MARS IN SITU RESOURCE UTILIZATION TECHNOLOGY EVALUATION. A. C. Muscatello[1] and E. Santiago-Maldonado[2], [1]National Aeronautics and Space Administration-Kennedy Space Center, Surface Systems Office, NE-S2, Kennedy Space Center, FL 32899, anthony.c.muscatello@nasa.gov, [2]National Aeronautics and Space Administration-Kennedy Space Center, Surface Systems Office, NE-S2, Kennedy Space Center, FL 32899, edgardo.santiago-maldonado-1@nasa.gov.

Introduction: We have examined the technologies required to enable Mars In-Situ Resource Utilization (ISRU) because our understanding of Mars resources has changed significantly in the last five years as a result of recent robotic missions to the red planet [1-4]. Two major developments, (1) confirmation of the presence of near-surface water in the form of ice in very large amounts at high latitudes by the Phoenix Lander and (2) the likely existence of water at lower latitudes in the form of hydrates or ice in the top one meter of the regolith, have the potential to change ISRU technology selection. A brief technology assessment was performed for the most promising Mars atmospheric gas processing techniques: Reverse Water Gas Shift (RWGS) and Methanation (aka Sabatier), as well as an overview of soil processing technology to extract water from Martian soil.

Results: We conclude that the basic technologies needed to (1) concentrate carbon dioxide, nitrogen, and argon on Mars, (2) separate them, (3) process them into oxygen, methane, and buffer gases, and (4) store them for use are available at a relatively high level of development (technology readiness level: TRL 4-5) at the component level. Future work should be focused on engineering development and field demonstrations of integrated systems of these processes. The effort of developing integrated systems, with a focus on operational life-cycle testing, will reveal further technology needs required to design and build a full-scale flight system. Advanced technologies that promise improvements in the performance of these subsystems, such as ionic liquids for carbon dioxide collection and electrolysis to oxygen, low temperature electrolysis of carbon dioxide and water to methane and oxygen, microchannel collectors and reactors, and advanced cryogenic liquefaction and storage, deserve closer scrutiny and require more development. These technologies, with a TRL range of 2-4, have the potential to significantly improve in the overall performance of the Mars ISRU system: reduce mass, power, and volume and increase reliability and operational life-cycle.

In addition, current lunar soil processing technologies (i.e. excavation, soil reactor, and fluid processing) have applicability to Mars soil processing to extract water and these efforts should continue further development. It is expected that these integrated system engineering units will also reveal remaining vulnerabilities caused by interactions of the various subsystems that are currently unknown, leading to new technological needs. Once satisfactory performance is demonstrated in the laboratory, oxygen, propellant, and buffer gas engineering units should be demonstrated at analog Mars sites along with other surface systems to demonstrate a full operational cycle (resource acquisition, processing, purification, storage, and utilization) to raise the TRLs to the 5-6 range. The time is right to push the development of these technologies to give mission planners the information and confidence they need to use Mars ISRU, which is a powerful tool for reducing costs and expanding exploration capabilities for Mars missions.

Moreover, we recommend that the decision on whether hydrogen for oxygen and propellant production on Mars should be imported from Earth or obtained from Martian water sources should be the use of Mars water resources. Years of debate on whether it is feasible to transport hydrogen in liquid or slush form to Mars is not likely to be resolved in the near future. The best strategy, which also enables future Mars ISRU, is to use the water resources that are already known by direct measurement to exist on Mars. The problem is then simplified to something we can address: the development and demonstration of efficient Mars water mining and refining technologies, which would also provide pure water, another extremely useful supply item for human missions for both drinking water and radiation shielding.

One other extremely important advantage of this strategy is that the amount of oxygen and propellant that could be produced would no longer be limited to the amount of hydrogen brought from the Earth; a virtually unlimited supply would become available, restricted by only the lifetime of the hardware needed and the energy supply. Looking to the more distant future, this strategy is precisely what needed for a Mars outpost and a future Martian civilization. The availability of local Martian water resources will limit landing sites somewhat to known locations, but this is a minor disadvantage because Mars is a large planet with the same surface area as the continents of Earth. Furthermore, exploring sites with water would enhance the possibilities of finding signs of past or current Martian lifeforms, a significant scientific goal for Mars exploration.

References:

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