**BIOLOGY AS A KEY TECHNOLOGICAL FOUNDATION FOR SETTLEMENT BEYOND EARTH.** L. J. Rothschild[1], J. Navarrete[2], R. E. Kent[3], G. McCutcheon[4], E. Pless[5], and I. G. Paulino-Lima[3], [1]NASA Ames Research Center, Mail Stop 239-20, Moffett Field, CA 94035 USA, Lynn.J.Rothschild@nasa.gov, [2]UC Santa Cruz at NASA Ames Research Center, Mail Stop 239-20, Moffett Field, CA, 94035 USA, junavarr@ucsc.edu, [3]Universities Space Research Association at NASA Ames Research Center, Mail Stop 239-20, Moffett Field, CA, 94035 USA, ryanearlek@gmail.com, ivan.g.paulinolima@nasa.gov, [4]NASA Millennium Engineering and Integration Co. at NASA Ames Research Center, Mail Stop 239-20, Moffett Field, CA, 94035 USA, griffin.c.mccutcheon@nasa.gov, [5]Department of Ecology and Evolution, Yale University, New Haven, CT 06511 USA, evlyn.pless@yale.edu

**The Problem.** Moving materials beyond Earth, whether spacecraft, living organisms, or both, is limited by mass constraints. Yet human survival requires an extensive infrastructure, from environmental regulation to life support. In practice this means habitats, food, oxygen, waste recycling, medicine and so on. Thus, there is a mismatch between what will be required in transit and at destination to fufill dreams of human settlements and what can realistically moved there. Further, settlement off planet with current transportation systems requires the ability to operate independently of the Earth for prolonged periods of time, requiring long-term storage of supplies and the flexibility to satisfy new needs.

**The vision [1].** Living off the land through *in situ* resource utilization (ISRU) will be vital, just as human migrations through Africa into Europe, the Middle East and beyond in the past have required the exploitation of local resources. The difference is that the infrastructure for human survival is not "user ready" elsewhere in our solar system. Some aspects of the infrastructure, such as habitats, could be built with locally-sourced materials but in the end, biological organsisms need a biological infrastructure. Now imagine a technology that is self-replicating and self-repairing, which in principle couldcircumvent the mass problem. Biology itself is that technology that can be used to build other aspects of the infrastructure such as clothing. Key to the use of biology as a technology for space is the ability to reprogram it through synthetic biology. Thus we can exploit the genetic hardware store inherent in our vast biodiversity moving capabilities from familiar forms such as trees for wood or sheep for wool to a more tractable space-faring chassis such as yeast or bacteria. Our lab has produced a variety of proof-of-concepts, such as engineering bacteria to mine metals from the regolith or spent electronics and producing nanocellulose, and exploited bioprinting to add hierarchical structure.

**Necessary steps.** In order to realize synthetic biology enabled settlement, issues such as the inputs for the production organisms must be dealt with. We have proposed "PowerCell" – a cyanobacterial interface between the raw materials on targets such as Mars and the production organisms [2,3]. In this vision, a diazotrophic cyanobacterium uses locally-sourced light, water, $CO_2$ and $N_2$ to produce fixed nitrogen and organic compounds that can then sustain a production organism such as a yeast. The production organisms then are engineered to produce a plethora of products, from food to glues to agglutinate the regolith, smart biosensors, clothes and so on. With the aid of synthetic biology, novel materials potentially with embedded biosensors could be imagined such as a nanocellulose-keratin composite or even balloons [4] and uncrewed arial systems (UAS) [5].

**Flight tests.** Synthetic biology requires technologies that may work differently in other gravity regimes. To this end, NASA's PowerCell Payload on the DLR Eu:CROPIS (*Euglena* Combined Regenerative Organic-food Production In Space) mission, will test the effect of gravity (approximating icrogravity, lunar and martian) on the growth of a common synthetic biology chassis organism, *Bacillus subtilus*, transformation and protein synthesis. The PowerCell concept also will be tested under the three gravity regimes. The 18 month mission is scheduled to launch in 2017.

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