

NASA Centennial Challenge

Sample Return Robot Challenge Rules V1.1

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OVERVIEW

The objective of the Sample Return Robot Challenge is to develop new technologies or apply existing technologies in unique ways to create robots which 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 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. It DOES NOT include the Home Beacon.
- 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 minimize the visibility of robot graphics and 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 designated platform.
- R10. Home Beacon may not contain any externally moving parts.
- 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 a 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.

- 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:
 - Unsealed fan-cooled motors and controllers
 - 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. On board computing hardware ONLY may utilize passive and forced air convective cooling systems, subject to judge and inspector approval.

- R17. Hazardous materials which 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 easily identified by the judges:

- Master Power Switch: The Master Power Switch must be an obvious on-off switch located at least .75 m from the ground. This switch must turn on power to ALL parts of the robot, including any on-board processing components. An event official will trigger this switch at the start of the competition run when time begins.
- 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, even if the robot is moving. It must be located in the center rear of robot at least .75m from ground, not to exceed 1.5m above ground. The E-stop must be hardware based and not controlled through software. Activating the E-Stop must shut down power. An event official may activate this E-stop when a robot has violated a boundary of the competition or otherwise caused a significant safety hazard.
- Pause Switch: The wireless Pause must be effective for a minimum of 30 meters. Activating the Pause must bring all motion of all robot components to a complete stop within 1 second of activation. An event official will carry this Pause Switch during the entirety of the competition run and utilize it to enforce right-of-way rules and prevent robot-to-robot interference. When a robot is paused, its official event clock will also be paused.
- Safety Light: Each robot must have an easily viewed indicator light which 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 which traverse the course (known as spawn), the following applies:
- There must be one pause switch supplied for each spawn. Activating any one pause button must pause motion of ALL spawn, whether or not they are within the 30-meter range.
 - There must be an E-stop button on every spawn.
 - There must be a safety light on every 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 on/off switches and e-stops on the robot and via the wireless pause switch.
- 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.

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. Teams who successfully complete Level 1 will be given the opportunity to attempt Level 2.

Each competitor will be given only one opportunity at Level 1 and Level 2 in any given Challenge. However, if no team successfully completes Level 1 on their first try, the judge committee may choose to re-run Level 1 for all competitors in attendance and forgo Level 2 for that year.

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 15-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. 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.
- C6. 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.
- 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 (C6) 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. Inspectors will be available during this time to offer advice and insight to teams.
- C12. During pre-inspection, teams may be asked by an inspector to power up their robot and show the functions of their robot, including the master power, E-Stop, and pause switch.

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 which 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 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, secure their robot to the starting platform in impound, and then all team members must leave the impound area immediately.
- C22. At the end of the competition, 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 front, center, and area for robot placement. The robot must be fully contained within the marked starting area.

- 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 (C5).

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 pre-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 keep the official time for that robot and monitor robot-to-robot interaction, safety hazards, and rule violations.
- 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 selected in random order to make their challenge attempt.
- C35. Teams will place their robot on the starting platform and their home beacon on its platform.
- C36. Teams will have a maximum of 10 minutes to place their robot on the platform, removing any transport aids, and setup any Home Beacon.
- 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. Using the orientation marked in the satellite image (E7) as a reference, the event official may rotate the front of the starting platform clockwise or counterclockwise up to 60 degrees from that orientation mark.
- 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 unpause any robot any number of times during their challenge attempt for any length of time.
- 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 unpause 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 unpause.
 - 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.
- 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 E-Stop a robot once during a challenge attempt. Activation of an E-Stop 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 may be E-Stopped by in the following situations:
- The robot contacts the outer boundaries of the roving area and would clearly continue past the boundary if left uninterrupted.
 - The robot poses an extreme safety hazard to event officials, spectators, or the environment.
 - The robot has shown no signs of activity for at least 15 minutes.
 - The robot 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 roving area for the robot during the sample collection attempt is approximately 80,000 square meters.
- E5. The borders of the roving area will be marked by orange fencing no less than ½ meter tall. Examples of this fencing are available in the FAQ.
- E6. Teams will be provided limited topographical data of the roving area in advance of the competition to include maximum grades, types of surfaces, and large fixed features for orientation.
- E7. A satellite image of the competition area will be provided to all competitors no less than 6 months prior to the date of the competition. 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 throughout the roving area. They may be placed close to obstacles, both movable and immovable.
- E9. Each sample will be no less than 1cm and no more than 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
 - Soft Shot Red Hockey Puck
 - 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 2-4g
 - Rock, painted yellow, with a its major dimension between 6 and 10cm, and a mass between ½ and 1kg
 - Wooden cube, approximately 10cm X 10cm X 10cm
 - 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 25 meters to each other within the roving area.
- 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 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.

4.1 LEVEL 1 PRIZE(S)

- P1. A pool of \$50,000 will be equally distributed among all teams successfully completing Level 1, with a maximum of \$5,000 per team.

4.2 LEVEL 2 PRIZE(S)

- P2. The amount of prize money available to all competitors will be set by the top-scoring team per the Prize Distribution Schedule in P7.
- P3. The amount of prize money available to any individual team will be based on the ratio of their score to the top three scores, and capped by the maximums allowed per the prize distribution schedule in P7. Examples of the prize money calculations are available in the FAQ.
- P4. Sample types are worth the following points:
- Easy - 1 point
 - Intermediate - 2 points
 - Hard - 5 points
- P5. 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.
- P6. Once all robots have made their attempts, the top three scoring robots will be identified by the judges as eligible for prize money.
- P7. Prize Distribution Schedule (less any funds distributed for Level 1):
- 3-5 Points: \$100,000
 - 6-8 Points: \$250,000
 - 9-14 Points: \$750,000
 - 15+ Points: \$1,500,000

CRITICAL DEADLINES AND DOCUMENTATION

- Prior to arrival at the event, teams will be required to submit significant documentation to the judges highlighting their approach to solving the challenge, detailed information about their robot, and video of their robot in action.
- Any information provided to the judges prior to the event will be accessible only to the judging committee and NASA personnel. This information will not be shared with other teams or posted publicly without the consent of the team leader as per the team agreement.
- Below is a schedule of critical deadlines for both the teams to submit information to the judging committee and for the judging committee to publish information to the teams. Additional deliverables and deadlines may be added throughout the course of the competition.
 - Registration Opens when Final Rules and Federal Register notice are published.
 - Due monthly (starting 8 months prior to event): Teams must submit a monthly progress report on the 4th of every month. Format for this report will be provided at registration.
 - 11:59 PM on 2-JAN-2012: Early Registration deadline. Any team wishing to register after this point is subject to approval by the judge committee.
 - 11:59 PM on 2-JAN-2012: Each team must submit a written proposal documenting the mechanical, electrical, and programming aspects of their robot. This preliminary proposal will include information on motors and sensors being utilized as well as the methodology for implementation and achieving challenge goals. If a team intends on utilizing local frequencies or similar technology it must be highlighted in this proposal. More detail on preferred proposal format will be provided to teams at least 30 days prior to the proposal submission deadline.
 - 150 days prior: Judge Committee will respond to each team with approval for their design as well as any frequency allowance or allotment to prevent interference.
 - 90 days prior: Late Registration deadline. Any teams registering after the 6 month mark will be directed by judges for the proposal deadline on a case-by-case basis.
 - 30 days prior: Teams must submit a video of their robot autonomously searching for, collecting, and returning to where they started with a sample as well as an updated version of their previous proposal to include any significant changes to their design. Teams must submit proof of their liability insurance coverage.
 - Upon arrival at the event: Each team must provide a full printout of their robot code along with a schematic of all electrical components for each robot as well as any other documentation requested by the judge committee to aid in the inspection process.