

Challenge Rules 2014

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SAMPLE RETURN CHALLENGE – RULES

OVERVIEW

The objective of the Sample Return Robot Challenge is to develop new technologies or apply existing technologies in unique ways to create robots that can autonomously seek out samples and return to a designated point in a set time period. Robots will be required to navigate over unknown terrain, around obstacles, and in varied lighting conditions to identify, retrieve, and return these samples.

RULES

The final interpretation of all rules is at the discretion of the judges.

1 THE ROBOT

R1. For the purpose of this challenge and rule set, a robot is defined as all mechanical and electrical components, except the home beacon and pause switch, provided by the team in order to successfully compete in the challenge. This includes but is not limited to motors, batteries, computers, decorations, required safety switches, and items that do not remain attached for the entire challenge.

R2. Robot may not exceed 80kg.

R3. Robot may not exceed 1.5m x 1.5m x 1.5m in its starting configuration.

R4. For the safety of event officials on the course, robots may not travel over the surface of the course faster than 2 meters per second (walking speed). Purposeful or sustained exceeding of this speed limit is subject to disqualification.

R5. Strategies or designs aimed at the disruption, destruction of, or damage to an opponent's robot or the field is not in the spirit of the challenge and will not be allowed. This includes intentionally leaving objects on the course of similar shape and color to samples or having distracting designs on your robot. Teams are specifically cautioned to minimize the visibility of robot graphics and to make them removable if requested. Violations of this rule may result in disqualification at the discretion of the judges.

1.1 HOME BEACON

R6. Each team may provide a Home Beacon and place it on the designated platform adjacent to their starting platform. A Home Beacon can be any combination of electro-mechanical items provided by the team that assists their robot in identifying their starting platform and complies with the weight, size, expansion, and power limitations listed in rules R6-R12.

R7. Home Beacon must comply with Section 1.3 Disallowed Technology and R21.

R8. Home Beacon may not exceed 15kg.

R9. Home Beacon may not exceed 2m x .43m (width x depth), can be no more than 2m in height at the start of the challenge attempt, and can never extend outside the vertical projection of the designated platform.

R10. Home Beacon may not contain any parts that move outside the vertical projection of the home beacon platform.

R11. Home Beacon may not interfere with another robot in their attempt to complete the challenge.

R12. Home Beacon may contain its own power and is not subject to the pause and E-Stop compliance rules. It must have no more than one clearly labeled master on/off switch and will only be turned off by an event official during a competition run due to safety concerns (this will not be considered an E-Stop).

1.2 REQUIRED PAYLOAD

R13. Each robot must have space to carry a required payload of .1m x .1m x .25m and approximately 5kg mass easily accessible to event officials. Each robot must provide one flat, .1m x .25m area on the outermost surface of the robot to attach the payload. This payload will be provided, along with the means of attachment, to each team by the event and is not included in the robot or sample mass. At the discretion of the judges, portions of the payload may be distributed across several robot components and the home beacon.

R14. The required payload may contain a strong magnetic source and frequency jammer to disable any inadvertent usage of prohibited signals and technologies.

1.3 DISALLOWED TECHNOLOGY

R15. As one of the goals of this competition is to develop robots, processes, and technologies that could be implemented in a lunar or Martian environment, the robot and any related technology cannot employ fundamental physical processes, gases, fluids, or consumables that would not work in such environments.

- Specifically disallowed technologies and components include:
 - Sensors that rely on the earth's magnetic field
 - Ultrasonic or other sound-based sensors
 - Earth-based or earth orbit-based radio aids (e.g. GPS, VOR, cell phone)
 - Open circuit pneumatics
 - Air-breathing systems
 - Any communication between robot components or between the robot and the home beacon that does not comply with FAA and/or FCC regulations.

R16. Fans are allowed solely for the purposes of cooling.

R17. Hazardous materials that pose a threat to teams, spectators, event officials, the environment or other robots are disallowed. Specifically, any Class 1, 3, 4, 5, 6, or 7 hazardous materials are strictly prohibited.

1.4 SAFETY AND ROBOT CONTROL FEATURES

R18. Each robot must have the following switches or indicators, provided by the team, and they must be easy to identify by the judges. Additional guidance for spawn robots can be found in R20:

- Master Power Switch: The Master Power Switch must be an identified and obvious switch that is easy to access from the rear-aspect of the robot. This switch must turn on power to ALL parts of the robot, including any on-board processing components. An event official will trigger only this switch on the robot at the start of the competition run.
- Mechanical E-stop: The E-stop button must be push-to-stop, red in color and a minimum of 2.5 cm in diameter. It must be easy to identify and activate safely from the rear-aspect, even if the robot is moving. For robots with a starting height over .75m, it must be located on the center-rear stable surface of robot at least .75m from ground, never to exceed 1.5m above ground. For robots with a starting height .75m or under, the switch must be located on the center-rear, top-most stable surface of the robot, never to exceed 1m above the ground. The E-

stop must be hardware based and not controlled through software. Activating the E-Stop must shut down all robot power.

- Pause Switch: The wireless Pause must be effective for a minimum of 30 meters. For the safety of event staff and spectators, activating the Pause must bring all motion of all robot components to a complete stop within 1 second of activation for non-spawn robots. Exceptions to the pause rule (like motion of internal robot components) may be considered solely at the judges' discretion. The team may present exception requests at any time for technical review and provisional approval. The judge committee will make final approval of all exemption requests on-site upon demonstration of the pause sequence. When a robot is paused, its official event clock will also be paused.
- Safety Light: Each robot must have an easily viewed indicator light that is turned on whenever the robot power is turned on. The light must be amber/orange in color, solid when the robot is paused, and flashing at a rate of approximately 1Hz when the robot is powered and enabled.

R19. The Master Power Switch and Mechanical E-Stop may be the same switch, provided they meet all the criteria of both.

R20. If a robot splits into multiple components that traverse the course (known as spawn), the following applies:

- There must be one pause switch supplied for each spawn, and both the pause switch and spawn must be clearly labeled to indicate which spawn the switch activates. Activating one pause button must pause motion of the designated spawn within 1 second.
- There must be an E-stop button on every spawn located .75m above the ground or on the top-most stable surface of the robot, whichever is lower. Activating a spawn E-stop must stop power to that spawn.
- There must be a safety light on each spawn.

1.5 ROBOT OPERATIONS AND COMMUNICATION

R21. Once the robot is in impound or during any competition run, human-to-robot communication is restricted to event officials. They will communicate via master power switches and E-stops on the robot and via the wireless pause switches.

R22. During the competition run, the robot may only communicate with items in the starting platform or roving area that were included in the robot mass and initial starting configuration size as well as their home beacon and pause switch(es).

2 THE CHALLENGE

In order to be eligible to win the Challenge, teams must successfully complete the Level 1 and Level 2 portions of the Challenge. Level 1 will be considered a qualifying portion of the Challenge in which all competitors will be given the opportunity to compete prior to attempting Level 2. Teams who successfully complete Level 1 will be given the opportunity to attempt Level 2.

In any given challenge year, the judge committee may choose to re-run Level 1 to provide teams an opportunity to auto-qualify for Level 2 in the next challenge year.

Any team who successfully completes Level 1 in 2014 will automatically qualify to move to Level 2 in this and future challenge years if all other conditions of that year are met and team remains able to demonstrate their robot's ability to complete the Level 1 Challenge. If a Team accepts this Level 2 auto-qualification status, the team will not be given a Level 1 attempt opportunity and is ineligible to win additional Level 1 prize money. However the team may opt to decline the auto-qualification and instead to retry Level 1 in the 2015 or any future Challenge, thereby forfeiting their auto-qualification to Level 2 and requiring they successfully complete Level 1 in order to re-qualify for Level 2. The team will be then be eligible to win Level 1 prize money, as well as advance to Level 2 during the first or potential re-run attempt of Level 1.

2.1 LEVEL 1

C1. For a robot to have successfully completed Level 1, one undamaged, pre-cached sample (described in section 3.1) must be autonomously returned to the starting platform within the 30-minute time limit.

C2. Only teams who complete Level 1 will be given an opportunity to compete in Level 2.

2.2 LEVEL 2

C3. Determination of the winners and final prize allocation will be determined by the:

- Total number of distinctly different samples collected (maximum 10)
- The point values of those samples

C4. For a robot to have successfully completed Level 2, it must autonomously return at least two undamaged samples, including the pre-cached sample, to their starting platform within the two-hour time limit.

C5. If at any time during the challenge attempt a sample comes in contact with another sample (“sterile handling”) neither sample will count towards that robot’s score.

2.3 LEVEL 1 AND LEVEL 2

C6. Only samples contained within the vertical projection of the starting platform when the event official signals the end of a team’s run will count.

C7. Samples must comprise at least 50% of the mass of any items returned to the starting platform (excluding the starting mass of the robot).

C8. Any samples contained within the robot at the end of the run must be easy and obvious to remove by an event official so that sterile handling (C5) and sample mass vs. collected mass (C7) can be determined. Team members will not be allowed to remove or assist in the removal of samples from their robot.

C9. The number of successfully retrieved samples in the starting platform will be counted at the end of the challenge attempt only.

2.3 PRE-INSPECTION

C10. Prior to the event, each team must submit all required documentation and deliverables required by the judge committee. Failure to comply could result in disqualification. Detailed list of deliverables is provided in the “Critical Deadlines and Documentation” section.

C11. Upon arrival at the event, each team must complete their own pre-inspection to validate the legality of their robot and to provide clear documentation of how event officials interact with the robot. Clear documentation includes, but is not limited to, written startup and safe shutdown procedures.

C12. During inspection, teams will be directed by an inspector to power up their robot and show the functions of their robot, including the master power, E-Stop, pause switch, and any requested exceptions to the pause rule.

2.4 ROBOT IMPOUND AND INSPECTION

C13. Once impounded, teams will not have access to their robots to make any mechanical, electrical, or programming modifications, with the exception of installing batteries and securing it on the starting platform.

C14. Teams are allowed to keep their batteries and chargers outside of the impound area and bring their batteries into impound during the inspection period. All batteries not kept in impound are subject to critical inspection.

C15. Teams who leave their batteries and chargers in the impound area will be allowed to install them during the inspection period. A team member may be granted permission to access their batteries in impound, solely for charging purposes, by a judge and under the direct supervision of an event official.

C16. Each robot will be impounded from the start of Level 1 until all teams have completed Level 1. Once Level 1 is complete, all teams will have access to their robots for a minimum of one hour.

C17. Each robot that successfully completed Level 1 will be re-impounded from the start of Level 2 until all teams have completed Level 2.

C18. Before their competition attempt, up to four team members will enter impound and meet with an inspector to review their robot. Size, weight, and compliance with all rules will be checked. Any robot that does not pass inspection will be disqualified.

C19. In Level 1, at the end of inspection, teams can install their batteries if required then transport their robot to a starting platform located on the competition field. Teams may make no modification or provide input to their robot after it leaves impound with the exception of placing it on the platform.

C20. After a team successfully completes Level 1, they will be asked to place all components they will utilize for Level 2 on a scale for a weight check.

C21. In Level 2, at the end of inspection, teams will install their batteries if required, move their robot to the starting platform, secure their robot to the starting platform in impound, and then all team members must leave for the viewing area immediately.

C22. At the end of Level 1 and Level 2 challenge attempts, all successful robots are subject to a critical re-inspection before the prize distribution is determined.

2.4.1 STARTING PLATFORM

C23. The starting platform is made of wood with a plywood top surface 2m x 2m in size.

C24. The starting platform will have a designated back, center, and area for robot placement. The robot must be fully contained within the marked starting area and the home beacon platform must be placed with its long edge adjacent to the back of the starting platform.

C25. When the starting platform is placed on the field, the robot will be approximately 15cm above the field surface.

C26. Ramps, approximately 15 degrees in slope, will be placed on the front and sides of the platform to assist in a smooth transition between robot and platform. Ramps are not considered part of the starting platform (C6).

2.4.1.1 LEVEL 2 STARTING PLATFORM CONFIGURATION

C27. An event official will transport the platform and robot using standard ground transportation operations, like a forklift. Robots must be secured to be able to endure transport.

C28. Six flush tie-down connections will be available for teams to use to secure their robot to the platform. The event will have a limited number of common ratchet straps and rope ratchets on site for use when available.

C29. Teams may secure their robot through other means, although they are not allowed to make any modification to the platform surface.

C30. Once placed on the field, an event official will be responsible for removing all securing devices from the robot. In the inspection, teams must clearly describe the removal process of any securing devices used.

2.5 CHALLENGE ATTEMPT

C31. Depending on the number of competitors, multiple robots may be running on the course at one time.

C32. During the challenge attempt, event official(s) will walk approximately 3 meters behind the robot with the designated pause switch. They will monitor robot-to-robot interaction, safety hazards, and rule violations as well as document the challenge attempt. Additional challenge officials will be located on the course, but

above the height of the boundary fencing (E5) or a minimum of 50 meters from the robot.

C33. If a robot's pause switch is activated by the event official, that robot's official event clock will be paused and restarted when the robot is unpaused.

2.5.1 LEVEL 1

C34. Teams will be randomly assigned to a start order, starting zone, and platform color.

C35. Teams will place their robot on the starting platform and their home beacon on its platform. The platforms will face the same direction for all teams, with the front generally aimed at the reference point marked in the satellite image (E7), and will not be intentionally moved during Level 1 attempts.

C36. Teams will have a maximum of 10 minutes to place their robot on the platform and remove any transport aids.

C37. An event official will trigger the master power switch of the robot and home beacon and the official time clock for that robot's challenge attempt will begin.

2.5.2 LEVEL 2

C38. Based on their weight (lightest to heaviest), each team will be allowed to select their order in the competition and approximate start time for Level 2. This selection will occur following the completion of Level 1.

C39. An event official will deliver the starting platform with robot to one of three designated starting zones. When the platform is delivered to the starting zone, an event official will direct its orientation and placement, rotating the front of the platform up to 60 degrees clockwise or counterclockwise from the reference point marked in the satellite image (E7).

C40. Once all securing apparatus are removed, an event official will trigger the master power switch of the robot and home beacon and the official time clock for that robot's challenge attempt will begin.

2.5.3 ROBOT PAUSE CONDITIONS

C41. An event official may pause or unpaue any robot any number of times during their challenge attempt for any length of time. When a pause is signaled, all followers on the course will activate all pause switches and the challenge clock will be paused.

C42. Robots will be paused to enforce robot right-of-way conditions when multiple robots are on the field. Right-of-way conditions include:

- Robots moving on diagonal paths towards each other. In this case, the farthest back will be paused until the other robot has passed.
- Robots approaching each other head-on. In this case, the robot on the event officials' left (Robot A) will be paused until Robot B navigates around it. If Robot B continues to approach without obvious avoidance, the event official will pause Robot B and unpaue Robot A. If neither robot is capable of avoiding the conflict, judges will confer and may choose to E-Stop both robots or shift both and unpaue.
- A faster moving robot approaching the rear of a slower moving robot. In this case, the slower moving robot will be paused to give the faster moving robot a passing opportunity. If the faster moving robot does not make the attempt to avoid the slower moving one, the faster robot will be paused until the slower one has cleared the area.
- Robots approaching the same sample. In this case, once more than one robot comes within 3 meters of the sample, any robot(s) that subsequently enter the area will be paused until such time that Robot A has retrieved the sample and moved out, or left the 3-meter radius of the sample. If Robot A retrieves the sample, a new sample will be placed in the exact same location so the next robot may continue its sample pursuit. No more than one robot will ever be active within a 3-meter radius of any sample.
- If it is not obvious which robot has the right-of-way, one will be chosen at the event official's discretion until the issue is resolved.

C43. Robots may be paused for safety considerations or if continued operation will likely cause significant damage to the robot or the field.

C44. Robots may be paused to allow an event official to evaluate if an E-Stop condition has occurred.

2.5.4 ROBOT E-STOP CONDITIONS

C45. An event official may activate each E-Stop on a robot once during a challenge attempt. Activation of all robot E-Stops means the robot's challenge attempt is complete even though the time limit has not been reached.

C46. Unless it is an offense that is subject to disqualification, E-stopped robots are still able to qualify and win prize money based on their performance prior to being E-stopped.

C47. Robots are subject to 'UNSAFE' or 'SAFE' E-Stops.

- UNSAFE E-Stops are situations where the robot or spawn is considered unsafe or there is an immediate safety threat at the event. In this case, the E-Stop may be hit directly with no concern or consideration to its effect on robot or spawn components. An UNSAFE E-stop may not always be preceded by a pause. UNSAFE E-stop situations may include:
 - The robot or spawn contacts the outer boundaries of the roving area and would clearly continue past the boundary if left uninterrupted.
 - The robot or spawn poses an extreme safety hazard to event officials, spectators, or the environment.
 - The robot or spawn is found to be in violation of any of the rules.
- SAFE E-Stops are situations where the robot or spawn may be operating 'normally', but nonetheless need to be disabled. A SAFE E-Stop will always be preceded by a pause. In the case of a SAFE E-Stop, the team may request, within reason, that the judges follow a special procedure to disable or shutdown the robot or spawn. SAFE E-Stop situations may include:
 - The robot or spawn has shown no signs of activity for at least 15 minutes.
 - The robot or spawn has shown no signs of meaningful activity for at least 5 minutes and the Team Leader requests to end the operation of that spawn or the challenge attempt as a whole.
 - Continued operation of the robot or spawn will likely cause significant damage to itself or the field.
 - The robot or spawn is found to be in violation of any of the rules.

2.6 DISQUALIFICATION

C48. A robot and team may be disqualified from the competition for rules violation at any time prior to, during, or after a challenge run at the discretion of the judges.

C49. Disqualified robots will not be allowed to participate in the challenge, continue with their challenge run, or win any prize money.

3 THE ENVIRONMENT

E1. Competition field is outdoors, over a large area, with both open rolling terrain and immovable obstacles (trees, large rocks, water hazards, etc).

E2. Competition will take place during daylight hours.

E3. Continuation of the competition in the event of inclement weather will be at the discretion of the judges. Competitors should anticipate and prepare for the competition continuing in most situations except lightning.

E4. The competition area for the robot during the challenge attempt is approximately 80,000 square meters.

E5. Orange fencing no less than ½ meter tall will mark the borders of the roving area. Examples of this fencing are available in the FAQ.

E6. Moving and stationary objects that are not part of the competition may be located outside but near to the orange fencing which marks the borders. These objects may include but are not limited to spectators and automobiles.

E7. Teams will be provided limited topographical data of the roving area in advance of the competition to include maximum grades, types of surfaces, man-made structures to aid navigation, and large fixed features for orientation. A satellite image of the competition area will be provided to all competitors by 7-JAN-2014. This imagery will include the location of the three starting zones and the area of interest for the pre-cached sample.

3.1 SAMPLES

E8. Samples will be randomly placed on the ground throughout the roving area. They may be placed close to obstacles, both movable and immovable.

E9. Each sample will have no overall dimension that is less than 1cm or exceeds 20cm.

E10. Each sample will be no less than 2g and no more than 1kg.

E11. One of each of the samples listed in E12 will be on the course during each robot challenge attempt.

E12. Samples are broken into three categories for the purpose of final prize determination. More details on some samples are available in the FAQ.

- Easy
 - Pre-cached Sample

- Represents a sample that has already been contained by a rover on the planet prior to your arrival and is awaiting collection.
 - A cylinder slightly under 8cm in diameter and 8cm in length
 - Has a standard hook interface
- Penn Pink Championship Extra Duty Tennis Ball (any lot number)
- Soft Shot Red Hockey Puck (any lot number)
- 20cm long Schedule 40, ¾" PVC Pipe (outside diameter of 2.67cm), spray-painted fluorescent orange
- Intermediate
 - Uniquely-colored spherical object between 20 and 60mm diameter and 20-60g
 - Rock, painted blue, with a its major dimension between 6 and 10cm
 - Wooden cube, 8-10cm in each dimension
- Hard
 - Non-ferrous metal object engraved with a unique, rectilinear, identifying mark #1
 - Non-ferrous metal object engraved with a unique, rectilinear, identifying mark #2
 - Non-ferrous metal object engraved with a unique, rectilinear, identifying mark #3

E13. No two samples will be closer than 10 meters to each other within the roving area and all samples will be placed at least 1 meter from the boundary fencing.

E14. In the event that a robot is E-Stopped on or within 1 meter of a sample, the sample may be moved to anywhere within a 3-meter radius of the original sample placement so that access by other robots is not impeded.

E15. In the event of multiple robots on the course at one time:

- Once a sample is collected by Robot A, it will be replaced with an identical sample for Robot B once Robot A has left the 3-meter radius of that sample.
- If Robot A continually attempts to retrieve the same sample that is replaced for Robot B, they may be subject to disqualification by the judges.

4 PRIZE DISTRIBUTION

Prize money will be distributed based on a pre-determined method described below. If some or all of the prize money is not distributed during the challenge, the challenge may be repeated, with or without modification, in the future.

Note that only one of each Technology Achievement Award, one Level 1, and one Level 2 prize is available to a team in a challenge attempt.

4.1 TECHNOLOGY ACHIEVEMENT AWARDS

P1. Teams that achieve certain technology milestones will be eligible for monetary awards independent of the prize money listed in sections 4.2 or 4.3.

- Each team who arrives on site of the competition with a robot that successfully passes Level 1 inspection by the posted deadline will receive \$500.
- Each team who, during their Level 1 challenge attempt, finds and picks up the pre-cached sample will receive \$500.

4.2 LEVEL 1 PRIZE(S)

P2. A pool of \$50,000 will be equally distributed among all prize-eligible teams successfully completing Level 1 within the time limit, with a maximum of \$5,000 per team.

4.3 LEVEL 2 PRIZE(S)

P3. The amount of prize money available to all competitors will be set by the top-scoring team who is eligible per the Prize Distribution Schedule in P8 and prize eligibility standards described in the Team Agreement.

P4. The amount of prize money available to any individual team will be based on the ratio of their score to the top three scores of prize-eligible teams, and capped by the maximums allowed per the prize distribution schedule in P8. Examples of the prize money calculations are available in the FAQ.

P5. Sample types are worth the following points:

- Easy – 1 point
- Intermediate – 2 points
- Hard – 5 points

P6. At the end of each robot run, the successfully retrieved samples will be counted and the score of each robot recorded. Robots will only receive credit for one of each of the 10 samples listed in section 3.1.

P7. Once all robots have made their attempts, the top three scoring robots will be identified by the judges as eligible for prize money.

P8. Prize Distribution Schedule (less any funds distributed for Level 1 or in previous challenge attempts):

- 3-5 Points: \$100,000
- 6-8 Points: \$250,000
- 9-14 Points: \$750,000
- 15+ Points: \$1,495,000

P9. In the case of a tie at Level 2, the following will occur:

- If possible, only the top 3 performing teams will receive prize money. In cases where this is possible, all 3 teams will receive a value based on their points scored.
- If a tie requires more than three teams to receive prize money, the tied teams will split the available funds equal to a single team scoring that number of points
- Additional explanation is available in the FAQ.

2013-14 Frequently Asked Questions (FAQ)

Below are FAQ regarding the Challenge Rules. Team Leaders of registered teams may submit questions about the rules by emailing challenge@wpi.edu. All new questions will be posted and answered in the online FAQ at <http://challenge.wpi.edu>.

Updated 27-Jun-2013 (F1-F68)

F1. Can you describe in more detail how the prize money could be distributed?

Yes.

For Level 1:

- All teams who successfully complete Level 1 will split \$50,000, with a maximum of \$5,000 per team.
- Prize money distributed in Level 1 becomes unavailable to be distributed for Level 2 prizes (i.e. they come from the same pool of \$1.495M).

For Level 2:

1. The top 3 scoring teams will be determined by adding up the points associated with their collected samples. A minimum of 3 points must be scored.
2. The total amount of prize money available to be distributed will be determined based on the 1st place performer.
3. The judges will add the score of the top teams together.
4. Starting with 3rd place, divide the 3rd place score by the total points to get a percentage of the prize money 3rd place will receive. That percentage is then multiplied by the prize money available. If the amount is higher than the max set by their point level, they are given that maximum amount.
5. Repeat steps 3-4 until all 3 teams have been awarded money.

Below are some specific examples:

Example 1:

- The top three teams score 10, 9, and 5 points respectively. Since the first place team scored 10 points, the total available to be distributed is \$750,000 (see P8).
- $10+9+5 = 24$ total points
- $5 \text{ pts} \div 24 \text{ total pts} = 20.8\%$
- $20.8\% \text{ of } \$750\text{K} = \156K However, the maximum that can be earned by someone who scores only 5 points, is \$100K (see P8), so the third place team receives \$100K.
- For second place, $10+9=19$. $9/19 = 47.4\%$. $47.4\% \text{ of } \$650\text{K} \text{ is } \$308,100$. Since the maximum a team can earn by scoring 9 points is \$750K, they receive their determined amount of \$308,100.
- For first place, $\$650\text{K} - \$308,100 = \$341,900$. Again, since the maximum that can be earned by someone scoring 10 points is \$750K, they receive all of their \$341,900.

Example 2:

- The top three teams score 8, 4, and 3 points respectively. Since the first place team scored 8 points, the total available to be distributed is \$250,000 (see P8).
- $8+4+3 = 15$ total points - $3 \text{ pts} \div 15 \text{ total pts} = 20.0\%$

- 20.0% of \$250K = \$50,000 Maximum for 3 points is \$100K so they can receive the full \$50,000.
- For second place, $8+4=12$. $4/12 = 33.3\%$. 33.3% of \$200K is \$66,600. Since the maximum a team can earn by scoring 4 points is \$100K, they receive their determined amount of \$66,000.
- For first place, $\$200K - \$66,600 = \$133,400$.

Example 3:

- The top 2 teams score 3 and 5 points. No other teams score points in Level 2. Since the first place team scored 5 points, \$100,000 is available to be distributed.
- $3+5 = 8 \dots 3/8 = 37.5\% \dots 37.5\%$ of \$100K is \$37,500. The second place team will win this.
- First place team will win $\$100,000 - \$37,500 = \$62,500$.

Example 4:

- Only one team successfully completes Level 2 and they score 7 points. They will win \$250,000.

F2. Will false samples be placed on the field?

No. We will not intentionally place any false samples on the field of play. For example, we would not place an out-of-spec tennis ball on the course of play and we will scan the entire course for debris that could potentially be misinterpreted as a sample prior to the start of the challenge attempts. However, if your robot collects an item that it thought was a sample that isn't, it will count towards your non-sample mass.

F3. Will all the samples be on the course for Level 1?

No. The Level 1 course contains only the pre-cached sample.

F4. Will we have access to the samples once we arrive on-site?

Yes and no. Teams will be given some access to samples in the robot pit area with the following restrictions. For the Easy samples, all teams will have access to see, feel, touch, and calibrate to the actual samples we will use. For the Intermediate samples, all teams will have access to view the samples from a distance of approximately 15 meters in a controlled area. No teams will have any access to the hard samples until they identify them on the course.

F5. Can you provide more information of the exact nature of known samples or obstacles on the course?

Yes. While we are not suggesting you should purchase the items from the following retailers or this is the only place from which they can be purchased, below are links to the actual items referenced in the rules:

- Orange Warning Fence (Field Boundary) – Please note we are showing this as a sample for anyone who may not know what we are describing. We will be seeking donors of this since there is a lot to purchase, so we may not know the final brand until we secure this. If what we end up getting for use is not available in retail quantities, we will do our best to get a sample to each team: <http://www.homedepot.com/buy/building-materials/fencing/tenax-guardian-safety-fence/4-ft-x-100-ft-orange-warning-barrier-20640.html>

- Pink Tennis Ball (Easy Sample): <http://amzn.com/B0010FW782> - Note colors may vary by lot
- Soft Shot Hockey Puck (Easy Sample): <http://amzn.com/B00017IBT4> - Note colors may vary by lot

F6. Is the robot allowed to climb “immovable obstacles” on the terrain?

Yes. However, be aware of R5 if these behaviors have the potential to severely damage the obstacle.

F7. What kind of surfaces can we expect to encounter on the course?

You can expect to encounter firm ground and a variety of walkable surfaces. This would include pavement, packed dirt, short grass, and possibly traversable rocks (i.e. gravel). You are not expected to move through loose mediums like sand, travel through water, or negotiate tall grass.

F8. How will an event official know when to turn on my robot and Home Beacon, respectively?

Just like you need to provide clear instructions for how the event official removes the securing straps from your robot, you should provide clear instructions for the order you would like your robot and Home Beacon turned on. To the best of their abilities, the event officials will follow your instructions on which one to trigger first ONLY. Do not expect them to follow more detailed instructions (for example, “turn on my robot EXACTLY 10 seconds after turning on the Home Beacon”). Your event clock starts when they turn the robot power on.

F9. Will people be allowed within view of the robot’s sensors?

There will be no spectators inside the boundaries of the course or inside the boundary fencing. The only people allowed on the course will be event officials or individuals approved by the event for specific purposes (e.g. filming). Those allowed on the course will be clearly identified by their badge and clothing.

F10. Will the samples be placed on a table or buried in the ground?

No. The best effort will be made to have all samples placed on the surface of the course. Absolutely none will be buried or in water. In some cases, like with the tennis ball, it may be raised very slightly or contained in order to prevent it from rolling far from its location. An example would be placing a small rubber O-ring under the ball for it to sit on, so it is not sitting directly on the ground but extremely close to the surface.

F11. If multiple robots must run on the course at the same time, will all teams have the same number of robots on the course?

Yes. Every attempt will be made to have the same number of robots on the course for every competing team. We do plan on staggering the starts for logistical reasons, so it is possible someone might start or end a run with only one robot on the course. For Level 2, this is one of the reasons we will allow teams some control over choosing their competition order/time.

F12. Can we get an unofficial inspection before our official one?

Yes. Any time before your robot is impounded your team may request an unofficial inspection. An inspector will review your robot for compliance and attempt to answer any questions you may have. A scale will also be available during this time. While these inspections are not final, our goal is to help make sure that every team that arrives with a robot is compliant with the rules and that does not stop them from competing.

F13. Can I move my robot from impound to the starting zone for Level 1 by driving it under its own power?

No. See rule R-11.

F14. If my team only has one member at the event, will I be able to get assistance to move my robot?

Yes. You can ask for help from other teams or event officials. However, moving the robot is ultimately your responsibility and any damage that may occur during this process is your responsibility.

F15. Is the Home Beacon platform considered part of the starting platform?

No. This means that no part of your robot can start on or overhanging the Home Beacon platform. Additionally, any home beacon components not completely contained within the home beacon platform for the duration of the run will be considered part of the robot. Additionally, any samples that end up on or overhanging the Home Beacon platform will not count.

F16. Are teams allowed to mark the starting platform? How will we know it is ours?

Each starting platform will be painted a bright color and teams will know which platform they are starting on prior to entering impound (although not which location that platform is in). In addition, teams are allowed to mark the platform as long as they do not permanently alter the platform and anything used to mark the platform is included in the robot mass, starts within the marked starting area, and violates no other rules. The Home Beacon starts on a separate platform directly behind the starting platform and is designed to aid competitors in this issue.

F17. How important is the separation of the samples from one another?

Obviously, when collecting samples from an unknown area, sterile handling would be extremely important for their scientific evaluation. For the purposes of this challenge, this is an important area but not a critical one we are looking to investigate. For example, teams may employ simpler methods like separate compartments within the same box or wrapping the samples individually and placing them in a single box. Judges will only be looking to ensure that the surfaces of any samples never come in contact with one another.

F18. How do we know if our samples are “easy and obvious to remove”?

The goal with this rule is to ensure that the judges can easily access the sample to determine if they have come in contact with other samples, to analyze the mass of all components returned, and to evaluate whether the samples are within the vertical projection of the starting platform. If a sample is incredibly difficult to access or

cannot be accessed without moving the robot, the judges may deem those samples inaccessible and not count them.

Teams will be asked to provide documentation to the inspector that clearly describes how to access where any items are stored within the robot. Accessing these items may require tools, and these must be provided by the team to the inspector.

F19. What will be interpreted as “damage” to a sample?

A sample will be considered damage if it has a permanent deformation or change in dimension.

F20. Will teams be given time to initialize their robot computers prior to their Level 1 attempt?

No. Teams must place their robot on the starting platform completely powered off. Once ready and the team has left the starting zone, an event official will trigger the Master Power Switch for that robot. At that time, the robot will power up and must complete all initialization processes on its own. After Level 1, teams will be given access to their robots to reset and restore them to compete in Level 2.

F21. When my robot is paused, what exactly needs to stop?

When your robot is paused, it will most likely be done so for the safety of an event official on the course, or to allow another robot to pass in the case of multiple robots. For the safety aspect, it is critical that driving cease as well any outboard motion. It is not expected that your computing or sensing systems shut down, as it would likely be a tremendous time penalty for them to restart. However, any teams that wish to have items that continue moving during a pause must request and be approved for a pause exception. All decisions on what is or is not allowed are at the discretion of the judges.

F22. Can my robot send information to me or a computer outside the course, as long as I am not transmitting any information back?

Absolutely not. There is no communication in any direction allowed with the robot from anything not contained within the course, inspected before the run, and included in the starting size and mass of the robot. While we understand this would be only to help you learn the robot's processes better, everyone has to understand it's a slippery slope. You are welcome to record data on-board.

F23. What does the 80kg mass of the robot apply to?

The 80kg mass applies to everything you as a competitor bring to the event and put on the starting platform to compete as part of your robot. This means it includes batteries, computers, e-stops, safety lights, and anything you might leave behind on the platform or on the course but needs to start with the robot. It does not, however, include the pause switch(es), the required payload in section 1.1, the home beacon, or any samples or materials collected during the run.

F24. Is there a maximum deployed height the venue will support?

There is no restriction on the maximum deployed height of any robot or its components. However, it is possible that some of the natural obstacles (like trees) have overhanging branches that would limit heights taller than an average person in some areas.

F25. Where can I find the parts to make my own pre-cached sample?

The pre-cached sample is made of two items only, a hook and polyethylene.

- Hook: Home Depot Part #864420.
- Polyethylene: McMaster.com Part #8701K55. Minimum size you can purchase in is 1 ft, then simply cut to 3 inches.

F26. Can we use a device onboard that has a GPS, accelerometer, compass, etc, as long as we don't use those features in our code or our challenge attempt at all?

Yes. We understand that it is tough today to purchase technology that doesn't include some of these components, even if they will not be used, and therefore we don't want to make the challenge even more difficult for anyone. If teams utilize devices with any of these disallowed technologies, the onus will be on the team to prove beyond a reasonable doubt that they are not using them during the competition. Teams should be aware that it will be the determination of judges and inspectors as to whether a team has proven compliance with these rules, and teams may be asked to modify or remove certain components to make their robot legal to compete.

F27. Are accelerometers allowed?

Yes, provided they comply with Section 1.3. Be aware that any sensors that utilize magnetic compensation will be disallowed.

F28. Are flying robots allowed?

Provided they comply with Section 1.3 and 1.4 of the rules and could be proven to work in lunar and Martian environments.

F29. Can we leave objects/beacons/robots on the field at the end of our competition run?

Yes. All items will be removed by event officials at the end of each competition run.

F30. Can we have multiple robots on the field as long as they all start within the specified dimensions?

Yes, see also Section 1.4 of the rules.

F31. Can we use spring-damper systems for shock absorption and suspension?

Yes, provided it is a sealed system and could theoretically work in a vacuum, and complies with Section 1.3 of the rules.

F32. Are spawn allowed to communicate with each other and with the home beacon?

Yes, provided the communication meets all rules on allowed communication, disallowed technology rules, and FCC regulations.

F33. “The required payload may contain a strong magnetic source and frequency jammer to....” Couldn’t this magnetic source directly interfere with R6? And what about R20, spawn and R22, communications?

The required payload is designed to aid judges and inspectors in enforcing the rules on allowed and disallowed technologies. Teams are required to submit documentation about their robots, beacons, and communication protocol approximately 6 months prior to the event with additional information on-site. Provided teams submit accurate and reasonable information about their plan and update any changes in a timely fashion, the required payload will not interfere with any allowed communication or technology.

F34. R6 states “any combination of electro-mechanical items provided by the team that assists their robot in identifying their starting platform” – does this mean there is no communication allowed between the home beacon and the robot(s)?

No, teams are allowed to communicate between their robot and home beacon (per R22), provided it complies with all Disallowed Technology rules and FCC regulations.

F35. Could clarification be provided on some of the following:

- Is the 80,000 square meters roving area one long strip, round, square, rectangular? (E4)
- When will “limited topographical data” be provided? (E6)
- When will the satellite imagery, including starting zones, be released? (E7)

See rule E7. Approximately 6 months prior, teams will be provided with the imagery of the area. This will include “the area of interest for the pre-cached sample”. While the whole course will be available, teams will know a specific area of it that the pre-cached sample is located in relative to the starting locations once this imagery is released.

F36. *REMOVED – Clarification was made to Rule R10*

F37. Could you clarify R18 and how the pause switch is supposed to work?

Yes. It is intended that the pause switch be a robust switch that, when triggered by an event official, sends a signal to the robot to pause all motion. When triggered again, another signal is sent which tells the robot it may resume motion. Among other things, since it is possible that a single team entry could require multiple pause switches (i.e. for spawn), the pause switch should not be designed such that an event official has to continually hold the button for the duration of the run or for the duration of the pause in order for the robot to remain in that state. We envision, as an example, a garage door opener as a simple potential solution. Teams should plan for these buttons to be robust, easy to use, and easy to hold because the onus is on the teams to ensure the switch works and remains active for the duration of the run.

F38. *REMOVED – No additional information on intermediate samples will be made available.*

F39. Will you be providing the brand/product number of paint used on the rock?

No.

F40. Will the PVC cylinder be completely fluorescent orange or will they show manufacturing markings? Will the inside be painted? Will you provide more information on the paint used?

Our plan is to lightly sand the PVC-then paint it orange. The inside will not intentionally be painted, although it is very likely in the process of spray painting it that some will get on the inside of the cylinder.

F41. How will you deal with samples that may roll or move because of wind, being hit by a robot, or being hit by an event official?

We anticipate placing samples such that they will not move because of natural (i.e. wind) forces. However, in any situation where movement of a sample is caused by natural forces or robot interaction, the sample will not be replaced to its original spot and it will 'play as it lies'. In these cases, it is possible a sample will move closer to the boundary fence than 1 meter or become within 10 meters of another sample. In the event that a sample is hit or moved by an unnatural or non-robot force (i.e. event official) it will be replaced as close as possible to its original spot. In the case of multiple robots on the course this situation will be reevaluated.

F42. What happens if an official inadvertently triggers an e-stop in the middle of a run?

We feel that the potential of an e-stop being accidentally or unintentionally triggered during a run is very, very small. The scenarios in which this could occur are hard to imagine and nearly impossible to name outcomes for at this time. If this were to happen in the challenge, on-site judges would convene to evaluate the situation and determine an appropriate resolution depending on the exact situation and circumstances. Some examples of potential outcomes we believe would be considered are: restarting the robot in base with the balance of time remaining and field in current status, restarting the entire run from base including removing and replacing any samples collected, or stopping the run and evaluating the team's performance based on the field as it currently stands. In no case will an inadvertent e-stop cause a disqualification of a team.

F43. Will you be providing additional information on the hard samples?

Yes. All fully registered teams will be provided with the potential rectilinear markings for the hard samples. Only samples with those markings are counted, but as per FAQ #2, we will not intentionally be placing false samples on the course.

F44. *REMOVED - Redundant*

F45. Are you planning to fully reveal the challenge location with either the topological data or satellite imagery?

Approximately six months from the event, we will release appropriate topographical data and imagery of the course to aid all competitors in successfully achieving the challenge. It is intended for this information to mimic the information a satellite or previous rover may have collected about the area. It is not our intention to reveal the actual location of the challenge at that time. While it is possible a team may be able

to guess a potential location from the information, it will not be confirmed until teams arrive at WPI and are then transported to the event.

F46. REMOVED – See modified E13

F47. Is it possible that the starting platforms will be set up as a “chute” entering the contest area with fencing on either side? Is it possible that the starting platform will be set up pointed directly at a close (< 2 m) snow fence?

Yes, it is possible the starting platforms will be setup with a ‘chute’ leading to an open area of the field. However, the robot will never be started pointed directly at a fence closer than 2 meters.

F48. Can rule E9 be interpreted to mean the hard sample could be 20x20x20cm?

At this time, we will not be providing any additional details or information on the hard samples. However, recall that the challenge is about searching for and identifying samples, so we do not anticipate any special manipulation being required to handle the hard samples versus the easy or intermediate samples.

F49. Will the wooden cube have sharp corners and edges or is it possible the corners will be significantly rounded?

No attempt will be made to intentionally chamfer the edges.

F50. REMOVED - See rules for clarification on spawn, particularly R20, C41, and C45

F51. May I test my robot on-site prior to the event?

Absolutely no testing of robots will be allowed on-site prior to the event. The rules and regulations of the competition site directly prohibit various activities, specifically the operation of any sort of motorized vehicle. Violating any rules of the site would likely disrupt and delay the schedule of the entire event (a probable result of your actions is that the property owners rescind their offer to allow us to host the competition there) and thus doing so would be considered a violation of Section 4 of the Team Agreement.

F52. Will samples be placed inside any structures in the competition area?

No. Samples will not be placed inside any structures (i.e. buildings, trash cans, etc) on the course. See also F10.

F53. May we use a solar tracking sensor?

There are no rules that prohibit the tracking of celestial bodies like the sun.

F54. What are the eligibility requirements for receiving awards? Is it open to the world this year, or still only primarily US citizens?

All teams are welcome to participate, but only US teams who meet the criteria outlined in the Team Agreement are eligible to win the \$1.495M in prize money outlined in Sections 4.2 and 4.3 of the rules.

However, all officially registered teams who meet the deadlines set forth in the rules and Team Agreements will be eligible for the Technology Achievement Awards described in Section 4.1 of the rules.

F55. REMOVED – See modified section 2.5.4.

F56. What happens to the prize distribution if a demonstration team (not prize eligible) places in the top three for Level 2?

If a team places in the top three of Level 2 but is ineligible for prize money per the team agreement, the money will be distributed to the top three prize-eligible teams per the outlined structure in P8. An example is below.

Example:

- The top 4 teams score 10, 8, 4, and 3 points respectively. However, the team who scored 10 points is a 'demonstration' team and not eligible for the prize. Therefore, the team who scored 8 is considered the top-scoring team for prize distribution and \$250,000 is available for distribution per (P8).
- Start with 3rd place... $8+4+3=15$... $3\text{pts}/15\text{ total pts} = 20\%$... 20% of \$250K is \$50,000 which the third place team will win.
- Second place is $8+4=12$ $4/12 = 33\%$... 33.3% of \$200K is \$66,600 which is what the second place team is awarded.
- $\$250,000 - \$50,000 - \$66,600 = \$133,400$ remains and is awarded to the top-scoring, prize-eligible team.

F57. R13 states that the required payload is not included in the robot's mass. Is it included in the robot's size?

No, the Required Payload is not included in the robot size.

F58. R16 does not say what the fans are cooling. Are there any restrictions?

No. This year we do not restrict what fans can cool. However, onus will be on the team to prove any fans on their robot are not doing other actions besides cooling (like the sample collection).

F59. Previous years you suggested that the pause switch be a 'two-button pause'. Is that suggestion the same for this year?

Yes, along with description in the rules (R18) and FAQ (F37), it is highly suggested, but not required, that you have a separate pause/unpause switch or a latching pause switch to aid the person controlling it in knowing what condition your robot is supposed to be in.

In the case of a single button, where the same button toggles pause/unpause, the event official may have no clear way of knowing the current state the robot should be in (i.e. did they push the button hard enough to unpause?). In the case of a two-button, latching, or other system that has other indicators, they know the state of their button or could hit 'unpause' again to ensure they had completed the action.

We feel this is the best situation for competitors to aid the event officials in doing their job efficiently and fairly.

F60. There are a lot of IMUs on the market now, but getting extremely hard to find without magnetometers on board. If we can show in our code where we are only using data from the accel/gyro sensors for our reference systems, will this be allowed?

Yes. The onus will be on the team to prove exactly what data is being accessed and how, and use of such devices will be under scrutiny of the Technical Review Committee and on-site judges. Bear in mind that per R14, the Required Payload is likely to contain a strong magnetic source which may interfere with the expected operation of your IMU even though you are not intentionally accessing those elements.

F61. Does having the Battery Management System (BMS) be “always on” (it draws some current even when the Master Power Switch or Mechanical E-Stop have cut power to the rest of the robot) violate the Master Power Switch or Mechanical E-Stop sections of R18?

The purpose of the E-stop is to prevent any injury to spectators, officials, or environment. Since a BMS actually can prevent such occurrence, by managing the status/condition of Lithium-based cells, this could be an allowed exception to this rule. Any teams wishing to make use of such a system must clearly outline and document the system in their required proposal. At the event, it would be imperative for the team to demonstrate that no other system receives power when the BMS is operating without the Master Power Switch on (or when the E-Stop is activated).

F62. *REMOVED* – See information in the Competition Area section of the event webpage

F63. *REMOVED* – See modified rule R10

F64. Are we allowed to place our home beacon in a specific alignment?

We will not regulate the orientation in which a teams places their home beacon on the home beacon platform, provided it complies with R9 and all other home beacon rules. However, please be aware of C27 and C39 when considering your home beacon setup (i.e. the home beacon must be secured to the platform in a remote location, will be transported by the event staff, and placed in conjunction with the starting platform in a random orientation).

F65. *REMOVED* – See modified rule C47

F66. The Hard Sample Documentation indicates the inscription will be in contrasting paint. Does this indicate the main body of the sample will be painted?

This statement is meant to describe that the engraved portion of the hard sample is filled in with a color (using paint) to help distinguish it from the main body of the sample. It is not intended to imply or indicate whether or not the main body is painted.

F67. Can we use the tie down hoops to strap something in position that is not moving off the platform for level 1?

Per Rule C24 and the Starting Platform drawing (located in the Competition Area Info, Drawings, and Pictures page), all robots must be placed within the designated starting area/square. Since the attachment points (“tie down hoops”) are located outside that square, being attached at the start would not be a legal starting configuration. The rules do not prevent being attached to the starting platform within the starting area before the challenge run commences or attaching to other areas after the start of the challenge run provided:

A.) It is non-destructive to the platform (creating a permanent mark, alteration, or deformation)

B.) It complies with all other robot starting rules

Please note that the starting platform is designed to hold a robot at the start of a challenge run and support reentry of the robot during the run only.

F68. REMOVED – See modified rule R18 and R20

F69. Can you provide further clarification on P9 and the Level 2 tiebreakers?

Yes. Consider these scenarios in Level 2:

- Three teams score 8 points each, another scores 7, and another scores 5. ONLY the three teams who scored 8 points will receive prize money. They will evenly split \$250,000.
- Two teams score 8 points each, another scores 7, and another scores 5. Each of the teams who scored 8 points receive 34.8% of the \$250,000 (\$87,000) and the team who scored 7 receives 30.4% (\$76,000).
- One team scores 8 points, two teams score 7 points each, and another scores 5. The team who scored 8 receives 36.4% (\$91,000) and each of the teams that scored 7 receives 31.8% (\$79,500)
- Four teams score 8 points and another scores 7 points. The four teams who scored 8 points will receive prize money. They will evenly split \$250,000.
- One team scores 8 points and 3 teams score 7 points. The team that scored 8 receives 53.3% (\$133,250). The three teams who score 7 evenly split 46.7% of the \$250,000 (\$38,916.67 per team).