Biotechnologies at Lunar Outpost and Beyond. I.I. Brown[1], J.A. Jones[1], D. Garrison[1], D. Bayless[2], S.A. Sarkisova[1], G.B. Sanders[1], D.S. McKay[1]. [1]NASA JSC, 2101 NASA Parkway Houston, TX 77058, e-mail: igor.i.broun@nasa.gov; [2]Department of Mechanical Engineering, Ohio University, 248 Stocker Center, Athens, OH 45701, e: mail: bayless@ohio.edu.

Introduction: A major goal for the Vision of Space Exploration is to extend human presence across the solar system. With current technology, however, all required consumables for these missions (propellant, air, food, water) as well as habitable volume and shielding to support human explorers will need to be brought from Earth. In situ production of consumables (In Situ Resource Utilization-ISRU), such as propellants, life support gas management, as well as support system construction materials, will significantly facilitate human hopes for exploration and colonization of the solar system, especially in reducing the logistical overhead such as recurring launch mass.

Methods and Results:

Lithotrophic bacteria for ISRU: The most challenging technologies for future lunar settlements are the extraction of elements (e.g. Fe, O, Si, etc) from local rocks and soils for life support, industrial feedstock and the production of propellants. While such extraction can be accomplished by purely inorganic processes, the high energy requirements and typically high mass of such processes drive the search for alternative technologies with lower energy and mass requirements and sustainable efficiency. Currently employed terrestrial industrial biotechnologies for metals extraction and refining could provide a basic foundation for the development of extraterrestrial biometallurgy. Our preliminary data showed that this CB strain is able to secret 2 keto-glutaric acid which leaches ilmenite, a main mineralized resource of O_2 on Moon. Special experiment on the leaching activity of a cyanobacteriumJSC-12 revealed that this stain was able to dissolve 11 mg of ilmenite (initial amount 1200 mg) during one month under non-optimized conditions.

Methanogenic bacteria for carbon recycling: Future systems for organic waste utilization in space may also benefit from the use of specific microorganisms. This janitorial job is efficiently carried out by microbes on Earth, which drive and connect different elemental cycles. It is possible that bioregenerative environmental control and life support systems will be capable of converting both organic and inorganic components of the waste at lunar settlements into edible biomass, thereby conserving precious carbon, nitrogen and sulfur.

Phototrophic bacteria for LSS: The life support, fuel production and material processing systems currently proposed for spaceflight are not completely integrated. The only bioregenerative life support system that has been evaluated on a habitat scale by NASA employed production from highest orders plants. This system has been proposed as a subsystem for a more comprehensive bioregenerative life support systems, even though the efficiency of higher plants for atmospheric revitalization is generally low. Thus, with the release of the NASA Lunar Architecture Team lunar mission strategy, the investigation of more efficient air bioregeneration techniques based on the metabolism of lower order photosynthetic organisms with higher capacity of CO_2 scrubbing and O_2 release appears to be very timely and relevant. The European Micro-Ecological Life Support System Alternative (MELiSSA) is an advanced idea for organizing a bioregenerative system for long term space flights and extraterrestrial settlements. In particular, feeding animals suffering from radiation-induced lesions, *c*-phycocyanin, extracted from strain 27G, led to a correction in the decrement of dehydrogenase activity and energy-rich phosphate levels, as well as improved antioxidant defense and pyruvate levels, compared to untreated animals [1].

We propose additional development and refinement of the MELiSSA system by the employment of the blue-green alga strain *Spirulina,* which possesses increased productivity of 50% of the essential amino acids, immunomodulators for astronaut health maintenance, as well as by the possible addition of biometallurgy and fuel production to the life support cycle.

Conclusion: Despite the harsh lunar environmental conditions, it seems possible to cultivate photosynthetic microorganisms using a closed bioreactor illuminated and heated by solar energy. Such bioprocessing might be employed in critical ISRU functions, e.g. air revitalization, propellant (oxygen and methane) and food production, and divalent cation extraction.

Thus, the most critical feature of our project is the proposal to combine biometallurgy with food and propellant production, to form an integrated bioindustrial system that would be the core of successful lunar outpost sustainability and growth. Such a synthesis of technological capability, as embodied in a lunar surface ISRU bioreactor, could decrease the demand for energy, transfer mass and cost of future lunar settlements.

Reference:

[1]. Bayless, D., Brown, II, *et all.* (2006) *HABITATION 2006.* Abstract #28.