

MoonROx Challenge Rules and Requirements Document

The MoonROx Challenge is designed to promote the development of technologies and equipment to extract oxygen from lunar regolith. *In-situ resource utilization* (ISRU) technologies have the potential to significantly contribute to the success of future lunar missions planned by NASA under the U.S. Vision for Space Exploration.

The MoonROx Challenge will be conducted by the California Space Education and Workforce Institute (CSEWI), in association with California Space Authority (CSA), in a “first to demonstrate” competition format. A \$1,000,000.00 MoonROx prize will be awarded to the first team whose hardware can quickly extract breathable oxygen from a supply of lunar regolith simulant using a steady-state process, within the constraints established in this rules and requirements document. The MoonROx Challenge, and the opportunity to win the prize purse, expire on (date TBD).

MoonROx Challenge Rules

Technical and operational requirements not already covered in these rules may be provided by CSEWI to the teams after registration.

Definitions are included at the end of this document.

General Overview

The basic competition is for teams to employ qualified reusable ISRU hardware weighing no more than 50 kilograms, to extract 2.5 kilograms of breathable oxygen from “JSC-1a” lunar regolith simulant, within a four hour period, using no more than 10 kilowatts of power. The attempts must be scheduled at a location in the United States provided by the competing team and approved by CSEWI. Qualified teams will be selected on a first-come, first-served basis.

CSEWI, at its sole discretion, may disqualify any team for noncompliance with MoonROx Challenge rules or other misconduct determined by CSEWI to be inconsistent with the spirit and intent of the MoonROx Challenge.

By signing the Team Agreement, teams understand that the development, testing, and operation of their ISRU hardware is potentially hazardous and is undertaken at their own risk. Teams will waive any claims of liability against CSEWI and the MoonROx Challenge sponsors related to any damage or injury that may occur as a result of the team’s participation in the MoonROx Challenge.

Registration & Qualification

Teams are required to submit a completed and signed Team Agreement and pay a non-reimbursable initial registration fee of \$5,000.

No later than 60 days after signing the Team Agreement, teams must submit Technical Documentation which includes hardware design, experimental system configuration (including drawings), operating procedures and a proposed competition attempt date/location. The proposed competition attempt must be no less than 90 days after Technical Documentation submittal. The Technical Documentation will be used to support an initial qualification review by CSEWI or its designated agents. The initial qualification review is intended to ensure safe and legitimate operation of the team’s hardware in accordance with the intent of the MoonROx competition. Failure to submit the required agreement, fees, or documentation will result in disqualification.

CSEWI, or its designated agents, and the MoonROx sponsors will not retain any team's Technical Documentation beyond the team's competition attempt. CSEWI will safeguard the documentation as proprietary information. CSEWI will share the documentation only with MoonROx sponsors engaged in the qualification processes. CSEWI and the MoonROx sponsors will claim no rights to any new technologies developed by any team.

No team may compete in a MoonROx competition attempt until they have passed the initial qualification review to the satisfaction of CSEWI or its designated agent. After the initial qualification review, CSEWI will notify the team on whether they can register for an official competition attempt. Teams that do not pass the initial qualification review will be informed as to the reason for their failure. The team may request another initial qualification review based on improvements or changes to their technical documents, procedures, or hardware since their failed initial qualification review. If more than two initial qualification reviews are requested, a team may be required to re-register.

Only those teams who pass their initial qualification review will be eligible to schedule an official MoonROx competition attempt. The official competition attempt date shall be set by CSEWI and will be no more than 90 days after a successful initial qualification review. For the competition attempt, teams are required to submit a pay a nonreimbursable final registration fee of \$20,000 and also pay for the regolith required for the competition attempt. The official MoonROx competition attempt will only be scheduled after receipt of the final registration fee.

Teams will be required to provide access to their ISRU hardware and measurement devices at the competition site at least 24 hours prior to the competition attempt to allow final qualification inspection. The team hardware and measurement devices must be in the configuration to be used during the competition attempt. The final qualification inspection is intended to ensure consistency between the technical documentation (approved through the initial qualification review) and the actual ISRU hardware, collection methods, processes, and performance indicators used by the team.

Competition Attempt and Successful Completion

CSEWI and the on-site judges will plan on being available at the competition location for three days. The first day will be used for the final qualification inspection. The second day is envisioned to include the competition attempt. The third day is a contingency day to allow for hardware modifications, more qualification inspection, or another competition attempt. CSEWI and on-site judges will be the sole authority to set and modify the schedule for competition-related activities during the three days.

Teams that do not pass the final qualification inspection will be informed as to the reason for their failure. The team may request another final qualification inspection based on minor improvements or modifications to their hardware or procedures. The changes will need to be made within 24 hours and the technical documents will need to be updated to reflect the change. The on-site judges will determine whether competition attempt will be allowed to proceed. Any non-coordinated hardware replacement occurring after the final inspection may result in disqualification.

The competition attempt will last up to four hours, but may be concluded early by CSEWI due to hazardous conditions or if requested by the team due to early completion of the competition requirements.

Teams will be provided Regolith to perform a competition attempt. Regolith to be used during the competition attempt must be purchased through CSEWI after submitting the final registration fee. CSEWI will make arrangements for delivery of the Regolith at the competition site on the date of the official competition attempt.

The first team that meets or exceeds the minimum production requirement and minimum purity requirement, and whose ISRU Hardware remains operable for long-term use, while satisfying all of the other MoonROx Challenge rules, will be declared the winner of the MoonROx Competition.

After the competition attempt is completed and a team does not win the competition, the team will be required to re-register in order to establish another competition attempt.

ISRU Hardware and Associated Systems

The teams are required to provide, as part of their competition attempt and at their own expense, all necessary systems for the measurement of extracted gas volume and purity. Volume measurements may be accomplished using either flow meters or gas collection vessels. The calibration of volume and purity measurement equipment must be calibrated and certified. Calibration and certification evidence will be verified by CSEWI or its designated agent prior to the competition attempt. The ISRU hardware will include a capability for the collection of extracted gas samples to be provided to CSEWI to allow additional off-site purity tests after the competition attempt.

Each team shall provide or make arrangements for the operation of the ISRU hardware and the provision of all the necessary test facilities, data acquisition instruments, computers, equipment, fluids, and consumables that will prove the performance of their ISRU hardware at their own expense.

Mass of the ISRU hardware as configured immediately prior to Regolith loading and starting the competition attempt, and including reactants intended to be used, shall not exceed 50 kilograms. This figure excludes the mass of the empty hopper and the mass of any components whose sole purpose is to ensure safety due to operating in a 1-G, non-vacuum environment. This figure shall also exclude the mass of any components whose sole purpose is the collection or measurement of extracted gas. The mass of the equipment will need to be verified by CSEWI and the on-site judges prior to the competition attempt, so the equipment will need to be placed on a scale to verify the weight.

Each team must include an emergency power-off capability for their ISRU hardware. This power-off capability will be employed at CSEWI or the on-site judge's discretion in the event of a hazardous situation resulting from the ISRU hardware's operation or malfunction.

Each team must monitor their ISRU hardware and advise CSEWI and the on-site judges during the competition attempt of the status of any potentially hazardous processes, including those identified during the qualification review and inspection.

ISRU hardware shall be fully autonomous and must remain stationary at all times during the competition attempt, with no excessive vibration or rotation.

ISRU hardware cannot employ any processes that would not work in a hard vacuum, lunar gravity environment (e.g., suction). Materials that may not be compatible with a hard vacuum environment may not be permitted. These issues will be addressed in the qualification review and inspection.

If the ISRU hardware produces other bi-products (gases/liquids/solids) not intended to be included within the extracted gas, these potentially toxic bi-products must be expelled safely, as described in the team's technical documentation. Hardware associated with the safe expulsion of these bi-products will be categorized as safety components and will not be included within the 50 kilogram limit for ISRU hardware mass.

The ISRU hardware cannot destroy itself or become inoperable as a result of its completion of the competition attempt. The ISRU hardware must remain in, or be capable of being returned to, its operational condition for long-duration use after the competition attempt without the need for repair or

refurbishment. The ISRU hardware will be inspected after the competition attempt and will be shut down and re-started to validate its continued long-term operability.

Teams are responsible for providing power to operate their ISRU hardware. Power consumption cannot exceed 10 kilowatts during the competition attempt. Teams must prove that their power consumption is within this allowable limit. The teams are required to use standard interfaces to the power source in order to allow for connection of CSEWI instrumentation to monitor power consumption.

MoonROx Challenge Definitions

The following definitions include some elaborations on how they apply to the rules above and the competition in general.

Extracted Gas – The gas product of the hardware system during the competition attempt, intended to meet or exceed the Minimum Production Requirement, and consist primarily of diatomic oxygen according to the Minimum Purity Requirement.

Fully Autonomous – No control of the ISRU Hardware is allowed during the entire time limit of the competition attempt.

Hopper – A container associated with the ISRU hardware that receives and holds the full volume of Regolith for the competition attempt and uses gravity to feed the Regolith into the ISRU hardware. The hopper mass is not counted toward the total mass of the ISRU hardware. Regolith excavation processes are not part of the MoonROx Challenge and need not be factored into the ISRU hardware design.

ISRU Hardware – Mechanical apparatus, hopper, and all reactants provided by the team to perform the MoonROx Challenge competition attempt.

Minimum Production Requirement – The mass of the extracted gas set at 2.5 kilograms, which must be met or exceeded during the competition attempt time limit.

Minimum Purity Requirement – A requirement that the extracted gas include 99% diatomic oxygen, by volume, and that the remaining 1% of gas, by volume, is not harmful for human consumption.

Reactants – Chemical agents (consumable or non-consumable, excluding Regolith) required by the ISRU hardware to perform the competition attempt.

Regolith – JSC-1a Standard, a lunar regolith simulant produced under contract to NASA and commercially available from Orbital Technologies Corp. (ORBITEC). Each Team will be allowed to consume a quantity of Regolith as determined by their calculations to perform a single competition attempt plus a 15% reserve.

Team – An individual, group of individuals, or organization registered with CSEWI to perform a competition attempt for the MoonROx Challenge.

Technical Documentation – The basic technical plans, processes/procedures, engineering drawings, descriptions, diagrams, material specifications (including all Reactants), and other documents required to allow CSEWI to conduct a thorough initial qualification review. The Technical Documentation will include sufficient details to allow CSEWI to understand any safety and technical issues related to the Team's ISRU hardware, operations, procedures, and validation methods. The Technical

Documentation will reflect the intended final configuration of the ISRU hardware to be used in the competition attempt. The specific chemical, electrical, and mechanical processes used to complete the competition attempt must be described including all applicable formulas and calculations.

Time Limit – The period of time allowed for the completion of the regolith oxygen extraction during the competition attempt, set at no more than four hours. CSEWI and the team will jointly determine when the four hour Time Limit starts on the date established for the competition attempt. The ISRU hardware may be started prior to the beginning of the Time Limit.