PowerCell Payload on Eu:CROPIS - Measuring Synthetic Biology in Space

A collaboration between NASA and DLR

**NASA Ames PowerCell Payload**

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2011 Brown-Stanford iGEM team (PowerCell)
2013 Stanford-Brown iGEM team (Eu:CROPIS)

**Eu:CROPIS**

Euglena Combined Regenerative Organic Food Production In Space
DLR satellite mission
scheduled launch: March 2017

DLR principals:
Hartmut Müller – Eu:CROPIS PM
Michael Leibert & Jens Hauslage Eu:CROPIS
Science & Technology
What is PowerCell?

- Investigating gravitational effects on synthetic biology
- Microfluidics platform based on PharmaSat design
- 2017 launch aboard the DLR’s Eu:CROPIS mission
What is Synthetic Biology?

“Synthetic biology, the design and wholesale construction of new biological parts and systems, and the re-design of existing, natural biological systems for tailored purposes, integrates engineering and computer-assisted design approaches with biological research.”

-White House National Bioeconomy Blueprint, 2012
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<th>Needs</th>
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<td>Upmass/ Cost</td>
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<td>Habitats</td>
<td>Volume</td>
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<td>Life support (food, oxygen, medicine, waste recycling, clothing, etc.)</td>
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Synthetic Biology: Enabling Exploration

• Genetically engineered organisms are a self-replicating and flexible platform for food, material, and specialty chemical synthesis.

• Microbes = robust nanofactories
  • “Fuel” brought from Earth, acquired in transit, or in situ.

• Genes are just information: Data transferred and recreated onsite
The Grand Vision

Production Cells Fed & Printed
- input: organic compounds, fixed N, O₂
- output: are fed by photosynthetic cells and used as “ink” for bioprinter

Material Production
- inputs: induction of cells
- outputs: structured materials of positioned and/or cross-linked biopolymers

PowerCell
- input: local resources (ISRU) (sunlight, CO₂, N₂, minerals) feed photosynthetic cells
- output: organic compounds, fixed N, O₂

Products
- fabrics
- clothing
- filters
- aerospace
- medical devices
- balloons
- sensors
Stanford Brown 2011: Original PowerCell Concept

Natural System

- Plants
  - Oxygen, Textiles, Wood, Medicine
- Animals
  - Textiles, Vitamins, Specialty chemicals

- Large infrastructure requirements
- High volume
- Inefficient mass conversion
- Inflexible, limited range of products
Engineered Ecology

- Photosynthetic microbes produce nutrients
- Feed productive microbes
- Programmed tasks
  - Chemical, Material or Food production?

- Algae
  - *Anabaena*
  - *Synechococcus*

- Microbial Producers
  - *Bacillus subtilis*
  - *Saccharomyces cerevisiae*

- Engineered Products
  - Medicine, Vitamins
  - Biomaterials
  - Specialty Chemicals
Anabaena spp. 7120

- Phototrophic
- Nitrogen-fixing
- Modified to secrete sucrose
Challenges of Space

• How can we operate bioreactors in Zero-G?
  • Bioculture System

• Radiation Effect on microorganisms
  • BioSentinel Mission

• How does variable gravity impact synthetic biology?
  • PowerCell: Genetic competency, Transformation, Protein production
Microgravity and Microbes

- Low convection
- Low hydrostatic pressure
- How does gravitational gradient differ from microgravity stress?
- Impact on synthetic biology?
Research Goals: Effect of Gravitational Gradient
1.4-52% of Earth Gravity

• Cell growth
  • Does nutrient convection follow linear relationship?
• Genetic Transformation
  • Does hydrostatic pressure influence DNA uptake?
• Protein production under gravitational gradient
  • Are controlling genes affected in a switch-like or linear manner?
• Proof-of-concept growth using “PowerCell” nutrients
Fluidic Card

- 48 Experimental Wells
- 70 μl volume
- 0.22 micron filters isolate samples
Optical System

- Optical Density based detection
  - 440, 515, 636 nm LEDs
- TAOS Light-to-Frequency photon detector
- Allows detection of bulk cells, colorimetric assays, photosynthetic pigments
Our Tools: The PowerCell Hardware

- PharmaSat Heritage
- Four experiment modules
- Microfluidic Experiment Card
- Three-Color optical density (OD) measurement system
- Thermal Control
Experiments: Protein Production

- *B. subtilis* 1A976 - model production organism
- Comparing promoter activity
  - veg, liaG promotor sequences
- X-Gluc assay
- Measure via LED absorbance ratios
  - 636nm: X-Gluc
  - 515nm: Cell Growth
PowerCell on Eu:CROPIS

• Synthetic Biology is an enabling technology for space exploration
• Measuring effect of gravitational force on performance
• Flexible, easy-to-use hardware for biological experiments
PowerCell onboard DLR Eu:CROPIS Mission