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NEW FOR RMC 2019

<u>The Caterpillar Mining Arena is moving indoors and has different dimensions than in previous competitions</u>

The Caterpillar Mining Area is moving indoors to The Astronauts Memorial Foundation's (AMF), Center for Space Education Building (CSE), Building M6-306.

CATERPILLAR MINING ARENA
The technical drawings for the arenas are a draft and not final technical drawings. Any changes to the technical drawings will be posted as a revision to the rules and rubrics on the NASA RMC website and a notice will be sent to the teams.

a. ***Arena lighting information is not available at this time and will be posted as a revision to the rules and rubrics.***

b. ***Steel, primer and paint specification are not available at this time and will be posted as a revision to the rules and rubrics.***

ROBOT DATA (required) - Due May 1, 2019
Provide information about your off-world mining robot as requested. The link is not available at this time and will be posted as a revision to the rules and rubrics.

<u>Plan for Project Systems Engineering</u> *– (optional) New deliverable. Early project definition and submittal of the Initial Project Schedule, Initial Project Budget, the Design Philosophy and the Initial Technical Budget. As you execute your project, things will change as your project will evolves. In your Systems Engineering Paper you can discuss the changes to your plan and how your project adapted.*

NEW FOR RMC 2019

PART I – GENERAL INFORMATION

INTRODUCTION

Vice President Mike Pence and NASA Administrator Jim Bridenstine announced that NASA is going back to the Moon with water and resource utilization as a key theme and then on to Mars. The presence of water at the lunar poles was detected by NASA's Synthetic Aperture Radar (Mini-SAR) on Chandrayaan-1 and confirmed by the Lunar Crater Observation and Sensing Satellite (LCROSS) space probe. Radar data collected by the European Space agency (ESA) Mars Express in 2018 points to a possible pond of liquid water buried under layers of ice and dust in the south polar region of Mars. Almost all water on Mars today exists as ice, though it also exists in small quantities as vapor in the atmosphere and occasionally as low-volume liquid brines in shallow Martian soil. The only place where water ice is visible at the surface is at the north polar ice cap with abundant water present beneath the permanent carbon dioxide ice cap at the Martian south pole and ice has been found at northern latitudes at shallow depths, as seen in NASA's Phoenix mission.

Capturing this water is the key to allow humans to "live off the land" or in scientific terms "In-Situ Resource Utilization (ISRU)". The water can be used for human consumption, hygiene, grow plants, provide radiation shielding and to make rocket propellant for the journey home.

NASA's Robotic Mining Competition is for university-level students to design and build a mining robot that can traverse the challenging simulated, chaotic, off-world terrain, excavate the icy-regolith simulant (rock/gravel) and return the excavated mass for deposit into the collector bin to simulate an off-world, ISRU mining mission. The complexities of the challenge include the abrasive characteristics of the regolith and icy-regolith simulant, the weight and size limitations of the mining robot and the ability to tele-operate it from a remote Mission Control Center. Teams must also submit a systems engineering paper that explains their design approach, perform K-12 outreach into their communities and a presentation about their design philosophy at the competition. Points from all the categories determine the winner of the Joe Kosmo Award for Excellence.

NASA directly benefits from the competition by encouraging the development of innovative robotic excavation concepts. Every year NASA receives over 40 proof of concept These concepts may result in unique or clever solutions that may be applied to an actual excavation device and/or payload on an ISRU mission. Our nation will need a future work force that has the skills for developing autonomous robotic mining on the Moon, Mars and other off-world locations. Advances in off-world mining have the potential to significantly contribute to our nation's space vision and NASA's space exploration operations.

Our nation will benefit by being leaders in a new resource based space economy. In addition, the systems engineering skills that RMC teaches are valuable in many other high technology industries that will add to the economic strength of the USA.

ACCREDITATION BOARD FOR ENGINEERING AND TECHNOLOGY (ABET)

The Accreditation Board for Engineering and Technology is the global standard for programs in applied science, computing, engineering, and engineering technology (http://www.abet.org). The Competition rules and rubrics meets the requirements for engineering and engineering technology accreditation.

WHO CAN COMPETE

Teams that are from post high school vocational/technical schools, colleges and or universities located in the United States, its Commonwealths, territories and / or possessions are eligible to register for the competition (one team per university campus is allowed). A team shall stand alone, and consist of:

- Undergraduate and graduate students (teams must have at least two undergraduate students) with submitted transcripts. Students must be enrolled during the current or previous school semester and are in good standing with their school. Faculty/staff members who are currently registered with the college or university. Students, faculty and staff not approved by security, cannot be a part of the competition.
- The number of team members on each team is at the discretion of the school but the team should have a sufficient number of members to successfully design, build and operate their mining robot.
- Each team will have 10 seats for the Award Ceremony, only registered students and registered faculty/staff members are eligible to attend the Award Ceremony.
- Participants can be members of only one team and each team must have its own working robot(s).

REGISTRATION

Students, faculty & teams register at:

https://www.spacegrant.org/forms/?form=nasarmc

DATES & DEADLINES

All items are due by 12:00 noon Eastern Time on the dates listed below. Do not wait until the last day to submit your items. Teams failing to meet the deadlines will be removed from the competition.

REQUIRED	
Outreach Project Report	March 28, 2019
Systems Engineering Paper	April 2, 2019
OPTIONAL	
Plan for Project Systems Engineering	November 1, 2018
Slide Presentation and Demonstration	April 20, 2019
REQUIRED DOCUMENTATION	
Letter from University's Faculty Advisor	**with application**
Letter from University's Dean of Engineering	November 14, 2018
Faculty Participation Form	November 14, 2018
Signed Media Release Form	November 14, 2018
Student Participant Form	November 14, 2018

Team Roster	November 14, 2018
Transcripts (unofficial copy is acceptable) - must be from the university with name of school - show name of student, coursework taken, grades - current student status 2018-2019 academic year	November 14, 2018
Student Resume (Optional)	November 14, 2018
Team Biography (200 words maximum)	January 17, 2019
Team Photo with Faculty (jpeg format only)	January 17, 2019
Corrections to NASA Generated Team Roster	February 15, 2019
Head Count Form	February 15, 2019
Final Team Roster (no changes after this date)	March 1, 2019
Shipping Bill of Lading/Commercial Invoice (both; to the competition and return home)	May 1, 2019
Robot Proof of Life	May 1, 2019
Robot Data	May 1, 2019
THE COMPETITION	
Team Check-In, 7 a.m. – 3 p.m. Eastern Time	May 6, 2019
Slide Presentation and Demonstration Days	May 7-9, 2019
Practice Days	May 6-7, 2019
Opening Ceremony	May 7, 2019
Competition Days	May 8-10, 2019
Awards Ceremony Friday Evening	May 10, 2019

ROBOT DETAILS AND PROOF OF LIFE

The following shall be provided:

- diagram of the robot and a basic parts list
- photo of your robot (photos shall be a minimum 1024 x 768 pixels in a JPEG format)
- a link to your YouTube video documenting proof of life (this "proof of life" documentation is solely for technical evaluation of the mining robot) of your mining robot in operation for at least one full cycle of operations (one full cycle includes excavation and depositing the material). Please begin the title of your presentation with: #RMC2019POL ___ and add your unique name to it: ex: #RMC2019POLLunaRocks!

SOCIAL MEDIA

See Robotic Mining Competition on YouTube, "Like" us on Facebook and "Tweet" using #NASARMC2019.

CODE OF CONDUCT

The Robotic Mining Competition is a NASA event and is held in a professional and positive environment. Competitors shall be courteous and conduct themselves with the integrity and respect to all individuals as required by this event. Behavior inconsistent with this philosophy is unacceptable and shall be grounds for assessment of penalty points, disqualification of an individual and or disqualification of the team. The Project Manager and Head Judge's decision is final.

COMPETITION EVENTS

Slide Presentation & Demonstration – (optional) provides the teams with the opportunity to present the spirit, intent and the technical outcome of their design project. This is another opportunity for the students to develop their presenting and public speaking skills. These skills will serve them in thesis defense and / or dissertations, grant requests, job interviews, etc.

Plan for Project Systems Engineering – (optional) New deliverable. Early project definition and submittal of the Initial Project Schedule, Initial Project Budget, the Design Philosophy and the Initial Technical Budget. As you execute your project, things will change as your project will evolves. In your Systems Engineering Paper you can discuss the changes to your plan and how your project adapted.

Systems Engineering Paper – (required) papers should discuss the Systems Engineering (SE) methods used to design and build the mining robot. The purpose of the SE paper is to encourage the teams to use the SE process while designing, building and testing their robots.

Outreach Project Report – (required) requires team to report the type of STEM outreach in their communities, activities provided, numbers reached and are encouraged to reach out to the under-served / under-represented K-12 students.

On-Site Mining – (required) requires the teams to design and build a mining robot that can traverse the simulated Martian chaotic terrain. The robot must then excavate the icy regolith simulant (gravel) and return the excavated mass for deposit into the Collector Bin to simulate an off-world mining mission. The teams will have two, 10-minute competition runs to mine the icy regolith. The abrasive characteristics of the basaltic regolith simulant, the weight and size limitations of the mining robot and the ability to tele-operate it from a remote Mission Control Center are some of the additional factors in the competition.

AWARDS

The Judges Innovation Award
Awarded to the team with best design based on creative construction, innovative technology and overall architecture.

NASA's Solar System Exploration Research Virtual Institute (SSERVI) Regolith Mechanics Award
Awarded for the best example of a granular materials related innovation that identified a specific regolith mechanics problem (e.g. regolith flowing around the grousers, angle of repose too high in the dump bucket) and improved their design to deal with it. From the NASA Solar System Exploration Research Virtual Institute (SSERVI's) Center for Lunar and Asteroid Surface Science (CLASS).

The Caterpillar Autonomy Award
Awarded to the teams with the first, second and third most autonomous points averaged from both mining attempts. In the event of a tie, the team that deposits the most simulated icy regolith (rock/gravel) will win. If no simulated icy regolith is deposited, the Mining Judges will choose the winner.

The Efficient Use of Communications Power Award
Awarded to the team for using the lowest average data utilization bandwidth per icy regolith point earned in the official runs. Teams must collect the minimum amount of simulated icy regolith to qualify for this award.

Systems Engineering Leaps & Bounds Award
Awarded to the team that made a significant improvement over the previous years (or consistently sustained improvement) in their application of systems engineering to the development of their robot as demonstrated by their systems engineering paper (teams placing in the top 3 are not eligible for this award; not necessarily awarded every year).

Slide Presentation and Demonstration Award

Plan for Project Systems Engineering Award

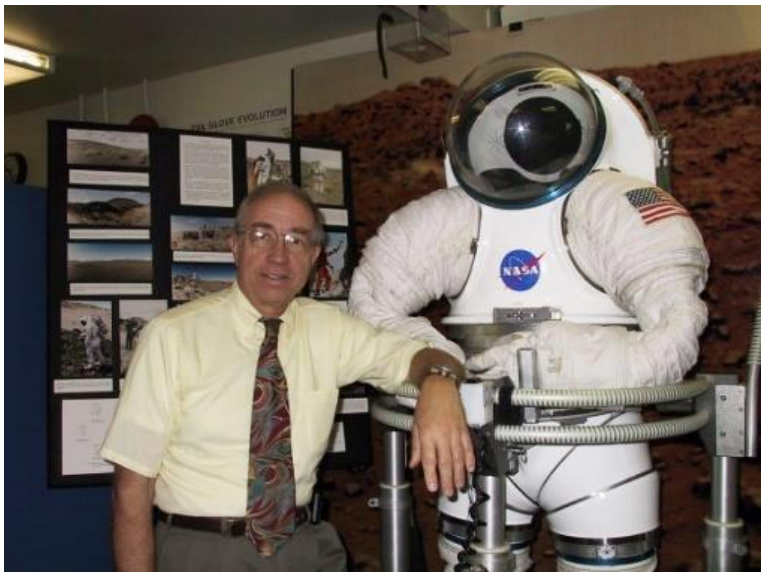
Systems Engineering Paper Award

Outreach Project Award

Robotic On-Site Mining Award

The Joe Kosmo Award for Excellence
Awarded to the team that scores the most points in all competition events.

Joseph Kosmo graduated from Pennsylvania State University in 1961 with a bachelor of science in aeronautical engineering and began his career with the NASA Space Task Group in the Crew Systems Division, working on the Mercury Program spacesuit. During the past 45 years, he has participated in the design, development, and testing of Mercury, Gemini, Apollo, Skylab, and Space Shuttle spacesuits, as well as numerous advanced technology configuration spacesuits and EVA gloves for future mission applications. Kosmo received the American Astronautical Society's Victor A. Prather Award, the NASA Exceptional Service Medal, and the Astronaut Silver Snoopy Award. He has pursued the development of advanced spacesuits, gloves, and ancillary EVA-supporting hardware concepts for future planetary surface exploration. In 2011, he retired from NASA after a 50-year career in the space industry. This award honors his service and contributions to America's space program.



Category	Award	Points
The Judge's Innovation Award	Trophy	
The SSERVI Regolith Mechanics Award	Trophy	
Caterpillar Autonomy Award	1st Place - $1,500	
	2nd Place - $750	
	3rd Place - $250	
Efficient Use of Communications Power Award	Trophy	
Systems Engineering Leaps & Bounds Award	$250	
Slide Presentation and Demonstration	$500	Up to 20
Plan for Project Systems Engineering Award	NA	Up to 10
Systems Engineering Paper	1st Place - $1,000 / Trophy	Up to 25
	2nd Place - $750	Up to 25
	3rd Place - $500	Up to 25
Outreach Project Award	$500 / Trophy	Up to 20
Robotic On-Site Mining	1st Place - $3,000 / Trophy	25
	2nd Place - $2,000	20
	3rd Place - $1,000	15
Teams not placing receive one point per 0.5 kilogram of icy regolith simulant (rock/gravel) mined and deposited up to 10 points		Up to 10
Joe Kosmo Award for Excellence	$5,000 / Trophy	

Emergency / Security Procedures

If you see something suspicious, if you see someone in distress or injured, have someone stay with the distressed party and then report it immediately to the RoboPits Chief, Arena Chief, or Staff.

- KSC Visitor Complex Nurse Station 321.449.4334
- NASA KSC Emergency 321.867.7911

Emergency Eyewash Stations, Hand Wash Stations & Water Dispensers are located in the RoboPits, Bot Shop and the Arenas.

Personal Protection in the Florida Weather
You and your off-world mining robots may be exposed to the Florida weather so be prepared for heat, humidity, wind and rain. You are responsible for protecting your robot from the elements while outdoors. Plan for weather when transitioning between the RoboPits (inside temperature approximately 24°C) and any outside location (outside temperature averaging 32°C & 95% humidity). Remember to have hats, sunglasses, insect repellent, sunscreen (SPF 50 or better) and a raincoat / poncho on hand for the competition. Stay hydrated, drink plenty of water.

Florida is the Lightning Capital of the U.S. the lightning phase conditions are as follows:

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

Unmanned Aerial Vehicles (UAV), Unmanned Aerial Systems (UAS)
The use of Unmanned Aircraft Systems (Drones) are prohibited at the Kennedy Space Center Visitor Complex (KSCVC) and The Astronauts Memorial Foundation (AMF) Center for Space Education Building (CSE) under all circumstances. If any member of the team is caught on KSCVC property with these types of items, the item will be confiscated and the team member shall be removed from the Competition. The UAV / UAS will not be returned.

Containers – This is a reminder that if your team uses any type of military containers (ex: "ammo cans") please spray over/cover up the former military content signage so we can avoid any work stoppages due to extra security checks.

Disputes – Disputes shall be forwarded to the Robotic Mining Competition Project Manager and Head Judge for resolution. The Project Manager and Head Judge's decision is final.

Frequently Asked Questions (FAQ) - The frequently asked questions (FAQ) document is updated regularly and is considered part of this document. It is the responsibility of the teams to read, understand, and abide by all of the Rules and Rubrics and FAQs, communicate with NASA's representatives and complete all surveys. Remember, tomorrow is too late to ask questions, submit inquiries to: KSC-Robotic-Mining-Competition@mail.nasa.gov

Updates
These rules and rubrics are subject to updates, it is the responsibility of the teams to stay current, please check NASA's Robotic Mining Competition website for updates at: http://www.nasa.gov/offices/education/centers/kennedy/technology/nasarmc.html

Shipping your Container (robot, parts, tools)
You are responsible for using a reputable shipping company. Your shipping company is responsible for providing all resources required to load and unload your container. You are required to submit both Bills of Lading (to and from the competition) by the due date via email to: KSC-Robotic-Mining-Competition@mail.nasa.gov

Batteries shall not be connected to the robot during shipping and it is your responsibility to ship your batteries in accordance with the manufacturer's specifications, notify your shipping company and comply with all state and Federal regulations.

Coordinate with your shipping company to ensure deliveries are made between Tuesday April 30, 2019 through Friday May 3, 2019 from (8 a.m. - 2 p.m.). The shipping company will go to the

NASA KSC Pass & ID Office on the south side of State Road 405. Please have the shipper call 321.749.0320 two (2) hours prior to their arrival and call again on arrival. ISC Central Receiving will send an escort to the shipper. Your container will be delivered to the front of the CSE on Monday morning May 6, 2019.

Ship To:
NASA John F. Kennedy Space Center
ISC Central Receiving - Bldg. M6-0744
Kennedy Space Center, FL 32899
Mark For: Robotic Mining Competition, Center for Space Education, Building M6-306

Your shipping company is responsible for providing all resources required to load and unload your container. Do not schedule pick-ups on Saturday or on Sunday. All containers not picked up by Wednesday May 15, 2019 will be discarded.

Pick-Up From:
The Astronauts Memorial Foundation (AMF)
Center for Space Education Building (CSE)
Mail Code AMF
State Road 405, Building M6-306
Kennedy Space Center, FL 32899

PART II – COMPETITION WEEK

Daily Schedule				
7am-7pm	*RoboPits Open*		*Noon-1pm*	*Lunch Mon-Fri*
7am-9am	*Robot Check-In Tues-Fri*		*1130-1pm*	*Lunch Thursday*
8am	*Mining Starts*			
Monday			***Wednesday***	
7 am	Team Check-In Opens		8 am	Competition Mining Begin
9 am	Inspections Open		1 pm	Competition Mining Resume
1 pm	Practice Mining Starts		***Thursday***	
3 pm	Team Check-In Closes		8 am	Competition Mining Begins
Tuesday			1130 am	Women in STEM Forum
8 am	Practice Mining Starts		1 pm	Competition Mining Resumes
9 am	Robot Check-In Closes		***Friday***	
11 am	Opening Ceremony		8 am	Competition Mining Begin
1 pm	Practice Mining Resumes		3 pm	RoboPits Close
			3 pm	Crates Out for Shipping
			545 pm	Bus Loading for Award Night
(schedule subject to change)				

Check-In Monday
Check-in begins Monday morning at 7:00 a.m. and will close at 3 p.m. local time. Show your parking pass to the attendant and proceed to the RMC Check-In tent located in Parking Lot 4 of the Kennedy Space Center Visitor Complex (KSCVC) and park your vehicle. All vehicles, robots and support equipment will be cleared by security before being allowed into the Complex. The RoboPits are located in the Astronauts Memorial Foundation's (AMF) Center for Space Exploration Building (CSE) (M6-306). Check-in staff will direct the teams on how to enter the park.

Check-Out, Monday-Thursday, Robots and Equipment
Teams can take their robots from the RoboPits and out of the Complex, once your robots are checked-out, there is no re-entry for the day. To bring your robot back to the competition, follow the Check-In, Robots and Equipment Tuesday - Friday, below.

Check-In, Robots and Equipment Tuesday - Friday
Check-in begins each morning at 7 a.m. and will close at 9 a.m. show your parking pass to the attendant and proceed to the RMC Check-In Tent located in Parking Lot 4 of the Kennedy Space Center Visitor Complex (KSCVC) and park your vehicle. All vehicles, robots and support

equipment will be cleared by security before being allowed into the Complex. Directions will be provided by the Check-In Staff.

Practice Runs for Monday and Tuesday
The spirit and intent is for each team to get at least one practice run and the opportunity to work out issues prior to the start of competition. You must complete your robot inspection, communications check and be cleared by the RoboPit Chief before you can sign up for your practice run. Practice runs are on a first come – first serve basis. Teams are encouraged to have their Mining Robots arrive in as complete condition as possible to take advantage of the practice runs. Practice sessions maybe shortened or eliminated due to weather or other issues.

Opening Ceremony Tuesday
Tuesday morning from 11 am to noon in the Astronauts Memorial Foundation's RoboPits.

Award Ceremony
The Award Ceremony is held at the KSCVC's Apollo-Saturn V Complex. Buses start loading Friday evening at 5:45 pm in front of the Center for Space Education Building. Each team is allocated 10 slots for the Award Ceremony and only registered students and registered faculty are eligible to attend.

PART III – PERSONAL PROTECTION IN THE COMPETITION

All RMC participants are required to don Personal Protective Equipment (PPE) before coming into contact with BP-1 (the regolith simulant).

::: IF YOU ARE ALLERGIC TO TALCUM POWDER, IT IS A GOOD INDICATOR THAT YOU WILL BE ALLERGIC TO THE BLACK POINT-1 (BP-1) REGOLITH SIMULANT :::

- **Respiratory** – Respiratory protection is required for participants before coming into contact with BP-1 and must be used in accordance with the manufacturer's operating instructions. The Black Point-1 (BP-1) Lunar / Martian Basaltic Regolith Simulant used in the competition contains a small percentage of crystalline silica, which is a respiratory hazard. All participants must use respiratory protection when required to prevent dust inhalation. Respiratory protection must be used in accordance with the manufacturer's operating instructions. Without exception, use of N-95 masks and/or tight fitting negative pressure respirators will require a clean, shaven face, no facial hair shall be in contact with any part of the mask/respirator in order to maintain the seal.

- **Skin & Eye** - The Black Point-1 (BP-1) Lunar / Martian Basaltic Regolith Simulant used in the competition is crushed lava basalt aggregate with a natural particle size distribution similar to that of lunar soil. It is alkaline and may cause skin and eye irritation. Personnel should avoid contact with BP-1 and use appropriate skin and eye protection when performing tasks, such as handling dusty robots**.**

PART IV – ROBOPITS

Day	Hours
Monday-Thursday	7am-7pm
Friday	7am-3pm

The RoboPits are located in the Astronauts Memorial Foundation's Center for Space Education Building M6-306. The RoboPits are air-conditioned and equipped with restrooms, emergency eyewash stations and disposal containers for used aerosol cans, batteries, degreasers and wipes used as cleaners. This is where you will be working on your robots, meeting other competitors and after spending months "Designing It" and "Building It", this is where you will get your robot inspected before it sets off to "Dig It!"

Personal Protection in the RoboPits
Remember to use good workshop and engineering practices and principles, use eye protection and hearing protection as needed, wear gloves and de-energize robots and equipment as needed. Use the right tool for the right job, bring jack-stands to support your robot (folding chairs are unacceptable), etc. Know where the fire exits, fire extinguishers and eyewash stations are located. Each team is responsible for bringing a First-Aid kit. Report any safety concerns to the RoboPits Chief.

RoboPits Check-in Protocol
You are responsible for checking in with the RoboPits Chief upon arrival on Monday morning. The RoboPits Chief will explain the process for inspections, signing up for practice runs, and all RoboPits protocols. The RoboPits Chief is your only point of contact to coordinate practice and competition runs, when things get hectic, be professional.

- The RoboPits Chief will require two contact phone numbers, in case the team needs to be reached at any point during the competition and cannot be found. These numbers will not be shared with anyone and will be disposed of at the end of the competition.
- The new layout for the Pits and the overall competition will be described
- Communication (Comm) and Mechanical Inspection locations
- Travel path from RoboPits to Arena
- RoboPits Chief will give team leader the Comm/Inspection card. The C/P card is used to ensure that all teams have had their 'bot checked out prior to entering the Arena.
- Either inspection can be performed first, and will not be scheduled; it is first-come, first-served.
- Return the card when you have passed both inspection and Comm check, and when you are ready for a practice run.
- The RoboPits Chief will schedule you for the next available practice slot
- Check with the RoboPits Chief before heading to the arena for your practice run, in case of a schedule change
- Let the RoboPits Chief know if you are headed to the sandbox and will go from there to the arena for your practice run.

RoboPits

- If you plan to take your robot out with you any evening, check out with the RoboPits Chief.
- You will need a placard to get through the gate.
- Check-in the following morning will be 7 am – 9 pm, no exceptions.
- Vacuums are provided, they are for use by all teams as needed
- When you are done using it, please return it to the designated area
- If you discover a full vacuum, please alert the RoboPits Chief
- NASA provided carts are for the use of all teams.
- Priority goes to those teams headed to the Arena for competition, and for teams going to presentations. Carts will be designated for these uses.
- Carts are NOT for use in your pit. Carts are not platforms for working on the robots.
- All pits have power strips provided. Do not daisy chain power strips.

Competition Runs for Wednesday - Friday

- The competition schedule will be sent out Tuesday afternoon to the team contact information provided. On competition days, teams will be brought to Inspection 45 minutes before the scheduled competition start time.
- It is recommended that the team be ready, with the robot on a cart, an hour prior to the scheduled competition start time, to ensure a smooth flow.
- An escort will come to your pit to retrieve you, do not leave without them.
- If you are not in your pit at that time, you run the risk of forfeiting your competition run.
- Following the inspection, the escort will take the team to the Arena, where Arena escorts will take over.
- Presentations and Demonstrations – an escort will come to your pit to retrieve you approximately 10 minutes prior to your scheduled presentation time, do not leave without them.

Clean-up and Check-out:

- Each night your pit is expected to be neat, with nothing outside of the pit boundaries. Try to keep your pit and the surrounding area neat and generally clean, use the provided vacuums as necessary. In the past teams have brought floor coverings/mats to facilitate this cleaning, which is recommended.
- Each team will leave their pit as they found it. Teams are required to clean their pit and the area around it. When you are ready to leave, check with the RoboPits Chief to ask for an escort to come inspect your pit and to check out. This process must be completed in order to attend the Award Ceremony Friday evening.
- Check with the RoboPits Chief no earlier than Wednesday afternoon regarding shipping if you are shipping your 'bot home.
- There will be a designated area for those 'bots, do not assume it can be left in your pit.

Waste Accumulation Containers

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

Batteries – Alkaline, Lithium, Ni-Cd. Oily wipes; IPA/solvent wipes; Solder waste; Acetone wipes. PVC cement - brushes, wipes, cans; PVC primer - brushes, wipes, cans; PVC cement - brushes, wipes, cans. Super glue; Epoxy tubes.

Aerosol cans, Spray paint, Spray foam, Spray adhesives. WD40; PB Blaster; Silicone Spray. Oil cans; 3 in 1 oil.

https://www.epa.gov/hww
https://floridadep.gov/waste/permitting-compliance-assistance/content/hazardous-waste-management-main-page

We need your help in following regulations and keeping the Merritt Island National Wildlife Refuge the pristine gateway site to the Florida Birding Trail for the next generation.

The Bot Shop

Day	Hours
Monday	Noon - 5pm
Tues, Weds, Thurs	9am - 5pm
Friday	9am - Noon

The Prototype Development Laboratory's Bot Shop is a "mobile machine shop" with grinding, sanding, mini-mill and mini-lathe, band saw, drill press and hand tools with no welding capability. They can help repair broken robots but do not have the capability to finish a started robot and only NASA machinists are allowed to use the equipment. The Bot Shop is busy throughout the week of competition. The PDL is a team of NASA engineers and engineering technicians whose primary purpose is the design, fabrication and testing of prototypes, test articles and test support equipment. You have the privilege of using this resource to make repairs and or modifications to your robots.

Test Bed (Sand Box)

The Sand Box is located under NASA Central. Teams can test their robots in a silica sand environment and interact with the Visitor Complex guests. While you are here, you represent yourself, your school and NASA. Remember when things go south on your robot (and they will), there are little ears and plenty of cell phones around you and your team.

Family and Friends Viewing the Competition

The Kennedy Space Center Visitor Complex (KSCVC) opens at 9 am. If you have family or friends that want to see your robot run and your run time starts before the park opens at 9 am, you need to notify the Project Management Staff to make arraignments the day before the run. Your family or friends must have a valid KSCVC Admission Ticket for that day.

Competition Schedule

You must complete your robot inspection, communications check and be cleared by the RoboPit Chief before you can sign up for your competition run. The schedule below is for planning purposes only and is subject to change to meet competition requirements. The updated competition schedule will be sent in the evening prior to the next day's run (see below). The schedule is based on 10 minutes to set up, 10 minutes to run and 5 minutes to remove your robot from the arena.

Competition Schedule

Wednesday			Thursday			Friday		
	Arena "A" Channel 1	Arena "B" Channel 11		Arena "A" Channel 1	Arena "B" Channel 11		Arena "A" Channel 1	Arena "B" Channel 11
Start	Team No.		Start	Team No.		Start	Team No.	
8:00 AM	1	2	8:00 AM	43	44	8:00 AM	31	32
8:25 AM	3	4	8:25 AM	45	46	8:25 AM	33	34
8:50 AM	5	6	8:50 AM	47	48	8:50 AM	35	36
9:15 AM	7	8	9:15 AM	49	50	9:15 AM	37	38
9:40 AM	9	10	9:40 AM	1	2	9:40 AM	39	40
10:05 AM	11	12	10:05 AM	3	4	10:05 AM	41	42
10:30 AM	13	14	10:30 AM	5	6	10:30 AM	43	44
10:55 AM	15	16	10:55 AM	7	8	10:55 AM	45	46
11:20 AM	17	18	Lunch			11:20 AM	47	48
Lunch						Lunch		
1:00 PM	19	20				1:00 PM	49	50
1:25 PM	21	22	1:25 PM	9	10	1:25 PM		
1:50 PM	23	24	1:50 PM	11	12	1:50 PM		
2:15 PM	25	26	2:15 PM	13	14	2:15 PM		
2:40 PM	27	28	2:40 PM	15	16	2:40 PM		
3:05 PM	29	30	3:05 PM	17	18	3:05 PM		
3:30 PM	31	32	3:30 PM	19	20	3:30 PM		
3:55 PM	33	34	3:55 PM	21	22	3:55 PM		
4:20 PM	35	36	4:20 PM	23	24	4:20 PM		
4:45 PM	37	38	4:45 PM	25	26	4:45 PM		
5:10 PM	39	40	5:10 PM	27	28	5:10 PM		
5:35 PM	41	42	5:35 PM	29	30	5:35 PM		

(subject to change)

PART V – ON-SITE MINING, MISSION CONTROL AND COMMUNICATIONS

ON-SITE MINING

SCORING

The arenas contain approximately 30 cm of BP-1 (regolith simulant) over approximately 15 cm of icy-regolith bed of gravel (icy regolith simulant). A minimum amount of 1.0 kg of rock/gravel must be mined and deposited during either of the two competition attempts to qualify to win in this category. If the minimum amount of 1.0 kg gravel is not met for an attempt, then the total score for that attempt will be 0. In the case of a tie, the teams will compete in a tie-breaking competition attempt. The teams with the first, second and third most mining points averaged from both attempts will receive 25, 20 and 15 points, respectively. Teams not winning first, second or third place in the mining category can earn one bonus point for each 0.5 kilogram of rock/gravel mined and deposited up to a maximum average of ten points. All decisions by the judges are final.

Mining Points Calculator

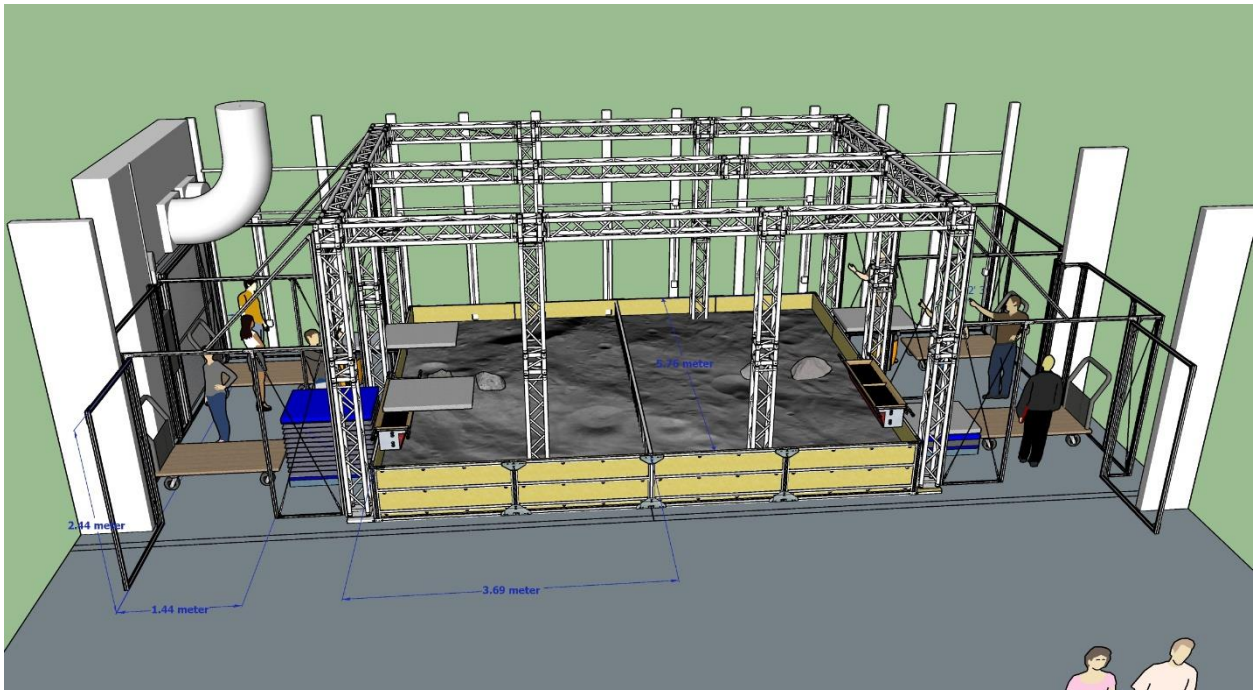
Mining Points Calculator				
Mining Category Elements	**Specific Points**	**Actual Points**	**Units**	**Mining Points**
Pass Inspections	0 or 1,000	0.00	1= Achieved	1,000.00
			0= Not Achieved	
Gravel (icy-regolith) over 1.0 kg:	15/kg	11.00	kg	150.00
Average Bandwidth	-1/50 kb/sec	1,066.00	Kbps/sec	-21.00
Camera Bandwidth Usage	200 kb/camera	400.00	Kpbs/camera	-8.00
Mining Robot Mass	-8/kg	62.55	kg	-500.40
Report Energy Consumed	-1/watt-hour	9.00	watt-hour	-9.00
Dust Tolerant Design (30%) & Dust Free Operation (70%)	0 to +100	30 / 19	judges decision (JD)	49.00
Autonomy	50, 150, 250 or 500	150.00	(JD)	150.00
Total Points				810.60

Table 1.

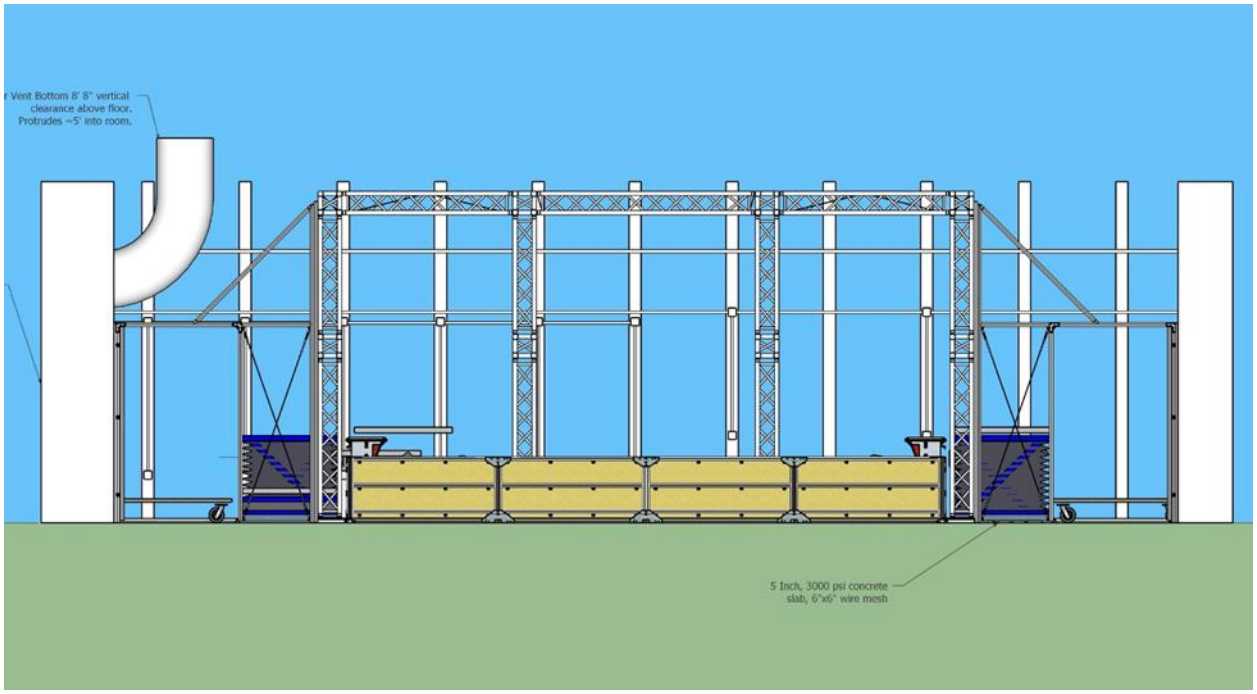
CATERPILLAR MINING ARENA

The following are the draft technical drawings for the arenas any changes will be posted as a revision to the rules and rubrics on the NASA RMC website and a notice will be sent to the teams.

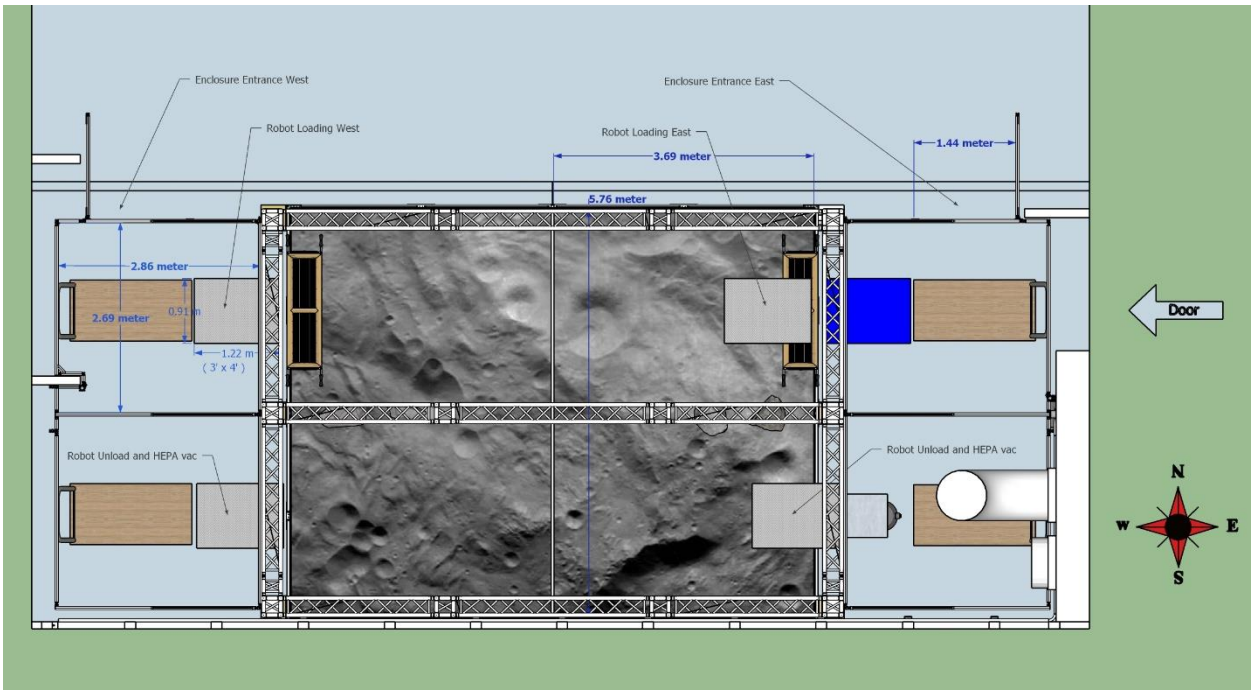
Enclosure View



Front View



Plan View



The Caterpillar Mining Arena

a. *Arena lighting information is not available at this time and will be posted as a revision to the rules and rubrics.*

b. *Steel, primer and paint specification are not available at this time and will be posted as a revision to the rules and rubrics.*

c. The arena will be indoors and the atmosphere will be an air-conditioned facility without significant air currents and cooled to approximately degrees 21 Celsius.

d. Inside dimensions of the arena:

Length Total North-South: 5.756 m

Width Total East-West: 3.691 m

Gravel approximate depth: 15.24 cm

BP-1 approximate depth over gravel: 30.5 cm

BP-1 approximate distance from the surface to the top of the walls 30.5 cm

(the Caterpillar Mining Arena will not have a level surface, since planetary surfaces are random and chaotic. Be prepared for slopes, irregularities and small rocks in the BP-1 simulant surface)

Collector Trough

a. The troughs are the same from the previous year. Now, the sieve back edge will be placed on a wall of the Caterpillar Mining Arena with the trough hanging over into the arena as shown in the drawings. The top opening inner dimensions for both the trough and the sieve screen placed above it are the same: 1.5 m long by 0.457 m deep with the same slope angles of 44 degrees long sides and 51 degrees at the ends.

b. With the addition of the sieve screen, the effective height of the collector trough lip is raised by 3.8 cm above the trough alone. The sieve screen is 6.4 cm below the sieve frame top.

c. The outside dimensions of the collector trough and sieve frame are 1.65 meters long and .48 meters wide.

d. The top edge of the sieve will be approximately 0.55 meter +/- 0.05 m from the top of the BP-1 surface directly below it. The sieve screen frame will have the same opening dimensions and internal slope angles as the trough but will be suspended above it.

e. The mesh is standard hardware mesh with the center to center distance of 12.7 mm and wire diameter of 1.58 mm with square openings 11.1 mm on a side.

RULES

1. Teams will be required to perform two official competition attempts (10 minutes each) to mine the rock/gravel in the arena. The mining area will contain BP-1 (lunar regolith simulant) to a depth of approximately 30 cm. Below the BP-1 lies the rock/gravel (icy-regolith simulant) with a mean particle size diameter of ~ 2 cm. Larger rocks may also be mixed in with the BP-1 and rock/gravel in a random manner. Note that rock/gravel may be mixed in with the BP-1, but the bulk of it will lie under the BP-1 in the mining area only. Surface features will consist of craters on each side of the arena with three, randomly placed obstacles. The mining robot will be placed in the arena in a randomly selected starting position. Each competition attempt will occur with two teams competing at the same time, one on each side of the arena. After each competition attempt, the obstacles and craters will be returned to their starting state.

2. Scoring for the Mining Category will require teams to consider a number of design and operation factors such as dust tolerance and projection, communications, vehicle mass, energy/power required, and autonomy. In each of the two official competition attempts, the teams will score cumulative mining points.

3. See Table 1 for the Mining Points Calculator. The teams' mining points will be the average of their two competition attempts.

   a. Each team will earn 1000 Mining points after passing the safety inspection and communications check.

   b. During each competition attempt, the team will earn 15 Mining points for each kilogram in excess of 1.0 kg of rock/gravel deposited in the Collector Bin. (For example, 11 kg of

gravel mined will earn 150 Mining points.) The rock/gravel will be sieved out at the Collector Bin and weighed separately from the BP-1.

c. During each competition attempt, the team will lose one (1) mining point for each 50 kilobits/second (kb/s) of average data used.

d. During each competition attempt, the team will lose 200 kb/s of data for each situational awareness camera used (Camera Bandwidth Usage 200 kb/camera)

e. During each competition attempt, the team will lose 8 Mining points for each kilogram of total mining robot mass. (For example, a mining robot that weighs 80 kg will lose 640 Mining points).

f. During each competition attempt, the team will lose one (1) Mining point for each watt-hour of energy consumed. The electrical energy consumed must be displayed by an (commercial off the shelf or "COTS") electronic data logger and verified by a judge.

g. During each competition attempt team can earn up to 100 Mining points for dust tolerant design features on the mining robot (up to 30 Mining points) and dust free operation (up to 70 Mining points). If the mining robot has exposed mechanisms where dust could accumulate during a Martian mission and degrade the performance or lifetime of the mechanisms, then fewer Mining points will be earned in this category. If the mining robot raises a substantial amount of airborne dust or projects it due to its operations, then, fewer Mining points will be earned. Ideally, the mining robot will operate in a clean manner without dust projection, and all mechanisms and moving parts will be protected from dust intrusion. The mining robot will not be penalized for airborne dust while dumping into the Collector Bin. All decisions by the judges regarding dust tolerance and dust projection are final.

h. DUST-TOLERANT DESIGN - The 30 points for dust-tolerant design will be broken down as follows:

i. -	Drive train components enclosed/protected and other component selections	10 points
ii.	Custom dust sealing features (bellows, seals, etc.)	10 points
iii.	Active dust control (brushing, electrostatics, etc.)	10 points

i. DUST-FREE OPERATION - The 70 points for dust-free operation will be broken down as follows:

i.	Driving without dusting up crushed basalt	20 points
ii.	Digging without dusting up crushed basalt	30 points
iii.	Transferring crushed basalt without dumping - the crushed basalt on your own Robot	20 points

j. AUTONOMOUS OPERATION - During each competition attempt, the team will earn up to 500 Mining points for autonomous operation. Mining points will be awarded for successfully completing the following activities autonomously:

i. Crossing the obstacle field (two times only, Outbound and back):	50 points
ii. Crossing the obstacle field, excavate and returning to the collection bin:	150 points
iii. Crossing the obstacle field, excavate and depositing regolith (two times):	250 points
iv. Fully autonomous run for 10 minutes:	500 points

k. The points earned for autonomy are not cumulative. Levels 1 through 4 points will be incrementally achieved. For example if level 2 is achieved then the points for level 1 are not counted. The autonomy points are awarded for the whole competition attempt and not for each run across the obstacle zone. If the robot fails to achieve autonomy during the competition attempt, and manual control is regained, then only autonomy points achieved to that point in time will be allowed.

l. For a team to earn mining points in the autonomous category, the team cannot touch the controls during the autonomous period. If the team touches the controls, then the autonomy period for that run is over; however, the team may revert to manual control to complete that run. Start and stop commands are allowed at the beginning and end of the autonomous period. Orientation data cannot be transmitted to the mining robot in the autonomous period. Telemetry to monitor the health of the mining robot is allowed during the autonomous period. The mining robot must continue to operate for the entire 10 minutes to qualify for a fully autonomous run.

m. The walls of the Caterpillar Mining Arena shall not be used for sensing by the robot to achieve autonomy. The team must explain to the inspection judges how their autonomous systems work and prove that the autonomy sensors do not use the walls. There are no walls on off-world locations and teams shall operate as closely as possible on that scenario of operations. Integrity is expected of all team members and their faculty advisors. Failure to divulge the method of autonomy sensing shall result in disqualification from the competition.

4. All excavated mass deposited in the Collector Bin during each official competition attempt will be weighed after the completion of each competition attempt. All rock/gravel will be sieved out from the BP-1 at the Collector Bin and weighed separately.

5. The mining robot will be placed in a randomly selected starting position.

6. A team's mining robot may only excavate BP-1 and gravel located in that team's respective mining area at the opposite end of the Caterpillar Mining Arena from the team's starting area. The team's starting direction will be randomly selected immediately before the competition attempt. Mining is allowed as soon as the mining line is crossed by the front end of the robot.

7. The mining robot is required to move across the obstacle area to the mining area and then move back to the Collector Bin to deposit the BP-1 and rock/gravel into the Collector Bin.

8. Each team is responsible for placement and removal of their mining robot onto the BP-1 surface. There must be one person per 20 kg of mass of the mining robot, requiring four people to carry the maximum allowed mass. Assistance will be provided if needed.

9. Each team is allotted a maximum of 10 minutes to place the mining robot in its designated starting position within the Caterpillar Mining Arena; and remove the mining robot from the

Mining arena after the 10-minute competition attempt has concluded and as directed by the Mining Judge.

10. The mining robot operates during the 10-minute time limit of each competition attempt. The competition attempts for both teams in the mining arena will begin and end at the same time.

11. The mining robot will end operation immediately when the power-off command is sent, and as instructed by the Mining Judge.

12. The mining robot cannot be anchored to the BP-1 and or rock/gravel surface prior to the beginning of each competition attempt.

13. The mining robot will be inspected during the practice days and right before each competition attempt. Teams will be permitted to repair or otherwise modify their mining robots while the RoboPits are open.

14. At the start of each competition attempt, the mining robot may not occupy any location outside the defined starting position in the mining arena.

15. Navigation

    a. Targets or beacons may be attached to the collector trough (not the sieve frame) for navigation purposes only. This navigational aid system must be attached during the setup time and removed afterwards during the removal time period. If attached to the collector trough, it must not exceed the length of the trough and not weigh over 9 kg.

    b. The navigational aid system may not be higher than 0.25 m above the Collector Trough, and cannot be permanently attached or cause alterations (ex: no drilling, nails, etc.).

    c. The mass of the navigational aid system is included in the maximum mining robot mass limit of 80.0 kg and must be self-powered.

    d. The target/beacon may send a signal or light beam or use a laser based detection system. Only Class I or Class II laser or low powered lasers (< 5mW) are allowed. Supporting documentation from the laser instrumentation vendor must be provided to the inspection judges for "eye-safe" lasers.

    e. The judges will inspect and verify that all laser devices are Class I or II lasers or low powered lasers (< 5mW) and laser based detection system products which have not been modified (optics or power).

    f. Inertial measurement units (IMU) are allowed on the mining robot. Teams have to explain to the judges how the compass feature will be switched off or the compass data is subtracted to ensure the internal calculations do not make use of the compass (from any magnetic field surrounding the robot).

    g. Compasses (analog, digital, etc.) are not allowed on the mining robot.

h. Global Positioning Satellite (GPS) or IMU-enabled GPS devices are not allowed. Teams have to explain to the judges how the device will be switched off or the data is subtracted and ensure the internal calculations do not make use of the GPS or IMU-enabled GPS device.

16. There will be at least three obstacles placed on top of the compressed BP-1 surface within the obstacle area before each competition attempt is made. The placement of the obstacles will be randomly selected before the start of the competition. Each obstacle will have a diameter of approximately 10 to 30 cm and an approximate mass of 3 to 10 kg. There will be two craters of varying depth and width, being no wider or deeper than 30 cm. No obstacles will be intentionally buried in the BP-1 by NASA, however, BP-1 includes naturally occurring rocks.

17. The mining robot must operate within the Caterpillar Mining Arena: it is not permitted to pass beyond the confines of the outside wall of the Arena and the Collector Bin during each competition attempt. The gravel must be mined in the mining area and deposited in the Collector Bin. A team that excavates any material from the starting or obstacle areas will be disqualified. The gravel must be carried from the mining area to the Collector Bin by any means and be deposited in the Collector Bin in its raw state. A secondary container like a bag or box may not be deposited inside the Collector Bin. Depositing a container in the Collector Bin will result in disqualification of the team. The mining robot can separate intentionally, if desired, but all parts of the mining robot must be under the team's control at all times. Any ramming of the wall may result in a safety disqualification at the discretion of the judges. The walls may not be used for the purposes of mapping autonomous navigation and collision avoidance (there are no walls on off world locations). Touching or having a switch sensor spring wire that may brush on a wall as a collision avoidance sensor is not allowed.

18. The mining robot must not use the wall as support or push/scoop the rock/gravel up against the wall to accumulate the excavated mass. If the mining robot exposes the mining arena bottom due to excavation, touching the bottom is permitted, but contact with the mining arena bottom or walls cannot be used at any time as a required support to the mining robot. Teams should be prepared for airborne dust raised by either team during each competition attempt.

19. During each competition attempt, the mining robot is limited to autonomous and telerobotic operations only.

    a. No physical access to the mining robot will be allowed during each competition attempt.

    b. Arena team members are not allowed to point out obstacles/arena surface conditions to the Mission Control Center team members. In addition, telerobotic operators are only allowed to use data and video originating from the mining robot and the NASA video monitors.

    c. Visual and auditory isolation of the telerobotic operators from the mining robot in the Mission Control Center is required during each competition attempt. Telerobotic operators will be able to observe the mining arena through overhead cameras in the mining arena via monitors that will be provided by NASA in the Mission Control Center. These color monitors should be used for situational awareness only.

d. No other outside communication via cell phones, radios, other team members, etc. is allowed in the Mission Control Center once each competition attempt begins. During the 10 minute setup period, a handheld radio link will be provided between the Mission Control Center team members and team members setting up the mining robot in the mining arena to facilitate voice communications during the setup phase only.

e. Team operators are not permitted to update or alter the autonomy program to account / detect or upload information about obstacle locations.

f. Teams are allowed to interact with an interface that allows different pieces of telemetry data to be viewed as long as there is no real time or other interaction to control or influence the robot. Teams must explain to the attending judge before each competition run how they are interacting with the telemetry system and the judge will observe to ensure compliance with all RMC rules.

20. The mining robot mass is limited to a maximum of 80.0 kg. Subsystems on the mining robot used to transmit commands/data and video to the telerobotic operators are counted toward the 80.0 kg mass limit. Equipment not on the mining robot used to receive data from and send commands to the mining robot for telerobotic operations is excluded from the 80.0 kg mass limit.

21. The mining robot must provide its own onboard power. No facility power will be provided to the mining robot during the competition runs. There are no power limitations except that the mining robot must be self-powered and included in the maximum mining robot mass limit of 80.0 kg. The energy consumed must be recorded with a "Commercial Off-The-Shelf" (COTS) electronic data logger device. Actual energy consumed during each competition run must be shown to the judges on the data logger immediately after the competition attempt.

22. The mining robot must be equipped with an easily accessible red emergency stop button or ""Kill Switch"". The emergency stop button or ""Kill Switch"" shall have a minimum diameter of 40 mm on the surface of the mining robot requiring no steps to access. The ""Kill Switch"" shall not cut power to the data-logger installed. There can be more than one ""Kill Switch"" on the robot. The spirit and intent of the ""Kill Switch"" is that it is easily accessible and can be safely activated by anyone in an easy and quick manner. Use good engineering practices and principles in placing the "Kill Switch" on your robot, failure to do so may result in a safety disqualification. The "Kill Switch" is required to be on the robot and enabled at all times during the competition week. Disabling the "Kill Switch" without authorization from the Competition Staff shall result in a safety disqualification. The emergency stop button or "Kill Switch" shall have a minimum diameter of 40 mm on the surface of the mining robot requiring no steps to access. The emergency stop button must stop the mining robot's motion and disable all power to the mining robot with one push motion on the button. It must be highly reliable and instantaneous. For these reasons an unmodified "Commercial Off-The-Shelf" (COTS) red button is required. A closed control signal to a mechanical relay is allowed as long as it stays open to disable the mining robot. This rule is to safe the mining robot in the event of a fire or other mishap. The button should disconnect the batteries from all controllers (high current, forklift type button) and it should isolate the batteries from the rest of the active sub-systems as well. Only laptop computers may stay powered on if powered by its internal battery.

23. The mining robot mass is limited to a maximum of 80.0 kg and must be contained within 1.5 m length x 0.75 m width x 0.75 m height. The mining robot may deploy or expand beyond the 1.5 m x 0.75 m footprint after the start of each competition attempt, but may not exceed a 1.5 meter height. The mining robot mass is limited to a maximum of 80.0 kg. During the excavated mass dumping operations only, the mining robot may deploy itself and exceed 1.5 m in height, but must be lower than the ceiling height which is less than 2.5 m above the surface of the regolith.

24. The mining robot may not pass beyond the confines of the outside wall of the Caterpillar Mining Arena and the Collector Bin during each competition attempt to avoid potential interference with the surrounding tent. The team must declare the orientation of length and width to the inspection judge. Because of actual Lunar/Martian hardware requirements, no ramps of any kind will be provided or allowed. An arrow on the reference point (the reference location and arrow pointing forward can be any point and direction of the team's choosing, except up) must mark the forward direction of the mining robot in the starting position configuration. The judges will use this reference point and arrow to orient the mining robot in the randomly selected direction and position (one or multiple permanent-type marker) indicating the team's choice of forward direction on any location on the robot is acceptable as long as multiple arrows do not conflict. The arrow does not have to indicate the robot's preferred forward direction. The arrow is used only to orientate the robot prior to starting the robot run to face the robot arrow either north, east, south or west after spinning the direction wheel). Multiple mining robot(s) systems are allowed but the total mass and starting dimensions of the whole system must comply with the volumetric dimensions given in this rule.

25. To ensure the mining robot is usable for an actual mission, the mining robot cannot employ any fundamental physical processes, gases, fluids or consumables that would not work in an off-world environment. For example, any dust removal from a lens or sensor must employ a physical process that would be suitable for the Lunar or Martian surface. Teams may use processes that require an Earth-like environment (e.g., oxygen, water) only if the system using the processes is designed to work in a Lunar or Martian environment and if such resources used by the mining robot are included in the mass of the mining robot. Closed pneumatic mining systems are allowed only if the gas is supplied by the mining robot itself. Pneumatic mining systems are permitted if the gas is supplied by the robot and self-contained.

26. Components (i.e. electronic and mechanical) are not required to be space qualified for Lunar or Martian atmospheric, electromagnetic, and thermal environments. Since budgets are limited, the competition rules are intended to require mining robots to show an off-world plausible system functionality but the components do not have to be traceable to an off-world qualified component version. Examples of allowable components are: Sealed Lead-Acid (SLA) or Nickel Metal Hydride (NiMH) batteries; composite materials; rubber or plastic parts; actively fan cooled electronics; motors with brushes; infrared sensors, inertial measurement units, and proximity detectors and/or Hall Effect sensors, but proceed at your own risk since the BP-1 is very dusty. Teams may use honeycomb structures as long as they are strong enough to be safe. Teams may not use GPS, rubber pneumatic tires; air/foam filled tires; open or closed cell foam, ultrasonic proximity sensors; or hydraulics because NASA does not anticipate the use of these on an off-world mission.

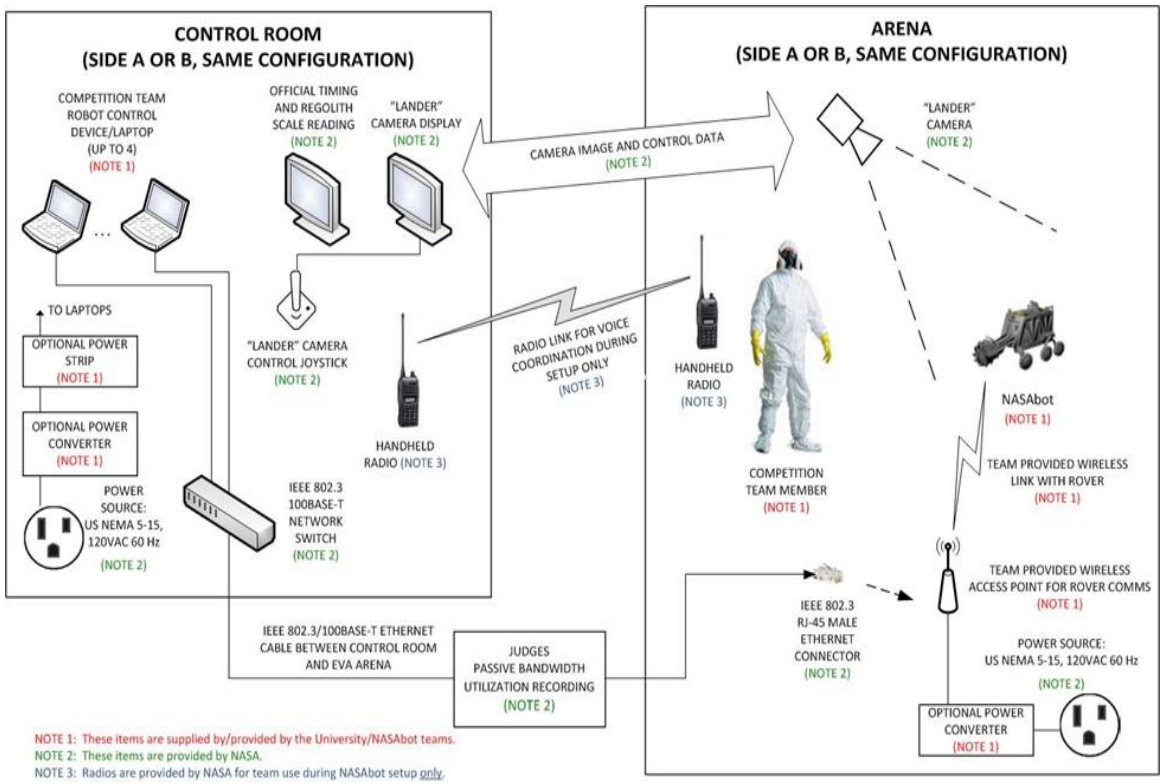
27. The mining robot may not use any process that causes the physical or chemical properties of the gravel to be changed or otherwise endangers the uniformity between competition attempts.

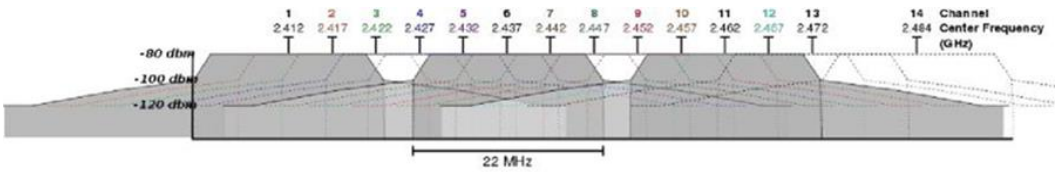
28. The mining robot may not penetrate the BP-1 surface with more force than the weight of the mining robot before the start of each competition attempt.

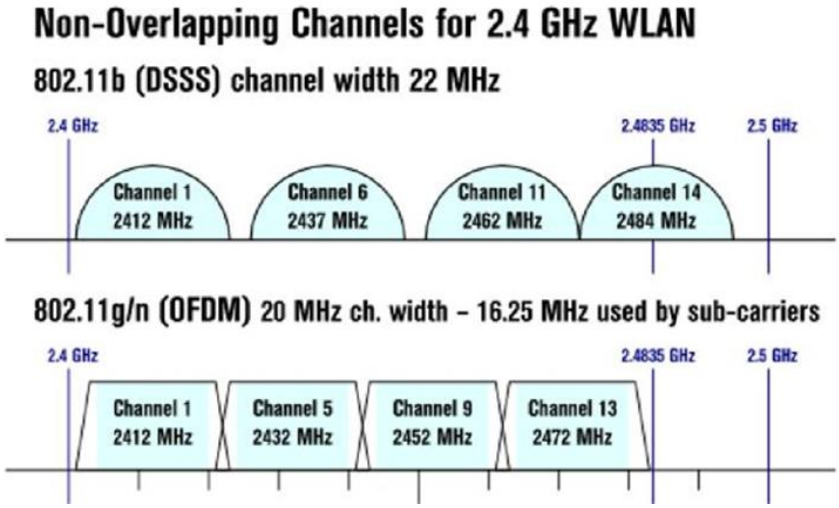
29. No ordnance, projectile, far-reaching mechanism, etc. may be used. The mining robot must move on the BP-1 surface.

30. No team can intentionally harm another team's mining robot. This includes radio jamming, denial of service to network, gravel manipulation, ramming, flipping, pinning, conveyance of current, or other forms of damage as decided upon by the judges. Immediate disqualification will result if judges deem any maneuvers by a team as being offensive in nature. Erratic behavior or loss of control of the mining robot as determined by the judges will be cause for immediate disqualification. A judge may disable the mining robot by pushing the red "Kill Switch" or emergency stop button at any time.

Mission Control and Communications







RULES

31. Mining Robot Wireless Systems Requirements

    a. Each team is required to command and monitor their mining robot over the NASA provided network infrastructure.
    b. This configuration must be used for teams to communicate with their robot.
    c. The "Lander" camera is staged in the Caterpillar Mining Arena, and Lander Control Joystick and camera display will be located with the team in the Mission Control Center (MCC).
    d. The MCC will have an official timing display, excavated mass display which would be weighed after the BP-1 is sifted through the sieve.
    e. Handheld radios will be provided to each team to link their Mission Control Center team members with their corresponding team members in the mining arena during setup.

32. Each team will provide the wireless link (access point, bridge, or wireless device) to their mining robot, which means that each team will bring their own Wi-Fi equipment/router and any required power conversion devices. Teams must set their own network IP addresses to enable communication between their mining robot and their control computers, through their own wireless link hosted in the Caterpillar Mining Arena.

    a. In the Caterpillar Mining Arena, NASA will provide an elevated network drop (male RJ-45 Ethernet plug) that extends to the Mission Control Center, where NASA will provide a network switch for the teams to plug in their laptops.
    b. The network drop in the Mining arena will be elevated high enough above the edge of the regolith bed wall to provide adequate radio frequency visibility of the Caterpillar Mining Arena.
    c. A shelf will be set up next to the network drop at a height 0 to 2 feet above the walls of the arena, and will be placed in a corner area on the same side as the collection bin. During robot system operations during the competition, there may be some dust accumulation in this area. This shelf is where teams will place their Wireless Access Point (WAP) to communicate with their mining robot.
    d. Teams are strongly encouraged to develop a dust protection cover for their wireless access point (WAP) that does not interfere with the radiofrequency signal performance.
    e. The WAP shelves for side A and side B of the Mining arena will be at least 20 feet apart to prevent electromagnetic interference (EMI) between the units.

33. Power Interfaces
    a. NASA will provide a standard US National Electrical Manufacturers Association (NEMA) 5-15 type, 110 VAC, 60 Hz electrical jack by the network drop. This will be no more than 5 feet from the shelf.
    b. NASA will provide standard US NEMA 5-15 type, 110 VAC, 60 Hz electrical connections in the Mission Control Center for each team.
    c. The team must provide any conversion devices needed to interface team access points or Mission Control Center computers or devices with the provided power sources.

34. During the setup phase, the teams will set up their access point and verify communication with their mining robot from the Mission Control Center.

35. The teams must use the USA IEEE 802.11b, 802.11g, or 802.11n standards for their wireless connection (WAP and rover client).
    a. Teams cannot use multiple channels for data transmission, meeting this rule will require a spectral mask or "maximum spectral bandwidth setting" of 20MHz for all 2.4 GHz transmission equipment.
    b. Encryption is not required, but it is highly encouraged to prevent unexpected problems with team links.
    c. During a match, one team will operate on channel 1 and the other team will operate on channel 11. See Figure 2. These channels will be monitored during the competition by NASA to assure there are no other teams transmitting on the assigned team frequency.

36. Teams must be able to use and switch between channel 1 and channel 11 for the competition.

37. Each team will be assigned an SSID that they must use for the wireless equipment for channel 1 and channel 11.
    a. SSID will be "Team_##."
    b. Teams are required to broadcast their SSID.

38. The use of specific low power (these power consumers are not part of the total power consumed COTS meter) Bluetooth transmission equipment in the 2.4 GHz range is allowed for sensors and other robot communications. Bluetooth is allowed only at power levels of Classes 2, 3, and are limited to a maximum transmit power of 2.5 mW EIRP. Class 1 Bluetooth devices are not allowed.
39. The use of 2.4 GHz ZigBee technology is prohibited because of the possibility of interference with the competition wireless transmissions.

40. Technology that uses other ISM non-licensed radio frequencies outside of the 2.4 GHz range, such as 900 MHz and 5 GHz, are allowed to be used for any robot or sensor systems, but these frequencies will not be monitored during the competition. Interference avoidance will be the responsibility of the Team and will not be grounds for protest by any team.

41. Radio Frequency Power:
    a. All Team provided wireless equipment shall operate legally within the power requirements power levels set by the FCC for Unlicensed Wireless equipment operating in the ISM radio band. The FCC Federal Regulations are specified in the Electronic Code of Federal Regulations, Title 47, Telecommunication, Part 15, and must be followed if any commercial equipment is modified. All unmodified commercial off the shelf access point equipment and computers already meet this requirement.
    b. If a team inserts any type of power amplification device into the wireless transmission system, this will likely create a violation of FCC rules and is NOT allowed in the competition.
    c. This radio frequency power requirement applies to all wireless transmission devices at any ISM frequency.

42. Data Utilization Bandwidth Constraints
    a. Use of the NASA provided situational awareness camera in the control room will add 200 kb/s of data use for each camera. If the team elects to turn on the camera during the match, they will be charged for the full 200 kb/s of data use.

b. The communications link is required to have an average data utilization bandwidth of no more than 5,000 kb/s. There will not be a peak data utilization bandwidth limit.

43. Radio Frequencies and Communications Approval
    a. Each team must demonstrate to the communication judges that their mining robot and access point are operating only on their assigned channel. Each team will have approximately 15 minutes at the communication judges' station.
    b. To successfully pass the communication judges' station, a team must drive their mining robot by commanding it from their mining robot driving/control laptop through their wireless access point. The judges will verify the course of travel and verify that the team is operating only on their assigned channel.
    c. The teams must identify and show to the judges all the wireless emission equipment on the robot, including amplifiers and antennas. If the team has added an amplifier, written documentation shall be submitted to the judges demonstrating that the limits as designated in these rules for power transmission levels are not being exceeded.
    d. If the team robot is transmitting low power Bluetooth, or is using any non-2.4 GHz frequency equipment, the following information must be provided to the judges during the communications checkout. Printed documentation from the manufacture with part numbers of all wireless transmission equipment. This printout must be from the manufacturer's data sheet or manual, and will designate the technology, frequency, and power levels in use by this type of equipment.
    e. If a team cannot demonstrate the above tasks in the allotted time, the team will be disqualified from the competition.
    f. On Monday of the competition week, on a first-come, first-serve basis, the teams will be able to show the communication judges their compliance with the rules.
    g. The NASA communications technical experts will be available to help teams make sure that they are ready for the communication judges' station on Monday and Tuesday of the competition week.
    h. Once the team arrives at the communication judges' station, the team can no longer receive assistance from the NASA communications technical experts.
    i. If a team is on the wrong channel during their competition attempts, the team will be disqualified and required to power down.

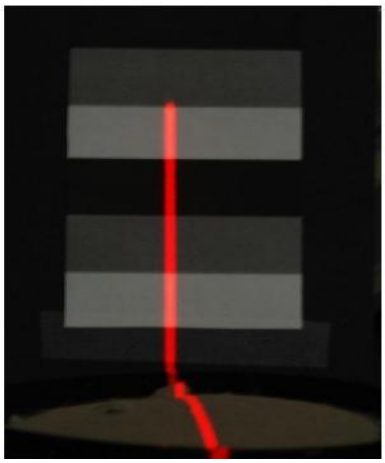
PART VI – GLOSSARY

Astronaut Memorial Foundation's Center for Space Education (CSE) Building M6-306 – located adjacent to the north-west end of the Kennedy Space Center Visitor Complex (KSCVC) at the eastern terminus of Florida S.R. 405. This is where the Caterpillar Mining Arenas, Slide Presentation and Demonstrations, RoboPits, Judge's and Volunteer areas are located.

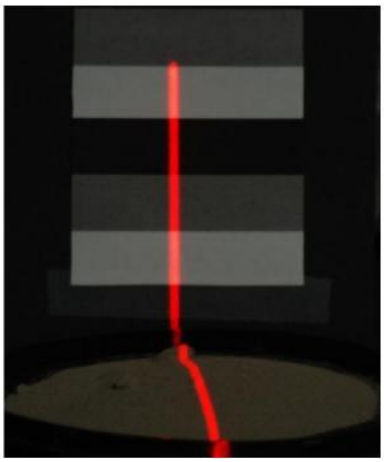
Autonomous – The operation of a mining robot with no human interaction.

Basaltic Regolith Properties – Since the properties of Mars regolith vary and are not well known, this competition will assume that Martian basaltic regolith properties are similar to the Lunar regolith as stated in the "Lunar Sourcebook: A User's Guide to the Moon", edited by G. H. Heiken, D. T. Vaniman, and B. M. French, copyright 1991, Cambridge University Press. http://www.lpi.usra.edu/publications/books/lunar_sourcebook/

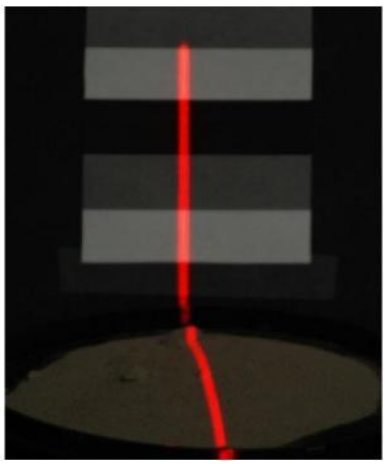
Black Point-1 (BP-1) Reflectivity – NASA performed tests to answer questions about BP-1 reflectivity for LIDAR (or other LASER-based) navigation systems. The laser is not a beam – it is spread out as a sheet that is oriented in the vertical direction, so it is draped across the BP-1 and across a white/gray/black target that is standing up behind the BP-1 in the images. The BP-1 is the mound at the bottom of each image. Teams can get the reflectivity of the BP-1 by comparing the brightness of the laser sheet seen reflected from the BP-1 with the brightness of the same sheet reflected from the white and black portions of the target. The three images are for the three angles of the laser. Note the BP-1 is mounded so they need to account for the fact that it is not a flat surface if they choose to analyze the brightness in the images. The three pictures below were shot with the camera at 10, 16, and 21 degrees relative to the surface. The laser was at an angle of 15 degrees. The camera speed and aperture were set to (manual mode): 1/8 s, f/4.5.



10 degree



16 degree



21 degree

Black Point-1 (BP-1) – The coefficient of friction and the cohesion of Martian soil have not been precisely measured due to a lack of scientific data from Mars. Instead, they have been estimated via a variety of techniques. Both parameters (coefficient of friction and cohesion) are highly dependent on the compaction (bulk density, porosity) of the Martian soil. Note the following:

1) It does not behave like sand.

2) There are naturally occurring rocks in the BP-1 aggregate.
3) The coefficient of friction has not been measured for BP-1.
4) It is a crushed lava basalt aggregate similar to Mars volcanic ash.
5) The density of the compacted BP-1 aggregate will be between 1.5 g/cm^3 and 1.8 g/cm^3.
6) BP-1 behaves like a silty powder soil and most particles are under 100 microns in diameter.
7) Will be compacted and the top layer will be raked to a fluffy condition of approximately .75 g/cm^3, similar to the Martian surface.
8) The study on BP-1 is available on http://www.nasa.gov/nasarmc "Soil Test Apparatus for Lunar Surfaces".
9) Dr. Philip Metzger, NASA Physicist and current University of Central Florida faculty member, describes BP-1 and its behavior at http://youtu.be/hMfrv7mlxbe
10) Teams are encouraged to develop or procure simulants based on basaltic minerals and lunar surface regolith particle size, shape, and distribution.
11) BP-1 is made from crushed basalt fines and not commercially available.
12) JSC-1A may be available from Orbital Technologies at https://isru.msfc.nasa.gov/lib/Documents/day1_11_JSC1A_Dev_MGustafson.pdf
13) NU-LHT may be available from Zybek Advanced Products (ZAP) at: http://government-contractors.insidegov.com/l/429936/Zybek-Advanced-Products-Incorporated

Mining arena– An open-topped container (i.e., a box with a bottom and 4 side-walls), containing BP-1, within which the mining robot will perform each competition attempt

Collector Bin – A Collector Bin in the mining arena for each competition attempt into which each team will deposit the excavated mass. The Collector Bin will be large enough to accommodate each team's excavated rock/gravel and BP-1. The Collector Bin will be stationary and located inside the Caterpillar Mining Arena.

Competition attempt – The operation of a team's mining robot intended to meet all the requirements for winning the mining category by performing the functional task. The duration of each competition attempt is 10 minutes.

Density – the density of regolith at the Apollo 15 landing site averages approximately 1.35 g/cm^3 for the top 30 cm, and it is approximately 1.85g/cm^3 at a depth of 60 cm.

Excavated mass – Mass of the excavated BP-1 and/or rock/gravel deposited to the Collector Bin by the team's mining robot during each competition attempt, measured in kilograms (kg) with official result recorded to the nearest one tenth of a kilogram (0.1 kg).

Functional task – The excavation of rock/gravel from the mining arena by the mining robot and deposit of the excavated mass from the mining robot into the Collector Bin.

Kennedy Space Center Visitor Complex – located at the eastern terminus of Florida S.R. 405.

Mining robot – A tele-operated or autonomous robotic excavator in the Robotic Mining Competition including mechanical and electrical equipment, batteries, gases, fluids and consumables delivered by a team to compete in the competition.

Mining points – Points earned from the two competition attempts in the Robotic Mining Competition will be averaged to determine ranking in the on-site mining category.

Mission Control – operations area where teams will tele-operate or autonomously control their robotic excavator to simulation an off-world mining mission. It is located outside of the Arenas.

Practice time – Teams will be allowed to practice with their mining robots in the Caterpillar Mining Arena. NASA technical experts will offer feedback on real-time networking performance during practice attempt. The spirit and intent is for teams to get one practice run on a first come, first served basis. Practice sessions maybe shortened or eliminated due to weather or other issues.

Reference point – A fixed location signified by an arrow showing the forward direction on the mining robot that will serve to verify the starting orientation of the mining robot within the Caterpillar Mining Arena.

Rock/Gravel - intended to simulate icy-regolith buried on the Moon and Mars. The gravel will be approximately 2 cm in diameter (minimum size) but will have random particle sizes larger than that also mixed into the gravel. The rock/gravel may be mixed in with the BP-1 in small quantities, but the majority of the gravel will be on the approximately lower 30 cm of the mining area regolith depth only. The gravel will be made of a hard rock material, and will not have a specific color.

Telerobotic – Communication with and control of the mining robot during each competition attempt must be performed solely through the provided communications link which is required to have a total average bandwidth of no more than 5.0 megabits/second on all data and video sent to and received from the mining robot.

Time Limit – 10 minutes to set up the mining robot in the mining arena and 10 minutes for the mining robot to perform the functional task per run and 5 minutes to remove the robot from the arena.

PART VII – RUBRICS & SCORESHEETS

RUBRICS

Plan for Project Systems Engineering– 10 Points

This is an initial plan. As you execute your project, things will change and your project will evolve. That's okay and expected. In your Systems Engineering Paper you can discuss the changes to your plan and how your project adapted. A minimum score of 6 out of 10 possible points must be achieved to qualify to win in this category. In the case of a tie, the judges will choose the winning Plan for Project Systems Engineering. The judges' decision is final.

Max length: 5 pages

Initial Project Schedule (3 points)
Design Philosophy (1 point)
Initial Project Budget (3 points)
Initial Technical Budget (3 points)

Initial Project Schedule (3 points) Provide a Gantt Chart or equivalent that shows the project's major due dates and events to include at least the five items listed below. Discuss these only as needed. 1) Start Date 2) Completion Date (after project decommissioning; this is the date when you have disposed of your robot system after the competition; e.g., you hand the system over to next year's team, broke it down for scrap, threw it in the trash, etc.) 3) Major review milestones (as a minimum, these must include Systems Requirements Review, Preliminary Design Review, Critical Design Review; others may be identified as you find appropriate) 4) Competition product delivery dates to RMC, including the planned date to submit "Robot Details/Proof of Life" to RMC. 5) Important milestones related to Project Cost Budget and Technical Budget as identified in the Initial Project Budget and Initial Technical Budget Optionally, you may also identify any major Systems Engineering activities in your Initial Project Schedule. **Discuss** how you will manage the evolution of the schedule during the life of the project (how often and when you will review project progress, and how you will adapt to schedule slips or schedule advance opportunities).	There are 3 points for 6 elements.
Initial Project Budget (3 points) Provide an estimate of the total project cost, inclusive of all possible costs. Provide a Table of Major Budget Categories and Items including the following list items as a minimum. Discuss only as needed. 1) Breakdown of total project cost estimate for at least the following major items. (Total should add up to the estimate of the total project cost.) a. Cost estimates for elements in the earliest level System Hierarchy b. Labor costs if any c. Material costs for competition (for production and completion of RMC deliverables)	There are 3 points for 3 elements.

d. Travel costs to KSC 2) Critical scheduling milestones for budget items or categories if any. [These should be reflected in item 5 for the Initial Project Schedule; e.g., dates funds will be needed, planned activities to raise funds, etc.] **Discuss** how you will manage the evolution of the budget during the life of the project (how often you will review budget progress and when, and how you will adapt to budget shortfalls or possible cost savings should they occur).	
Design Philosophy (1 point) Provide a short discussion, in the context of systems engineering, of what your team intends to optimize in your robot system design and operations (e.g., light weight, automation, collection of icy regolith simulant, low bandwidth, etc.)	There is 1 point for 1 element.
<u>Initial Technical Budgets</u> (3 points) Provide Table of Technical Budget Items that you deem are important to the Design Philosophy (e.g., mass, size, bandwidth, speed, etc.) including the following as a minimum. Discuss only as needed. 1) Technical Budget Items 2) Initial Target for each Technical Budget Item to be achieved by the competition 3) Allocation of each Technical Budget Item across the elements of the earliest System Hierarchy **Discuss** any critical schedule milestones for achieving critical technical performance levels (e.g., decision points in the design process where if you are unable to achieve for example a certain total mass, you would change the design). [These should be reflected in item 5 for the Initial Project Schedule.] **Discuss** how you will manage the evolution of the Technical Budgets during the life of the project (how often will review technical budget item progress, and how you will adapt to performance shortfalls should they occur).	There are 3 point for 5 elements.

Systems Engineering Paper– 25 Points

Each team must submit a Systems Engineering Paper electronically in PDF. The purpose of the systems engineering paper is for a team to demonstrate how they used the systems engineering process in designing, building and testing their robot. All required elements of the rubric must be discussed in the main body of the paper; you may reference the appendix and provide supporting information there. A minimum score of 20 out of 25 possible points must be achieved to qualify to win in this category. In the case of a tie, the judges will choose the winning Systems Engineering Paper. The judges' decision is final. For reference, undergraduate course materials in NASA Systems Engineering are available at www.spacese.spacegrant.org.

Elements	Points
Content	There are 3 points for 3 elements
* **Format:** The RMC Systems Engineering Paper shall be formatted professionally as if for submission to a professional journal: organized clearly; with correct grammar and spelling; with text no smaller than size 12 point font in the main body and appendices; text no smaller than size 9 point font in graphics and tables; using professional journal margins; single spaced; and, consist of a maximum of 20 pages in the main body not including the cover page, title page, table of contents, and references pages. Up to five additional pages of appendices shall be allowed and shall be referenced and discussed in the main body. Only the first 20 pages of the main body and the first five pages of appendices will be subject to judging. The cover page must include: team name, title of paper, full names of all team members, university name, and faculty advisor's full name.	
* **Faulty Signature:** The cover or title page shall include the signature of the sponsoring faculty advisor and a statement that he/she has read and reviewed the paper prior to submission to NASA.	
* **Reason for using Systems Engineering:** A statement shall be included in the front section of the main body explaining the reason for using systems engineering to develop your robot (beyond that it is required). (e.g. What benefit did it provide? How was systems engineering valuable to your project?)	

Project Management Merit	There are 8 points for discussion of 5 elements. Up to 2 points may be awarded for exceptional work in Intrinsic Merit, for a total of 10 points.
*** Design philosophy:** in the context of systems engineering; discuss what your team intends to optimize in your robot system design and operations (light weight? automation? collection of icy regolith simulant? low bandwidth? etc.)	
* **New Design or Design Update**: Clearly identify the new elements in this competition year's robot system (either state that the robot system is an entirely new design, or identify the specific subsystems or components that were changed on a previous robot system). Explain how you arrived at your decision to make these changes to a previous design. Focus the rest of the paper on the systems engineering work you performed to develop the	

new/updated subsystems/components and incorporate them into the whole system to perform the mission.	
* **Major reviews**: At a minimum, descriptions of what took place at the System Requirements Review (SRR), Preliminary Design Review (PDR), and Critical Design Review (CDR).	
* **Schedule of work**: from inception to disposal of robot system (original planned schedule before project start; and actual schedule performance with schedule changes tracked against the original schedule, reported as a minimum at major reviews)	
* **Cost budget**: budget for total project costs including travel; estimated predicted costs before project start, with actual costs tracked against estimated, reported as a minimum at major reviews as the project matures)	
Systems Engineering Merit	There are 8 points for 8 elements. Up to 4 additional points may be awarded for exceptional work on required elements, or for descriptions of systems engineering technical elements applied beyond the required eight, for a total of 12 points.
* **Concept of operations** (descriptions of how the robot system elements defined across each system hierarchy level will be operated under the environmental conditions of the competition to accomplish the robot system mission)	
* **System hierarchy:** (a top-down breakdown of the system design into the elements to be baselined at each control gate or major review)	
* **Interfaces** (identification, management, and verification of key interfaces identified for each system element in the system hierarchy at each system hierarchy level, including external interfaces)	
* **Requirements** (key driving requirements for robot system design, operations, interfaces, testing, safety, reliability, etc., stated in proper "shall" language) Address system and lower level requirements.	
* **Technical budgets** (e.g., mass, power & data allocated initially to system elements in the system hierarchy when baselined at a major review, with actual values tracked against the initial allocation reported as a minimum at each subsequent major review as the system matures through verification)	
* **Trade Studies** (how important robot system decisions were made using a trade study methodology, with key decision results captured as robot system derived requirements)	
* **Reliability** (design and operations considerations for assuring safety in the event of a system component failure during operations; and design and operations considerations for assuring successful completion of the mission without a failure)	
* **Verification of system meeting requirements** (how you assure or intend to assure that the as-built system satisfies, in the context of the concept of operations and under the environmental conditions of the competition, all of the key driving requirements identified and discussed in the paper)	

Outreach Project Report – 20 Points

Each team must participate in an educational outreach project in their local community to engage students in STEM (Science, Technology, Engineering and Math). Outreach activities should capitalize on the excitement of NASA's discoveries to spark student interest and involvement in STEM. Outreach strategies may include lessons and classroom materials using emerging communications and educational technologies to promote STEM; hands-on science and engineering activities that draw on NASA's unique missions; and community demonstrations that have a hands-on component involving K-12 students. Teams are encouraged to connect with a diverse student population including women, minorities and persons with disabilities.

Each team must submit a report of the Outreach Project electronically in PDF by the deadline. A minimum score of 16 out of 20 possible points must be achieved to qualify to win in this category. In the case of a tie, the judges will choose the winning outreach project. The judges' decision is final.

Outreach Project Report Scoring Rubric	
Elements	**Points**
Structure, Content and Intrinsic Merit: • Formatted professionally, clearly organized, correct grammar and spelling, size 12 font; single spaced, maximum of 5 pages not including the cover. Appendices are not allowed, however, a link in the body of the report to a multimedia site with additional photos or videos is allowed. Cover page must include: team name, title of paper, full names of all team members, university name and faculty advisor's full name. • Purpose for this outreach project, identify outreach recipient group(s). • Illustrations must appropriately demonstrate the outreach project. • The report must contain a table that includes each event, age/grade level, and number reached	There are 4 points for 4 elements.
Educational Outreach Merit: • The report must effectively describe what the outreach activity(s) was. • The report must describe exactly how the Robotic Mining Competition team participated, including the number of team members present. • The report must reflect how the outreach project inspired others to learn about robotics, engineering or Martian activities. The outreach must be STEM focused. • The report must demonstrate the quality of the outreach including how hands-on activities were used to engage the audience at their level of understanding.	There are 10 points for 5 elements.

• The report must show statistics on the participants. How many children did you reach? What age range/grade-level? Female/male students? EACH EVENT NEEDS STATISTICS.	
Additional points for exceptional work: • The report must clearly describe activities, processes, and milestones used to engage underserved and underrepresented populations. • The report must reflect how the outreach project inspired participant's interest in STEM. • Using survey methodology, the report must provide data on the demographic, geographic, and participant's perception of the outreach project. • The report must provide a summary of survey comments from each outreach event. • The report must show how you used engineering to improve/enhance either the experience of those you worked with or some aspect of your community. The report must clearly describe activities used to inspire, engage, and educate underserved and underrepresented participants on STEM.	There are 6 points for 6 elements.

Slide Presentation and Demonstration – 20 Points

The Slide Presentation and Demonstration is an optional category in the overall competition. The presentation and demonstration must be no more than 20 minutes with an additional 5 minutes for questions and answers. It will be judged at the competition in front of an audience including NASA and private industry judges. The presentations must be submitted electronically in PDF and teams **MUST** present the slides turned in. Visual aids, such as videos and handouts, may be used during the presentation but videos must be presented using the team's own laptop. You may NOT update/modify your slide presentation and present it from your laptop. A minimum score of 16 out of 20 possible points must be achieved to qualify to win in this category. The content, formatting and illustration portion of the score will be judged prior to the live presentation and scored based on the presentation turned in. In case of a tie, the judges will choose the winning presentation. The judges' decision is final.

Notes on Demonstration

- Safety is of the utmost importance. You are expected to be aware of the specific hazards associated with your robot and plan safe practices for demonstration. Everyone shall adhere to safe practices at all times during the demonstration, especially when troubleshooting unexpected issues in real-time. A clear zone shall be established around the robot, and no one shall enter that zone while the robot is in operation. All content from this paragraph shall be addressed when presenting the "Safety plan" topic.

- "Demonstration" defined: We prefer that you perform a live demonstration of all functions, however we recognize that this is not always possible. If parts or the entire robot cannot be controlled at the time of demonstration, it is acceptable to move parts by hand (power must be turned off), show video from practice runs, etc. to communicate the functionality and attributes of the system.

- In the presentation room: The competition staff will display the presentation as submitted (see "Dates & Deadlines"); we'll provide you with a remote control. An area will be set aside to set up your robot for demonstration. Note: you must move the robot from the cart to support stands if the tracks/ wheels will be operated during the demonstration. Teams may either use the provided jack stands or bring their own.

- Safety: Re-read the above note on safety, and plan how to safely handle the unexpected!

Scoring Rubric - Presentation and Demonstration	
Elements	**Points**
General content, formatting, and illustrations: • Cover sheet includes team name, university name, names of team members, and faculty advisor's name. • Utilize proper grammar and spelling. Include illustrations to support slide content (technical content, progression of the project, etc.). Ensure that formatting is readable and there is a good balance of text-to-graphics. • Presentation is well organized and slides flow smoothly. Use an appropriate number of slides and amount of material for the time allotted.	There are 3 base points for this element. 1 additional point may be awarded for a total potential score of 4 points.

Topics to Cover:
• Introduction
• Safety Plan
  ○ Demonstration safety
  ○ Robot safety features
• Project and System Performance Goals
	5 base points will be awarded if all content is covered.
	
	Failure to address each topic will automatically limit the maximum

○ Quantitative: Specify target values/ ranges ○ Qualitative • Design Process ○ Philosophy ○ Alternative Analysis – comparison and selection process: ▪ Mining functionality ▪ Component selection ○ Methodology ○ The Final Product ▪ Final configuration and functionality ▪ Performance: testing results vs. goals • Innovation: ○ Comparison to last year and evolution from previous years ○ Identify efforts to evolve processes, features, hardware, software, etc. • Project Management – Management of budget, schedule, team, risk, etc.	potential score to "3" points. Exception: lack of "innovation" topics will not count against teams in their first year at the competition. Up to 3 additional points may be awarded for exceptional coverage of content, for a total potential score of 8 points.
Delivery: • Explanation of content: presenters are knowledgeable and effectively communicate slide content. • Quality of delivery • Time management and professional cadence • Question and Answer session	There are 4 base points for this element. Up to 2 additional points may be awarded for exceptional performance, for a total potential score of 6 points.
Demonstration: • Live Demonstration ○ **Live demonstration will not be permitted if the "Demonstration Safety" component of the Safety Plan was not addressed prior to the intended movements.** • Adherence to the safety plan	There are 2 base points for this element. Failure to adhere to safe practices will automatically result in a score of "0" points.

SCORESHEETS

SCORESHEETS – Inspection and Arena

RMC | Inspection & Arena | Score Sheet

Team: _____ **Team #:**_____

Day:

M T W Th F

Attempt	Channel	Arena
☐ 1	☐ 1	☐ A
☐ 2	☐ 11	☐ B

[redacted]

Judge(s) Name: _____

Robot Mass: _____ **(***Max = 80kg*)

Measurements
Mass _____ *(not to exceed 80 kg)*

Width: _____ **Length:** _____ **Height:** _____
Dimensions (1.5 m width x .75 m length x .75 m height) Robot may deploy beyond the 1.5 m x .75 m footprint after the start of the competition attempt, but may not exceed a 2.5 meter height.

Dust Tolerant Design

0-10 pts ____ Drive train components enclosed/protected and other component selection

0-10 pts ____ Custom dust sealing features (bellows, seals, etc.)

0-10 pts ____ Active dust control (brushing, electrostatics, etc.)

Pass Inspection
☐ Achieved
☐ Not Achieved

[redacted]

Judge(s) Name: _____

_____ **Total Gravel Collected in kg (1kg to qualify, value = 15 points/kg)**

_____ **Total BP-1 Collected in kg (data only, value = no points)**

Energy Consumed

Start Value:_____ Units: _____

End Value: _____ Units: _____

Calculated Watt Hours: _____

Dust Free Operation

0-20 pts _____ Driving without dusting up crushed basalt

0-30 pts _____ Digging without dusting up crushed basalt

0-20 pts _____ Transferring regolith without dumping crushed basalt on your own robot

Any Rule Infractions?

_____

_____

_____

Constructive Feedback to Students *(will be copied verbatim)*:

_____

_____

_____

SCORESHEETS - Communication

RMC | Communication | Score Sheet

Team: _____ **Team #:**_____

Day:

M T W Th F

Attempt	Channel	Arena
☐ 1	☐ 1	☐ A
☐ 2	☐ 11	☐ B

[redacted]

Judge(s) Name: _____

_____ **Average Bandwidth** *Max = 5000 kb/sec*

Pass Comm Check

☐ Achieved
☐ Not Achieved

[redacted]

Any Rule Infractions?

_____

_____

Constructive Feedback to Students *(will be copied verbatim)*:

_____

_____

Team Spirit Comments

_____

_____

SCORESHEETS – Mission Control

RMC | Mission Control | Score Sheet

Team: _____ **Team #:** _____

Day:

M T W Th F

Attempt	Channel	Arena
☐ 1	☐ 1	☐ A
☐ 2	☐ 11	☐ B

MISSION CONTROL

Judge(s) Name: _____

Autonomy

- ☐ 0
- ☐ 50 *Successfully crossing the obstacle field—two times only—outbound and back*
- ☐ 150 *Successfully crossing the obstacle field, excavating, and returning to the collection bin*
- ☐ 250 *Successfully crossing the obstacle field, excavating and depositing regolith 2 times*
- ☐ 500 *Successful fully autonomous run for 10 minutes*

Average Bandwidth (Kb/s): _____

Camera Usage

- ☐ Lander Camera Used
- ☐ Lander Camera NOT Used
- ☐ Bin Camera Used
- ☐ Bin Camera NOT Used

COMMENTS

Any Rule Infractions?

Constructive Feedback to Students *(will be copied verbatim)*:

Comments

PART VIII – ROBOT DATA

ROBOT DATA (required) - Due May 1, 2019
Provide information about your off-world mining robot as requested. The link is not available at this time and will be posted as a revision to the rules and rubrics.

// end of rules and rubrics //