PROJECT RIGEL: MARS SAMPLE RETURN WITH IN SITU PROPELLANT PRODUCTION.
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Introduction: This is in response to Challenge 19: "Concepts for in situ resource utilization (ISRU) to enable robotic ascent of samples for return to Earth or other science purposes that also serve as demonstration for future ISRU support for human surface exploration purposes. May include concepts for the extraction and long-term storage of oxygen and/or hydrogen from in situ martian resources in (a) the martian atmosphere; (b) hydrated minerals and regolith at the martian surface; or (c) access to and extraction from surface, near-surface, or subsurface ice(s)." This design also addresses Area 13 concerning game-changing ascent systems and Area 17 for advanced spacecraft subsystems – which in this case would refer specifically to advanced power systems.

Project Rigel won the MarsDrive Mars Sample Return Design Competition in 2008. This contest was judged by Chris McKay of NASA and Louis Friedman of The Planetary Society. Entrants were required to use ISRU for propellant, and keep full mission costs under $2 billion. The work shown here is from my Project Rigel design and subsequent refinements.

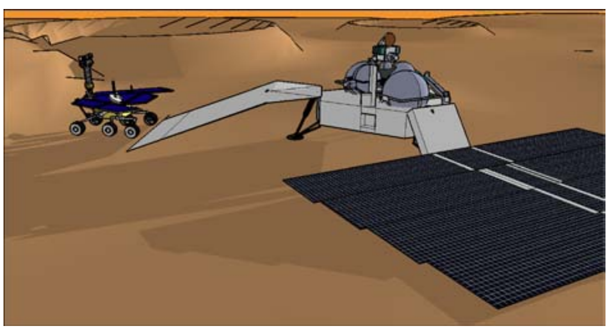

Figure 1: Rigel with main solar array deployed.

Design Solution Summary: The Rigel design solution involved the following elements: Design the vehicle to fit in the size and mass of the Curiosity aeroshell design to reduce cost/risk. Produce ethylene and oxygen to reduce the size of the return vehicle tanks, as well as the size of the tank needed for hydrogen feedstock, versus a methane fuel production approach. Use a large solar array that can be deployed in rough, rocky terrain. Use a stripped-down version of the MER rover platform and modify it for sample collection, thus using a proven design. Take advantage of the day-night temperature cycle as part of the propellant production workflow, doing liquefaction compression operations at night. Take advantage of waste methanol as it accumulates in ethylene production and recycle it. Scale the design to be as simple as possible while still offering multiple overlapping capabilities to solve problems if they occur.

Maximizing Feasibility: To reduce costs and maximize the cost estimate accuracy and mission feasibility, the design had three key principles. First, use flown technology where possible, such as the Curiosity areoshell or MER rover platform. The lander/return vehicle antenna is also a MER repeat. All solar array calculations used MER array output and degradation data over a 530 day mission. Second, if not flown, keep it simple. The solar array deployment scheme, sample collection devices, and so on can be prototyped by a reasonably good hobbyist, let alone an engineer. Doing low cost iterations of these designs, possibly by crowdsourcing, will refine the designs at minimal expense. Third, take the best of the rest. Some concepts are taken from earlier NASA and industry studies to leverage what would otherwise have been paper studies. Deepening the design heritage in this way also minimizes risk. For example, a US government study contributed a piston-driven fuel pump designed specifically for MSR missions.

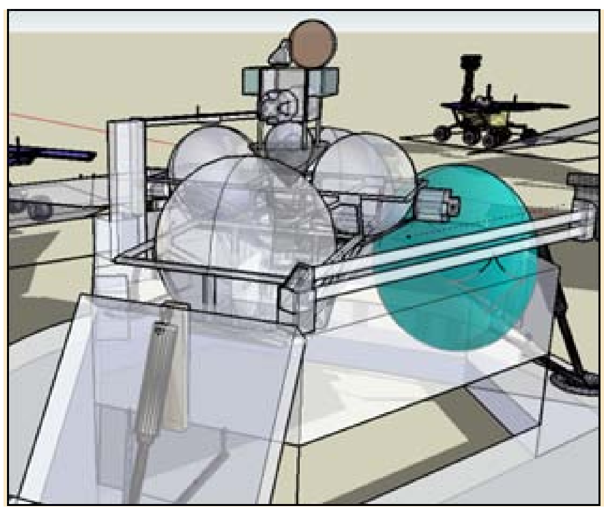

Figure 2: Translucent Rendering of Rigel.

Design Methodology: The main goal in phase one was to determine the design envelope in every parameter possible and then stay as far away from the edges as possible. A spreadsheet was built to calculate propellant masses for each stage, solar array size and mass required to make the propellant, engine masses, and so on. Every parameter possible was included, including tank sizes and masses based on propellant demands, and so on. In the end, the sheet calculated the minimal values and buffer amounts for over 40 major parameters, with thirty variants of each based on sample size. As the design progressed, it was also used in the third iteration to determine that the first stage should be used to circularize the orbit prior to the second stage returning the payload to Earth.

Full Global Landing Capacity: The Rigel design has three versions: An equatorial version that uses a single large solar array and rover. A mid-latitude version that uses two such arrays, and a polar version that dispensed with the hydrogen feedstock to drop a melt water probe down through the ice cap. The water extracted in this way is converted to propellant. Dust captured in the polar ice meltwater, along with the ice itself, is the sample return payload. This last option would have to launch a minimal payload into orbit long before the return window to Earth, because there wouldn't be enough time before winter to fully fuel a return vehicle.

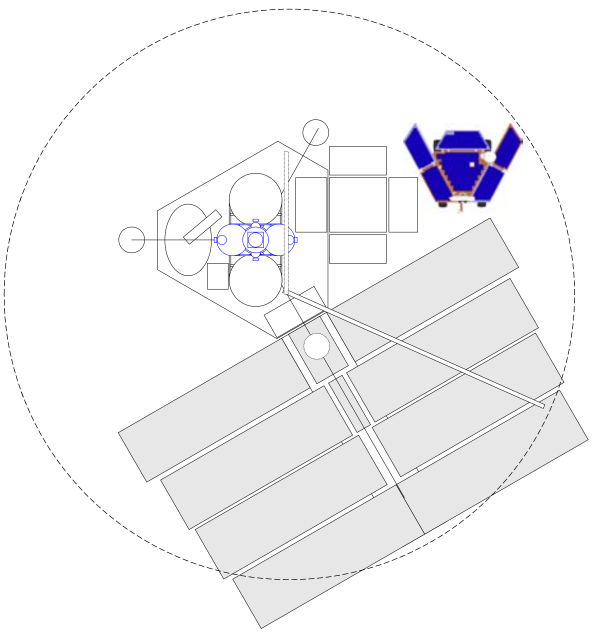

Figure 3: Rigel lander, MER-derived rover, and solar array to scale. Reach of main manipulator arm shown by circle relative to the solar array.

Reports Available: The Rigel design was refined once during the competition and expanded to 92 pages. It was also the basis for the Mars Workbench concept for crowdsourcing MSR component designs as a new competition. This came in second of the forty entrants in the Mars Society's Mars Project Challenge later in 2008.

Presentations are available on both Rigel and Mars Workbench concepts. The work in this project was also the source for the Sample Return Capsule and Sample Collection abstracts, also submitted to this workshop.