Robotic Mining Competition Questions & Answers (new Q&As in red)

Competition Questions

Q. Can more than one team register from a single university?

A. Yes, more than one team can register from a university provided the dean of engineering approves both teams.

Technical Questions

Q. Rule 17 states "The walls may not be used for the purposes of mapping autonomous navigation and collision avoidance." If we cannot use the walls for collision avoidance, how would we stop our robot from crashing into the walls? We intend to create a map of the ground and avoid obstacles that are in the way, and were thinking that we should treat the walls like any other obstacle and simply avoid it, but not follow it. Is this acceptable to keep autonomous status?

A. In the potential World Finals competition in Hawaii there will be no walls on the volcano competition site and on Mars we will not have walls. Therefore the walls cannot be treated as an obstacle and used for autonomous collision avoidance with the walls. The arena may be mapped to the limits of the walls, but no active sensors are allowed to use the walls for navigation during the competition run. Collision with the wall can be avoided by placing a virtual boundary on the map created.

Q. Can you provide more clarification regarding how walls can and can't be used during autonomous operation? Our confusion stems from the fact that every sensor that "sees" the environment will "see" the walls. Most of the more advanced navigation sensors likely have a range that extends beyond the dimensions of the arena therefore "seeing" the walls by default. Even if a sensor has a limited range, as the robot moves, walls will be brought into the field of view. The FAQ says that collision with the walls can be avoided by placing a virtual boundary on the map created. However, to place a virtual boundary, the sensors would have to "see" the walls and recognize them as walls. So, even to ignore the walls, the walls have to be first sensed and recognized and then used to map the arena boundaries. Can a robot update these boundaries during the run? If so, then the robot will be repeatedly sensing and detecting the walls to update its map. While we understand the spirit of the rules (i.e. not using the walls to define robot navigation), the exact implementation of the rules remains confusing, and we would need to see a more detailed explanation of exactly what is and is not allowed in order to properly design an autonomous approach to fit within those rules.

A. On Mars there will be no walls. The rules intend to make the competition as realistic as possible in the constraints of the KSC regolith simulant arena. Please detect the walls initially, to determine the physical boundaries and then use a method that does not rely on scanning the walls repeatedly. The boundaries shall not be updated repeatedly by using the walls during the run. If the sensor sees the walls repeatedly during the competition run then that is not a problem – as long as the robot does not rely on this data to navigate.

Q. Is the front of the deposition bin considered a wall? If so, then beacons that are placed on the bin would allow the robot to "see" the bin/wall for navigation purposes thus violating the "wall rule". Similarly, no tactile sensors would be allowed to touch the front of the bin during docking. Is this the correct interpretation of the new navigation rules?

A. The front of the deposition bin is not considered a wall. Tactile sensors may be used at the bin to detect it.

Q. Is it allowable for robots to contact the back wall in front of the bin for alignment while maintaining autonomy points?

A. A lander on another planetary surface would not have a back wall, so contacting the back wall is not realistic and is not allowed for autonomy. The bin itself may be contacted.

Q. The autonomy scoring is described as:

"1. Successfully crossing the obstacle field autonomously: 50 pts (two times only – outbound and back, point and shoot does not count for partial autonomy points)
2. Successful partial autonomy: crossing the obstacle field, excavating & returning to the collection bin. 150 pts
3. Successful partial autonomy: crossing the obstacle field, excavating & depositing regolith, 2 times. 250 pts
4. Successful fully autonomous run for 10 minutes: Successfully crossing the obstacle field, excavating and depositing regolith, a minimum of 3 times. 500 pts"

Does "2 times" in #3 mean that the robot must complete two complete cycles (Cycle 1: navigate, dig, navigate, dump; Cycle 2: navigate, dig, navigate, dump) to be awarded these 250 points? What if the robot doesn't complete 2 full cycles within the 10 minutes, but operates with full autonomy? For example, the robot is slow and completes one full cycle only in 10 minutes but does so autonomously?

A. #3 – two full cycles must be completed.
#4- The requirements of #3 must be completed and exceeded, before being awarded the full autonomy points. i.e. a minimum of three fully autonomous runs must be completed in 10 minutes

Q. Rule 15 states that the Collector Bin will be placed at 0.5 meter +/-0.2 m. Is this intended to be +/- 0.02 m, or do we need to build a robot capable of depositing at 0.7 m in height?

A. The bin height tolerance with respect to the regolith surface is +/- 20 cm, therefore your robot must be capable of depositing at any height between 0.3m and 0.7m..

Q. How does NASA plan to maintain the integrity of the separation of regolith from gravel in the mining area? As we understand the rules, the regolith layer will be approximately 12" deep. Below this layer, there is a layer of gravel for which bonus points are awarded for mining. At the start of the competition, I expect that there will be a clean separation (as much as possible) of gravel and regolith as the mining area has been prepared and undisturbed. However, as the competition progresses and teams penetrate into the gravel layer, it will become almost impossible to return the mining area to its pre-disturbed condition. Gravel will obviously mix with the upper layers of regolith resulting in easier extraction of the gravel. The teams that compete early in the competition will have a distinct disadvantage since all the gravel will be neatly tucked below the regolith (at depths of 12+ inches), while teams competing later in the round will have the benefit of mining loose gravel lifted and mixed into the upper regolith layers by previous mining robots. How will this situation be addressed to ensure that all teams encounter a consistent mining environment?

A. NASA does not plan to maintain the integrity of the separation plane between gravel and the regolith. On Mars there will be rocks mixed in with the regolith. The judges will make every attempt to return the gravel to the bottom layer, but some will be mixed in as the arena is excavated – so you should design for that possibility. The arenas will be used during the practice days – so it will already be in a disturbed state. Each team will get two competition attempts, and there should be no expectation of a clean separation of gravel from regolith dust. Please design your robots to be versatile and robust so that they can accommodate gravel mixed in with the regolith. The majority of the gravel will still be at the bottom of the bin, so plan your strategy accordingly.

Q. We need custom designed laser modules. Can we do the custom design through the staff-run machine shop / electronic shop in the ECE department of our university? Or must we get the custom design from a commercial laser company?

A. Please reference Rule 15:

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. Supporting documentation from the laser instrumentation vendor must be given to the inspection judge for "eye-safe" lasers. 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).

The laser must be provided by a commercial vendor with supporting documentation. If the laser is incorporated into a custom sensor system, then the team must present the design and evidence of safe operations to the RMC judges at the competition. Failure to document that the laser device is a class I or II product will result in disqualification.

Q. The rules say the gravel has an average diameter of about 2 cm, but my team was wondering how much variation is in that number.

A. The gravel will be basalt lava rock sized approximately 2 cm in diameter but it will be random. As a result, some gravel pieces may be as large as 3 cm in diameter.

Q. What is the angle of repose for the BP-1? Since we will need to dig 30 cm through it to get to the gravel, we would like to know what angle it would rest at to optimize our design.

A. The angle of repose for dry BP-1 is between 39 degrees (medium) to 51 degrees (dense) depending on the state of compaction. The Lunar regolith angle of repose varies from 25 degrees to 50 degrees. Reference: Suescun-Florez, E., Roslyakov, S., Iskander, M., & Baamer, M. (2014). Geotechnical Properties of BP-1 Lunar Regolith Simulant. *Journal of Aerospace Engineering*.

Q. Are we allowed to use magnetometers?

A. Most magnetometers contain a magnetic device sensitive to an external magnetic field. Since the moon has no global magnetic field, it will not be very helpful to make accurate measurements. Magnetometers are not allowed in the Robotic Mining Competition.

Q. What are the specifications of the controller that we will be using at the Robotic Mining Competition?

A. RMC does not provide a controller. Teams must provide their own controllers. Please reference the RMC rules.

Q. Do we have to log KW/Hr data and display it on the robot via an LCD?

A. Yes. The judges need to be able to verify the energy consumed after each competition run.

Q. Will we be disqualified if we do not log this data?

A. Yes. You will be disqualified, since the energy consumption contributes to your final score.

Q. What are the maximum number of points we can be deducted for KW/Hr usage?

A. Please reference rule 3F:
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 electrical data logger and verified by a judge.

Q. Is it ok if we log data for the drivetrain electronics and the onboard computers separately and then combine the usage to display for NASA? (asked due to the onboard computers potentially being run off of laptop batteries and not the main batteries for the robot).

A. Yes. That is acceptable.

Q. On page 2 it stipulates that '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 electronic data logger and verified by a judge.'

Our team was curious to know how the power consumption of our robot will be verified by a judge, and if that has any implications for the method we use to report our energy consumption. As of now we are planning to use a BeagleBone microcontroller and a current transducer to calculate our power consumption, and display that value on a laptop computer. Will this suffice, or do we need to purchase an off-the-shelf electronic data logger?

A. An off-the-shelf electronic data logger is required.

Q. We desire to build a small test area to simulate the conditions at competition while testing our robot. We consulted with a professor on campus in Civil Engineering Technology to get a recommended source of gravel. She says there is not enough information currently given in the rules to make a recommendation. Having some more information such as gradation, specific gravity, or angularity would help her make a recommendation. Can you give us more guidance on the properties of the gravel? As an alternative, can you recommend a source for comparable gravel?

A. The gravel will be commercially available basalt lava rock sized from 2-3 cm in diameter. It is available at many landscaping materials suppliers.

Q. We thought we fully understood the rules disallowing the use of the walls for any navigation, because we agree that there won't be walls at all on Mars. We are now confused because your October 7th FAQ update says that walls may be used to map the arena initially. This seems to be in contradiction to prior rulings on walls and not in the spirit of simulating a Martian mission. Can you clarify your thoughts?

A. The walls may not be used during the competition run. You may use the wall during your set-up period.

Q. We had a question about the RMC laser rules. We need custom designed laser modules. Can we do the custom design through the staff-run machine shop / electronic shop in the ECE department of our university? Or must we get the custom design from a commercial laser company?

A. A commercial laser system with documentation on the hazard level is required.

Q. Is the entirety of the "wall" in front of the dump bin considered a wall or only the part with the bin behind it? Also, can we use a sensor to continuously sense that wall without beacons? (Say we have a laser range finder constantly pointed at the wall to get our distance from it.)

A. The whole wall in front of the dump bin is considered a wall in this competition. No use of this wall is allowed during the competition run.

Q. If we have bumpers on our robot that we use for deciding when we hit the bin and these bumpers hit another wall during the run, can we use the fact the bumpers were hit to change the direction of the robot? Or do we have to use our generated map to avoid the wall to begin with? What happens if there is a slight error in our position in the generated map and we hit the wall with the bumpers anyway?

A. Due to this conflict (which is hard to resolve), Rule 17 that all tactile sensors (bumpers) shall not be Allowed will be enforced. The previous FAQ also in green is considered void.

Q. We can do an initial mapping of the walls when we start but cannot continuously sense the walls? Can we do our initial scan, do a run and dump, then scan again to make sure we are where we think we are? Or only the initial scan?

A. A perimeter wall scan is only allowed during the initial setup period, not during the actual run.

Q. We completely understand that under no circumstances should the walls of the arena be used for navigation or sensing of any kind, and that no tactile sensors may be used. However, when a bin target is hung from the lip of the bin, it will lay flush with the "back wall," and sensing the wall is not allowed. Is it acceptable to hang a rover interface target (specifically a vision target) from the bin? Or must this target be affixed to the bin in an upright fashion, so it does not lay flush with the back wall?

A. The back wall may not be used as stated in the rules. A target must be affixed to the top edge of the bin in an upright fashion.

Q. Since tactile sensors have been disallowed, but teams will still need to stop when backing up to the bin, may non-contact optoelectronic sensors be used to detect the bin and/or the target we attach to the bin? We understand that the sensors may not sense the walls, only the bin. For instance, short-range IR rangefinders or commercially-available laser proximity sensors with the proper "eye-safe" documentation would be oriented downward so that when the edge of our rover extended over the lip of the bin, we would know our location was suitable for delivering a payload of regolith?

A. Non-contact optoelectronic sensors may be used to detect the bin and/or the target attached to the top of the bin.

Communication Questions

Q. You use the term "bandwidth" in the rules several times referring to measurements of MHz, Kbps, and Mbps. These are completely different type of measurements and they're both different from my definition of bandwidth. There's no definition in the rules at the bottom for "bandwidth" either. In these rules, is "bandwidth" synonymous with frequency and data rates? If not, could we get the definition you're using for the competition?

A. 1. In the rules, the word “bandwidth” is used in both the context of network utilization and in the context of radiofrequency spectrum width.. This term is typically used in these manners interchangeably in the industry, but we agree, it can be confusing. “Spectral bandwidth” in megahertz (MHz) is indeed different than “network utilization bandwidth” in megabits/second (Mb/s). We will further clarify this distinction in the rules at a later date. These references will give you greater insight into the differences between spectral and network bandwidth, but the later comments in this answer will hopefully answer your questions.

   a. http://en.wikipedia.org/wiki/Bandwidth_(computing)

   b. http://en.wikipedia.org/wiki/Bandwidth_(signal_processing)

2. In Section Section 3 (H) on Table 1: Mining Category Scoring Example

   a. In this table the context of “bandwidth” is for network utilization.

   b. The mining category element of “Average Bandwidth” may be a bit misleading, a better way to refer to this element would be the Average Data Network Utilization. For this table, the units are in kilobits per second (kb/sec). This will be changed as in future versions of this table.

3. Section 23 (A) 5 (a) refers to the requirement for teams to configure their wireless systems to use a “maximum bandwidth setting” of 20 MHz.

   a. In this section the context used for “bandwidth” is radiofrequency spectral bandwidth.

   b. This rule requires teams to “spectrally limit” their emissions using a common setting on the wireless access point (AP) used by each team, because spectrum is limited. The requirement is to have a maximum frequency transmission width or span of 20 MHz. Some AP devices allow a wider setting of 40MHz, this is not allowed because it increases the risk of interference between teams.

4. Section 23 (B) BANDWIDTH CONSTRAINTS

   a. In this section the context used for “bandwidth” is for network utilization.

   b. This section refers to an award for the team that uses the lowest average data network utilization during the completion.

5. Definitions:

   a. 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 (Mb/s) on all data and video sent to and received from the mining robot.

   b. Bandwidth -- In this section the context used for “bandwidth” is for network data utilization

Q. Rule 23 Part B Paragraph 1 states "Using the NASA provided Situation Awareness Camera in the control room will add 120 Megabits (Mb) of data use … ". Based on the rubric in Rule 3, Part H of "...-1/50kb/sec .. ", this amounts to a 4 point penalty. Please verify whether our assumptions and calculations are correct.

A. Your assumptions and calculations regarding use of the Situational Awareness camera are correct, there will be a 4 point penalty.

Q. Will any communication between the robot, its beacons, or any satellite robots using Bluetooth or infrared communication count toward the bandwidth penalty part of the mining score during a competition run?

A. The bandwidth penalty is calculated by measuring the data rate going from the arena to the control room only. Any on-field communications between sensors or devices are not measured or used in the bandwidth penalty calculation.

Q. Will the control room operators have access to NASA's side view camera at the collection bin?

A. The side view collection bin camera will be made available to the teams for use in the mission control room. Use of this camera is optional, and will cost the team 4 points for network utilization bandwidth.