NASA's Eighth Annual Robotic Mining Competition
May 22-26, 2017
Rules and Rubrics

OVERVIEW & INTRODUCTION

Recent discoveries by NASA missions to Mars such as the Mars Science Laboratory (MSL) rover named "Curiosity" and instruments on orbiting satellites have found large amounts of water in the form of water ice at the higher latitudes and also hydrated minerals globally on Mars. They are the result of ancient clays and clay-like minerals called phyllosilicates, or other poly-hydrated sulfates that formed millions of years ago in wet environments on the surface or underground. 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, make rocket propellant for the journey home, grow plants, provide radiation shielding and for use in various manufacturing processes. Before the water can be used in a human Mars station, the granular minerals which contain the water must be mined, or the soil overburden must be removed, to expose the water ice. The minerals and soil are typically in the form of crushed and weathered rock called "regolith".

This competition is for university-level students to design and build a mining robot that can traverse the challenging simulated Martian terrain. The mining robot must then excavate the regolith simulant and/or the ice simulant (gravel) and return the excavated mass for deposit into the collector bin to simulate an off-world, in situ resource mining mission. The complexities of the challenge include the abrasive characteristics of the regolith simulant, the weight and size limitations of the mining robot and the ability to tele-operate it from a remote Mission Control Center. The on-site mining category will require teams to consider a number of design and operation factors such as dust tolerance and dust projection, communications, vehicle mass, energy/power required and autonomy. In addition to the on-site mining category, teams must also submit a systems engineering paper that explains their design philosophy. The teams also get extra points for engaging in social media and public engagement throughout the year, and have the option of giving a presentation to judges while at Kennedy Space Center. Points from both the mandatory and optional categories are tallied for the grand prize, The Joe Kosmo Award for Excellence.

NASA directly benefits from the competition by encouraging the development of innovative robotic excavation concepts from student teams which may result in clever ideas and solutions which could be applied to an actual excavation device and/or payload on an ISRU mission. The unique physical properties of basaltic regolith, reduced 3/8th of Earth gravity and other factors make off-world excavation a difficult technical challenge. Advances in Martian mining have the potential to significantly contribute to our nation's space vision and NASA space exploration operations.

A MESSAGE FROM THE PROJECT MANAGER

Long-duration habitation, surface systems and human life support systems will evolve through NASA's capability-driven approach to exploration, but even the most sophisticated designs must include ISRU components when possible. These research and technology development areas will focus on technologies necessary to extract consumables (O_2, H_2O, N_2, He, etc.) for human life-support system replenishment. The technologies can also be used to mine source materials for in-situ fabrication, repair technologies, and source materials (composites, etc.) such as radiation shielding for shelters. Mission capabilities and return on investment multiply when human consumables and spacecraft propellant can be harvested from extraterrestrial environments. As we embark on deep-space missions with months or longer travel times, ISRU becomes increasingly important because resupply missions are expensive and exclusively relying on them may put crews at risk. Each year university-level teams design and build robots to dig in the simulated basaltic regolith at the Kennedy Space Center to find alternative practices of harnessing resources from off-world exploration sites. Since its inception RMC has hosted over 300 different robots and 3,000 students from across the country including Alaska, Hawaii and the Commonwealth of Puerto Rico.

The Robotic Mining Competition Three Lines of Business Focus

- **Technology - Technology Drives Exploration.** We develop, test and fly transformative capabilities and cutting edge exploration technologies. Our technology development provides the onramp for new ideas, maturing them from early stage through flight and giving wings to the innovation economy. **#NASATech**

- **Mars - We are on a journey to Mars.** Today our robotic scientific explorers are blazing the trail. Together, humans and robotics will pioneer the next giant leap in exploration. **#JourneytoMars**

- **Solar System and Beyond NASA - We're Out There.** NASA's exploration spans the universe. Observing the sun and its effects on Earth. Delving deep into our solar system. Looking beyond to worlds around other stars. Probing the mysterious structures and origins of our universe. Everywhere imaginable, NASA is out there. **#NASABeyond**

The Robotic Mining Competition NASA Education Plan 2015-2017(E3) Jan 2016 Focus

- **NASA Strategic Objective 2.4** Advance the Nation's STEM education and workforce pipeline by working collaboratively with other agencies to engage students, teachers, and faculty in NASA's missions and unique assets.

- **NASA Education Performance Goals 2.4.4** and Annual Performance Indicator ED-16-4.

- **CoSTEM Strategic Plan** by enhancing the STEM experience of Undergraduate Students and Build and Use Evidence-Based Approaches.

The Robotic Mining Competition Accreditation Board for Engineering and Technology (ABET) Focus

- 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 most of the requirements for engineering, and engineering technology accreditation.

NASA's resources and personnel provide a unique experience available nowhere else giving students the opportunity to create off-world technologies from this on-world competition.

Good for NASA, Good for America
Good for All of US

THE COMPETITION EVENTS

On-Site Mining – (MANDATORY) requires the teams to design and build a mining robot that can traverse the simulated Martian chaotic terrain. The robot must then excavate the basaltic regolith simulant (called Black Point-1 / BP-1) and the ice 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 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.

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

Outreach Project Report – (MANDATORY) requires team to detail the type of STEM outreach in their communities, activities provided, numbers reached and are encouraged to reach out to the underserved / underrepresented K-12 students.

Slide Presentation & Demonstration – (OPTIONAL) provides the teams with the opportunity to talk and 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 that will serve them in thesis and / or doctoral dissertations, job interviews, grant requests, etc.

Social Media and Public Engagement – (OPTIONAL) requires the teams to creatively engage the public using social media in robotics and STEM related topics, showcases their universities progress in the design and build of their robot, motivates and encourages K-12 robotic groups to showcase their robots and educates the public about robotics and current NASA missions.

AWARDS

The Efficient Use of Communications Power Award
Awarded to the team for using the lowest average data utilization bandwidth per regolith points earned in both the timed and NASA monitored portion of the competition. Teams MUST collect the minimum amount of regolith to qualify for this award.

The Regolith Mechanics Award
Awarded to the team with the best example of a real granular innovation that identified a specific regolith mechanics problem (like the way the soil flows around the grousers, or angle of repose too high in their dump bucket, etc.) and intentionally improved their design to deal with it. Courtesy of the Center for Lunar and Asteroid Surface Science (CLASS), part of NASA's Solar System Exploration Research Virtual Institute (SSERVI) Network.

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

The Judge's Innovation Award
Awarded to the team that demonstrates the most innovative design.

Social Media and Public Engagement
Awarded to the teams that uses various social media platforms to engage the public in their participation with MC and engages with NASA and other robotic teams.

Slide Presentation and Demonstration
Awarded to the team that best presents their project at the competition in front of an audience including NASA and private industry judges.

Outreach Project Report
Awarded to the teams with the best 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 (K-12) interest and involvement in STEM.

Systems Engineering Paper
Awarded to the team that best discusses the Systems Engineering methods used to design and build their mining robot. The paper is peer reviewed by support and operations personnel from across the Administration.

Robotic On-Site Mining
Awarded to the team that: passes robot and communication inspections, mines more than 10 kg of regolith, most efficient use in bandwidth, minimizes robot mass, reports energy consumed, has a dust tolerant design & performs dust free operations, performs tele-robotic and / or autonomously and mines the most resources.

… and finally

THE JOE KOSMO AWARD FOR EXCELLENCE

Awarded to the team that scores the most points in both the mandatory and optional competition events.

Summary

Category	Award	Maximum Points for Joe Kosmo Award
On-Site Mining in the Caterpillar Mining Arena (required)	1st place $3,000 team scholarship 2nd place $2,000 team scholarship 3rd place $1,000 team scholarship Teams not placing 1st, 2nd, or 3rd will receive one point per kilogram of BP-1 and/or icy regolith simulant (gravel) mined and deposited up to 10 points	25 20 15 Up to 10
Systems Engineering Paper (required)	$500 team scholarship	Up to 25
Outreach Project Report (required)	$500 team scholarship	Up to 20
Slide Presentation and Demonstration (optional)	$500 team scholarship	Up to 20
Social Media and Public Engagement (optional)	$500 team scholarship	Up to 10
The Judges' Innovation Award	Trophy	NA
Caterpillar Autonomy Award	1st place $1,500 team scholarship 2nd place $750 team scholarship 3rd place $250 team scholarship	NA
The Regolith Mechanics Award	Trophy	NA
Efficient Use of Communications Power Award	Trophy	NA
Joe Kosmo Award for Excellence (Grand Prize)	Trophy and $5,000 team scholarship	

ELIGIBILITY AND REGISTRATION

Teams that are from colleges / universities located in the United States, its Commonwealths and territories and / or possessions are eligible to register for the competition (no more than one team per university campus is allowed).

REGISTRATION IS NOW CLOSED FOR RMC 2017

What is a Robotic Mining Competition Team?

A team shall stand alone and consist of:

- Undergraduate and graduate students (minimum of two undergraduate students) enrolled during the current or previous school semester
- A current faculty member / advisor with the college or university.
- The number of team members is at the discretion of the school but should have a sufficient number of members to successfully design, build and operate their mining robot.
- Participants can be members of only one team
- Each team must have its own working robot

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. These rules and rubrics are subject updates check NASA's Robotic Mining Competition at
http://www.nasa.gov/offices/education/centers/kennedy/technology/nasarmc.html

ADVISORIES

Code of Conduct – The Robotic Mining Competition is a NASA event and shall be held in a professional and positive environment. Competitors shall be courteous, professional and conduct themselves with the professional integrity required by this event. Behavior inconsistent with this philosophy (e.g. profanity, pranks, safety violations, deception to circumvent rules/regulations) will not be tolerated and shall be grounds for assessment of penalty points and/or disqualification from the Competition.

Disputes – Disputes shall be forwarded to the Robotic Mining Competition Project Manager for resolution. The decision of the Project Manager is final.

Emergency Procedure – Use the Buddy System:

- If you see someone in distress or injured, have someone stay with the distressed party and then report it immediately to the RoboPit Chief, Arena Chief, Volunteers or Volunteer Coordinator.
- If you see something suspicious, say something immediately to the RoboPit Chief, Arena Chief, Volunteers or Volunteer Coordinator.

OR CALL

- NASA / KSC 911 Emergency ---------- 321.867.7911
- KSC Visitor Complex Emergency Support ------ 321.449.4334

GO WITH YOUR GUT FEELING

Eyewash, Hand Wash Stations & Water Dispensers – Emergency eyewash stations, hand wash stations and water dispensers are located in the RoboPits, Bot Shop and both the PPE side and HEPA-Vac side of the Competition Arenas.

Personal Protection – Remember to have hats, sunglasses, insect repellent, sunscreen (SPF 50 or better) and a raincoat / poncho on hand for the Competition AND REMEMBER TO STAY HYDRATED - DRINK PLENTY OF WATER.

Questions – Submit inquiries to:
KSC-Robotic-Mining-Competition@mail.nasa.gov

Respiratory – 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 – (BP-1) is crushed lava basalt aggregate with a natural particle size distribution similar to that of lunar soil. BP-1 is alkaline and may cause skin and eye irritation. All personnel should avoid contact with BP-1 and use appropriate skin and eye protection when performing tasks (such as handling dusty robots) where they may be exposed to BP-1.

Unmanned Aerial Vehicles (UAV), Unmanned Aerial Systems (UAS) – The use of Unmanned Aircraft Systems (Drones) are prohibited at the Kennedy Space Center Visitor Complex 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 you will be removed from the KSCVC. The UAV/UAS will not be returned.

Weather and Lightning Conditions – You and your off-world mining robots will be exposed to the Florida weather so be prepared for heat, humidity, rain and remember to bring a rain cover (approx. 1.5 m x 1.5 m) and tie downs for your robot. Plan for weather when transitioning between the RoboPits (inside temperature approximately 24°C) and the Caterpillar Competition Arenas (outside temperature averaging 32°C & 95% humidity). Florida is the Lightning Capitol, lightning phases are based on distance broken out as the following conditions and actions.

- Phase I Condition – prepare to close down the Competition Arena and seek shelter.
- Phase II Condition – close down and seek shelter and wait for "All Clear" before going outside

DEADLINES

All items are due by 12:00 p.m. noon Eastern Time on the dates listed below, do not wait until the last day to submit your items. Failure to submit required items by the due date will lead to disqualification.

REQUIRED	
Registration Opens (limited to one team per university campus)	August 15, 2016
Systems Engineering Paper	April 10, 2017
Outreach Project Report	April 10, 2017
OPTIONAL	
Slide Presentation and Demonstration	April 18, 2017
Social Media and Public Engagement	May 25, 2017

REQUIRED DOCUMENTATION	
Letter of from University's Faculty Advisor	**With Application**
Letter of from University's Dean of Engineering	November 16, 2016
Faculty Participation Form	November 16, 2016
Signed Media Release Form	November 16, 2016
Student Participant Form	November 16, 2016
Team Roster	November 16, 2016
Transcripts (unofficial copy is acceptable)*	November 16, 2016
Team Biography (200 words maximum)	January 18, 2017
Team Photo W/Faculty	January 18, 2017
Corrections to NASA Generated Team Roster	February 15, 2017
Head Count Form	February 15, 2017
Final Team Roster (no changes after this date)	March 1, 2017
Rule 31 Shipping Bill of Lading/Commercial Invoice	May 1, 2017
Rule 32 Robot Information	May 1, 2017
Rule 33 Proof of Robotic Life Video	May 1, 2017
OPTIONAL DOCUMENTATION	
Student Resume	November 16, 2016
*student's transcript must be from the university and show:	
a. Name of student and name of school, coursework taken and grades	
b. Current student status within the 2016-2017 academic year	
THE COMPETITION	
Team Check-In, 7 a.m. - 3 p.m.	May 22, 2017
Slide Presentation and Demonstration Days	May 22-26, 2017
Practice Days	May 22-23, 2017
Opening Ceremony	May 23, 2017
Competition Mining Days	May 24-26, 2017
Awards Ceremony Friday Evening	May 26, 2017

COMPETITION WEEK

Check-In Monday

Check-in begins Monday morning at 7:00 a.m. and will close at 3:00 p.m. Eastern Standard Time (EST). 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 follow the directions to park your vehicle.

The Astronauts Memorial Foundation's Center for Space Education Building - All vehicles containing robots and support equipment must be cleared by security. After you are cleared by security you will be provided a temporary placard that will allow one vehicle to proceed through the gate.

REMEMBER TO KEEP THE EMERGENCY LANE CLEAR AT ALL TIMES

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You will then proceed to the Astronaut Memorial Foundation's Center for Space Education (CSE) Building (M6-306), where you will drop off your robot and equipment to awaiting team members who have already entered through the park's main entrance.

Teams will then return to Parking Lot 4, return the temporary placard to the RMC check-in tent and then enter through the Kennedy Space Center Visitor Complex (KSCVC) main entrance.

Proceed to the RoboPits and check-In with the RoboPit Chief.

Practice Schedule for Monday and Tuesday

The practice schedule is only a rough guideline and is subject to change at any time. The practice period will allow each team one practice run and give all parties 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.

MONDAY MAY 22, 2017		
	Arena "A" Channel 1	Arena "B" Channel 11
Time	Team No.	Team No.
1:00 p.m.	1	2
1:40 p.m.	3	4
2:20 p.m.	5	6
3:00 p.m.	7	8
3:30 p.m.	9	10
4:00 p.m.	11	12
4:30 p.m.	13	14
4:55 p.m.	15	16
5:20 p.m.	17	18
5:45 p.m.	19	20
6:10 p.m.	21	22

TUESDAY MAY 22, 2017		
8:00 a.m.	23	24
8:25 a.m.	25	26
8:50 a.m.	27	28
9:15 a.m.	29	30
9:40 a.m.	31	32
10:05 a.m.	33	34
12:00 Noon	Lunch	
1:00 p.m.	35	36
1:25 p.m.	37	38
1:50 p.m.	39	40
2:15 p.m.	41	42
2:40 p.m.	43	44
3:05 p.m.	45	46
3:30 p.m.	47	48
3:55 p.m.	49	50
4:40 p.m.	51	52
5:05 p.m.	53	

Check-Out, Robots and Equipment
Teams are allowed to 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 procedures.

Check-In, Robots and Equipment Tuesday - Friday
Check-in begins each morning at 7:00 a.m. and will close at 9:00 a.m. without exception. Follow the directions to park your vehicle, all vehicles containing robots and support equipment must be cleared by security. After you are cleared by security you will be provided a temporary placard that will allow one vehicle to proceed through the gate to drop off your robot and support equipment in front of the Center for Education. You will then take your vehicle out to Parking Lot 4, return the temporary placard to the RMC check-in tent and enter through the Kennedy Space Center Visitor Complex (KSCVC) main entrance.

Opening Ceremony
Will be held on Tuesday morning from 11 a.m. to noon under the sunshade in front of the Caterpillar Arenas.

College Recruitment Fair
Will be held Thursday from 11 a.m. to 3 p.m. Contact SECOR LLC (Paul@secorstrategies.com) if your school wants to participate in this event designed for high school seniors.

Closing Ceremony
Will be held Friday evening from 7 p.m. to 9 p.m., each team is allocated 10 slots to attend the Ceremony. Due to safety capacity regulations, only teams are permitted to attend the Award Ceremony.

The RoboPits
The RoboPits are located in the Astronauts Memorial Foundation's Center for Space Education Building M6-306, located adjacent to the west end of the KSCVC. The RoboPits are air-conditioned and equipped with restrooms, an eyewash station, and hand wash station and disposal containers for used aerosol cans, batteries, degreasers and wipes used as cleaners. This is where you will be working on your 'bots, meeting other competitors and after spending months "Designing It" and "Building It", this is where you will step off to the arenas to "Dig It!"

RoboPits Check-in Protocol
Check in with RoboPits Chief. A volunteer will escort the team with the robot to the team pit. The team leader and another representative will remain behind to ensure that the following information has been communicated to and understood by the team:

- 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
- Comm and mechanical inspection locations
- Travel path from RoboPits to Arena
- RoboPits Chief will give team leader the Communications (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's 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

RoboPits
- If you plan to take your 'bot 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 a.m. - 9 a.m., no exceptions.
- Vacuums are provided for the BP-1, they are for use by all teams as needed
- When you are done using it, please return it to the designated area near the RoboPits Chief
- 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 are NOT for use in your pit. Carts are not to be used as platforms for working on the 'bots.
- All pits have power strips provided. DO NOT DAISY-CHAIN POWER STRIPS.

Competition:
- 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.
- A volunteer will come to your pit to retrieve you, do not leave without the volunteer.
- If you are not in your pit at that time you run the risk of forfeiting your competition run.
- Following the inspection, the volunteer will escort the team to the Arena, where Arena volunteers will take over.
- Presentations and demonstrations:
- A volunteer will come to your pit to retrieve you approximately 10 minutes prior to your scheduled presentation time, do not leave without the volunteer.

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.
- Each team is expected to leave their pit as they found it. When you are ready to leave, go to the RoboPits Chief to ask for a volunteer to come inspect your pit.
- 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
- Teams are required to clean their pit and the area around it and meet with the RoboPit Chief to checked-out at the end of the competition. This process must be completed in order to attend the Award Ceremony Friday evening.

Waste Accumulation Containers

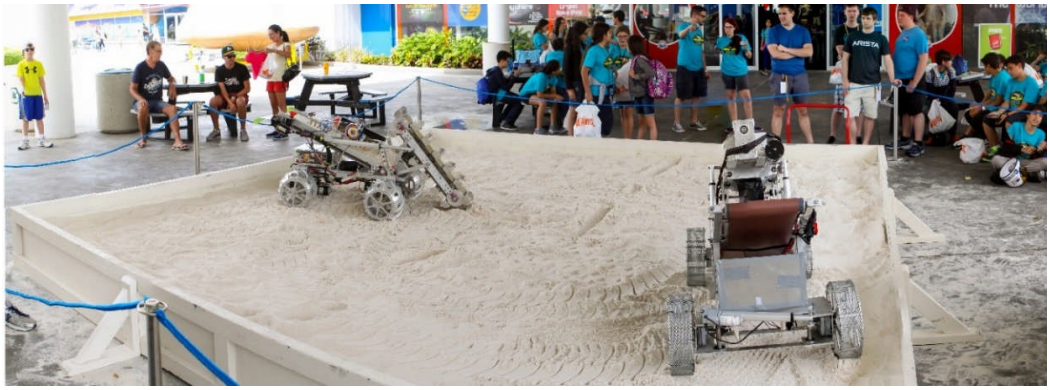
Teams will comply with Federal and Kennedy Space Center hazardous and controlled waste program requirements. Regulations requires that you coordinate with the RoboPit Chief before disposing of the items listed below (specially marked containers will be provided):

- Spent aerosol cans, Oily rags, Used oils/lubricants, Acetone
- Scrap metal, PVC primer and cement
- Tote trays for any other chemical products
- Spent batteries deposit at the RoboPit Chief Station

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.

Sand Box

The Sand Box is located in the Kennedy Space Center Visitor Complex south of the IMAX Theater under NASA Central. Teams can test their robots in a silica sand environment and interact with the Park's guests. While you are at this competition you not only represent yourself and your school, you also represent NASA. Remember there are little ears and plenty of cell phones around you and your team.



Robot Inspections, Communications Inspections, Slide Presentation and Demonstration, Practice Runs and Competition Runs

You are responsible for checking in with the RoboPit Chief for the process and to find out when your team is scheduled to have your robot inspected for volumetric and communications compliance and when you are scheduled to present and demonstrate your team concept and robot. The RoboPit Chief is your only point of contact to coordinate practice and competition runs, things get hectic, be professional.

The Bot Shop

The Bot Shop is supported by David, Jim, James and Otis – from KSC's Prototype Development Laboratory (PDL). 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.

The PDL supports research and technology development laboratories at KSC as well as all of the major engineering programs and projects in development at KSC. You have the privilege of using this resource to make repairs and or modifications to your robots.

ON-SITE MINING

The arenas contain 30 cm of regolith simulant over 30 cm of icy regolith simulant. A minimum amount of 10 kg of BP-1 and / or icy regolith must be mined and deposited during either of two competition attempts according to the rules to qualify to win in this category.

If the minimum amount of 10 kg of BP-1 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. All judges' decisions are final. 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 kilogram of BP-1 and/or icy regolith simulant (gravel) mined and deposited up to a maximum average of ten points.

Mining Points Attempt				
Mining Category Elements	**Specific Points**	**Actual**	**Units**	**Mining Points**
Pass Inspections:	0 or 1000	1	1=Achieved 0=Not Achieved	1000
BP-1 over 10 kg:	+3/kg	0	kg	0
Gravel (Icy Regolith Simulant) kg:	+15/kg	0	kg	0
Average Bandwidth:	-1/50kb/sec	1066	Kbps/sec	-21
Camera Bandwidth Usage	200kb/camera	400	Kbps/camera	-8
Mining Robot Mass:	-8/kg	62.55	kg	-500.4
Report Energy Consumed:	-1/Watt-hour	9	Watt-hour	-9
Dust Tolerant Design (30%) & Dust Fee Operation (70%)	0 to +100	30/19	Judges' Decision	49
Autonomy:	50, 150, 250 or 500	0		0
Total:				0

Table 1: Mining Category Scoring Sheet

1. Competition Teams will be required to perform two official competition attempts (10 minutes allowed for each run) using BP-1 in the Caterpillar Mining Arena. The Arenas are filled with compacted BP-1 that approximates basaltic Martian regolith. The mining area will contain BP-1 up to a depth of approximately 30 cm. Below the BP-1 there will be approximately 30 cm depth of gravel with a mean particle size diameter of ~ 2 cm which simulates icy regolith buried in the Martian regolith. Larger rocks may also be mixed in with the gravel and BP-1 in a random manner. Note that gravel may be mixed in with the BP-1, but the bulk of it will be in the bottom 30 cm of the mining area only. Three obstacles will be randomly placed and create two craters on each side of the Arenas. 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 gravel will be returned to the lower 30 cm of the mining area and the BP-1 will be returned to the top 30 cm in a compacted state, and the obstacles and craters will be re-set in the Arena. The competition attempts will be chosen at NASA's discretion.

2. The 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 Category Scoring Sheet. The teams' Mining Points will be the average of their two competition attempts.

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

b. During each competition attempt, the team will earn 3 Mining points for each kilogram in excess of 10 kg of BP-1 deposited in the Collector Bin. (For example, 110 kg of BP-1 mined will earn 100 Mining points.)

c. During each competition attempt, the team will earn 15 Mining points for each kilogram of simulated icy regolith (gravel) deposited in the Collector Bin. The gravel will be sieved out at the Collector Bin and weighed separately from the BP-1.

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

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

f. 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).

g. During each competition attempt, the team will lose 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.

h. During each competition attempt, the judges will award the team 0 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 awarded 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 awarded. 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.

i. ***DUST-TOLERANT DESIGN*** - The 30 points for dust-tolerant design will be broken down as follows:
   i. Drive train components enclosed/protected
   ii. and other component selections — 10 points
   iii. Custom dust sealing features (bellows, seals, etc.) — 10 points
   iv. Active dust control (brushing, electrostatics, etc.) — 10 points

j. ***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 — 30 points

k. ***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

l. 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.

m. 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.

n. 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 Mars and teams shall operate as closely as possible to a Mars 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 gravel will be sieved out from the BP-1 at the Collector Bin and weighed separately.

5. The mining robot will be placed in the randomly selected starting positions (see graphics).

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 gravel into the Collector Bin. See Diagrams 1 and 2.

8. Each team is responsible for placement and removal of their mining robot onto the BP-1 surface. There must be one person per 23 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 5 minutes to place the mining robot in its designated starting position within the Caterpillar Mining Arena; and remove the mining robot from the Caterpillar 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 Caterpillar 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, as instructed by the Mining Judge.
12. The mining robot cannot be anchored to the BP-1 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 Caterpillar Mining Arena. See Caterpillar Mining Arena definition for description of the competition field.

15. The collector trough/sieve top front edge will be placed so that it is in the vertical plane of the adjacent end wall of the Caterpillar Mining Arena. 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. See Diagram 3.

    a. The top opening inner dimensions for both the trough and the sieve screen placed above it are the same: 1.575 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. See Graphics

    c. Target(s) or beacon(s) 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 Collector trough and it must not weigh over 9 kg.

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

    e. 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.).

    f. 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.
    g. The target/beacon may send a signal or light beam but lasers are not allowed for safety reasons except for Visible Class I or II lasers or low power lasers and laser based detection systems.

    h. Supporting documentation from the laser instrumentation vendor must be given to the inspection judge for “eye-safe” lasers.

    i. The judges will inspect and verify that all laser devices are a class I or II product and they have not been modified (optics or power).

16. There will be 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 BP-1 and/or gravel must be mined in the mining area and deposited in the Collector Bin. A team that excavates any BP-1 from the starting or obstacle areas will be disqualified. The BP-1 and/or 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 Mars). Touching or having a switch sensor springwire 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 BP-1 and/or gravel up against the wall to accumulate BP-1. If the mining robot exposes the Caterpillar Mining Arena bottom due to excavation, touching the bottom is permitted, but contact with the Caterpillar 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. No physical access to the mining robot will be allowed during each competition attempt. In addition, telerobotic operators are only allowed to use data and video originating from the mining robot and the NASA video monitors. 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 Caterpillar Mining Arena through overhead cameras in the Caterpillar 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. 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 5 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 Caterpillar Mining Arena to facilitate voice communications during the setup phase only.

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. 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 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 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 height of the ceiling of the tent, which is less than 2.5 m above the surface of the regolith. 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 Martian hardware requirements, no ramps of any kind will be provided or allowed. An arrow on the reference point 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. 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.

24. To ensure that the mining robot is usable for an actual Martian mission, the mining robot cannot employ any fundamental physical processes, gases, fluids or consumables that would not work in the Martian environment. For example, any dust removal from a lens or sensor must employ a physical process that would be suitable for the 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 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.

25. Components (i.e. electronic and mechanical) are not required to be space qualified for Martian atmospheric, electromagnetic, and thermal environments. Since budgets are limited, the competition rules are intended to require mining robots to show Martian plausible system functionality but the components do not have to be traceable to a Martian 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 a Mars or off-world mission.

26. The mining robot may not use any process that causes the physical or chemical properties of the BP-1 and/or gravel to be changed or otherwise endangers the uniformity between competition attempts.

27. 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.

28. No ordnance, projectile, far-reaching mechanism (adhering to Rule 24), etc. may be used. The mining robot must move on the BP-1 surface.

29. No team can intentionally harm another team's mining robot. This includes radio jamming, denial of service to network, BP-1 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.

30. ROBOT COMMUNICATIONS

"Remember to Turn-Off your Local Wireless in the Arenas and Mission Control Laddie"

TELE-ROBOTIC OPERATIONS

a. Mining Robot Wireless Systems Requirements
   i. Each team is required to command and monitor their mining robot over the NASA provided network infrastructure shown in Figure 1.
   ii. This configuration must be used for teams to communicate with their robot.
   iii. The "Mars Lander" camera is staged in the Caterpillar Mining Arena, and Mars Lander Control Joystick and camera display will be located with the team in the Mission Control Center (MCC).
   iv. The MCC will have an official timing display, which includes a real-time display of BP-1 collected during the match.
   v. Handheld radios will be provided to each team to link their Mission Control Center team members with their corresponding team members in the Caterpillar Mining Arena during setup.

b. 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.

c.
   i. 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.
   ii. The network drop in the Caterpillar 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.
   iii. 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.
   iv. 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.
   v. The WAP shelves for side A and side B of the Caterpillar Mining Arena will be at least 25 feet apart to prevent electromagnetic interference (EMI) between the units.

d. Power Interfaces
   i. 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.
   ii. NASA will provide standard US NEMA 5-15 type, 110 VAC, 60 Hz electrical connections in the Mission Control Center for each team.
   iii. 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.

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

f. The teams must use the USA IEEE 802.11b, 802.11g, or 802.11n standards for their wireless connection (WAP and rover client).

   i. 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.
   ii. Encryption is not required, but it is highly encouraged to prevent unexpected problems with team links.
   iii. 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.

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

h. Each team will be assigned an SSID that they must use for the wireless equipment for channel 1 and channel 11.

   i. SSID will be “Team_##.”
   ii. Teams are required to broadcast their SSID.

i. The use of specific low power 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.

j. The use of 2.4 GHz ZigBee technology is prohibited because of the possibility of interference with the competition wireless transmissions.

k. 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.

l. Radio Frequency Power:

   i. 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.
   ii. 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.
   iii. This radio frequency power requirement applies to all wireless transmission devices at any ISM frequency.

m. Data Utilization Bandwidth Constraints

   i. 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.
   ii. 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.

n. Radio Frequencies and Communications Approval

   i. 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.

   ii. 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.

   iii. 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.

   iv. 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.

   v. If a team cannot demonstrate the above tasks in the allotted time, the team will be disqualified from the competition.

vi. 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.

vii. 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.

viii. Once the team arrives at the communication judges' station, the team can no longer receive assistance from the NASA communications technical experts.

ix. If a team is on the wrong channel during their competition attempts, the team will be disqualified and required to power down.

"I cannae change the laws of physics!"

ROBOT LOGISTICS

31. Shipping Your 'Droids

You are responsible for the cost of shipping and tracking your 'droid, uncrating and crating your 'droid for the voyage home. Your shipping company is responsible for providing a forklift, pallet jack, lift gate, etc. to load and unload your droid's crate; use a reputable shipping company and start this process in a timely manner.

Submit via email both of your Shipping Bills of Lading (to the competition and return to home school) by May 1, 2017.

Shipping to the Competition:

NASA John F. Kennedy Space Center
ISC Central Receiving - Bldg. M6-0744
Kennedy Space Center, FL 32899
Mark For: Robotic Mining Competition at the Kennedy Space Center Visitor Complex

- Do not have the shipping company deliver the mining robot directly to the Kennedy Space Center Visitor Complex.
- The shipping company will go to the NASA KSC Pass & ID Office on the south side of State Road 405 (call 321.749.0320 four hours prior to your arrival and again on arrival) and ISC Central Receiving will send an escort to the shipper
- Your shipping containers will be accepted from 8:00 a.m. Monday May 15, 2017, through 2:00 p.m. Wednesday May 17, 2017.
- Coordinate with your shipping company to ensure deliveries are made within this time period. The containers will be placed in each team's assigned RoboPit for the competition.

Shipping Back to Home School - follow these instructions to start your 'droid's voyage home.

The "Pick-Up Address" and instructions are as follows:

Kennedy Space Center Visitor Complex
Delaware North Companies (DNC)
Robotic Mining Shipping Area - Mail Code: DNPS
State Road 405
Kennedy Space Center, FL 32899

- At the end of the RMC prepare your robot(s) for shipment and place in the designated location as directed by the RoboPit Chief

- You are responsible for attaching the Shipping Bill of Lading/Commercial Invoice on the shipping crates must have your “Ship To” information clearly labeled on the crate. You must also have the shipping company name clearly labeled on the crate.
- Drivers will go directly to the Kennedy Space Center Visitor Complex retail warehouse (behind the DNC Administration Building) through Guard Post 4; from there, the DNC warehouse team will take the driver to the appropriate site where the robots are being stored for pick up.
- The on-site P.O.C. is Charlie Lamattina 321.449.4252, clamatti@dncinc.com
- All mining robots must be picked up no later than June 1, 2017.
- Robots remaining after June 1, 2017 will be considered abandoned and will be offered to local area high school robotic programs for adoption.

If you would like to leave your robot to donate to local area high school robotic programs notify the RoboPit Chief.

32. **Robot Details**
Teams must submit the following by May 1, 2017:

- photo of your robot (photos shall be 1024 x 768 pixels in a JPEG format)
- a description of your robot, robot’s operation and potential safety hazards
- diagram of the robot and a basic parts list
- a link to your YouTube video documenting (this “proof of life” documentation is solely for technical evaluation of the mining robot) between 30 seconds and 5 minutes of their mining robot in operation for at least one full cycle of operations (one full cycle includes excavation and depositing the material).

PLANNING

Each year, the Robotic Mining Competition seeks to maximize the number of teams which successfully complete the challenge, from its pool of entries. While miscellaneous unforeseen circumstances cause teams to drop out from the competition, a historical analysis of the RMC shows that the number one reason teams fail to compete is because of a lack of adequate funding. Adequate funding is required to build the robot and travel to the event, and teams sometimes fall short of raising the funds they originally projected in their budget. In addition, parts and equipment can sometimes unexpectedly fail causing the need for funds to replace these items, and teams are unprepared to cover such expenses.

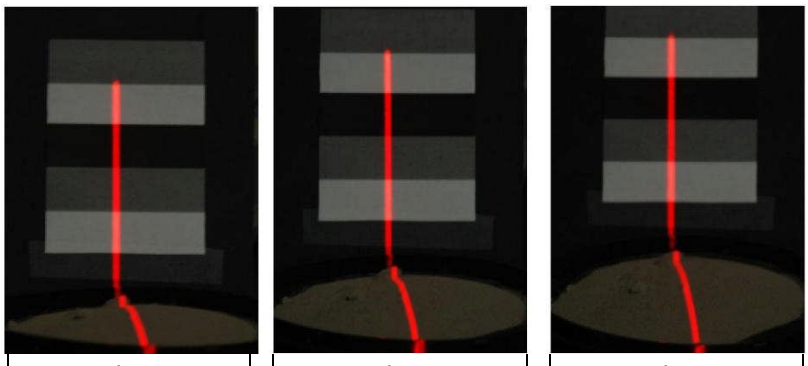
GLOSSARY

Astronauts Memorial Foundation's Center for Space Education (CSE) Building M6-306 – located adjacent to the west end of the KSCVC. The Slide Presentation and Demonstrations, RoboPits, Bot Shop, Judge's and Volunteer areas are located here.

Autonomous – The operation of a team's 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.



10 degree	16 degree	21 degree

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.

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:

- It does not behave like sand.
- There are naturally occurring rocks in the BP-1 aggregate.
- The coefficient of friction has not been measured for BP-1.
- Is a crushed lava basalt aggregate which is similar to Mars volcanic ash.
- The density of the compacted BP-1 aggregate will be between 1.5 g/cm^3 and 1.8 g/cm^3.
- BP-1 behaves like a silty powder soil and most particles are under 100 microns in diameter.
- 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.
- The study on BP-1 is available on http://www.nasa.gov/nasarmc "Soil Test Apparatus for Lunar Surfaces".
- Dr. Philip Metzger, NASA Physicist (ret) and current University of Central Florida faculty member, describes BP-1 and its behavior at http://youtu.be/hMfrv7mlxbE .
- Teams are encouraged to develop or procure simulants based on basaltic minerals and lunar surface regolith particle size, shape, and distribution.
- BP-1 is not commercially available and it is made from crushed basalt fines.

  However, JSC-1A is available from Orbital Technologies at http://www.orbitec.com/store/simulant.html, and

  NU-LHT is commercially available from Zybek Advanced Products (ZAP) at: http://www.zybekap.com

Caterpillar 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. The inside dimensions of the each side of the Caterpillar Mining Arena will be 7.38 meters long and 3.88 meters wide, and 1 meter in depth. The BP-1 aggregate will be approximately .3 meters in depth and approximately .5 meters from the top of the walls to the surface. There is no guarantee that the BP-1 in the mining arena will 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. The Caterpillar Mining Arena for the practice days and official competition will be provided by NASA. The Caterpillar Mining Arena will be outside in an enclosed tent. The Caterpillar Mining Arena lighting will consist of high intensity discharge (HID) lights such as metal halide lights inside a tent structure with clear sides, which is not quite as bright as outdoor daylight conditions. The atmosphere will be an air-conditioned tent without significant air currents and cooled to approximately 70 – 75 degrees Fahrenheit. See Graphics. The Caterpillar Mining Arena steel, primer and paint specifications are as follows:

- Steel: A-36(walls) & A-992(I-beams) structural steel.
- Primer: Devran 201 epoxy primer, 2.0 to 3.0 mils, Dry Film Thickness (DFT).
- Paint: Blue Devthane 379 polyurethane enamel, 2.0 to 3.0 mils, DFT (per coat).

Collector Bin – A Collector Bin in the Caterpillar Mining Arena for each competition attempt into which each team will deposit excavated BP-1. The Collector Bin will be large enough to accommodate each team's excavated BP-1. The Collector Bin will be stationary and located adjacent to the Caterpillar Mining Arena. See Graphics.

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. Each team will have 5 minutes to enter and set up their mining robot in the Caterpillar Mining Arena, each team will then have 10 minutes for the mining robot to perform the functional task. At the end of time, the team will safe and de-energize the robot and remove it from the mining arena quickly and as directed by the mining judge. Each team will get two, 10 minute, competition attempts

Excavated mass – Mass of the excavated BP-1 and/or 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 BP-1 and/or icy regolith simulant from the Caterpillar Mining Arena by the mining robot and deposit of BP-1 icy regolith simulant from the mining robot into the Collector Bin.

Gravel - This is intended to simulate icy-regolith buried on 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 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.

Kennedy Space Center Visitor Complex – located at the eastern terminus of Florida S.R. 405. The Competition Arenas are located in the Rocket Garden, the practice Sand Box is located under NASA Central and the Awards Ceremony is held here on Friday evening.

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.

Practice time – Each team will have 5 minutes to enter and set up their mining robot in the Caterpillar Mining Arena, each team will then have 10 minutes for the mining robot to perform the functional task. At the end of time, the team will safe and de-energize the robot and remove it from the mining arena quickly and as directed by the mining judge. NASA technical experts will offer feedback on real-time networking performance during the practice attempt. Every team will get one practice run on a first come, first served basis.

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.

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.

RUBRICS

Systems Engineering Paper – 25 Points

Each team must submit a Systems Engineering Paper electronically in PDF. Your paper should discuss the Systems Engineering methods used to design and build your mining robot. The purpose of the systems engineering paper is to encourage the teams to use the systems engineering process while designing, building and testing their robot as opposed to writing a paper after the fact. All pertinent information required in the rubric must be in the body of the paper. 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 Systems Engineering Paper. The judges' decision is final. For reference, undergraduate course materials in NASA Systems Engineering, are available at www.spacese.spacegrant.org.

Scoring Rubric - Systems Engineering Paper	
Elements	Points
Content	There are 3 points for 3 elements
* Formatted professionally, clearly organized, correct grammar and spelling, size 12 font; single spaced, maximum of 20 pages not including the cover, table of contents, and source pages. Appendices are allowed, are limited to 5 pages, and should be referenced in the main body. Cover page must include: team name, title of paper, full names of all team members, university name, and faculty advisor's full name.	
* Title page must 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.	
* Purpose Statement must be included and related to the application of systems engineering to NASA's Robotic Mining Competition.	

Intrinsic Merit:	There are 8 points for 4 elements
* Cost budget (estimated costs vs. actual costs)	
* Design philosophy in the context of systems engineering; discuss what your team is optimizing in your design approach (light weight? automation? BP-1 capacity? Ice simulant, etc.)	
* Schedule of work from inception to arrival at competition	
* Major reviews: system requirements, preliminary design and critical design	

Technical Merit	There are 8 points for 8 elements. Up to 6 points may be awarded for exceptional work
* Concept of operations	
* System hierarchy	
* Interfaces	
* Requirements	

* Technical budgets (mass, power & data allocated to components vs. actual mass, power, & data usage)	related to systems engineering technical merit, for a total of 14 points.
* Trade-off assessments	
* Reliability	
* Verification of system meeting requirements	

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. 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.

Scoring Rubric - Outreach Project Report	
Elements	Points
Structure, Content and Intrinsic Merit:	There are 3 points for 3 elements
*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.	

Educational Outreach Merit:	There are 10 points for 5 elements.
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 team thinks 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.	
* The report must show statistics on the participants. How many children did you reach? What age range/grade-level? 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.	There are 7 points available.
* The report must provide a summary of any feedback comments from each outreach event.	
* The report must clearly describe how Science, Technology, Engineering, and Mathematics (STEM) relates to the development of robotic mining.	
* The report must provide two illustrations that clearly demonstrate how Science, Technology, Engineering, and Mathematics (STEM) relates to the development of robotic mining.	

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 **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.

Scoring Rubric - Slide Presentation and Demonstration	
Elements	Points
Content, formatting, and illustrations::	There are 4 points for 4 elements
* Content includes a cover slide (with team name, presentation title, names of team members, university name, and faculty advisor's name). Also includes an introduction slide and referenced sources.	
* Formatting is readable and aesthetically pleasing with proper grammar and spelling.	
* Illustrations support the technical content	
* Illustrations show progression of the project and final design	

Technical Merit:	There are 5 points for 5 elements. Up to 2 additional points may be awarded for exceptional work related to technical merit, for a total of 7 points.
* Design Philosophy and Process	
* Design Alternative Analysis and Final Design	
* Mining functionality	
* Special features – highlight what makes the robot unique or innovative	
* Project Management	

Additional points for exceptional work:	There are 5 points for 5 elements. Up to 4 additional points may be awarded for an
* Handles slides and equipment professionally	
* Engages audience and infuses personality	

* Creative and inspirational	exceptional presentation, for a total of 9 points.
* Demonstrates Robot	
* Answers Questions	

Social Media and Public Engagement – 10 Points

Social Media and Public Engagement is an optional category in the overall competition. A minimum score of 7 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 team. The judges' decision is final.

Scoring Rubric - Social Media and Public Engagement	
Elements	Points
Social Presence:	3 points for 3 elements clearly, 2 points for 2 or less elements clearly and 1 - 0 points for 1 or 0 elements clearly demonstrated.
* Uses various social media platforms to engage the public in their participation in RMC introduction slide and referenced sources.	
* Engages with NASA and other robotic teams	
* Encourages other groups to engage in social media activities with their team	

Content	4 point for 4 elements exceptional, 3 points for 3 elements exceptional, 2 points for 2 or less elements clearly and 1 - 0 points for 1 or 0 elements clearly demonstrated.
* Creatively engages the public in robotics and STEM related topics	
* Showcases their universities progress in the design and build of their robot	
* Motivates and encourages K-12 robotic groups to showcase their robots	
* Educates the public about robotics and the current NASA missions	

On-Site Public Engagement	3 points for 3 elements clearly, 2 points for 2 or less elements clearly and 1 - 0 points for 1 or 0 elements clearly demonstrated.
* Exudes a positive attitude in all interactions	
* Conducts themselves as positive role models	
* Demonstrates courtesy with authority & competitors	
* Decorates team's Pit to reflect school/team spirit	