ALIGNMENT WITH NATIONAL STANDARDS IN ENGINEERING AND SCIENCE

The Human Exploration Rover Challenge (HERC) is a rigorous, relevant, 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 (NGSS) 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.

**ACCREDITATION BOARD FOR ENGINEERING AND TECHNOLOGY (ABET); CRITERIA 3. STUDENT OUTCOMES:**

1. an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics
2. 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
3. an ability to communicate effectively with a range of audiences
4. 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
5. 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
6. an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions
7. an ability to acquire and apply new knowledge as needed, using appropriate learning strategies.
TABLE OF CONTENTS

1. Background: the NASA Human Exploration Rover Challenge ........................................ 1
2. HERC Objective ............................................................................................................. 2
3. Timeline ....................................................................................................................... 3
4. Glossary of Terms and Acronyms .............................................................................. 4
5. Rules and Regulations ................................................................................................ 6
   General Rules and Regulations .................................................................................. 6
6. Competition Day Rules, Regulations, and Information ............................................. 7
   Pit Area Rules and Regulations .................................................................................. 8
7. Registration and Proposal ............................................................................................ 8
   U.S. Teams Registration Process .............................................................................. 8
   International Teams Registration Process ................................................................ 8
   International Team Proposal Requirements .............................................................. 9
8. Requirements ................................................................................................................ 11
   Communication & Documentation Requirements ...................................................... 11
   Team Member Requirements .................................................................................... 11
   Safety Requirements .................................................................................................. 12
   Vehicle Requirements ................................................................................................ 13
   Task Tool Requirements ............................................................................................. 14
   STEM Engagement Requirements ............................................................................ 15
   Excursion Day Requirements & Information ............................................................. 15
   Mission Readiness Review Requirements ................................................................ 16
   Excursion Readiness Review Requirements ............................................................... 18
9. Reports and Reviews: Criteria and Deliverables ...................................................... 18
   Design Review Criteria and Deliverables .................................................................. 18
   Operational Readiness Review Criteria and Deliverables ......................................... 19
10. Points Breakdown and Allocation .............................................................................. 20
    Table 1: Mission Readiness Review ...................................................................... 21
    Table 2: Excursion Challenge Reviews .................................................................... 22
    Table 3: Challenge Obstacles .................................................................................. 23
Table 4: Challenge Obstacles Continued ................................................................. 24
Table 5: Challenge Tasks ............................................................................................. 25
Table 6: Challenge Tasks Continued ........................................................................ 26

11. Awards ................................................................................................................. 27
Table 7: Awards Breakdown ....................................................................................... 27
Table 8: Awards Breakdown Continued ..................................................................... 28

12. Course Descriptions and Design ......................................................................... 29
Obstacle 1: Undulating Terrain .................................................................................. 29
Obstacle 2: Crater with Ejecta .................................................................................... 29
Obstacle 3: Transverse Incline ................................................................................... 30
Obstacle 4: Martian Terrain High Butte ...................................................................... 30
Obstacle 5: Large Ravine – Martian Terrain ............................................................... 31
Task 1: Spectrographic Analysis ................................................................................. 31
Task 2: Instrument Deployment .................................................................................. 33
Obstacle 6: Crevasses ................................................................................................. 34
Obstacle 7: Ice Geyser Slalom .................................................................................... 34
Obstacle 8: Lunar Crater ............................................................................................. 35
Task 3: Core Sample Retrieval ................................................................................... 35
Obstacle 9: Bouldering Rocks ..................................................................................... 36
Task 4: Solid Soil Sample Retrieval .......................................................................... 36
Obstacle 10: Tilted Craters ......................................................................................... 37
Task 5: Liquid Sample Retrieval ............................................................................... 38
Obstacle 11: Loose Regolith ...................................................................................... 39
Obstacle 12: Pea Gravel ............................................................................................. 39

13. Appendices ............................................................................................................ 41
Appendix A – Cover Page Template ......................................................................... 42
Appendix B – DR Report Outline .............................................................................. 43
Appendix C – ORR Report Outline .......................................................................... 45
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. In its second year as an Artemis Student Challenge, HERC draws inspiration from the Apollo and Artemis missions, emphasizing designing, constructing, and testing technologies, and traversing in unique environmental terrains.

In 1971, astronauts Alan Shepard, Stuart Roosa, and Edgar Mitchell launched on Apollo 14, an extraordinary, complex mission to the Moon. Like other missions, their story is humankind’s battle against almost impossible odds, a story of highs and lows. While Roosa remained in orbit aboard the capsule, one task assigned to Shepard and Mitchell was to explore Cone Crater to better understand the Moon’s early history. Scientists believed that rocks near the crater’s edge would yield some of the oldest material. At one point during the trek, Shepard’s heart rate reached 150 beats per minute (bpm). Both astronauts were stopping to take breaks, perspiring and gulping intakes of oxygen, and the internal temperature of their suits was rising dramatically. The crew had been gone from the lunar module Antares for two hours and were running out of time and oxygen. They had difficulty navigating the slopes and fell 30 minutes behind schedule. As a result, they reached a point within 50 feet of the rim of the crater before turning back toward Antares. The crew gathered 99 pounds (45 kilograms) of lunar material and achieved the goal of reaching the vicinity of the crater.

Later that year on July 26, 1971, David R. Scott, James B. Irwin, and Alfred M. Worden launched on Apollo 15, a three-day mission during which they 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 goal with the Artemis’ mission is to send the first woman and first person of color for exploration and to develop a sustained human presence on the Moon. Lunar science on the surface of the Moon will be conducted with polar and nonpolar 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 designs and unique perspectives. The challenge 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.
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 task tools 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 mission tasks. The team with the highest number of points accumulated throughout the project year in each category (high school and college/university) will be the winner.

The competition course requires two students, at least one female, use the student-designed vehicle to traverse a course of approximately half-mile that includes a simulated field of asteroid debris, boulders, erosion ruts, crevasses, and an ancient streambed. The challenge’s weight and time requirements encourage the rover’s compactness, light weight, high performance, and efficiency. As part of the competition, rover entries are tested to ensure they would fit into a lander storage area, a maximum 5 feet long by 5 feet tall by 5 feet in volume. 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 three competition days on a roving vehicle while carefully collecting terrain material and conducting science experiments that are crucial for the mission.
3. **TIMELINE**

_Dates Are Subject to Change_

**July 29, 2021** ........................................ Handbook Released
Request for Proposal Released for International Teams

**September 9, 2021** ............................... Registration for U.S. Teams Opens
Electronic Copy of International Team Proposals
Due By 4:00 P.M. CDT (9:00 P.M. UTC)

**October 7, 2021** ................................. Registration for U.S. Teams Closes
All U.S. Teams Shall Have Completed Registration
International Team Selections Announced

**October 8, 2021** ................................ Registration for Selected International Teams Opens

**October 14, 2021** .............................. Registration for Selected International Teams Closes
Team Social Media Presence Established and
Social Media Links List Submitted

**October 21, 2021** ............................... Kickoff Webinar And Q&A

**November 18, 2021** .............................. Design Review (DR) Report Submission Due

**November 29 – December 17, 2021**  .... DR Presentations
Design Completed and Construction in Progress

**February 3, 2022** ............................... Final List of Team Members Due
Team Photo Due

**March 3, 2022** ..................................... Operational Readiness Review Report Submission Due
Photos of Completed Rover for Verification Due

**March 7 – 24, 2022** ............................. ORR Presentations
Rover/Components Completed, and Testing in Progress

**April 28, 2022** ................................. Competition Day 1
- Team Check-In
- Mission Readiness Review (MRR)
- Course Walk-Through
- Safety Briefing

**April 29, 2022** ................................. Competition Day 2
- Excursion 1
- Surveys Completed

**April 30, 2022** ................................. 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** - Is defined as both drivers 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.

**Driver** – Synonymous with crew; one or both student team members (at least one female) that propels the vehicle over the course.

**ERR** – Excursion Readiness Review; events that occur both days prior to course excursion and include safety and task material inspection.

**Excursion** – An attempt to traverse the course tasks and transverse challenges to accumulate points. Teams will have two excursion opportunities (weather permitting), one on Friday and one on Saturday of the competition. 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 on both days.

**FMEA** – Failure Modes and Effect Analysis

**HEO or HEOMD** – Human Explorations and Operations Mission Directorate provides the Agency with leadership and management of NASA space operations related to human exploration in and beyond low-Earth orbit. HEOMD is a contributor to this competition.

**HERC** – Human Exploration Rover Challenge

**kg** - Kilograms

**MRR** – Mission Readiness Review; the events occur the day before the first excursion runs. This includes the volume constraint, weighing the vehicle and unfolding/assembling the vehicle.

**MSAT** – Marshall Safety Action Team

**MSFC** – Marshall Space Flight Center

HERC@mail.nasa.gov  www.nasa.gov/herc
**mL** - Milliliter

**NASA** – National Aeronautics and Space Administration

**ORR** – Operational Readiness Review; examines the actual system characteristics and procedures used in the system or end product’s 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, MRR, plus the Obstacles and Tasks Competition.

**PDF** – Portable Document Format; is a file format developed by Adobe in 1993 to present documents, including text formatting and images, in a manner independent of application software, hardware, and operating systems.

**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.

**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.

**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 cameras, instrument deployment equipment, collection tools, 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)](https://www.nasa.gov/mission_pages/ARM/acronyms.html)
5. RULES AND REGULATIONS

GENERAL RULES AND REGULATIONS

1. 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.

2. 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.

3. 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.

4. Any team member or advisor found to be exhibiting unsportsmanlike conduct may be disqualified from the challenge individually or as a team.

5. All scoring decisions are final. If an appeal is warranted, the advisor or the 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.
6. 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, but teams may use vehicles designed in 2020.

7. Each team is required to submit a DR report 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.**

8. Each team is required to submit an ORR report, and required to 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.**

9. Teams not meeting any requirement listed may be disqualified.

---

6. COMPETITION DAY RULES, REGULATIONS, AND INFORMATION

1. Rovers may be shipped to the 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):

   **ATTN: Warehouse Manager**
   
   U.S. Space & Rocket Center
   
   1 Tranquility Base
   
   Huntsville, AL 35805
   
   USA

2. 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.

3. Neither USSRC nor HERC Staff will provide a facility, tools, or equipment for assembling or disassembling rovers (in any condition), and/or opening crates.

4. The consumption of alcoholic beverages and/or controlled substances is strictly prohibited 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.
5. 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.

6. In accordance with Federal Aviation Administration (FAA) regulations, the use of drones during any HERC activity is strictly prohibited.

7. Driving the rover on the course, or in the parking lot, in a reckless or unsafe manner is not permitted, and disqualification may result.

**PIT AREA RULES AND REGULATIONS**

1. Teams are provided two pit parking spaces 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 nearby general parking area.

2. Parking passes, inclusive of contact information, must be displayed in the front windshield of registered vehicles in the pit area.

3. 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 prior to the MMR on Thursday of the event).

7. **REGISTRATION AND PROPOSAL**

**U.S. TEAMS REGISTRATION PROCESS**

1. Online registration for the competition is automated and electronically monitored. All U.S. teams shall register during the open period via the site link provided on the HERC website (www.nasa.gov/herc).

2. All registration form information shall be completed for the registration to be valid.

3. Teams registration will be confirmed via email upon approval of registration.

4. Each U.S. school or institution may register **ONE** team.

**INTERNATIONAL TEAMS REGISTRATION PROCESS**

1. International teams shall submit a proposal for consideration to compete. A written proposal submission shall follow and answer the requirements outlined in section: *International Team Proposal Information*, pg. 9.

2. Teams will be scored based on a rubric developed from the International Team Proposal Requirements.
3. International teams may propose **ONE** team per school or institution for consideration.

4. Proposals shall be written solely by the student members of the team.

5. Proposals submitted after the deadline (date and time received) will not be considered.

6. Top scoring proposals will be selected to compete and allowed to register for the competition. A team whose proposal is selected will be provided access to the registration website.

7. All registration form information shall be completed for the registration to be valid.

8. A Team’s registration will be confirmed via email upon approval of registration.

**INTERNATIONAL TEAM PROPOSAL REQUIREMENTS**

1. At a minimum, the proposing team shall identify the following in a written proposal due to NASA MSFC by the dates specified in the timeline.

2. Proposals shall not exceed 10 pages in length not including the cover page, index, or appendices. Additional pages will not be considered as part of the proposal.

3. Format:
   a. Proposals must be submitted in a PDF format;
   b. Size 12 Times New Roman font or similar;
   c. 8.5” x 11” paper size with 1-inch margins;
   d. A cover page that includes:
      I. The name of the college/university or secondary education institution and mailing address;
      II. Date;
      III. Name, Title, Email Address of:
         i. The advisor;
         ii. The student team leader;
         iii. The student team safety officer.
      IV. List of up to ten participating student team members (inclusive of the Team Leader and Safety Officer) who will be committed to the project and their proposed duties.

4. Facilities and Equipment:
   a. Description of the facilities, hours of accessibility and necessary personnel that are required to design and manufacture the vehicle components.
5. Description of the facilities equipment and supplies that are required design and manufacture the vehicle components.

6. Safety (FMEA):
   a. 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;
   b. Describe the plan for briefing students on hazard recognition and accident avoidance;
   c. Describe methods to include necessary caution statements in plans, procedures, and other working documents (including the use of proper PPE).

7. Technical Design
   a. A detailed explanation of the rover and its components with justifications and implementation;
   b. All general vehicle dimensions, construction methods, and overall design;
   c. A detailed description of all major new or used components;
   d. Wheel design and fabrication plans;
   e. Drivetrain concept and design with fabrication plans;
   f. Provide an initial strategic plan for the course obstacles and mission support tasks;
   g. Summarize driver’s interaction with the rover and its components;
   h. Address major technical challenges and possible solutions the team will face during the engineering design and manufacturing phase.

8. Project Plan
   a. Provide a detailed development schedule/timeline covering all aspects necessary to meet all milestones and complete the project successfully;
   b. Provide a budget to cover all aspects necessary to complete the project successfully, inclusive of team travel.

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

10. Funding Plan
    a. Develop a plan for activity sustainability in the local area. This plan should include established partnerships and an approach to regularly engage successive classes of students in STEM. It should include partners (industry/community), recruitment of team members, funding sustainability, and STEM engagement activities.
8. **REQUIREMENTS**

**COMMUNICATION & DOCUMENTATION REQUIREMENTS**

1. Communication to the activity leads of HERC 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).

2. The team shall establish a social media presence to inform the public about day-to-day team activities.

3. Teams shall email all deliverables to the HERC project management team via the email provided 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”.

4. All verbal and written communication shall be in English.

5. The DR and ORR reports shall follow format and outline guidance found in Section Report and Reviews: Criteria and Deliverables, pg. 19.

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

7. Each team is required to submit their participation survey by the beginning of Competition Day 2. A team will not be allowed to start their Competition Day 2 until every team member, including the advisor, has completed the excursion day survey.

**TEAM MEMBER REQUIREMENTS**

1. 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.

2. High School teams will be composed of students ages 14 through 19.

3. Accredited institutions of higher learning (College/University) teams shall be composed of undergraduate students.

4. 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.

HERC@mail.nasa.gov

www.nasa.gov/herc
5. 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.

6. **Age and enrollment verification may be requested at any time.**

7. 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.

8. 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 drivers (at least one female) to propel the vehicle through the course.

**SAFETY REQUIREMENTS**

1. Teams must utilize appropriate PPE when performing construction activities, such as welding, handling metal components, and using tools anywhere on the USSRC property or neighboring areas. Teams shall also exercise appropriate safety precautions during the design, build, and test phases of this competition.

2. Each rover shall have robust, practical seat restraints for each of the drivers. The restraints must be capable of preventing the drivers 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 driver 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.

3. Each rover shall have at least one adequate mechanical braking system to ensure the safety of the drivers, HERC staff and fellow participants. Braking system(s) shall be able to hold the rover and accompanying drivers 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.

4. All sharp edges and protrusions must be eliminated and/or guarded, as necessary to ensure safety of the driver’s, participants and HERC Staff as determined by the safety judge.

5. Your safety is our biggest priority. Drivers 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 drivers to ensure safety hazards are clear.
before proceeding. Drivers will be asked to describe their communication plan to the MSAT and/or another judge before the excursion.

6. Using poles or other devices to propel or push the rover is not allowed. A driver’s use of his or her hands on the wheels (as with a wheelchair) to facilitate vehicle movement is not permitted.

7. Specific PPE is required prior to any teams being allowed to traverse the course during the entirety of the excursion:
   a. Eye protection, e.g. safety glasses, goggles, or face shield;
   b. Commercially manufactured head protection, e.g. bicycle helmet;
   c. Full-fingered gloves;
   d. Long-sleeved and long-torso shirts;
   e. Long pants (dangling pants shall be wrapped and/or taped down);
   f. Long Socks;
   g. Enclosed shoes (shoelaces shall be wrapped and/or taped down);
   h. No apparatuses, such as stilts, may be used on the feet of the drivers.

**VEHICLE REQUIREMENTS**

1. Teams shall design, build, and test rovers capable of traversing hills up to 5 feet high and inclines up to 30 degrees. Vehicles shall be capable of turning radius of 15 feet or less. Rovers shall be designed for both ruggedness and the ability to perform on the unique terrain.

2. The following must be adhered to or teams forfeit the opportunity to place overall in the challenge.
   a. 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.
   b. 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;
   c. Vehicles, inclusive of drivers, shall have a center of gravity low enough to safely handle slopes of 30 degrees front-to-back and side-to-side;
   d. Rover shall have a mechanical braking system as per requirements in Safety Requirement Section, #3 pg.13.
e. Chain-drive systems are strongly discouraged and use of alternative drive-systems are encouraged and rewarded with a 5% bonus to the overall score. **NOTE: Rovers utilizing a chain-drive chain system will be ineligible for an overall challenge award.**

**TASK TOOL REQUIREMENTS**

1. Teams shall design/procure a tool or tools that can collect liquid samples and shall provide methods for preventing cross-contamination during sample collection and transport. Teams are not limited to the number of sample retrieval devices.

2. Teams may choose to design, in conjunction with middle school students, and build a 3D-printed tool for Task 5 for additional points. The tool shall be 100% 3D-printed except for the uncontaminated container and storage area. Including middle school students in this effort is meant to not only be part of the team’s STEM Engagement but act to encourage younger students, through engagement in the engineering design process, to pursue STEM careers. Points will be award for the use of a 3D-printed task tool during the MRR.

3. Five tasks are located throughout the course and may or may not be attempted for points within the allotted time. **NOTE:** only two of the five task tools requires documentation in the DR and ORR.

4. Task tools shall be stowed on the rover throughout the entirety of the excursion except for the instrument package, which is left at the TS, if attempted. Task materials cannot be shared with other teams. Teams must come to a complete stop immediately adjacent to each task to attempt the task.

5. Each sample shall be stored in a sealed and clean container, which is also provided by the team. Teams shall also provide detailed discussion in the DR and ORR for mitigations to prevent contamination. The collection of samples shall be contained in a storage area on the rover and be secure.

6. Cross-contaminated samples will not receive points. Sample collection will be monitored by the accompanying task judge. This includes contamination through participant interaction on sample collection device(s) that have direct contact with the sample (i.e. jar, scoop, bag, or vile). Judges will look for the riders to make clear effort to avoid the transfer of material between sample sources, such as by using the same sample system to collect different samples or by the appearance of sample material outside enclosed sample containers in the transport holder on the rover.

7. If teams fail to have tools for a task at ERR points will not be awarded for that task.
STEM ENGAGEMENT REQUIREMENTS

1. Teams must engage a minimum of 200 participants in educational, hands-on Science, Technology, Engineering, and Mathematics (STEM) activities.

2. The content of the STEM engagement activities must be connected to HERC activities (i.e. engineering design process, vehicle infrastructure, physics, mechanics, etc.).

3. Teams are recommended to provide tangible evidence of active participation of conducted events.

4. All events shall occur between the dates of team acceptance and the ORR due date where the team’s final report of STEM Engagement activities will be documented.

5. Teams are highly encouraged to collect participants’ demographics information.

6. Teams are highly encouraged to continue STEM Engagement activities/events after ORR.

EXCURSION DAY REQUIREMENTS & INFORMATION

1. Upon successful completion of MRR, teams are permitted two excursions of the course, one on Competition Day 2 and one on Competition Day 3, weather permitting.

2. Teams have a total of 8:00 minutes to complete each excursion. Teams will receive points by successfully traversing obstacles and completing mission tasks.

3. Teams failing to complete an excursion under 8:00 minutes are ineligible for competition awards based on excursion performance. They will be notified that their excursion is aborted, and either be removed from the course or shall proceed with haste to the end, utilizing each available bypass and will not accrue additional points.

4. Drivers must be on the vehicle, with safety belt fastened, and all safety equipment (PPE) in place before driving their rover during an excursion attempt.

5. The excursion time stops when a team either crosses the finish line or reaches the 8:00-minute limit, whichever comes first.

6. Judges may make drivers aware of their 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 judging officials will maintain the official excursion time.

7. The drivers for the first excursion shall be the same as those who conducted MRR. Driver’s substitutions may be made for the second excursion, or Competition Day 3.

8. Communication devices are allowed if at least one driver can hear ambient sounds/instructions from judges.
9. Drivers attempting but unsuccessfully completing an obstacle will earn one point for that obstacle. Indirectly approaching the obstacle, getting off the vehicle (pushing, pulling) or veering off is considered an unsuccessful attempt.

10. The course is comprised of 12 obstacles and five mission tasks. 10 of the obstacles have bypasses, where teams can strategically choose to either attempt the obstacle for points or bypass it for zero points.

11. Judges have the authority to remove a disabled or slow rover from the course when it will affect the excursion time of the next successive rover. The excursion time for the disabled/slow vehicle halts at the point of removal and resumes once the successive vehicle has passed.

12. Individuals (team members and supporters) may not follow the rover around the course during the excursion time. If desired, teams can post members at locations along the course per the staff’s discretion.

13. Rover numbers will be provided in the registration packet on two printed 8.5 by 11-inch waterproof sheets and shall be affixed to the front and left side of the rover, in an unobstructed view for the judges.

**MISSION READINESS REVIEW REQUIREMENTS**

1. Teams will complete MRR during the pre-determined time window on Competition Day 1. Time windows, and the method for obtaining a time window, will be communicated to teams well in advance of the competition.

2. A team who arrive late to, and/or are not ready to participate during, their time window for MRR will receive a five-point penalty for the challenge.

3. Vehicles must meet the 5 x 5 x 5-foot volume constraint or five cubic feet in the stowed configuration, and a jig will be placed over the rover for volume constraint verification.
   a. No modifications or team rover interaction is permitted during this verification.
   b. 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.
   c. Teams may or may not include task materials (i.e. instrument panel, tools for collecting samples, storage containers, camera).
   d. Teams will receive 4 points for passing the volume constraint. No points will be awarded if volume constraint is not met.

4. The challenge-ready rover must be no wider than five feet, as measured from the outside of one wheel to the other, with the GREATEST distance considered and riders on the rover.
5. There are no constraints for overall height and length of the assembled rover; however a rover with occupied drivers 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 high by judges.

6. The vehicle will be weighed in the stowed position with all necessary mission components, to include ALL task materials.
   a. Vehicles weighing less than 130 lbs. will receive five points;
   b. Vehicles weighing 131 to 170 lbs. will receive three points;
   c. Vehicles weighing 171 to 210 lbs. will receive one point;
   d. Vehicles weighing over 210 lbs. will receive zero points.

7. From the stowed position, a signal will be given, and a timer will start for the two drivers to unfold and/or assemble their rover. The timer stops when the vehicle is in challenge-ready configuration with drivers in place, and all assembly tools and implements properly stowed on the rover, or in the marked tool area adjacent to the assembly location.
   a. Assembly times of 2:00 minutes or less will receive two points;
   b. Assembly times of 2:01 to 4:00 minutes will receive one point;
   c. Assembly times of more than 4:00 minutes will receive zero points.

8. Any component not used for traversing the course shall be left in the tool area before the assembly is considered complete. The tool area is a marked, rectangular area that is near the assembly judging location.

9. Rovers with drivers in position, must have clearance greater than or equal to 12 inches between the ground and the lowest point of the driver’s appendage as shown in figure 1.

10. Drivers shall demonstrate readiness to proceed to ERR by powering the team’s rover back to the pit area without aid. Teams unable to prove the rover is ready for competition will receive a five-point penalty.

Figure 1: Vehicle Height Requirement
EXCURSION READINESS REVIEW REQUIREMENTS

1. Teams arriving late to their time window or being unprepared to participate in the Excursions will receive a five-point penalty. This penalty also applies to incomplete survey submissions and is grounds for being determined “unprepared”.

2. Judges will photograph each vehicle and conduct an inspection of task materials and safety requirements.

3. All task materials will be inspected prior to the excursions. Task materials shall have the team number marked on each item.

4. Task tools may be used at multiple tasks, barring any cross contamination for sample retrieval tasks (i.e. cameras, appendages).

5. Teams will be awarded 1 point for having all tools necessary to attempt the task. Maximum total is five points.

6. On excursion days, the order of teams entering the course may not follow the exact order indicated by the HERC team numbers. The readiness by the teams will determine the ultimate excursion order.

9. REPORTS AND REVIEWS: CRITERIA AND DELIVERABLES

DESIGN REVIEW CRITERIA AND DELIVERABLES

1. The Design Review makes up 20% of the overall score for the competition.
   a. It demonstrates that the maturity of the design is appropriate to support proceeding to full-scale fabrication, assembly, and integration; showing that the technical effort is on track to complete the operation and system development and mission operations in order to meet overall requirements within the identified cost and schedule constraints.
   b. Progress against management plans, budget, and schedule, as well as risk assessments are presented. This DR is a review of the final design of the rover and task components.
   c. All analyses should be complete, and some critical testing should be complete.
   d. The presentation portion will be worth 10% of the total DR points.

2. Page Limit: 20 pages, not including the cover page and table of contents.

3. DR Report: The panel expects a professional and polished engineering report that follows the order of sections as they appear below. Outline located in the appendices. DR report should be written in Times New Roman and submitted in PDF format.
4. 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. Language interpreting is only permitted for translating asked questions of feedback. Interpreters are not allowed to speak on behalf of any team member.

   a. There is a 30-minute time-limit for presentation. A 15-minute question and answer will follow the presentation.

   b. The presentation shall include an overview of each section of DR report.

**OPERATIONAL READINESS REVIEW CRITERIA AND DELIVERABLES**

1. The ORR makes up 20% of the overall score for the competition and is a continuation of the Design Review Report.

   a. The ORR provides an assessment of the readiness of the personnel, processes/procedures, along with vehicle and components to safely execute the mission.

   b. The ORR provides support of tests and due diligence exercised in demonstrated readiness of engineering, operations, as well as processes and procedures.

   c. The vehicle and components should be complete with critical testing in the final phases.

   d. The Presentation portion is worth 10% of the ORR points.

2. Page Limit: 20 pages, not including the cover page and table of contents.

3. ORR Report: The panel expects a professional and polished report that follows the order of sections as they appear below. Outlines are in the appendices of this handbook. ORR report should be written in Times New Roman and submitted in PDF format.

4. 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. Language interpreting is only permitted for translating asked questions of feedback. Interpreters are not allowed to speak on behalf of any team member.

   a. There is a 30-minute time-limit for presentation. A 15-minute question and answer will follow the presentation.

   b. The following presentation shall include an overview of each section of the ORR Report.
## 10. POINTS BREAKDOWN AND ALLOCATION

<table>
<thead>
<tr>
<th>POINTS BREAKDOWN</th>
<th>POINTS</th>
<th>WEIGHT (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DR</td>
<td>40</td>
<td>20%</td>
</tr>
<tr>
<td>ORR</td>
<td>40</td>
<td>20%</td>
</tr>
<tr>
<td>MRR</td>
<td>11</td>
<td>5%</td>
</tr>
<tr>
<td>OBSTACLES</td>
<td>46</td>
<td>23%</td>
</tr>
<tr>
<td>TASKS</td>
<td>63</td>
<td>32%</td>
</tr>
<tr>
<td>TOTAL POSSIBLE POINTS</td>
<td>200</td>
<td>100%</td>
</tr>
</tbody>
</table>

**HERC POINTS BREAKDOWN**

- **DR**: 20% (Green)
- **ORR**: 20% (Blue)
- **MRR**: 5% (Light Grey)
- **Obstacles**: 23% (Orange)
- **Tasks**: 32% (Yellow)
### Table 1: Mission Readiness Review

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
<th>Possible Points</th>
<th>Summary of Points Breakdown</th>
</tr>
</thead>
<tbody>
<tr>
<td>MRR Late Penalty</td>
<td>Teams arriving outside their time window for MRR, or not being ready for the MRR.</td>
<td>5-point penalty (−5 Points)</td>
<td>Penalty can be assessed once at MRR and will carry over in the MRR score for both excursion days.</td>
</tr>
<tr>
<td>MRR Readiness Penalty</td>
<td>Teams not able to demonstrate the vehicle is ready to proceed to ERR, not being ready to compete.</td>
<td>5-point penalty (−5 Points)</td>
<td>Penalty can be assessed once at MRR and will carry over in the MRR score for both excursion days.</td>
</tr>
<tr>
<td>Volume Constraint</td>
<td>Vehicles shall fit in 5 x 5 x 5-foot volume constraint.</td>
<td>4</td>
<td>4 points for meeting requirement 0 points for not meeting requirement</td>
</tr>
<tr>
<td>Weight</td>
<td>Vehicle and, optionally, task materials will be weighed.</td>
<td>5</td>
<td>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.</td>
</tr>
<tr>
<td>Unfolding/Assembly</td>
<td>Teams will be assessed on the amount of time it takes to unfold/assemble and ready the vehicle for course excursion.</td>
<td>2</td>
<td>2 points for 0:00 – 2:00 minutes 1 point for 2:01 – 4:00 minutes 0 points for more than 4:00 minutes</td>
</tr>
</tbody>
</table>
## TABLE 2: EXCURSION CHALLENGE REVIEWS

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
<th>Points</th>
<th>Summary of Points Breakdown</th>
</tr>
</thead>
<tbody>
<tr>
<td>Late Penalty</td>
<td>Teams arriving outside their time window, not being ready for Excursion Days.</td>
<td>5-point penalty</td>
<td>Penalty can be assessed once per day for arriving outside their excursion window or not being ready to compete.</td>
</tr>
<tr>
<td>ERR Inspection</td>
<td>Teams will be inspected for safety requirements and task material requirements. Photos of Rover taken.</td>
<td>N/A</td>
<td>See each task for point reference earned at ERR.</td>
</tr>
<tr>
<td>Post-Excursion Review</td>
<td>Inspection</td>
<td>N/A</td>
<td>See each task for point reference earned at PER.</td>
</tr>
</tbody>
</table>

*Detailed point breakdown included in each obstacle task description. (TS – Judged at Task Site; PER – Judged at Post-Excursion Review)
<table>
<thead>
<tr>
<th>Obstacle</th>
<th>Description</th>
<th>Bypass</th>
<th>Points</th>
<th>Points Breakdown</th>
</tr>
</thead>
</table>
| 1        | Undulating Terrain        | Y      | 2      | 2 points for successful completion  
1 point for attempt  
0 points for bypass                                                                |
| 2        | Crater with Ejecta        | Y      | 2      | 2 points for successful completion  
1 point for attempt                                                               |
| 3        | Transverse Incline        | Y      | 4      | 4 points for successful completion  
1 point for attempt  
0 points for failure to attempt                                                    |
| 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      | 3      | 3 points for successful completion  
1 point for attempt  
0 points for bypass                                                                |
| 7        | Ice Geyser Slalom         | N      | 4      | 4 points for successful completion  
1 point for attempt  
0 points for failure to attempt                                                    |
| 8        | Lunar Crater              | Y      | 5      | 5 points for successful completion  
1 point for attempt  
0 points for bypass                                                                |
<table>
<thead>
<tr>
<th>Obstacle</th>
<th>Description</th>
<th>Bypass</th>
<th>Points</th>
<th>Points Breakdown</th>
</tr>
</thead>
</table>
| 9        | Bouldering Rocks  | Y      | 4      | 4 points for successful completion  
|          |                   |        |        | 1 point for attempt  
|          |                   |        |        | 0 points for bypass                                                               |
| 10       | Tilted Craters   | N      | 4      | 4 points for successful completion  
|          |                   |        |        | 1 point for attempt  
|          |                   |        |        | 0 points for failure to attempt                                                   |
| 11       | Loose Regolith    | Y      | 4      | 4 points for successful completion  
|          |                   |        |        | 1 point for attempt  
|          |                   |        |        | 0 points for bypass                                                               |
| 12       | 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 TASKS

<table>
<thead>
<tr>
<th>Task</th>
<th>Description</th>
<th>Bypass</th>
<th>Points</th>
<th>Points Breakdown</th>
</tr>
</thead>
<tbody>
<tr>
<td>Task 1</td>
<td>Spectrographic Analysis</td>
<td>Y</td>
<td>13</td>
<td>Four photographs&lt;br&gt;1 point for having all tools necessary to attempt the task (ERR) 1 point for each photograph taken at the site (4 points) (TS) 1 point for each photograph returned before 8:00 (4 points) (PER)</td>
</tr>
<tr>
<td></td>
<td>(Obstacle 5 shall be attempted to attempt Task 1.)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Task 2</td>
<td>Instrument Deployment</td>
<td>Y</td>
<td>10</td>
<td>2 points for having all tools and instruments necessary to attempt the task (ERR) 3 points for deploying and correctly orienting instrumentation (TS) 4 points for demonstrating instrumentation properly functions (turn switch, light illuminates) (TS) 1 point for photograph of functioning device if returned before 8:00 minutes (PER)</td>
</tr>
<tr>
<td></td>
<td>(Bypass cannot be used to complete the task.)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Task 3</td>
<td>Core Sample Retrieval</td>
<td>Y</td>
<td>9</td>
<td>1 point for having all tools necessary to attempt the task (ERR) 4 points for successful core sample extraction (TS) 4 points for successful return of core sample that meets designated criteria (PER)</td>
</tr>
<tr>
<td></td>
<td>(Obstacle 8 shall be attempted to attempt Task 3.)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### TABLE 6: CHALLENGE TASKS CONTINUED

<table>
<thead>
<tr>
<th>Task</th>
<th>Description</th>
<th>Bypass</th>
<th>Points</th>
<th>Points Breakdown</th>
</tr>
</thead>
</table>
| Task 4 | Solid Soil Sample Retrieval             | Y      | 13     | **3 separate soil sample collections**  
1 point for having all tools necessary to attempt the task (ERR)  
1 point for return of each sample, uncontaminated before 8:00 (3 points) (PER) |
| Task 5 | Liquid Sample Retrieval (This task may be attempted before Obstacle 2 or after Obstacle 10) | Y      | 13+5 = 18 | **3 separate liquid sample collections**  
1 point for having all tools necessary to attempt the task (ERR)  
5 bonus points for the use of a middle school student designed 3D printed tool at the task after inclusion in the DR and ORR repo and tool verification (ERR)  
3 points for each successful collection, baggage, storage (9 points) (TS)  
1 point for return of each sample, uncontaminated before 8:00 (3 points) (PER) |
## 11. AWARDS

### Table 7: Awards Breakdown

<table>
<thead>
<tr>
<th>Award</th>
<th>Description of Award</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall Winner</td>
<td>Awarded to the top overall team. Design reviews, educational engagement, safety, and a successful excursion will all factor into the Overall Winner.</td>
</tr>
<tr>
<td>STEM Engagement</td>
<td>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.</td>
</tr>
<tr>
<td>Project Review</td>
<td>Awarded to the team that is deemed to have the best combination of written reviews and formal presentations.</td>
</tr>
<tr>
<td>Phoenix</td>
<td>Awarded to the team that demonstrates the greatest improvement between Design Review and Operational Readiness Review.</td>
</tr>
<tr>
<td>Social Media</td>
<td>Awarded to the team that has the most active and creative social media presence throughout the project year.</td>
</tr>
<tr>
<td>Task Challenge</td>
<td>Awarded to the team that best demonstrates a 3D printed tool design for the liquid sample retrieval task.</td>
</tr>
<tr>
<td>Featherweight</td>
<td>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. <em>(Only awarded to one team overall.)</em></td>
</tr>
</tbody>
</table>
### TABLE 8: AWARDS BREAKDOWN CONTINUED

<table>
<thead>
<tr>
<th>Award</th>
<th>Description of Award</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ingenuity</td>
<td>Awarded to the team that approaches complex engineering problems in unique and creative ways.</td>
</tr>
<tr>
<td>Pit Crew</td>
<td>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</td>
</tr>
<tr>
<td>Safety</td>
<td>Awarded to the team that best demonstrates a comprehensive approach to system safety as it relates to their vehicle, personnel, and operations.</td>
</tr>
<tr>
<td>Team Spirit</td>
<td>Awarded to the team that is judged by their peers that display the &quot;Best Team Spirit&quot; during the onsite events.</td>
</tr>
<tr>
<td>Crash and Burn</td>
<td>Awarded to the team that embraces failure as a learning lesson for future success. (Only awarded to one team overall).</td>
</tr>
<tr>
<td>Rookie of the Year</td>
<td>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)</td>
</tr>
<tr>
<td>Other Awards</td>
<td>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.</td>
</tr>
</tbody>
</table>

**Note:** Awards are given to a team in each category (high school and college/university) unless otherwise noted. Awards are subject to change without notice.
12. COURSE DESCRIPTIONS AND DESIGN

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

OBSTACLE 1: UNDULATING TERRAIN

![Figure 2: Obstacle 1 – Undulating Terrain (2 Points)](image)

This gently uneven surface is replicated by wooden ramps 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. Note: Task 5 may be attempted before Obstacle 2 or during the return after Obstacle 11.

OBSTACLE 2: CRATER WITH EJECTA

![Figure 3: Obstacle 2 – Crater with Ejecta (2 Points)](image)

This large crater is about three feet in diameter with a vertical height of eight inches. Rays of ejecta, the material thrown out of the crater on impact, with the whole assembly is covered by gravel. Boulders are added to direct the rovers to traverse the large crater.
**Obstacle 3: Transverse Incline**

*Figure 4: 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.

**Obstacle 4: Martian Terrain High Butte**

*Figure 5: 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.
OBSTACLE 5: LARGE RAVINE – MARTIAN TERRAIN

Figure 6: 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.

TASK 1: SPECTROGRAPHIC ANALYSIS

Figure 7: Task 1 – Spectrographic Analysis (13 points)

The aim of this task is for teams to have some fundamental knowledge of planetary geology that would be required of astronauts and planetary surface explorers, and to utilize rapid decision-making skills. The ability to rapidly identify geologic samples is of high importance, and Apollo and Artemis Astronauts have all received geology training in hand-sample identification.

A simulated terrain containing five different commonly encountered planetary geology rock specimens will be present for identification and rudimentary spectral analysis. The driver will need to correctly identify one of the rocks and conduct a multi-band color filter imaging task. Five different rocks will be present: 1. “Lunar” basalt, 2. “Lunar” anorthosite, 3. Weathered “Martian” basalt, 4. “Martian” sandstone, 5. Asteroid iron meteorite. A judge will direct the team to image one of the five specimens, by calling out the name of the rock, randomly assigned to the team at the time of the task. The driver will then proceed to photograph only the assigned rock, whichever the team believes is the correct choice, utilizing a red, a blue, and a yellow color filter.
One driver may dismount the rover to make the appropriate photographs. Teams shall photograph the site once unfiltered and once with each filter such that both encompass the same area. Internal filters that are optical/mechanical and part of the camera/device are acceptable; however, the use of software that applies a filter to the camera is prohibited. The camera should be able to display the photographs quickly for the PER judge. Following photography, equipment must be properly stored before continuing to traverse the course.

1. Teams receive one point for having all tools necessary to attempt the task. This inspection will be made during the ERR.

2. Teams will receive four points for correct identification of the rock and photographing only the rock type called out by the PER judge.

3. Teams receive one point for each of the four total photographs taken at the analysis site, for a possible four points.

4. Teams receive one point for each photograph returned and successfully demonstrated to the PER judge. Teams shall finish before 8:00 minutes to receive these points, for a total of four points.

Descriptions of geologic samples in this task are listed below:

1. **Lunar Basalt**: Basalt is a fine-grained extrusive igneous rock formed by the rapid cooling of lava and is a common rocky-planet crust-forming rock. Basalt is a common lunar rock-type and makes up large areas on the Moon known as “Mare” (the dark areas on the near-side of the Moon). “Lunar” basalt in this task will be dark gray to black and un-weathered.

2. **Lunar Anorthosite**: Anorthosite is an intrusive igneous rock, typically white to light gray in color. Anorthosite is a common lunar crust-forming rock, and is visible as the light-colored, highly reflective parts of the Moon’s surface known as the lunar highlands.

3. **Mars Weathered Basalt**: Due to the presence of an atmosphere, basalts on Mars have undergone weathering, chemical alteration of the primary rocks and minerals into other minerals. A typical Martian basalt will have weathered to a rusty-red color due to the oxidation of iron in the basalt.

4. **Mars Sandstone**: Layered sedimentary deposits are widespread on Mars, having formed through the slow deposition of aeolian (wind), fluvial (river), or lacustrine (lake) sediments. These rocks contain distinctive visible banding from the buildup of layers of sediment.

5. **Asteroid Iron Meteorite**: Metallic Iron meteorites are fragments of the cores of planetesimals and sourced from within the asteroid belt. They are composed primarily of an iron-nickel alloy. Through the heat of traveling at hypersonic speed through the Earth’s atmosphere the outer surface of iron meteorites has a distinctive texture known as
regmaglypts (“thumbprints”), rounded and irregular shaped pits formed through melting and ablation.

**TASK 2: INSTRUMENT DEPLOYMENT**

![Figure 8: Task 2 – Instrument Deployment (10 points)](image)

A simulated remote location needs instrumentation deployed and correctly oriented to support mission objectives. For this task, the instrumentation will be a solar-powered instrument that the teams shall deploy in the proper compass orientation. The device shall be built by the teams and will require the following components: A solar cell, a functioning on/off switch, and a power-indication light that illuminates when the switch is on and operates on solar power. (A light source will be provided to simulate the Sun and accommodate for the possibility of inconsistent Sun coverage.) Teams will need to provide their own compasses. Teams will be required to deploy the instrument in a designated compass orientation and demonstrate successful operation by turning switch to the “on” position with the indicator light illuminated by the solar power. At the TS, teams will be given a compass orientation (relative to magnetic north) in which to deploy the instrument. Teams will need a marker or fiducial on the instrument to properly orient and for judges to verify orientation. The instrument will also need to be open on the bottom such that it can be inspected to verify that no stored energy power sources are present. All the components to build the instrument package may be purchased.

1. Teams receive two points for having all tools or instruments necessary to attempt the task. This inspection will be made during the ERR.

2. Teams receive three points for deploying and successfully orienting the instrumentation at the TS.

3. Teams receive four points if the instrumentation functions properly after orientation and deployment, i.e., the switch is turned on and light illuminates with judge verification.

4. Teams receive one point for demonstration of photograph of functioning device to the PER judge. Teams shall finish before 8:00 minutes to receive these points.
OBSTACLE 6: Crevasses

Figure 9: Obstacle 6 – Crevasses (3 Points)

Crevasses result from cracks in the surface regolith or from erosion by liquid and/or molten material forming ruts in underlying material. The crevasses vary in width between one (1) and four (4) inches. Avoid having the rover wheels stuck in these cracks, which are four (4) to six (6) inches deep.

OBSTACLE 7: Ice Geyser Slalom

No Bypass Available

Figure 10: Obstacle 7 – Ice Geyser Slalom (3 Points)

A series of simulated Ice Geysers impede the path down this long curving hill. This obstacle requires that teams carefully navigate down to the bottom of the hill without encountering any of the geysers. Steering and braking systems will be of utmost importance to do this. The steep incline will be followed by a marked exit lane through which rovers shall pass without touching its boundaries.
**OBSTACLE 8: LUNAR CRATER**

![Figure 11: Obstacle 8 – Lunar Crater (5 points)](image)

This area surrounding the Lunar Excursion Module replica consists of asphalt lava with craters of various sizes and strewn boulders. The large crater will test the surface clearance of the rovers. A wide circle is traversed within this large crater.

**TASK 3: CORE SAMPLE RETRIEVAL**

![Figure 12: Task 3 – Core Sample Retrieval (9 points)](image)

Drivers will need to collect one core sample while on or off the rover. The sample consists of loose rock or mineral grains bound together by a liquid. The sample shall be taken to a depth of at least 7.87 inches and contain a volume of at least 0.95 cubic inches. The dimensions of the sampling area measure approximately 14 inches deep and 11.8 inches in diameter. Core samples deeper than the container will not be possible.

1. Teams receive one point for having all tools necessary to attempt the task. This inspection will be made during the ERR.

2. Teams receive four points for a successful core sample extraction at the TS.
3. Teams receive four points for a successful return of the core sample that meets the designated criteria during the PER. Teams shall finish before 8:00 minutes to receive these points.

**OBSTACLE 9: BOULDERING ROCKS**

![Bouldering Rocks](image.png)

*Figure 13: Obstacle 9 – 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. Proceed with caution.

**TASK 4: SOLID SOIL SAMPLE RETRIEVAL**

![Solid Soil Sample Retrieval](image.png)

*Figure 14: Task 4 – Solid Soil Sample Retrieval (13 Points)*

Teams will need to collect three separate soil samples of different sizes and consistencies while remaining on the rover (one sample from each of the three sample containers that are part of the display). The dimensions of the containers measure 3-inch-deep and 5.5-inch-across the tip, with a slight taper down (fig. 16).
Teams receive one point for having all tools necessary to attempt the task. This inspection will be made during the ERR.

2. Teams receive three points for each sample that is successfully retrieved and placed in the sample container. Each sample shall be at least 50 ml in volume. Individual sample containers are required for each collected sample to prevent cross-contamination. The sample container shall be sealable.

3. Teams receive one point for each sample that is successfully returned uncontaminated and provided to the PER judge. Teams shall finish before 8:00 minutes to receive these points.

**OBSTACLE 10: TILTED CRATERS**

*No Bypass Available*

Rovers travel up a slope and then encounter medium craters on the descending side. The slope is gentle, about 15 degrees. Boulders force the rovers to traverse the two craters, and the whole obstacle is covered by gravel.
**TASK 5: LIQUID SAMPLE RETRIEVAL**

![Image](image.png)

Figure 17: Task 5 – Liquid Sample Retrieval (13 points +5 bonus points)

Teams shall collect three separate liquid samples in a diorama of different colors while remaining on the rover. The dimensions of the containers measure three-inch-deep and 5.5-inch-across the tip, with a slight taper down (fig. 16). The task tool should be conceptualized and designed by the middle school students. The task tool shall be 100% 3D printed except for the uncontaminated container and storage area. In addition to the sample collection component teams may also 3D print supporting components. Although, supporting components and/or add-ons for the sample collector do not have to be 3D printed. Teams shall also provide detailed discussion of this collaboration in the DR and ORR.

1. Teams receive one point for having all tools necessary to attempt the task. This inspection will be made during the ERR.

2. Teams receive a bonus five points for the design, build, and use of a 3D printed tool. The five points will be awarded after all requirements are met including details in reports, inspection at ERR, use at the TS, and returning within the 8:00 minutes.

3. Teams receive three points for each sample that is successfully retrieved and placed in the sample container. Each sample shall be at least 50 ml. Individual sample containers are required for each collected sample to prevent cross-contamination. The sample container shall be sealable.

4. Teams receive one point for each sample that is successfully returned uncontaminated and provided to the PER judge. Teams shall finish before 8:00 minutes to receive these points.
OBSTACLE 11: LOOSE REGOLITH

Figure 18: Obstacle 11 – Loose Regolith (4 Points)

Meteoroid collisions with extraterrestrial surfaces produce fine-grain material, which is difficult to traverse. Beach sand (rounded grains) simulates this material, which allows wheel penetration. The depth of this simulant is six to eight inches.

OBSTACLE 12: PEA GRAVEL

Figure 19: Obstacle 12 – Pea Gravel (4 Points)

This ancient stream bed consists of small rounded pebbles deposited to a depth of about six inches. Rover wheels might sink in this smooth obstacle material.
13. APPENDICES
APPENDIX A – COVER PAGE TEMPLATE

Title
Team Name and Number

Institution (School) Name

Institution (School) Mailing Address

Advisor Name and Title

Advisor Email Address

Team Leader Name

Team Leader Email Address

Safety Officer Name

Name(s) and Role(s) of Remaining Team Member(s)

Date: mm/dd/yyyy
APPENDIX B – DR REPORT OUTLINE

1. Abstract – Provide a brief overview of your project and vehicle design.

2. Table of Contents

   a. 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;
   b. For each alternative, briefly present research on why the alternative should not be chosen;
   c. After evaluating all alternatives, present the chosen vehicle design.
   d. Describe each subsystem and the components within those subsystems
   e. Describe how the design meets requirements for size, weight, volume, assembly, and clearance constraints;
   f. Provide dimensional drawings of the leading design;
   g. Provide estimated masses for each subsystem;
   h. Provide enough justification for design selections;

4. Task and Other Mission Components for at least two (2) tasks (i.e. telemetry, tools, containers)
   a. Describe the objective of each mission component tool or equipment that supports the excursion.
   b. If attempting the Task Challenge (3D-printed tool), the team shall state the plans for middle school engagement.
   c. Review the designs at a system level, briefly discussing alternative designs to each component and evaluating the pros and cons;
   d. Describe the preliminary interfaces with the drivers, vehicle, and mission;
   e. Include drawings and schematics for all elements of the task or mission components.

5. Mission Performance Predictions
   a. Demonstrate any simulated vehicle data and management through course design;
   b. Demonstrate any simulated component data and management through course design.
6. **Safety**
   
a. Demonstrate an understanding of all components needed to complete the project and how risks/delays impact the project;

b. Provide a preliminary Personnel Hazard Analysis. The focus of the Hazard Analysis at this design review is identification of hazards, their causes, and resulting effects;

c. Preliminary mitigations and controls can 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 each hazard for both likelihood and severity.

d. Provide a preliminary Failure Modes and Effects Analysis (FMEA) of the proposed design of the vehicle and components. The focus is identification of hazards, causes, effects, and proposed mitigations. Rank each risk of each hazard for both likelihood and severity.

7. **Project Plan**
   
a. Requirements Verification to demonstrate that the vehicle, drivers, and mission requirements identified in this handbook are being met;

b. Timeline Verification to demonstrate that the timeline is on schedule to meet the requirements of this project.

8. **STEM Engagement Plan**

9. **Appendix**
**Appendix C – Orr Report Outline**

1. **Abstract** – Provide a brief overview of your project and vehicle design.

2. **Vehicle Criteria** – Design and Construction of the Vehicle
   
   a. Describe any changes in the rover from the previous design review and explain why those changes are necessary;
   
   b. Describe features that enable the vehicle to be excursion safe and ready;
   
   c. Demonstrate that the design can meet mission success requirements;
   
   d. Prove that the vehicle is fully constructed and document the construction process;
   
   e. Include schematics and/or images of the completed rover.

3. **Task and Other Mission Components for at least two (2) tasks** (i.e. telemetry, tools, containers)
   
   a. Describe any changes in the task and mission support components since the design review and why those changes are necessary;
   
   b. If attempting the Task Challenge (3D-printed tool), the team shall state the attempt and outline the tool features including schematics;
   
   c. Describe features that enable the task and other mission components to be excursion safe and ready;
   
   d. Prove that the task and other mission components are fully constructed and document the construction process;
   
   e. Include schematics for all elements of the task or mission components.

4. **Mission Performance Predictions**
   
   a. Describe how the vehicle is expected to perform through the course design;
   
   b. Describe how the task and mission components are expected to perform through the course design;
   
   c. Describe any strategies the team has for successful performance through the course design.
5. **Safety**
   
a. Update the Personnel Hazard Analysis and the Failure Modes and Effects Analysis to include:
   
   I. Finalized hazard descriptions, causes, and effects of the vehicle and mission components the team has built;
   
   II. A completed list of mitigations addressing the hazards and/or their causes;
   
   III. 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.
   
   b. Include a list of procedures and checklists for competition days.

6. **Project Plan**
   
a. Requirements Compliance – review and update the verification plan demonstrating that the vehicle, drivers, and mission requirements identified in this handbook are met;
   
   b. Discuss any testing plans, completion of tests, and discussion of results;
   
   c. Timeline Verification – Demonstrate that the timeline is on schedule to meet the requirements of this project.

7. **STEM Engagement Results**

8. **Appendix**