission, competing teams must be prepared to traverse rough terrains over the course of two excursions on a roving vehicle while carefully performing tasks related to the mission narrative.

3. TIMELINE

Dates Are Subject to Change
All deadlines at 5:00 PM CDT/CST

August 10, 2023 .... Handbook Released

August 24, 2023 .... Proposal Expectations Webinar

September 21, 2023 .... Proposals Due

October 12, 2023.. Team Selections Announced

October 12, 2023.. Registration for Selected Teams Opens

October 19, 2023.. Registration for Selected Teams Completed.

October 19, 2023.. Team Social Media Presence Established and Social Media Links List Submitted

October 19, 2023.. Kickoff Webinar with Q&A Session

November 16, 2023 .... Design Review (DR) Report and Presentation Due

November 27 – December 15, 2023 .... DR Presentations
Design Completed and Construction in Progress

February 1, 2024 .... Final List of Team Members Due
Team Photo Due

March 7, 2024... Operational Readiness Review (ORR) Report and Presentation Due
Photos of Completed Rover for Verification Due

March 11 – 29, 2024 .... ORR Presentations
Rover/Components Completed, and Testing in Progress

March 21, 2024 .... STEM Engagement Report(s) Due

April 18, 2024... Competition Day 1

- Team Check-In
- Course Walk-through
- Event Expectations and Safety Briefing

April 19, 2024... Competition Day 2

- Excursion 1
- 30th Anniversary Celebration

April 20, 2024... Competition Day 3

- Excursion 2
- Awards Ceremony

4. GLOSSARY OF TERMS AND ACRONYMS

Assembly Tools	Any tools, straps, etc., that teams need to contain the rover in the 5-ft cube configuration or to assemble the rover, but not needed for traversing the course or completing the tasks. These assembly tools may be left in the designated tool area adjacent to the assembly area as part of the timed assembly process.
CAD	Computer Aided Design; the use of computers (or workstations) to aid in the creation, modification, analysis, or optimization of a design
Challenge Ready Configuration	Defined as both pilots seated in the rover with all task materials and PPE, including seat restraints, fixed in place, feet on drive input devices, and hands up to signal completion
DR	Design Review; demonstrates that the maturity of the design is appropriate to support proceeding with full-scale fabrication, assembly, integration, and test. It determines that the technical effort is on track to complete the mission operations, meeting mission performance requirements within the schedule constraints.
ERR	Excursion Readiness Review; event that occurs prior to any course excursion and include safety and task material inspection. The ERR will be combined with the MRR for the first excursion.
ESDMD	The Exploration Systems Development Mission Directorate defines and manages systems development for programs critical to NASA's Artemis program and planning for NASA's Moon to Mars exploration approach. ESDMD manages the human exploration system development for lunar orbital, lunar surface, and Mars exploration.
Excursion	An attempt to traverse the course tasks and complete challenges to accumulate points. Teams will have two excursion opportunities (weather permitting), one each on Friday and Saturday. Final rankings are based on the greater point total of the two possible excursion attempts and points accumulated during design and readiness reviews. Teams are not required to attempt excursions both times.
FMEA	Failure Modes and Effect Analysis
HERC	Human Exploration Rover Challenge
kg	Kilograms
MRR	Mission Readiness Review; the event occurs the morning before the first excursion run. This includes the volume constraint, weighing the vehicle and unfolding/assembling the vehicle. The MRR will be combined with the ERR for the first excursion.
MSAT	Marshall Safety Action Team
MSFC	Marshall Space Flight Center
mL	Milliliter

NASA	National Aeronautics and Space Administration
NASA STEM Gateway	Comprehensive tool designed to allow individuals to apply to NASA STEM engagement opportunities. The information collected will be used by the NASA Office of STEM Engagement (OSTEM) and other NASA offices to review applications for participation in NASA STEM engagement opportunities and to fulfill federally mandated performance reporting on these activities.
ORR	Operational Readiness Review; examines the actual system characteristics and procedures used in the system or end products and establishes that the system is ready to transition into an operational mode through examination and analysis
Overall Score	The total cumulative points awarded to a team, including DR, ORR, STEM Engagement, MRR, plus the Obstacles and Tasks Competition
PPE	Personal Protective Equipment
PER	The Post-Excursion Review, or PER occurs after course completion and includes task completion inspection
Pit Area	The area designated for preparing the team’s vehicle and task components
Pilot	Synonymous with crew; one or both student team members (at least one female) that propels the vehicle over the course
Pit Crew & Machine Shop	Employees of the NASA Metallic Materials and Processes Division of the Materials and Processes Laboratory and Jacobs Engineering utilizing a machine shop to assist with repairs
Requirements	The set of standard rules for all participants that must be followed to compete in the Human Exploration Rover Challenge.
STEM	Science, Technology, Engineering and Mathematics
Task Materials	Task materials include all equipment needed for completing the tasks on the course. This may include items such as collection tool, storage containers, etc.
TS	Task site(s)
USSRC	U.S. Space & Rocket Center
Vehicle	Synonymous with rover, the vehicle is the student-built rover designed to traverse the course during excursions.

To learn more about NASA’s acronyms, visit the official site: Acronyms | Science Mission Directorate (nasa.gov)

5. GUIDELINES AND REGULATIONS

General Regulations

- Individuals or teams may be excluded from participation at the discretion of NASA for unauthorized behavior, including but not limited to
  - (i) impersonating a NASA official whether intentionally or in a manner that results in confusion,
  - (ii) misuse of the logos or identifiers of NASA, any sponsoring organization, or any infringement of a commercial logo or trademark,
  - (iii) failure to abide by competition rules, directives or instructions from the competition host or organizer, and
  - (iv) asserting or implying a NASA affiliation or sponsorship where none exists.
- Additionally, the NASA Human Exploration Rover Challenge does not host pre-competitions or competitions conducted by any organization other than NASA Marshall Space Flight Center's Office of STEM Engagement. This NASA competition is neither affiliated with, nor sponsors or endorses any Rover Challenge competition other than the NASA Human Exploration Rover Challenge. Outside competitions have no bearing on the NASA Human Exploration Rover Challenge qualification or registration process, and representation to the contrary is strictly prohibited. No competition may imply any affiliation with NASA or use the NASA logo without permission of NASA Headquarters. Any assertions made by organizations that represent themselves as "NASA Outreach Program Europe Director," "Official NASA Rover Ambassador," "International Judge," or any similar titles suggesting a tie to NASA are unauthorized. Representations or suggestions that any organization or individual can assure teams of being accepted for registration or participation in the challenge are unauthorized. All requirements for participation in the NASA Human Exploration Rover Challenge are outlined in this handbook.
- Participant hereby waives any claims against NASA, its employees, its related entities, (including, but not limited to, contractors and subcontractors at any tier, grantees, investigators, volunteers, customers, users, and their contractors and subcontractors, at any tier) and employees of NASA's related entities for any injury, death, or property damage/loss arising from or related to the NASA Human Exploration Rover Challenge, whether such injury, death, or property damage/loss arises through negligence or otherwise, except in the case of willful misconduct.
- All team members shall be currently enrolled students from a high school, an accredited institution of higher learning, or an institution such as a science center, museum, planetarium, or youth-serving organization. Multi-institutional teams are permitted for same level of education, i.e., two or more high schools on one team. Students from high schools and accredited institutions of higher learning shall not be combined.
- High School teams will be composed of students ages 14 through 19.
- Accredited institutions of higher learning (College/University) teams shall be composed of undergraduate students.
- Accredited institutions of higher learning (College/University) undergraduate teams will be composed of students ages 18 and older. Students who are younger than 18, may require age and enrollment verification.
- Centers or youth-serving organization teams must follow educational level age requirements listed above and shall not have students from both high school AND accredited institution of higher learning.
- Age and enrollment verification may be requested at any time.

- Each team, regardless of division, shall identify and be accompanied by an adult age 21 or older to serve as an advisor. This person shall be employed by the registered institution or organization.
- All team members are required to be engaged in the design and build of the rover. Each person must have an active role that must be communicated to the NASA panel during DR and ORR presentations. Teams will identify two team members as pilots (at least one female) to propel the vehicle through the course.
- Any team member or advisor found to be exhibiting unsportsmanlike conduct may be disqualified from the challenge individually or as a team.
- All scoring decisions for the excursion are final. If an appeal is warranted, the advisor or the student team leader shall submit the appeal in writing for consideration to the Activity Lead within 30 minutes of the posting of score(s) in question. The final decision of the Activity Lead and Head Judges shall prevail.
- Students on the team will do 100% of the project, including design, construction of their vehicle and task components (including performing work that is supported by a professional machinist for the purpose of training or safety), written reports, presentations, and competition preparation. Any team found in violation of this will be disqualified. Excessive use of past work will result in disqualification.
- Teams not meeting all requirements (Section 6) listed may be disqualified.

Competition Guidelines, Regulations and Information

- Rovers may be shipped to USSRC in advance of the competition via the following address (the USSRC will not receive any rovers that do not have pre-paid return shipping documents with their rover equipment):
  USSRC, 1 Tranquility Base Dr., Huntsville, AL 35805
  ATTN:Warehouse Manager
- For return shipping pickup, rovers are required to be fully packaged in an appropriate crate by the team and include all necessary label(s) for shipping by the end of the competition.
- Neither USSRC nor HERC Staff will provide a facility, tools, or equipment for assembling or disassembling rovers (in any condition), and/or opening crates.
- The consumption of alcoholic beverages and/or controlled substances is strictly prohibited by HERC teams on USSRC grounds and use of or possession by any HERC participant or affiliate at any time during the event is grounds for disqualification of the team and/or other repercussions.
- U.S. federal, Alabama state, and Huntsville city laws and regulations solely define what is legally permitted on the grounds. As such, firearms and other weapons are not permitted to be carried by facility visitors on USSRC property.
- In accordance with Federal Aviation Administration (FAA) regulations, the use of drones during any HERC activity is strictly prohibited.
- Driving the rover on the course, or in the parking lot, in a reckless or unsafe manner is not permitted, and may result in disqualification.
- Your safety is our biggest priority. Pilots who are injured, bleeding, or incapacitated will be safely attended to and receive any necessary medical attention. Injuries may occur when adjusting vehicle components, such as drivetrain components, during the excursion. Each team must develop a signal system between the two pilots to ensure safety hazards are clear before proceeding. Pilots will be asked to describe their communication plan to the MSAT and/or another judge before the excursion.
- Using poles or other devices to propel or push the rover is not allowed. A pilot's use of his or her hands on the wheels (as with a wheelchair) to facilitate vehicle movement is not permitted.
- Upon successful completion of MRR/ERR, teams are permitted two excursions of the course.
- Teams have a total of 8:00 minutes to complete each excursion. Teams will receive points by successfully traversing obstacles and completing mission tasks.
- Teams failing to complete one of the two excursions in under 8:00 minutes are ineligible for competition awards based on excursion performance.
- Pilots must be on the vehicle, with safety belt fastened, and all safety equipment (PPE) in place before driving their rover during an excursion attempt.
- The excursion time stops when a team either crosses the finish line or reaches the 8:00-minute limit, whichever comes first. Teams will be allowed to finish their excursion if it isn't impeding progress of successive teams.
- On-course judges may make pilots aware of their unofficial excursion times periodically, however teams are encouraged to use their own timing devices on the vehicle for strategic on-course decisions. Teams should not be reliant on excursion times announced by judges. The timing judges will maintain the official excursion time.
- The pilots for the first excursion shall be the same as those who conducted MRR/ERR. Pilot substitutions may be made for the second excursion.
- Communication devices are allowed if at least one pilot can hear ambient sounds/instructions from judges.
- Indirectly approaching an obstacle, getting off the vehicle (pushing, pulling), or veering from an obstacle will be considered an unsuccessful attempt.

- The course is comprised of 10 obstacles and 5 mission tasks. Some obstacles will have a bypass, where teams can strategically choose to either attempt the obstacle for points or bypass it for zero points.
- Judges have the authority to remove a disabled or temporarily suspend a slow rover from the course when it will affect the excursion time of the next successive rover. The excursion time for the slow vehicle halts at the point of suspension and resumes once the successive vehicle has passed.
- Individuals (team members and supporters) may not follow the rover around the course during the excursion time.
- Rover numbers will be provided in the event packet on two printed 8.5” × 11” waterproof sheets and shall be affixed to the front and left side of the rover, in an unobstructed view for the judges.

Deliverables Guidelines and Information

- All potential teams are required to submit a proposal to compete. A written proposal submission shall follow and answer the requirements outlined in Deliverable, Proposal Section 7:
  - The Student Team Leader will submit the team’s proposal for consideration via email to: HERC@mail.nasa.gov. Please follow proper deliverable nomenclature.
  - Teams will be scored based on a rubric developed from the Team Proposal Requirements.
  - Teams may propose only **ONE** team per school or institution for consideration.
  - Proposals shall be written only by the student members of the team.
  - Proposals submitted after the deadline (date and time received) will not be considered.
  - Top scoring proposals will be selected to compete. Student Team Leader will be allowed to register for the competition through NASA STEM Gateway (stemgateway.nasa.gov). Once the student team leader’s application is completed, they will receive an offer email from NASA STEM Gateway and will need to accept the offer. Once accepted, the Student Team Leader will send invitations through NASA STEM Gateway to each team member to register as part of the team.
- Each team member must complete a NASA STEM Gateway profile for the registration to be valid.
- A Team’s registration will be confirmed via email upon approval of registration.
- Each team is required to submit a Design Review Report and Presentation and participate in a virtual presentation that will make up 20% of the team’s overall score. **DR must be completed to progress onto the ORR portion of the challenge.**
- Each team is required to submit an Operational Readiness Review Report and Presentation and participate in a virtual presentation that counts towards 20% of the team’s overall score. **ORR must be completed to progress onto the excursion portion of the challenge.**
- Each team is required to submit STEM Engagement Report(s) that counts towards 10% of the team’s overall score.
- Late submissions of Design Review, Operational Readiness Review and/or STEM Engagement Activity Report deliverables will be accepted up to 24 hours after the submission deadline. Late submissions will incur a 10% penalty. Submissions will not be accepted after the 24-hour window. Teams that fail to submit a deliverable document will be eliminated from the competition.

Team Pit Area Guidelines and Regulations

- Each team is provided one 18' x 18' space for their pit area and must fit all equipment needed in the space provided. Only vehicles registered for the competition during team check-in will be allowed. All other vehicles and/or trailers shall be parked in the designated general parking area.
- All vehicles without identification, or those blocking other team spaces, will be towed at the owner's expense. (Exception: loading/unloading the vehicle and equipment on Thursday of the event).
- Teams shall exercise appropriate safety precautions during the design, build, and test phases of this competition and utilize appropriate PPE when performing construction activities, such as welding, handling metal components, and using tools anywhere on the USSRC property or neighboring areas.

Mission Readiness Review Guidelines

- Teams will complete MRR during the pre-determined time window on Competition Day 2. Time windows, and the method for obtaining a time window, will be communicated to teams well in advance of the competition.
- Teams must arrive on time and ready to participate in their MRR as scheduled. Failure to arrive on time or perform MRR as scheduled will result in a penalty to the team's overall score.
- Vehicles will be inspected for the 5 × 5 × 5-ft volume constraint in the stowed configuration during MRR. A jig will be placed over the rover for volume constraint verification.
  - No modifications or team rover interaction is permitted during this verification.
  - Tapes, straps, and/or other devices may be used to confine the rover in the collapsed or stowed configuration; however, all such devices will be included in total weight measurement of the rover.
  - Teams must include task materials during this verification.
- There are no constraints for overall height and length of the assembled rover; however, a rover with pilots that is found to have too high of a center of gravity and/or found to have a weight imbalance will be assessed and may not be allowed to traverse the course if risk of tipping over is deemed too great by judges.
- The vehicle will be weighed in the stowed position with all necessary mission components, to include ALL task materials. Point breakdown for weight categories is listed in Section 8.
- From the stowed position, a signal will be given, and a timer will start for the two pilots to unfold and/or assemble their rover. The timer stops when the vehicle is in challenge-ready configuration with pilots in place, and all assembly tools and implements properly stowed on the rover, or in the marked tool area adjacent to the assembly location. Point breakdown for assembly time is listed in Section 8.
- The MRR will be combined with the ERR for the first excursion, and this score will be used on subsequent excursions.

Excursion Readiness Review Guidelines

- Teams must arrive on time and ready to participate in their ERR as scheduled. Failure to arrive on time or perform ERR as scheduled will result in a penalty to the team's overall score.
- Judges will photograph each vehicle and conduct an inspection of task materials and safety requirements.
- All task materials will be inspected prior to the excursions. Task materials should have the team number marked on each item.
- Task tool may be used at multiple task sites.
- The ERR will be combined with the MRR for the first excursion.

6. REQUIREMENTS

6.1 Safety Requirements

6.1.1 Each rover shall have robust, practical seat restraints for each of the pilots. The restraints must be capable of preventing the pilots from being ejected from their seats should the vehicle be forced to a sudden stop. The preferred method of restraint is a 3-point motor vehicle seat belt. Seat restraints shall always be worn when the vehicle is being driven on or off the course. A vehicle will be stopped by an official or judge if either pilot is not secured by the seat restraint while the vehicle is in motion. Vehicles will be held in the stopped position until the required restraint(s) are firmly in place.

6.1.2. Each rover shall have at least one adequate mechanical braking system. Braking system(s) shall be able to hold the rover and accompanying pilots when placed in-line on a 30-degree incline. Braking system(s) can be cable, hydraulic, or other mechanical mechanism that applies or translates a braking force to the rotating member(s) of the rover. No use of hands or body can be used on the wheels and/or drivetrain to slow or stop the rover from motion during regular excursion activity.

6.1.3 Teams shall design to eliminate or guard against any sharp edges or, as necessary to ensure safety of the pilot's, participants and HERC Staff. Final evaluation will be made by the safety judge at the HERC event.

6.1.4 Team pilots shall always utilize appropriate PPE when on rover during event. Specific PPE is listed below:

6.1.4.1. Eye protection, e.g., safety glasses, goggles, or face shield

6.1.4.2. Commercially manufactured head protection, e.g., bicycle helmet

6.1.4.3. Full-fingered gloves

6.1.4.4. Long-sleeved and long-torso shirts

6.1.4.5. Long pants (dangling pants shall be wrapped and/or taped down)

6.1.4.6. Long socks

6.1.4.7. Enclosed shoes (shoelaces shall be wrapped and/or taped down)

6.1.4.8. No apparatuses, such as stilts, may be used on the feet of the pilots.

6.2 Communication & Documentation Requirements

6.2.1. Communication to the HERC staff shall be through the advisor and/or team lead. All communication shall be sent via email to HERC@mail.nasa.gov. The subject line shall include the subject matter of the communication and school name (Subject Description — Your School's Name).

6.2.2. Teams shall establish a social media presence to inform the public about day-to-day team activities. Teams are encouraged to update their social media accounts weekly.

6.2.3. Accepted teams shall send all deliverables, with the exception of STEM Engagement Reports, through HERC@mail.nasa.gov by the deadline specified in the handbook. All deliverables shall be in PDF format and meet the requirements outlined in this handbook. File name must follow the nomenclature *School_Name_Year_Deliverable Type*.

6.2.4. All verbal and written communication shall be in English (this includes communication of team members during DR and ORR presentations).

6.2.5. The DR and ORR reports shall follow format and outline guidance found in Deliverable, Section 7.

6.2.6. The team must provide computer equipment necessary to perform a videoconference with the HERC scoring panel during DR and ORR presentations. This includes, but is not limited to, a computer system, video camera(s), speakers, and a stable internet connection.

6.3 Vehicle Requirements

6.3.1. Vehicles, inclusive of pilots, shall have a center of gravity low enough to safely handle slopes of 30 degrees front-to-back and side-to-side.

6.3.2. Vehicles shall be capable of turning radius of at most 10 ft.

6.3.3. The competition ready rover shall be no wider than five ft, with the **GREATEST** distance considered.

6.3.4. Rovers with pilots in position, shall have clearance greater than or equal to 12 inches between the ground and the lowest point of the pilot's appendage as shown in Figure 1.

6.3.5. Teams shall design and fabricate non-pneumatic wheels, inclusive of the outer surface (treads) contacting the terrain and the supporting structure (rims, spokes, etc.). The only commercial wheel component that can be used as part of a team's wheels are wheel hubs containing bearings and/or bushings.

6.3.6. Vehicles shall be human-powered. Energy storage devices, such as springs, flywheels, or batteries are not allowed to be used as part of the drivetrain.

6.3.7. Storage of task materials shall not interfere with the pilots in any way that creates the potential for injury.

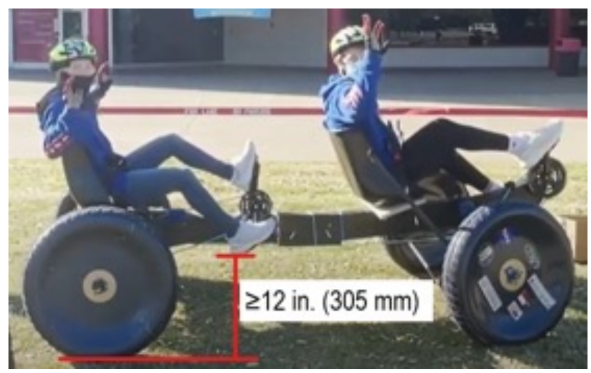

Figure 1. Vehicle Height Requirement

6.4 Task Tool Requirements

6.4.1. Teams shall design/procure ONLY one tool with multiple capabilities for completing mission tasks. Five task sites are located throughout the course and may or may not be attempted for points within the allotted time.

6.4.2. Teams shall provide detailed discussion in the DR and ORR reports for how their task tool is designed to accomplish each task.

6.4.3. Task materials cannot be shared with other teams. Teams must come to a complete stop immediately adjacent to each task to attempt the task.

Failure to meet any of the requirements listed above may result in penalties including ineligibility for overall prizes or complete disqualification at the discretion of the HERC staff.

7. DELIVERABLES

Proposal

The purpose of the proposal is to demonstrate that the team has the knowledge, resources, and administrative support to effectively and completely participate in the HERC program. Emphasis is placed on a team's available facilities, financial and technical support from the educational institution and community, and the team's ability to plan and schedule appropriately for the commitment HERC demands. The designs in this section are expected to be conceptual sketches and ideas.

Student Team Leader shall submit the proposal on their team's behalf via email to HERC@mail.nasa.gov by the deadline specified in the handbook. Proposal File name must follow the nomenclature *School_Name_Year_ Proposal*.

At a minimum, the proposing team shall identify the following in a written proposal due by the date specified in the timeline:

Format:

- Proposals must be submitted in a PDF format.
- Size 12 Times New Roman font or similar.
- 8.5” × 11” paper size with 1-inch margins.
- A cover page that includes:
  - The name of the college/university or high school institution and mailing address
  - Division: High School or College/University
  - Date
  - Name, Title, Email Address of:
    - The advisor
    - The student team leader
    - The student team safety officer
    - List of participating student team members (inclusive of the Student Team Leader and Safety Officer) who will be committed to the project and their proposed duties

Proposal Outline

Page Limit: Proposals will only be scored using the first 10 pages of the report (not including cover page). Any additional content will not be considered while scoring.

1. Facilities and Equipment

1.1. Description of the facilities, equipment, and supplies that are required to design and manufacture the vehicle components. Identify hours of accessibility, training, and necessary personnel that are required for any facilities.

2. Safety

2.1. Provide a written safety plan for addressing the safety of the materials and tools used, and the student responsible, i.e., safety officer, for ensuring that the plan is followed.

2.1.1. This section is NOT a Hazards Analysis. This section is intended to address HOW your team will institute safety during your design, build, and operation.

2.2. Describe the plan for briefing students on hazard recognition and accident avoidance.

2.3. Describe methods to include necessary caution statements in plans, procedures, and other working documents (including the use of proper PPE).

3. Technical Design

3.1. A basic design overview of rover concept and components.

3.2. Wheel design and fabrication plans.

3.3. Drivetrain concept and design with fabrication plans.

3.4. Identify task sites the team plans to attempt and provide preliminary designs for associated task tool.

3.5. Address major technical challenges and possible solutions the team will face during the engineering design and manufacturing phase.

4. Project Plan

4.1. Provide a detailed development schedule/timeline covering all aspects necessary to meet all milestones and complete the project successfully.

4.2. Provide a budget to cover all aspects necessary to complete the project successfully, inclusive of team travel. The budget should include both materials and supplies the team already has on hand, and those the team will need to purchase.

4.3. Provide a funding plan including sources of funding and estimated (or confirmed) amounts.

5. STEM Engagement

5.1. Include plans and evaluation criteria for the required STEM Engagement activities.

Design Review (DR)

The purpose of the DR is to demonstrate that the overall design meets all requirements with acceptable risk, within the cost, schedule, and technical performance constraints, and establish the basis for proceeding with fabrication, assembly, and integration. It should show that the correct design options have been selected, and interfaces have been identified. Full baseline cost and schedules, as well as all risk assessment, management systems, and metrics, should be presented.

- The Design Review Report accounts for 20% of the overall score for the competition.
- The Design Review Presentation will be worth 10% of the total Design Review points.

Teams shall submit their Design Review Report and Design Review Presentation via email to HERC@mail.nasa.gov. Submit by the deadline specified in the handbook. Design Review file name must follow the nomenclature *School_Name_Year_Design Review*.

Format:

- Design Review must be submitted in a PDF format
- Size 12 Times New Roman font or similar
- 8.5” × 11” paper size with 1-inch margins
- A cover page that includes:
  - The name of the college/university or secondary education institution and mailing address
  - Division: High School or College/University
  - Date
  - Name, Title, Email Address of:
    - The advisor
    - The student team leader
    - The student team safety officer
    - List of participating student team members (inclusive of the Student Team Leader and Safety Officer) who will be committed to the project and their proposed duties

DR Presentation: It is expected that the team participants deliver the report in a professional manner and answer all questions to their best ability. The advisor may attend but shall not deliver the presentation or answer any questions pertaining to the project other than when directed. The entire presentation will be delivered in English and translators will not be permitted.

- There is a 30-minute time-limit for presentation. A 15-minute feedback discussion will follow the presentation.
- The presentation should include an overview of each section of DR report.

Design Review Report Outline

Page Limit: DRs will only be scored using the first 30 pages of the report (not including cover page and abstract). Any additional content will not be considered while scoring,but may be appended for clarification.

1. **Table of Contents**
2. **Vehicle Criteria** — Selection, Design, and Rational of Vehicle Design
   - 2.1. Review the design at a system level (i.e., wheel design, drivetrain design, suspension), going through each system's alternative designs, and evaluating the pros and cons of each alternative.
   - 2.2. For each alternative, briefly present research on why the alternative should not be chosen.
   - 2.3. After evaluating all alternatives, present the chosen vehicle design.
   - 2.4. Describe each subsystem and the components within those subsystems
   - 2.5. Describe how the design meets size, weight, volume, assembly, and clearance constraints.
   - 2.6. Provide dimensional drawings of the leading design.
3. **Task Tool**
   - 3.1. Review the designs at a system level of a multi-task tool that supports the selected task-sites, briefly discussing alternative designs to each component and evaluating the pros and cons.
   - 3.2. Describe the preliminary selected design of the multi-task tool and describe how task tool interfaces with the pilots, vehicle, and missions.
   - 3.3. Include drawings and schematics for all elements of the multi-task tool.
4. **Analysis of Design**
   - 4.1 Provide analysis of the rover and any subsystems demonstrating design sufficiency for expected obstacle performance requirements. Include any simulated vehicle data and/or calculations.
   - 4.2 Provide analysis of the task tool demonstrating design sufficiency for expected task site performance requirements. Include any simulated data and/or calculations.
5. **Safety**
   - 5.1 Provide a preliminary Personnel Hazard Analysis (PHA). This should include all phases of operation including construction/fabrication, testing, performance/competition.
   - 5.2 Provide a preliminary Failure Modes and Effects Analysis (FMEA) of the proposed design of the vehicle and components.
   - 5.3 The focus of the safety analyses at the design review is identification of hazards/failure modes, their causes, and resulting effects.
   - 5.4 Preliminary mitigations and controls should be identified, but do not need to be implemented at this point unless they are specific to the construction of the vehicle or components. (i.e., cost, schedule, personnel availability). Rank the risk of all hazards and failure modes for both likelihood and severity.
6. **Project Plan**
   - 6.1 Requirements verification to demonstrate all requirements in Section 6 of this handbook are being met.
   - 6.2 Provide a timeline update to demonstrate that the team is on schedule to meet the requirements of this project. Include deliverable dates, and planned fabrication and testing.
   - 6.3 Provide a budget update to demonstrate that the team is within budget. Include funding updates since proposal.

Operational Readiness Review (ORR)

The ORR examines construction, tests, demonstrations, and analyses to determine the overall rover and task tool readiness for a safe and successful excursion. The rover is expected to be complete and begin the testing phase. Performance data should be included validating the analyses from Design Review and that the team is ready to safely compete in the in-person competition.

- The Operational Readiness Review Report accounts for 20% of the overall score for the competition.
- The Operational Readiness Review Presentation will be worth 10% of the total ORR points.
- The ORR report and presentation should be given as a stand-alone deliverable. No information from the Design Review should be assumed as known by the scorers and panel participants. All relevant design information should be stated again.

Teams shall submit their ORR Report and ORR Presentation via email to HERC@mail.nasa.gov. Submit by the deadline specified in the handbook. Operational Readiness Review file name must follow the nomenclature School_Name_Year_Operational Readiness Review.

Format:

- ORR Report must be submitted in a PDF format
- Size 12 Times New Roman font or similar
- 8.5” × 11” paper size with 1-inch margins
- A cover page that includes:
  - The name of the high school and college/university and mailing address
  - Division: High School or College/University
  - Date
  - Name, Title, Email Address of:
    - The advisor
    - The student team leader
    - The student team safety officer
    - List of participating student team members (inclusive of the Student Team Leader and Safety Officer) who will be committed to the project and their proposed duties.

ORR Presentation: It is expected that the team participants deliver the report in a professional manner and answer all questions to their best ability. The advisor may attend but shall not deliver the presentation or answer any questions pertaining to the project other than when directed. The entire presentation will be delivered in English and translators will not be permitted.

- There is a 30-minute time-limit for presentation. A 15-minute feedback discussion will follow the presentation.
- The presentation shall include an overview of each section of the ORR Report.

Operational Readiness Review Report Outline

Page Limit: ORRs will only be scored using the first 30 pages of the report (not including cover page and abstract). Any additional content will not be considered while scoring, but may be appended for clarification.

1. **Table of Contents**
2. **Vehicle Criteria** — Design and construction of the vehicle
   - 2.1 Provide a final design summary of the as-built rover. Include dimensions, materials, and masses of major subsystems.
   - 2.2 Describe any major changes to the rover from the Design Review and explain why those changes are necessary.
   - 2.3 Prove that the vehicle is fully constructed and explain the construction process for major subsystems.
   - 2.4 Include schematics and/or images of the completed rover.
3. **Task Tool**
   - 3.1. Provide a final design summary of the as-built Multi-Task Tool. Include dimensions, materials, and masses.
   - 3.2. Describe any major changes to the Multi-Task Tool from the Design Review and explain why those changes are necessary.
   - 3.3. Prove that the task tool is fully constructed and explain the construction process.
   - 3.4. Include schematics and/or images of the completed task tool.
4. **Excursion Performance Predictions**
   - 4.1. Describe a strategy for optimizing points earned by your team's excursion performance on the course.
   - 4.2. Estimate how long it will take to complete each task and obstacle to be included in your excursion strategy.
   - 4.3. Explain how the rover will overcome each obstacle your team plans to attempt. This should include the physical aspect or parameter of each obstacle that is most important to complete it. Explain how your rover interfaces with those aspects or parameters.
   - 4.4. Identify parts or subsystems of that rover that are most critical (i.e., greatest potential for failure). Provide data showing these systems will perform successfully under nominal conditions.
   - 4.5. Describe how the task tool is expected to perform through the course design.
   - 4.6. Include contingency planning. How and why might your rover team adjust your excursion strategy while on the course?
5. **Safety**
   - 5.1. Update the Personnel Hazard Analysis and the Failure Modes and Effects Analysis to include:
     - 5.1.1. Finalized hazard descriptions, causes, and effects of the vehicle and mission components the team has built.
     - 5.1.2. A completed list of mitigations addressing the hazards and/or their causes.
     - 5.1.3. A completed list of verifications for the identified mitigations. This should include methods of verifying the mitigations and controls are (or will be) in place, and how they will serve to ensure mitigation.
   - 5.2. Include a list of procedures and checklists for competition days.

6. **Project Plan**
   6.1. Update the requirements verification plan demonstrating that all requirements from Section 6 in this handbook are met.
   6.2. Discuss any remaining test plans. Estimate test dates.
   6.3. Discuss the final budget and expense report.

STEM Engagement

- As part of the HERC Competition, teams should engage a minimum of 250 participants in direct educational, hands-on science, technology, engineering and mathematics (STEM) activities. These activities can be conducted in-person or virtually. To be considered for scoring, all events shall occur between project acceptance and the STEM Engagement Activity Report due date and must be submitted for each event via email to HERC@mail.nasa.gov by the due date. Content of the STEM engagement activities should be related to HERC activities (ex: mechanical design, vehicle infrastructure, physics, engineering design process, etc.).
- Teams must engage a minimum of 250 participants in Educational/Direct Engagement activities in order to be eligible for STEM Engagement scoring and awards. For a definition of what constitutes an Educational/Direct Engagement Activity see below. These definitions are also found in the STEM Engagement Activity Report for reference.
- Teams are encouraged to engage as many other participants as possible in other types of STEM Engagement activities. Although they will not count for points, activities completed before or after the submission window are encouraged and can still be submitted.
- STEM Engagement Activity Types:
  - **Education/Direct Engagement** (minimum 250 participants required)

    Instructional, hands-on activities 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 basic rover challenges through designing and building their own basic rover or students learn how to use CAD software to design the engineering parts. This type of interaction will count towards your requirement for the project/STEM Engagement Scoring.
  - **Education/Indirect Engagement**

    Participants are engaged in learning a STEM concept through instructor-led facilitation or presentation. Example: Students learn about center of gravity and balance of weight forces in basic movement of objects through a presentation or lecture.
  - **Outreach/Direct Engagement**

    Participants do not learn a STEM concept but are able to get hands-on exposure to STEM-related hardware. Example: The team does a presentation for students about their HERC project by bringing their rover and components to the event then demonstrates their rover performance to the students.
  - **Outreach/Indirect Engagement**

    Participants interact with the team in an informal setting. Example: the team sets up a display at a local museum during science night. Students come by, talk to the team and learn about their project.

STEM Engagement Activity Report

Each activity report submitted should represent one activity. There may be multiple events listed for the same activity. The template can be found below. Activity report should be fully completed and list all the event dates and information for an activity.

- The STEM Engagement Activity Type must be correctly identified for the activity. The NASA Review Panel reserves the right to change the activity type if the activity is categorized incorrectly.
- Activity descriptions should be clear and thorough. Learning targets should be clear and specific.
- Include with your report any documents, evaluations, surveys, questionnaires, handouts, videos or presentations (etc.) used in your activity.
- If you hold multiple events utilizing the same activity, only one report needs to be submitted with all the events.
- For numerous NASA STEM engagement ideas, educational resources, games, videos, and PowerPoint presentations; visit www.nasa.gov/stem. NASA educational resources can be searched and filtered by subject (e.g., space science, NASA history, technology, etc.). Below are three examples of Educator Guide that can be used with students.

    Landing Humans on the Moon Educator Guide

    Build, Launch, Recover Educator Guide

    Deep Space Communications Educator Guide

STEM Engagement Activity Report Outline

Please submit any pictures, presentations, or feedback documents which you would like to share with this document.

Activity Title: ______________________________

Type of Activity: ______________________________

Choose from these Types of Engagement Activities: Education/Direct Engagement, Education/Indirect Engagement, Outreach/Direct Engagement, Outreach/Indirect Engagement

Learning Target for the activity: *(Describe the learning target for this activity. What did you want your participants to learn from this activity? Be specific.)*

Describe your activity with this group: *(Please also submit any pictures, presentations, or documents which you would like to share.)*

Did you conduct an evaluation of your learning target? If so, what were the results? *(Please include a copy of your evaluation and a summary of your results.)*

Describe any feedback received from your participants about your activity overall. *(Please include any feedback forms or surveys that were used. Submit actual feedback from participants if able.)*

Event information *(For each event that was held for this activity, please enter the information in a table with the following headings. Each participant for each event should only be counted once.)*

Event Date	Name of Group	In-person or Virtual	Number of participants Preschool – 4 grade	Number of participants 5 – 8 grade	Number of participants 9 – 12 grade	Under-graduates	Educators	Adult (non-educators)

8. POINTS BREAKDOWN AND ALLOCATION

Table 1. Points Breakdown

Points Breakdown	Points	Weight (%)
Design Review (DR)	36	20%
Operational Rediness Review (ORR)	36	20%
Mission Readiness Review (MRR)	12	10%
Obstacles	41	20%
Tasks	60	20%
STEM Engagement	12	10%
Total Possible Points	200	100%

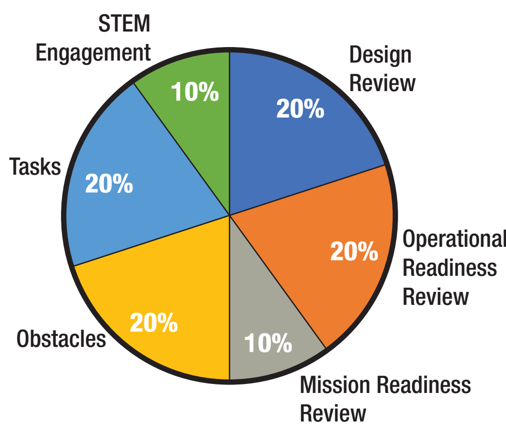

Figure 2. HERC Points Breakdown

Table 2. Mission Readiness Review

Item	Description	Possible Points	Summary of Points Breakdown
MRR Late Penalty	Teams arriving outside their time window for MRR, or not being ready for the MRR.	5-point penalty (– 5 Points)	Penalty can be assessed once at MRR and will carry over in the MRR score for both excursions.
ERR Readiness Penalty	Teams not able to demonstrate the vehicle is ready to proceed to ERR, not being ready to compete.	5-point penalty (– 5 Points)	Penalty can be assessed once at MRR and will carry over in the MRR score for both excursions.
Volume Constraint (This point total is carried over both excursions).	Vehicle measured to fit inside 5 × 5 × 5-foot volume constraint.	5	5 points for success 0 points for failure
Weight (This point total is carried over both excursions).	Vehicle and task tool will be weighed.	5	5 points for less than 130 lbs. 3 points for 131 – 170 lbs. 1 point for 171 – 210 lbs. 0 points for more than 210 lbs.
Unfolding/Assembly (This point total is carried over both excursions.)	Teams will be assessed on the amount of time it takes to unfold/assemble and ready the vehicle for course excursion.	2	2 points for 0:00 – 0:30 seconds 1 point for 0:31 – 1:00 minutes 0 points for more than 1:00 minute

Table 3. Excursion Readiness Review

Item	Description	Possible Points	Summary of Points Breakdown
Late Penalty	Teams arriving outside their time window, not being ready for excursions.	5-point penalty (– 5 Points)	Penalty can be assessed once per excursion for arriving outside their excursion window or not being ready to compete.
ERR Inspection	Teams will be inspected for safety requirements and task material requirements. Photos of Rover taken. The MRR will be combined with ERR for the first excursion.	N/A	See each task for point reference earned at ERR.
Post-Excursion Review	Inspection	See Task descriptions.	See each task for point reference earned at PER.

Detailed point breakdown included in each obstacle task description. (TS – Judged at Task Site; PER – Judged at Post-Excursion Review)

Table 4. Challenge Obstacles

Obstacle	Description	Bypass	Points	Points Breakdown
1	Undulating Terrain	Y	3	3 points for successful completion 1 point for attempt 0 points for bypass
2	Crater with Ejecta	Y	3	3 points for successful completion 1 point for attempt 0 points for bypass
3	Transverse Incline	Y	4	4 points for successful completion 1 point for attempt 0 points for bypass
4	High Butte	Y	6	6 points for successful completion 1 point for attempt 0 points for bypass
5	Large Ravine	Y	4	4 points for successful completion 1 point for attempt 0 points for bypass
6	Crevasses	Y	5	5 points for successful completion 1 point for attempt 0 points for bypass
7	Ice Geyser Slalom	Y	4	4 points for successful completion 1 point for attempt 0 points for bypass
8	Bouldering Rocks	Y	4	4 points for successful completion 1 point for attempt 0 points for bypass
9	Loose Regolith	Y	4	4 points for successful completion 1 point for attempt 0 points for bypass
10	Pea Gravel	Y	4	4 points for successful completion 1 point for attempt 0 points for bypass

Detailed point breakdown included in each obstacle task description. (TS – Judged at Task Site; PER – Judged at Post-Excursion Review)

Table 5. Challenge Mission Tasks

Task	Description	Bypass	Points	Points Breakdown
Task 1	Find ARV-30	Y	10	4 points for having the tool necessary to attempt the task (ERR) 6 points for successful activation of photocell indicator (TS)
Task 2	Regolith Removal	Y	10	4 points for having the tool necessary to attempt the task (ERR) 6 points for successful removal of enough debris to light indicator (TS)
Task 3	Moon Maintenance	Y	10	10 points for successfully opening cover plate (TS)
Task 4	Power It Up	Y	14	4 points for having the tool necessary to attempt the task (ERR) 5 points attaching one clamp (TS) 5 points for attaching both clamps (TS)
Task 5	Rover Redundancy	Y	16	4 points for having the tool necessary to attempt the task (ERR) 2 points for each sample container retrieved (TS) 1 point for each sample container retained until course completion (PER)

9. COURSE TASKS AND OBSTACLES

Note: All course obstacles and tasks outlined below are subject to change. Photos and drawings are provided for illustration purposes only and may or may not represent actual course design.

HERC 2024 Story Narrative

The tasks for 2024 will focus on an immersive story based on several of the proposed NASA use cases for crewed and uncrewed rovers during upcoming Artemis missions, namely: Exploring Permanently Shadowed Regions (PSRs), positioning to recharge batteries, power and data exchange with other surface assets, and storing collected samples. These are design considerations that NASA and partner engineers are currently working around to develop the next generation of lunar rovers.

Although the story takes place in one static location, the task sites will be arranged in different locations around the course. No obstacle traversing will be required to access any task sites.

> As part of the crew on a future Artemis mission, you are living in a Surface Habitat (SH) on the surface of the Moon and performing both scientific experiments and tasks to prepare for future missions. While most of the exploration of the Moon's surface is being done by Robotic Lunar Rovers (RLRs) and orbital observation; a pilotable rover, the Lunar Terrain Vehicle (LTV) is available for crew missions.
>
> During routine tasks inside the SH it is relayed to you by the crew aboard the orbiting Gateway that an RLR, designated ARV-30, that was operating just inside the Permanently Shadowed Region (PSR) of the moon has lost communications with Gateway. Crew aboard Gateway can spot the location of the rover, which is now completely stationary, but are unable to get any information as to why ARV-30 isn't communicating.
>
> To complicate the mission, the crew must travel in Extravehicular Activity (EVA) suits, as the LTV has no pressurized cabin. Most of the oxygen available for the trip will be used in traversing the distance required, leaving only 8 minutes available to attempt to diagnose and repair ARV-30. Crew have limited tools available for this mission, and a multi-use tool designed for general maintenance tasks is the only thing available beyond basic hand tools. If repair isn't possible, the samples collected by ARV-30 over the duration of its mission should be salvaged.

Mission

To determine why an autonomous rover exploring the PSR has gone out of contact, and if possible, attempt to repair the robotic rover.

TASK 1

Find ARV-30

10 Points

Story

> Two crew members are tasked to pilot the LTV to the location of ARV-30 to see if anything can be done with the limited tools available. Since the RLR in question was exploring in the absolute darkness of the PSR, crew must use handheld light sources to examine ARV-30 for signs of damage and to check the status indicators located on the external hull of ARV-30.

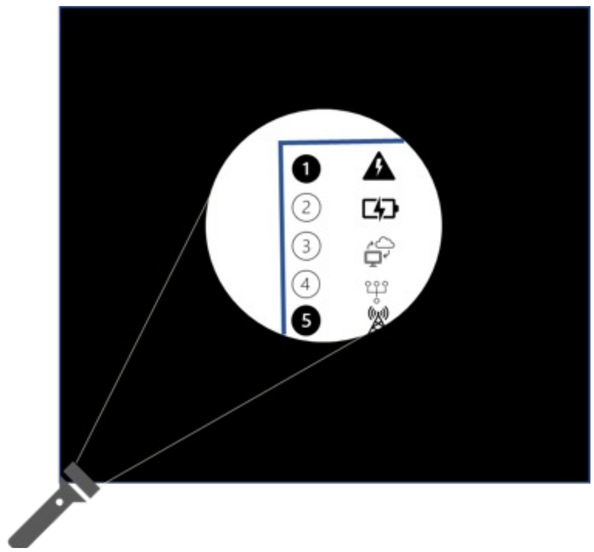

Figure 3. Task 1 – Find ARV-30 (10 points)

Pilots must use a task tool-mounted light source to examine a simulated instrumentation panel, which will be in complete darkness. Instrumentation and status lights on the panel should give an indication as to what the problem is. A photosensor will detect the light from the task tool and signal to the pilots that the task is complete.

TASK 2 Regolith Removal

10 Points

Story

> Upon further examination it is apparent that the solar cells on ARV-30 are completely covered in lunar regolith. While this has no effect in the PSR, it is imperative for the RLR to be able to freely move into a sunlit area to recharge when necessary.

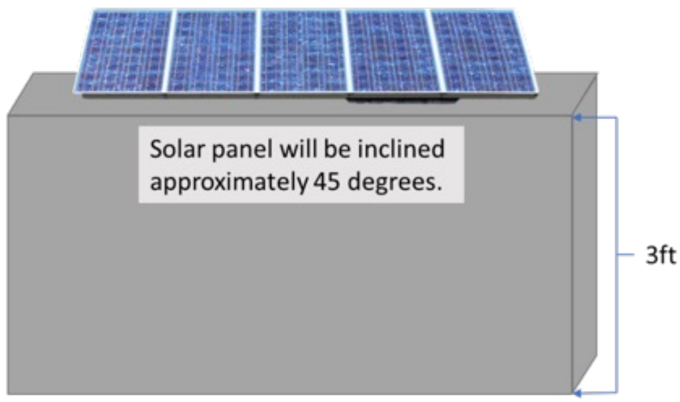

Figure 4. Task 2 – Regolith Removal (10 points)

Pilots must use their task tool to remove the regolith from a solar panel without damaging or moving it. Pilots are to remain on their rover and may use any non-destructive methods to remove a thin covering of simulated regolith; this is a working solar panel, and enough surface area must be cleared to generate the power required to light an indicator light.

TASK 3 Moon Maintenance

10 Points

Story

> The solar panels are now operational, but the rover is stranded in the PSR. The crew decides that they may be able to charge ARV-30 with enough power from the LTV batteries for it to pilot itself back to sunlight to fully charge. To access the necessary connections, a crew member must disembark the LTV and remove a cover plate by hand.

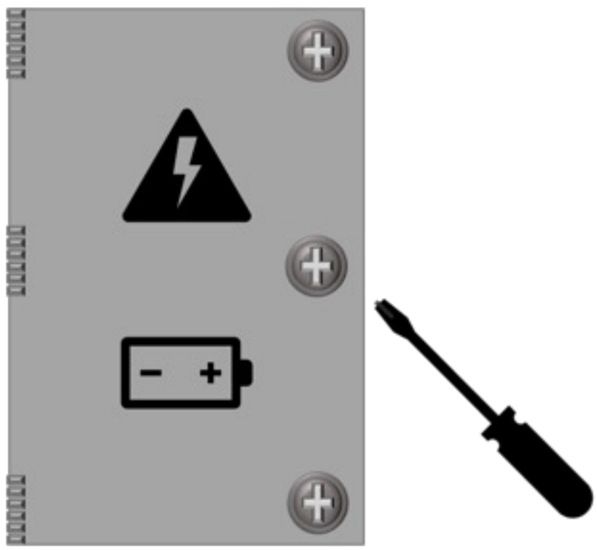

Figure 5. Task 3 – Moon Maintenance (10 points)

One rover pilot must safely disembark their rover and approach the task site. Using simulated EVA gloves and a provided hand tool they must remove several fasteners securing the cover plate. The plate is hinged and will not fall open or to the ground. Opening the cover plate and safely returning to and mounting your rover will constitute a successful task.

TASK 4 Power It Up

14 Points

Story

> With the cover plate removed it is now possible to charge ARV-30 with enough power to pilot itself into the sun to fully charge using the now-operational solar panels. A cable connection must be made between the LTV batteries and the batteries on the RLR. Due to the voltage of these batteries and the danger to crew, the task must be done with the multi-use tool.

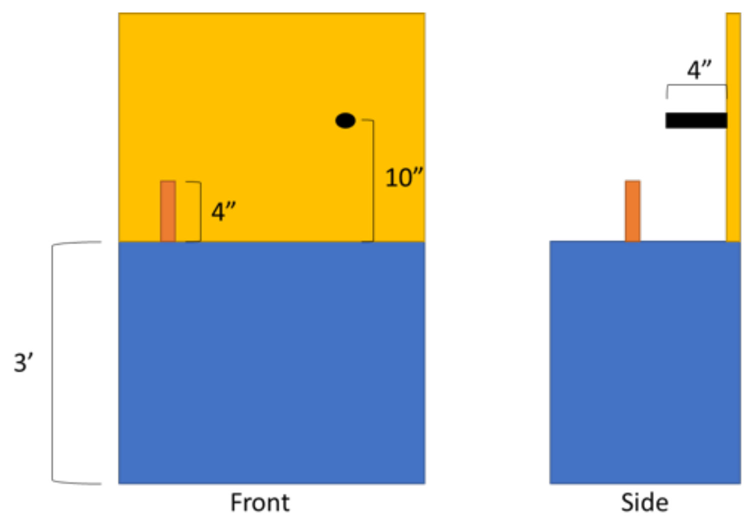

Figure 6. Task 4 – Power It Up (14 points)

A cable connection must be made between two simulated batteries with one side of the connection already made. Using the task tool, pilots must attach a provided clamp-ended positive/negative cable to two battery posts. The clamping force of these cables will not be as strong as an automotive jumper/booster cable but will operate similarly. The force required to open the clamps will be less than 15 lbs. Successfully attaching the cable to both posts will constitute a successful task. The cable clamps will not be over 3” wide at a neutral state.

TASK 5 Rover Redundancy

16 Points

Story

> While the RLR is charging, the pilots are advised by Gateway crew that the samples aboard ARV-30 should be retrieved and stored aboard the LTV as both a redundancy against ARV-30 not being able to return to the SH, or to extend the mission life of ARV-30 by giving more room for sample storage if the repairs were successful.

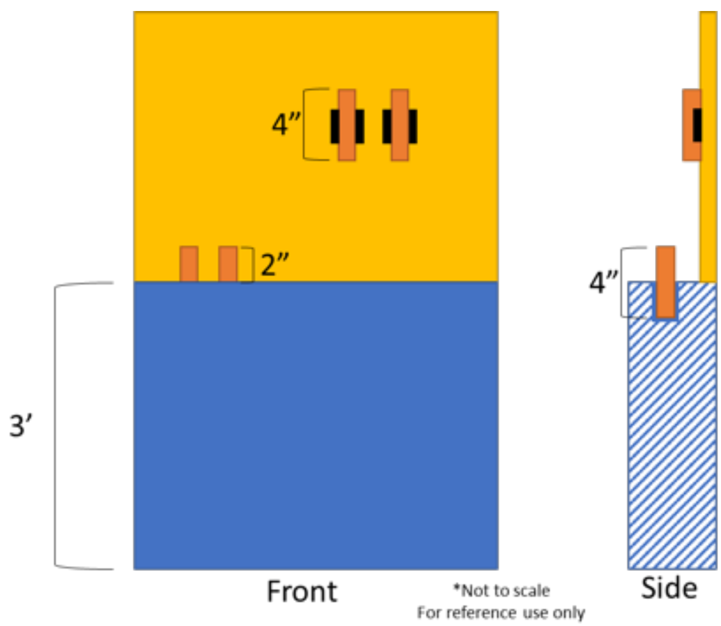

Figure 7. Task 5 – Rover Redundancy (16 points)

Using the task tool, four cylindrical sample containers with a diameter of 2” ± 0.125” and a length of 4 – 6” must be transferred from the task site to the rover and must be stored on the rover until the end of the course. Collection of the sample from the task tool and storing them on the rover may be done by hand, but the sample must be taken from the task site using only the task tool. Not all samples will be presented in a way that allows a full circumference grip, but a full diameter grip will at minimum be available. All samples are stored vertically.

OBSTACLE 1

Undulating Terrain

3 Points

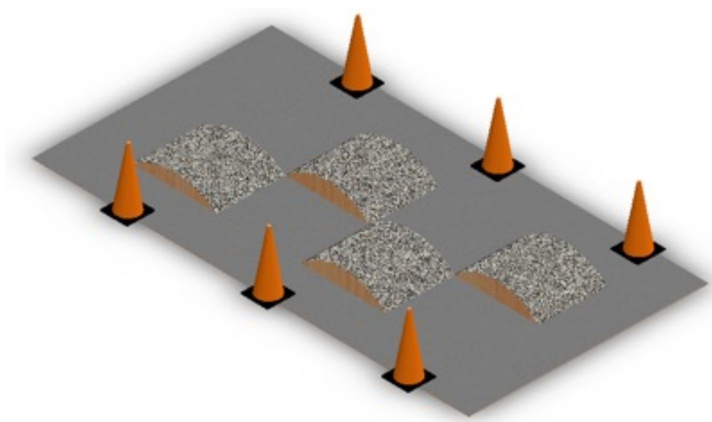

Figure 8. Obstacle 1 – Undulating Terrain (3 Points)

This gently uneven surface is replicated by four wooden ramps located alternating pattern causing the rover to be tilted to the right or to the left as only the wheels on one side of the rover are elevated at a time. The ramps range from six to twelve inches in height with gradual ingress and egress slopes, all covered with gravel. The length of each ramp is around 5 feet long and the width is around 4 feet as shown in Figure 8.

OBSTACLE 2

Crater with Ejecta

3 Points

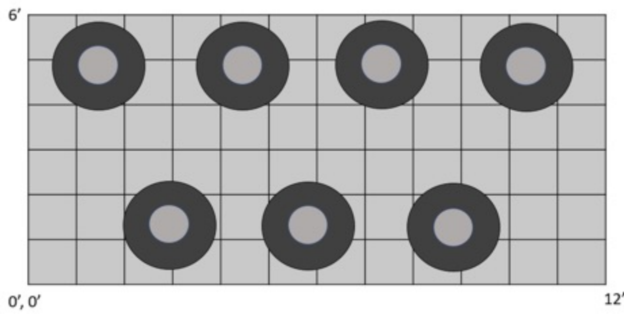

Figure 9. Obstacle 2 – Crater with Ejecta (3 Points)

This large crater is about two feet in diameter with a vertical height of eight inches. The craters are located offset from one another on opposite sides. The schematic in Figure 9 is for illustration purposes only and may or may not represent actual course design. Rays of ejecta, the material thrown out of the crater on impact, with the whole assembly is covered by gravel. The length of the obstacle is approximately 12 feet and the width is around 6 feet. Straws are added to direct the rovers to traverse the large crater.

OBSTACLE 3 Transverse Incline

4 Points

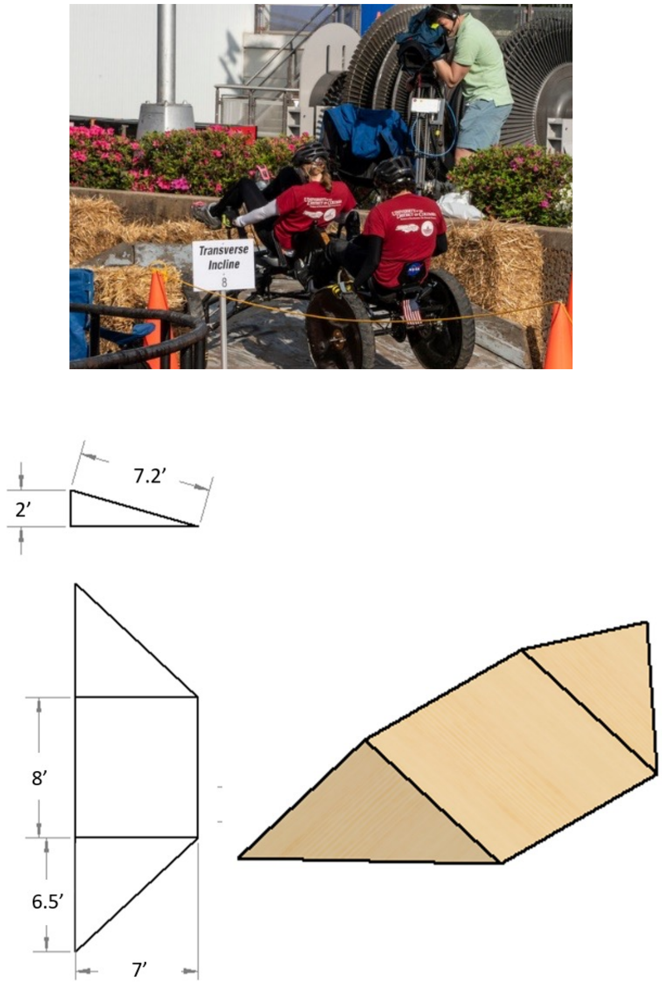

Figure 10. Obstacle 3 – Transverse Incline (4 Points)

The slope of this obstacle is perpendicular to the direction of rover traverse. The simulated lava or rock outcropping surface is smooth, and the angle of elevation of the incline is about 20-degrees. The total length of the obstacle is 21 feet as shown in Figure 10.

OBSTACLE 4

Martian Terrain High Butte

6 Points

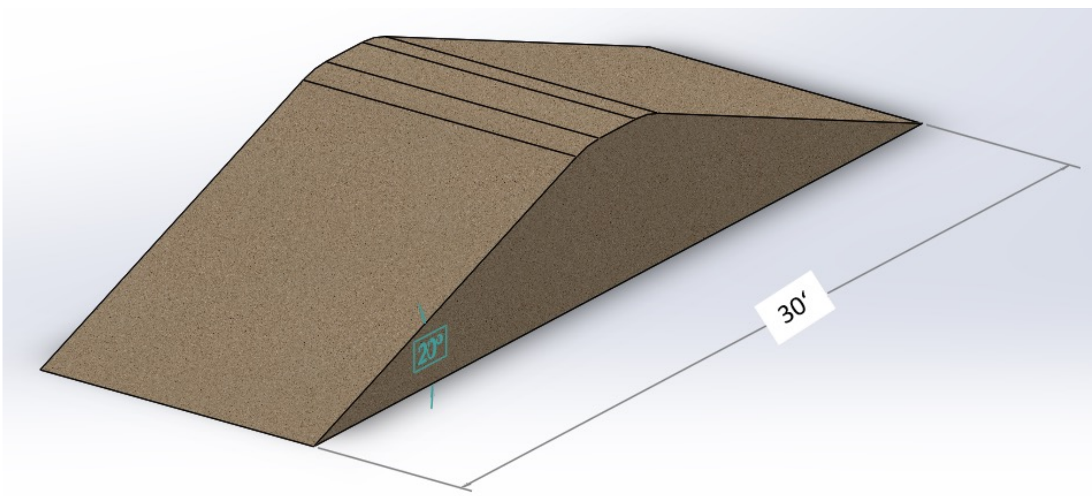

Figure 11. Obstacle 4 – Martian Terrain High Butte (6 Points)

This feature is a test of the rover's climbing ability. This butte is five feet high with a 20-degree incline before and after the peak and with a flat surface of 2 feet at the top. The butte is made from stone and soil. Figure 11 shows the dimensions of obstacle 4.

OBSTACLE 5

Large Ravine — Martian Terrain

4 Points

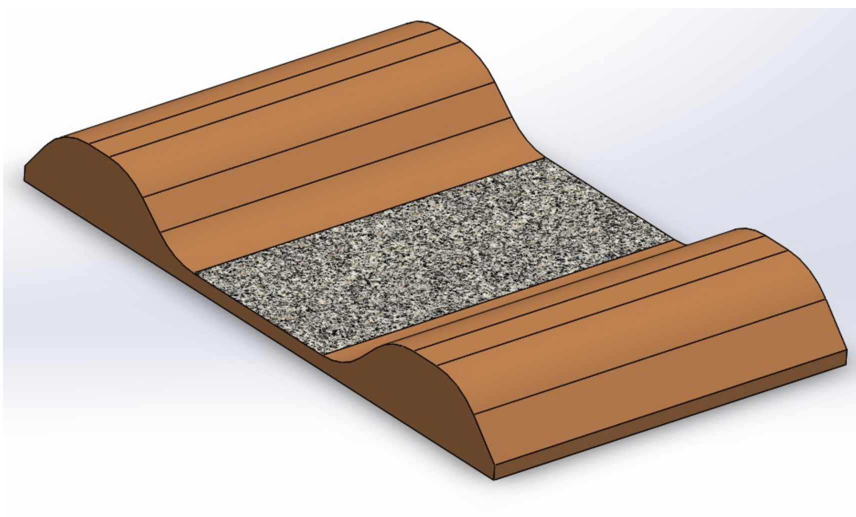

Figure 12. Obstacle 5 – Large Ravine – Martian Terrain (4 Points)

A remnant of an ancient erosion channel, this two-foot depression, about eight-feet wide, provided a conduit for liquid runoff on the Martian surface. The bottom of the depression is filled from gravel to simulate the Martian surface.

OBSTACLE
6

Crevasses

5 Points

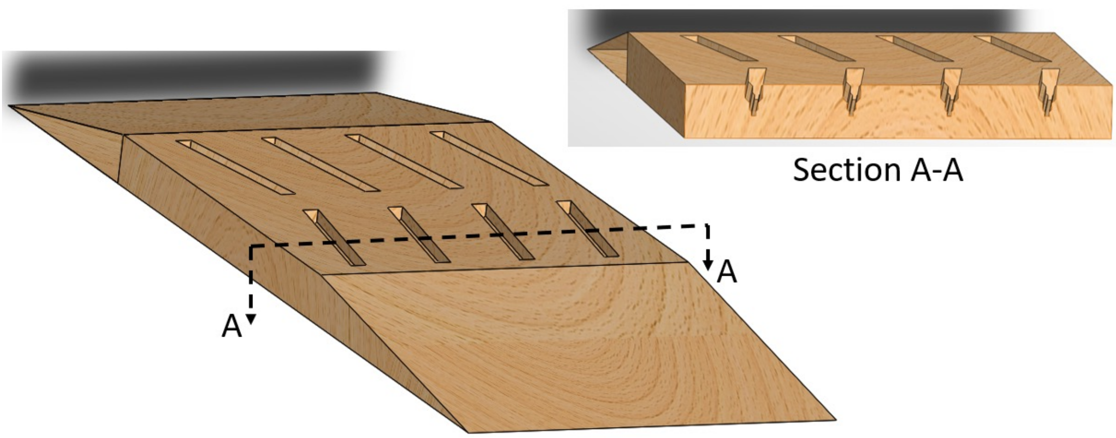

Figure 13. Obstacle 6 – Crevasses (5 Points)

Crevasses result from cracks in the surface regolith or from erosion by liquid and/or molten material forming ruts in underlying material. There are four sets of parallel cracks located along with the direction of rover traverse. Each crevasse consists of multi-level cracks, and the depth of each crack varies between 4 to 7 inches and the width varies throughout between 1 to 4 inches as shown in Figure 13. The length of each set of cracks is around 4 feet long and the total length of the obstacles is around 12 feet. Teams shall design the wheel of the rover to avoid having the rover wheels stuck in these cracks.

OBSTACLE
7

Ice Geyser Slolam

4 Points

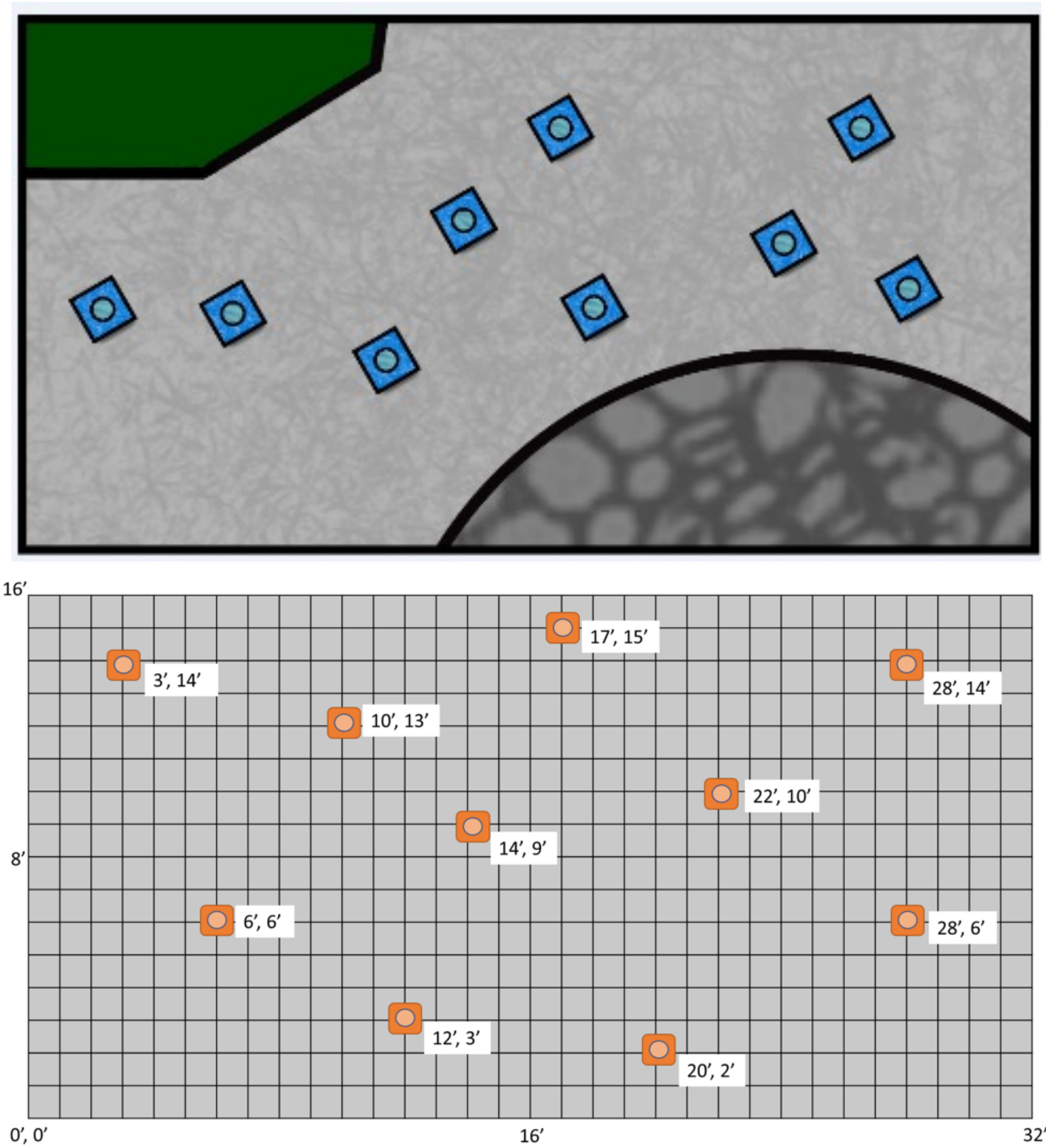

Figure 14. Obstacle 7 – Ice Geyser Slalom (4 Points)

A series of simulated ice geysers impede the path. This obstacle requires that teams carefully navigate without encountering any of the geysers. The approximate places of the ice geysers and approximate total length and width of obstacles are shown in Figure 14. Steering systems will be of utmost importance to do this. There will be a marked exit lane through which rovers shall pass without touching its boundaries.

OBSTACLE 8

Bouldering Rocks

4 Points

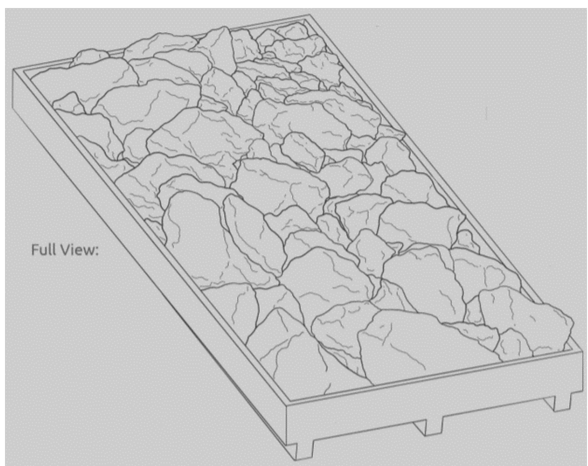

Figure 15. Obstacle 8 – Bouldering Rocks (4 Points)

Rovers shall navigate over this field of simulated asteroid debris (boulders) while not avoiding the debris. The asteroid fragments range in size from three to 12 inches and are situated close together. The total length of the obstacle is around 10 feet, and the width is around 6 feet. Proceed with caution.

OBSTACLE 9

Loose Regolith

4 Points

Figure 16. Obstacle 9 – Loose Regolith (4 Points)

Rovers shall navigate over this field of simulated asteroid debris (boulders) while not avoiding the debris. The asteroid fragments range in size from three to 12 inches and are situated close together. The total length of the obstacle is around 10 feet, and the width is around 6 feet. Proceed with caution.

OBSTACLE 10

Pea Gravel

4 Points

Figure 16. Obstacle 10 – Pea Gravel (4 Points)

This ancient stream bed consists of fine rounded pebbles deposited to a depth of about six inches. Rover wheels might sink in this smooth obstacle material. The total length of the obstacle is 10 feet and the width is around 6 feet.

10. AWARDS

Table 6. Awards Breakdown

Award	Description of Award
Overall Winner	Awarded to the top overall team. Design reviews, educational STEM engagement, safety, and a successful excursion will all factor into the Overall Winner.
STEM Engagement	Awarded to the team that is determined to have best inspired the study of STEM-related topics in their community to include collaboration with middle school students for the Task Challenge. This team not only presented a high number of activities to a large number of people, but also delivered quality activities to a wide range of audiences.
Project Review	Awarded to the team that is deemed to have the best combination of written reviews and formal presentations.
Phoenix	Awarded to the team that demonstrates the greatest improvement between Design Review and Operational Readiness Review.
Social Media	Awarded to the team that has the most active and creative social media presence throughout the project year.
Task Challenge	Awarded to the team that best demonstrates a multi-tool design for the mission tasks.
Featherweight	Awarded to the team that best addressed the ongoing space exploration challenge of weight management, delivering an innovative approach to safe minimization of rover weight. (Only awarded to one team overall.)
Ingenuity	Awarded to the team that approaches complex engineering problems in unique and creative ways.
Pit Crew	Awarded to the team as judged by the pit crew that best demonstrates resourcefulness, motivation, good sportsmanship, and team spirit in repairing or working on their rover while the teams are in the pit area.
Safety	Awarded to the team that best demonstrates a comprehensive approach to system safety as it relates to their vehicle, personnel, and operations.
Team Spirit	Awarded to the team that is judged by their peers that display the “Best Team Spirit” during the onsite events.
Crash and Burn	Awarded to the team that embraces failure as a learning lesson for future success. (Only awarded to one team overall.)
Rookie of the Year	Awarded to the top overall newcomer team. (Same judging criteria as overall award. If rookie team is awarded an overall award, the 2nd place standing rookie team will receive the award, and so forth. Only awarded to one team overall.)
Other Awards	Other awards will be given based on components of the competition, such as discussions within Design Review and Operational Readiness Review reports or the in-person competition.

Note: Awards are given to a qualified team in each category (high school and college/university) unless otherwise noted. Awards are subject to change without notice.

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