

## **ABSTRACT**

Agricultural systems for space have been discussed since the works of Tsiolkovsky in the early 20th century. Central to the concept is the use of photosynthetic organisms and light to generate oxygen and food. Research in the area started in the 1950s and 60s through the works of Jack Myers and others, who studied algae for O<sub>2</sub> production and CO<sub>2</sub> removal for the US Air Force and the National Aeronautics and Space Administration (NASA). Studies on algal production and controlled environment agriculture were also carried out by Russian researchers in Krasnoyarsk, Siberia beginning in the 1960s including tests with human crews whose air, water, and much of their food were provided by wheat and other crops. NASA initiated its Controlled Ecological Life Support Systems (CELSS) Program ca. 1980 with testing focused on controlled environment production of wheat, soybean, potato, lettuce, and sweet potato. Findings from these studies were then used to conduct tests in a 20 m<sup>2</sup>, atmospherically closed chamber located at Kennedy Space Center. Related tests with humans and crops were conducted at NASA's Johnson Space Center in the 1990s. About this same time, Japanese researchers developed a Controlled Ecological Experiment Facility (CEEF) in Aomori Prefecture to conduct closed system studies with plants, humans, animals, and waste recycling systems. CEEF had 150 m<sup>2</sup> of plant growth area, which provided a near-complete diet along with air and water regeneration for two humans and two goats. The European Space Agency MELiSSA Project began in the late 1980s and pursued ecological approaches for providing gas, water and materials recycling for space life support, and later expanded to include plant testing. A Canadian research team at the University of Guelph developed a research facility ca. 1994 for space crop research. The Canadian team eventually developed sophisticated canopy-scale hypobaric plant production chambers ca. 2000 for testing crops for space, and have since expanded their testing for a wide range of controlled environment agriculture topics. Most recently, a group at Beihang University in Beijing designed, built and tested a closed life support facility (Lunar Palace 1), which included a 69-m<sup>2</sup> agricultural module for air, water, and food production for three humans. As a result of these studies for space agriculture, novel technologies and findings have been produced; this includes the first use of light emitting diodes for growing crops, one of the first demonstrations of vertical agriculture, use of hydroponic approaches for subterranean crops like potato and sweet potato, crop yields that surpassed reported record field yields, the ability to quantify volatile organic compound production (e.g., ethylene) from whole crop stands, innovative approaches for controlling water delivery, approaches for processing and recycling wastes back to crop production systems, and more. The theme of agriculture for space has contributed to, and benefited from terrestrial, controlled environment agriculture and will continue to do so into the future.

## **AGRICULTURE FOR SPACE: PEOPLE AND PLACES PAVING THE WAY**

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