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Leveraging Terrestrial Industry for Utilization of Space Resources

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NASA's Journey to Mars: Pioneering Next Steps in Space Exploration released in October of 2015 states that NASA is working toward the capability to work, operate, and sustainably live safely beyond Earth. To progress from our current "Earth-Reliant" approach to exploration and eventually become "Earth Independent", we need to first identify resources in space and then learn to use and harvest them to minimize logistics from Earth, reduce costs, and enable sustainable and affordable space transportation and surface operations. Known as *In Situ* Resource Utilization (ISRU), the collection and conversion of space resources into products such as propellants, fuel cell reactants, and life support consumables can greatly reduce the mass, cost, and risk of space exploration. Also, the ability to perform civil engineering, construction, and manufacturing at sites of exploration can also allow for increased crew safety and sustainable growth in critical infrastructure. Much of what NASA wants to do on the Moon and Mars with respect to harnessing and utilizing space resources has been performed and perfected on Earth over the centuries. While minimizing mass and operating in the vacuum of space may be unique challenges to NASA, both terrestrial industry and NASA face many of the same challenges associated with operating in severe environments, minimizing maintenance and logistics, maximizing performance per unit mass and volume, performing remote and autonomous operations, and integrating hardware from many vendors and countries. In the end, both NASA and terrestrial industry need to obtain a return on the investment for the development and deployment of these capabilities.

This paper will first examine what is ISRU and what are the space resources of interest. The paper will than discuss what are NASA's approach, life cycle, and economic considerations for

implementing ISRU. The paper will outline the site and infrastructure needs associated with a phased implementation of ISRU into human missions to the Moon and Mars. The paper will than assess what technologies and operations from terrestrial industries are relevant and synergistic with ISRU (from prospecting to product storage), and what challenges and similarities between the two can be exploited. Lastly, the paper will end with a discussion on where do we go from here for industry and NASA to collaborate.