NASAfacts

Space Technology
Game Changing Development
Synthetic Biology: Biomanufacturing in Space

Overview

As we extend our reach into space, there is a need to make missions more self-sustaining. Conducting long-duration lunar and Mars missions will require that we minimize the amounts of supplies launched, increase reuse and recycling, and use local resources to make crucial products for the crew.

In an effort to improve the capability and efficiency of current chemical and mechanical life support systems, researchers are investigating the role of biology-based techniques. For example, plant growth systems are being developed to produce food and convert carbon dioxide to oxygen. Biological wastewater systems are also being developed to make current water treatment technologies more sustainable. Future missions will also a need to make complex organic products such as vitamins, medicines, bioplastics, adhesives, fuels, and many other chemicals from local resources to reduce launch mass and address product shelf-life issues.

The Space Synthetic Biology (SynBio) project is performing research and development at NASA's Ames Research Center in California's Silicon Valley to demonstrate the ability of advanced biotechnology methods to impact mission architectures by developing biomanufacturing methods that can produce high-value products on-demand, and using local resources.

BioNutrients Flight Experiment

Upcoming extended missions to the Moon and Mars pose significant challenges in maintaining astronaut health. A critical need is supplying adequate nutrition from stored foods.

BioNutrients on-orbit production pack.

Studies have shown that certain vitamins and nutrients in supplied foods and supplements degrade during extended storage. A deficiency in only one required nutrient can lead to serious diseases such as scurvy (vitamin C deficiency).

The BioNutrients project is demonstrating a platform technology for the on-demand, in-space production of critical nutrients. The concept is similar to making familiar fermented foods like yogurt, but in this case with a focus on the production of a very specific quantity and quality of nutritive products.

A five-year BioNutrients system demonstration on the ISS began on April 2019. The on-orbit vitamin production process utilizes a small "production pack" system that encloses a dried, edible, extended shelf-life growth substrate and baker's yeast that has been genetically engineered to produce specific antioxidants. Periodically over the five-year demonstration, the crew will add water to the pack to activate it, grow it in an incubator, and then freeze the pack before returning to Earth for further analyses. When this technology is ready for operational use, the crew would activate a packet to grow what is needed, heat treat it for safety and then consume.

Additional BioNutrients studies include storing and returning different microbial strains to assess their long-term survival in the space environment. Strains include probiotic organisms, yogurt-producing strains, and strains that have been engineered for increased desiccation tolerance. Genetic analyses will be conducted to determine if organisms that survive long periods demonstrate unique properties that adapt them to space. These properties could then be used to engineer "space-adapted" production host organisms.

CO_2-Based Manufacturing for Mission Extensibility

While the BioNutrients project is using premade microbial media, being able to make microbial media using local resources will enable biomanufacturing of much larger quantities of mission products. To address this need, SynBio's CO_2-Based Manufacturing project is developing a platform technology that uses non-biological methods to rapidly convert carbon dioxide and water to organic compounds that then "feed" microbial biomanufacturing systems to make a wide range of products. Because this approach is rapid, energy efficient, and low waste, it could surpass common photosynthetic processes. Ample carbon dioxide is readily available in spacecraft and habitats from human respiration and solid waste processing during future lunar missions. Carbon dioxide is also available from the Martian atmosphere.

A major technical challenge with this approach involves the development of novel non-biological Carbon dioxide conversion systems that can make microbially favorable substrates. Other biomanufacturing efforts outside SynBio include the work by academic partners at Stanford University and the Space Technology Research Institute the Center for the Utilization of Biological Engineering for Space, who are working to create advanced media synthesis methods to support biomanufacturing. In addition, the NASA CO_2 Conversion Centennial Challenge competition, announced in 2018, is currently focused on the production of glucose and other sugars from Carbon dioxide. As substrate quality increases, bioreactor efficiency will also increase and allow use in NASA's future long-duration habitation missions.

Game Changing Development Program

The Game Changing Development (GCD) program is part of NASA's Space Technology Mission Directorate. The GCD Program aims to advance exploratory concepts and deliver technology solutions that enable new capabilities or radically alter current approaches.

For more information about GCD, please visit http://gameon.nasa.gov/

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