THE DEVELOPMENT AND PERSPECTIVES OF BIO-ISRU. I. I. Brown[1], D. H. Garrison[1], J. A. Jones[1], C.C. Allen[1], G. Sanders[1], S. A. Sarkisova[1], D. S. McKay[1]. [1]NASA JSC (Mail code: ARES-KA, 2101 NASA Road One, Houston, TX, 77058; igor.i.brown@nasa.gov; david.s.mckay@nasa.gov).

Introduction: In-situ production of consumables using local resources (In-Situ Resource Utilization-ISRU) will significantly facilitate current plans for human exploration and settlement of the solar system. With few exceptions [1], nearly all technology development to date has employed an approach based on inorganic chemistry [2]. None of these technologies include concepts for integrating the ISRU system with a bioregenerative life support system and a food production system. The investigation of Biotechnological (Bio) ISRU based on the metabolism of lower order photosynthetic organisms with ability to leach rocks and minerals appears to be very timely and relevant. Cyanobacteria (CB) are known as very effective producers of O_2, proteins, vitamins, immunomodulators [3] and as very effective litholyts [4] to supply themselves with different elements.

Using organic acids, bacteria are able to dissolve different rocks, including such hard rocks as volcanic glass [5], granites, hornblende, and basalts [6]. Bioweathering of lunar regolith has been considered by studies on the preparation of lunar-derived soil [7]. Because the Moon is practically free of organic compounds but is rich in inorganic elements, it makes sense to use autotrophic CB for future extraterrestrial biotechnologies [8].

Results: We have found that CB secrete organic acids when mixed with lunar regolith; secreted organic acids possess chelating properties. These chelators react with Fe^{2+} in lunar minerals such as ilmenite ($FeTiO_3$), ferrous oxides, and iron-bearing silicates (Fe_2SiO_4). Iron oxide interacts with acids liberating iron and generating water[1] (equation. 1):

$$FeO + 2\,H^+ \rightarrow Fe^{2+} + H_2O \quad (1).$$

If protons are generated by organic carboxylic acids, Fe^{2+} ions will coordinate with carboxylate oxygens (equation 2):

$$FeO + 2\,RCOOH \rightarrow (RCOO)2Fe^{2+} + H_2O \quad (2).$$

Newly generated water can be split into molecular O_2 and H_2 by CB, electrolysis, or both. The freed H_2 can be recycled in many (bio)chemical reactions. Dissolved iron species can be recovered by electrolysis of the growth medium at low temperatures.

Our concept of the development of a biotechnological loop for *in-situ* resources extraction, propellant and food production at the lunar outpost is based on the cultivation of litholytic CB with lunar regolith in a sunlight driven geobioreactor (Figure 1).

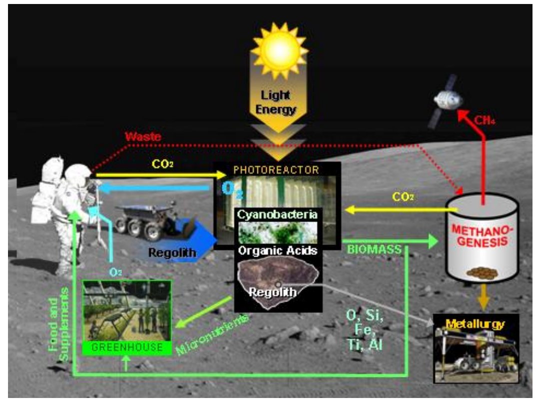

Fig. 1. Author's concept of a biotechnological loop for in situ resources extraction, propellant, and food production at the lunar outpost.

As a result of pilot studies, we are developing a concept for a semi-closed integrated system that uses a bioreactor containing CB for extracting useful elements from the regolith. This bioreactor, powered by sunlight, can revitalize air by utilization of CO_2 and production of O_2. Some components of cyanobacterial biomass can be used directly as nutritional supplements [3]. Such a system could be the foundation of a self-sustaining extraterrestrial outpost [9].

Perspectives: The most critical conclusion is that a semi-closed life support system tied to an ISRU biofacility might be more efficient for support of an extraterrestrial outpost than closed environmental systems. Such a synthesis of technological capability could decrease the demand for energy, transfer mass and cost of future exploration.

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