Version 1.1, 06/12/2009

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Regolith Excavation Challenge

October 17-18, 2009 NASA Research Park, Moffett Field, California

Competition Rules

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On the Internet: **Regolith Excavation Challenge:** http://regolith.csewi.org **California Space Education and Workforce Institute:** http://csewi.org **NASA Centennial Challenges:** http://centennialchallenges.nasa.gov

1.0 Introduction

The 2009 Regolith Excavation Challenge ("CHALLENGE") is designed to promote the development of mechanical designs to excavate lunar regolith. Excavation is a necessary first step towards utilization, and the unique physical properties of lunar regolith make excavation a difficult technical challenge. Advances in lunar regolith extraction have the potential to significantly contribute to the Nation's Space Vision and space exploration operations.

The CHALLENGE will be conducted by the California Space Education and Workforce Institute (CSEWI), an Allied Organization, selected by NASA to administer the Regolith Excavation Challenge at no cost to NASA. The prize funding for the Regolith Excavation Challenge is provided by NASA through the Centennial Challenges program.

The TEAMs that can, using telerobotic or autonomous operation, excavate the most lunar regolith simulant (above the Minimum Excavation Requirement of 150.0 kg and within Excavation Hardware mass limit of 80.0 kg) from a supplied quantity of regolith within a specified Time Limit of 30 minutes will win the CHALLENGE and are eligible to receive First, Second or Third Prize of US\$500,000.00, US\$150,000.00 and US\$100,000.00, respectively.

2.0 Definitions

Allied Organization – The organization, California Space Education and Workforce Institute, responsible for administering the Competition.

Collector – A device provided by the Allied Organization for the Competition Attempt into which TEAM will deposit excavated Regolith. The Collector will be large enough to accommodate each TEAM's excavated Regolith. The Collector will be stationary and located adjacent to the Sandbox. Excavated Regolith mass will be measured after completion of the Competition Attempt. The Collector mass will not be counted towards the Excavated Mass or the mass of the Excavation Hardware. The Collector will be sized approximately 1 meter wide and long and the walls will rise to an elevation between 56 cm and 66 cm above the average elevation of the Regolith surface closest to the collector.

Competition Attempt – The operation of TEAM's Excavation Hardware intended to meet all the requirements for winning the CHALLENGE by performing the Functional Task. The duration of the Competition Attempt is the Time Limit.

Excavated Mass – Mass of the excavated Regolith delivered to the Collector by the Team's Excavation Hardware during the Competition Attempt, measured in kilograms (kg) with official result recorded to the nearest one tenth of a kilogram (0.1 kg).

Excavation Hardware – Mechanical and electrical equipment, including any gases, fluids and consumables delivered by TEAM to compete in CHALLENGE.

Telerobotic – Communication with and control of the Excavation Hardware during the Competition Attempt is performed solely through the provided communications link, required to include a delay and bandwidth limit on all data sent to and received from the Excavation Hardware.

Functional Task – The excavation of Regolith from the Sandbox by the Excavation Hardware and deposit from the Excavation Hardware into the Collector.

Minimum Excavation Requirement – The total Excavated Mass, 150.0 kg, that must be exceeded in order to win the CHALLENGE.

Reference Point – Each team must select a fixed location on the Excavation Hardware that will serve as the Reference Point. The Reference Point will be used to verify the starting location and traversal of the Excavation Hardware within the Sandbox.

Regolith – JSC-1A standard fraction lunar regolith simulant provided by the Allied Organization during the Competition Attempt.

Sandbox – An open-topped container (i.e., a box with a bottom and four side walls only), containing Regolith, within which the Excavation Hardware will perform the Competition Attempt. The dimensions of the Sandbox will be approximately 4 meters wide and long, and one-half meter in depth, and there will be a vertical wall on the perimeter of the Sandbox that rises above the Regolith surface. The Sandbox for the Competition Attempt will be provided by the Allied Organization.

Time Limit – The amount of time within which the Excavation Hardware must perform the Functional Task, set at 30 minutes.

3.0 Rules

- 1 These rules and specifications may be subject to future updates by the Allied Organization at its sole discretion.
- 2 The CHALLENGE will be conducted in a "head to head" format, in which the teams will be required to perform a Competition Attempt using the Regolith, Sandbox and Collector provided by CSEWI. The Allied Organization will fill the Sandbox with Regolith, and compact it, and place rocks in the Sandbox. Each Competition Attempt will occur sequentially. Between each Competition Attempt, the rocks will be removed, the Regolith will be returned to a compacted state and the rocks will be returned to the Sandbox. Consideration of prize awards will be based on each team's performance during the official Competition Attempt.
- 3 All Excavated Mass deposited in the Collector during the Competition Attempt will be weighed after completion of the Competition Attempt.
- 4 The TEAMs that excavate the first, second and third most lunar regolith simulant mass over the Minimum Excavation Requirement within the Time Limit will respectively win First, Second and Third place CHALLENGE prizes. In the case of a tie, the Prize(s) will be equally divided between all Teams tied for First, Second, or Third place. For example: In the case of only two teams qualifying for a prize and tying for First place, each would receive US\$325,000.00 and US\$100,000.00 in prize money would remain available for a potential future competition.
- 5 The Sandbox internal surface area will be divided with an imaginary 3 x 3 grid so that each of the nine resulting (imaginary) cells have equal side dimensions and areas. Each of the four sides of the Sandbox will have two corner cells and one middle cell associated with it. There is one center cell in the middle of the Sandbox area that is not adjacent to any of the Sandbox sides.

6 The Collector will be placed so that it is adjacent to the outer wall of one of the Sandbox sides. The Sandbox side next to which the Collector will be placed will be selected based primarily with the intent of easing operational and logistical considerations. If no one Sandbox side is preferential to another, the selection of Sandbox sides next to which the Collector will be placed will be made randomly. The placement of the Collector will then be randomly assigned to either be aligned with the imaginary middle cell or either of the two corner cells associated with the chosen Sandbox side. Alignment of the Collector with the selected cell entails matching the center lines of the cell and the Collector.



- 7 Location of the Collector will remain the same for each team and all Competition Attempts.
- 8 The surface between the inside-side edge of the Sandbox and the inside-edge of the Collector will span between 17 and 30 centimeters.



TOP VIEW

- 9 There will be four large rocks placed on top of the compressed regolith surface within the Sandbox before each of the Competition Attempts are made. Each rock will have a diameter of approximately 20 to 30 cm and an approximate mass of 7 to 10 kg. Rocks placed in the Collector will not be counted as part of the Excavated Mass.
- 10 The placement of each rock will be determined by randomly selecting four of the Sandbox's imaginary cells prior to each Competition Attempt. Each rock will be placed in a different imaginary cell after the excavation hardware has been placed in its starting position and any teleoperators have been visually isolated from the Sandbox. No rock will be placed in the imaginary cell closest to the Collector. The minimum distance between any two rocks is 40 cm.
- 11 The Excavation Hardware will be placed such that the Reference Point aligns

vertically with the center of the cell nearest the Collector prior to the start of the Competition Attempt. The starting direction will be defined by each team.

- 12 At the start of the Competition Attempt, the Excavation Hardware may not occupy any location outside the footprint defined by the area of the cell adjacent to the Collector, the top surface of the Sandbox and Collector walls, and a 8 cm buffer around the outside surface of the Sandbox and the Collector.
- 13 The Excavation Hardware shall not excavate regolith located in the area within the starting cell at any time during the Competition Attempt.
- 14 The Excavation Hardware is required, at least once during the Competition Attempt, to traverse across the regolith surface such that the Reference Point crosses the boundary of a cell that is not adjacent to the starting cell and subsequently traverse such that the Reference Point crosses back into the starting cell. Cells sharing a corner with the starting cell are considered adjacent to the starting cell.
- 15 Each Team is responsible for placement and removal of their Excavation Hardware onto the Regolith surface for each Competition Attempt.
- 16 Each team is allotted a maximum of 10 minutes to place the Excavation Hardware in its designated starting position within the Sandbox and 10 minutes to remove the Excavation Hardware from the Sandbox after the Competition Attempt has concluded.
- 17 The current consumption of each power supply utilized by the Excavation Hardware shall be limited by a single fuse for safety (Cooper Bussman BK/AGC-15). Fuses will be provided by the Allied Organization. For safety reasons, power supply voltage shall not exceed 40.0 V.
- 18 Mass of the Excavation Hardware shall not exceed 80.0 kg. Equipment used to receive or transmit commands to and from the Excavation Hardware for telerobotic operations is excluded from the 80.0 kg mass limit. Subsystems used to transmit data to the telerobotic operators is counted towards the 80.0 kg mass limit.
- 19 The Excavation Hardware operates during the Time Limit of the Competition Attempt.
- 20 The Excavation Hardware will end operation immediately when the power-off command is sent, as instructed by the competition judges.
- 21 During the Competition Attempt, Excavation Hardware will be limited to autonomous and Telerobotic operations only. No physical access to the excavation hardware will be allowed during the Competition Attempt. In addition,

Telerobotic operators are only allowed to use data originating from the Excavation Hardware. Visual and auditory isolation of the telerobotic operators from the Excavation Hardware are required during the Competition Attempt.

- 22 The communications link used for telerobotic operations is required to introduce a delay of at least 2.0 seconds for both sending and receiving of data and the excavation hardware must utilize a total bandwidth of no more than 1.0 Mbps, as averaged over the entire Competition Attempt. The provided network link will implement the required delay by routing network traffic between the teleoperators and the excavation hardware through it.
- 23 To ensure that the Excavation Hardware is usable for an actual lunar mission, the Excavation Hardware cannot employ any fundamental physical processes (e.g., suction or water cooling in the open lunar environment), gases, fluids or consumables that would not work in the lunar environment. In example, any dust removal from a lens or sensor must employ a physical process that would be suitable for the lunar surface. TEAMs may use processes that require an Earth-like environment (e.g., oxygen, water) only if the system is designed to work in a lunar environment and if such resources used by the Excavation Hardware are included in the mass of the Excavation Hardware.
- 24 Components (i.e. electronic and mechanical) are not required to be space qualified for the lunar vacuum, electromagnetic, and thermal environments.
- 25 The teams may not use any process that causes the physical or chemical properties of the regolith to be changed or otherwise endangers the uniformity between Competition Attempts.
- 26 Excavation Hardware will operate within the Sandbox and is not permitted to pass more than 15 cm beyond the confines of the outside wall of the Sandbox and the Collector during the Competition Attempt.
- 27 The Excavation Hardware will not push Regolith up against the wall to accumulate Regolith.
- 28 If the Excavation Hardware exposes the Sandbox bottom due to excavation, touching the bottom is permitted, but contact with the Sandbox bottom cannot be used at any time as a required support to the excavation hardware.
- 29 The Excavation Hardware cannot be anchored to the Regolith surface prior to the beginning of the Competition Attempt.
- 30 The Excavation Hardware shall not penetrate the regolith surface with more force than the weight of the excavation hardware before the start of the Competition Attempt.

- 31 No ordnance may be used.
- 32 Teams will not be permitted to alter or otherwise modify the Excavation Hardware after either the first Competition Attempt has started, or after completing the safety and rules compliance inspections.
- 33 Teams must submit documentation containing a description of the Excavation hardware, a description of its operation, a description of potential safety hazards, a diagram, and basic parts list. Each team will deliver to the Allied Organization their written documentation 30 days before the Competition Attempt for normal registration, and 15 days before the Competition Attempt for late registration.
- 34 Teams must submit video documentation no less than 15 days before the start of the competition. The video documentation must contain no less than 30 seconds of Excavation Hardware operation, and at least one full cycle of operation. One full cycle of operations includes excavation and depositing material.

Video Specifications:

Formats/Containers:	.avi, .mpg, .mpeg, .ogg, .mp4, .mkv,
Codecs:	MPEG-1, MPEG-2, MPEG-4 (including
Minimum frame rate:	24 fps
Minimum resolution:	320x240 pixels