Autonomous Mars In-Situ Resource Utilization Robot for Water Recovery Using Centrifugal Processing

Nick Orenstein
Department of Astronautical Engineering,
University of Southern California (norenste@usc.edu)

44th LPSC Abstract #1843

USC Viterbi School of Engineering

Water Reclamation & Centrifugal Furnace

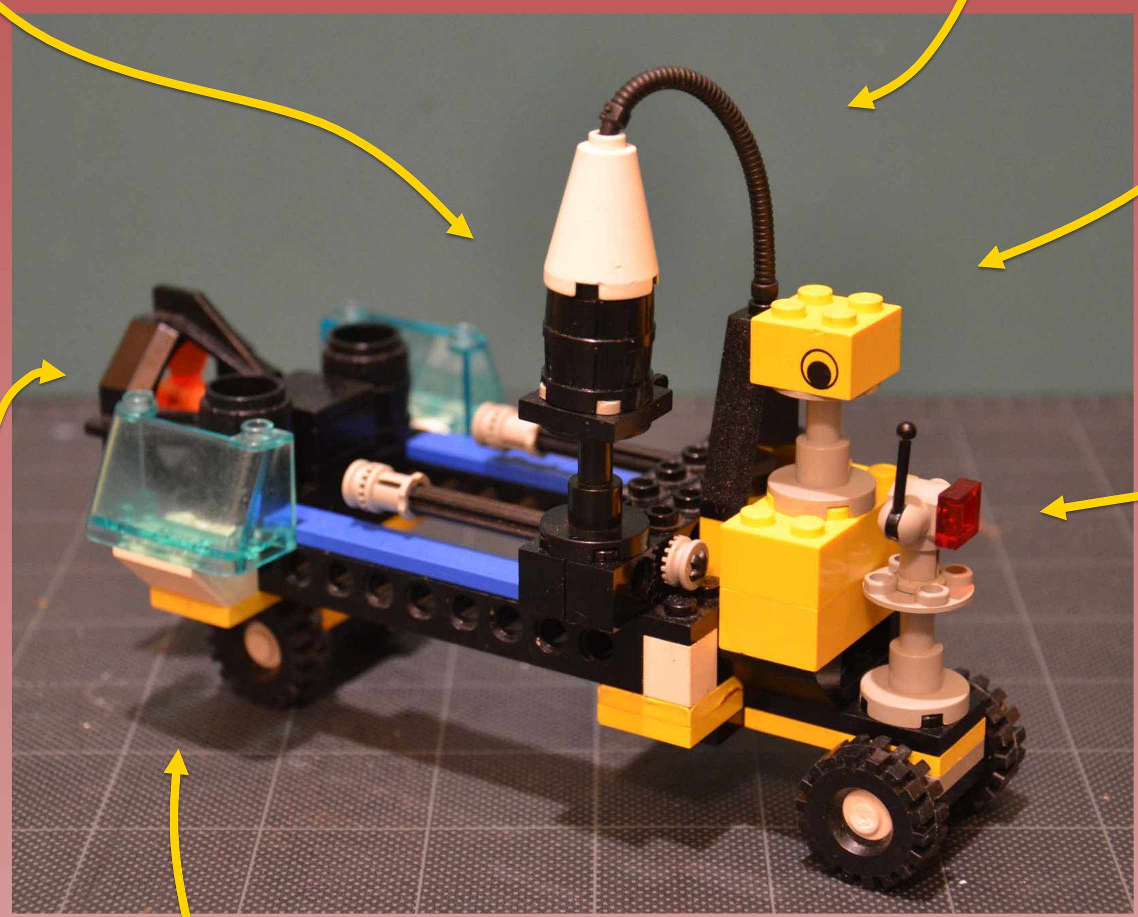
- ✧ Multipurpose integration for capturing water and refining metal
- ✧ Centrifuge enables separation of multiphase, multicomponent flows in fractional gravity
- ✧ Adequately supply a complete human mission
- ✧ Fast, reliable, robust, high volume throughput, minimal power
- ✧ Much is still to be discovered of the fundamental physics of metallurgy in low gravity environments
- ✧ Prototypes could be demonstrated on parabolic flights or aboard International Space Station

Rock & Soil Retrieval

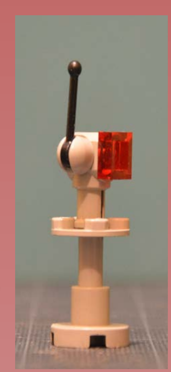
- ✧ Grabs rocks up to the size of a basketball
- ✧ Scoops soil
- ✧ Deposits into refiner
- ✧ Moves refiner between robot and planet surface for operation

AI-Controlled Robot Vision

- ✧ Optical cameras to determine local topography and negotiate across terrain
- ✧ Fast laser spectroscopy and optical rock coloration use pattern recognition to identify resource rocks and soil
- ✧ Artificial Intelligence (AI) knowledge, preprogrammed and dynamic, to improve functional rock/soil acquisition

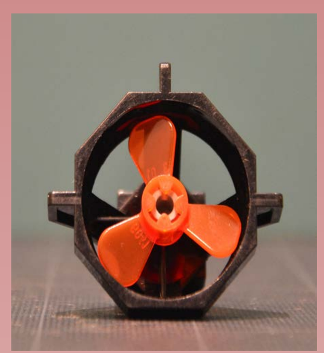


Communications



- ✧ Mars Orbiters to relay commands, resource references, field data, and diagnostics
- ✧ Mars Orbiters for geolocation coordinates
- ✧ Rover network to optimize resource acquisition over a large area
- ✧ Primary storage depot to relay supply levels, filtration purity
- ✧ Human habitat for status reports and real-time operation updates

Power System



- ✧ Nuclear powered by fission reactor or RTG
- ✧ High power requirements given nature of onboard rover features
- ✧ Electrical power conversion and insulated harness system
- ✧ Capacity for continual multi-year use
- ✧ Shielded to protect water storage from radiation

Storage Units

- ✧ One for water, one for metal
- ✧ Thermal control required
- ✧ Optimize single-trip capacity
- ✧ Contents transferable to large permanent tank

Rover Mobility

- ✧ Ground maneuverability and shock absorption to handle both soft and rocky terrain
- ✧ Consider MSL articulating axles or tank treads

Background

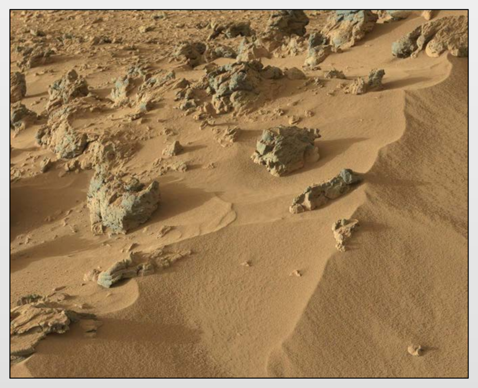
Self sufficient human missions will require materials for fuel, life support, and habitats to be made on site. It is mass and cost prohibitive to send all of these resources from Earth. In-situ resource utilization (ISRU) on Mars must be done on a large scale – thousands of tons of material must be processed. ISRU on Mars must be done quickly – astronauts don't have time to wait for fresh water and oxygen. ISRU on Mars must be done efficiently – the bucket of Mars rocks put into the refinery should be squeezed for all of its resources with little, if any, waste. The ability to accomplish these tasks by ISRU can significantly reduce the cost, mass, and risk of sustained human activities beyond Earth. Furthermore, an autonomous system would free astronauts from the work required. A cadre of robots could be sent to Mars before the astronauts arrive to prepare a site for them.

I will complete a systems-level design of a resource identification, acquisition, and utilization robot based on water reclamation and centrifugal metal refining.

Mission Proposal

- Send ISRU robot(s) up to one synodic cycle (780 days) early to prepare landing site for human expedition.
- Autonomous rover with robot vision uses optical and spectroscopic imaging for object determination.
- Captures rocks and icy soil (basketball-sized rock maximum) then crushes into to mineral grains.
- Alters chamber properties to free water from rocks. Collects water in small storage units to be later transferred to large storage unit
- Utilizes centrifugal furnace to refine minerals to raw metals. Can set furnace on surface using the retrieval arm so that vibrations don't transfer to the rover.
- Tangential exit nozzles on furnace to create wire or powder for 3D printing; or cool metal into ring ingots.
- Potential business opportunity supplying "printer ink."
- Powered by nuclear reactor or radioisotope thermoelectric generator (RTG).
- Communications between: multiple rovers, rover and base station, rover and satellite.
- Additional potential to refine return propulsion fuel from captured water via hydrolysis.

Martian Resources



MSL MastCam (top) and MAHLI (bottom) photos of Martian terrain and cleaved rock.
Credit: NASA/JPL-Caltech/Malin Space Science Systems

Hydrated Minerals
- Ferric oxides (eg. hematite, limonite)
- Aluminum oxides (eg. kaolinite)
- Perchlorate salts

Briny and/or Icy Soil
- Alluvial fans
- Channels
- Recurring Slope Linae

Industrial Metals
- Aluminum, Silicon, Iron, Nickel, Zinc

Interfacial Water?
- Liquid several cm below surface

Reference: The Present-Day Habitability of Mars 2013 Conference, UCLA Institute for Planets and Exoplanets / UK Center for Astrobiology / NASA Astrobiology Institute, Feb. 4-6, 2013. Abstracts and videos available at http://planets.ucla.edu/meetings/mars-habitability-2013/program/

Implications

ISRU benefits science:
- Enhances knowledge of how to create reliable, sustainable human Mars missions.
- Deepens modest understanding of microgravity metallurgy.
- Increases Technology Readiness Level (TRL) of refining tools and processes.

ISRU benefits human exploration:
- Access to water for drinking, fuel, and radiation protection.
- Adaptable design for Lunar and Asteroid missions.

ISRU benefits robots:
- Resource identification via optical and spectrographic vision.
- Cooperative task-based autonomy.

ISRU benefits America's economic future
- Creates tools for the productive use of space.
- Commercial contractors could create profitable businesses by supplying a Mars station with its resources.