

**NCERA-101 Station Report  
Sierra Space, Madison WI**

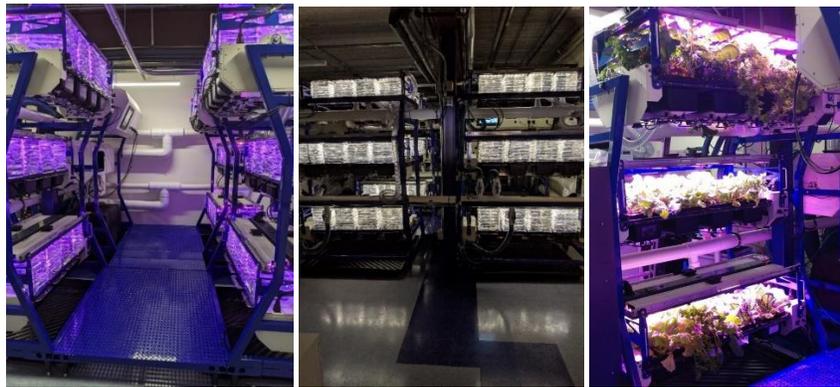
**April 1, 2019 – October 29, 2021**

Robert C. Morrow, 1212 Fourier Drive, Madison WI, 53717  
Phone: 608 229-2728, E-mail: [robert.morrow@sncorp.com](mailto:robert.morrow@sncorp.com)

## 1. New Facilities and Equipment.

### Sierra Space Controlled Environment Plant Facilities

Sierra Space is in the process of testing the Astro Garden® test facility (Figure 1). The Astro Garden is a testbed for vegetable crop production in space habitations. The system has approximately 5.4 m<sup>2</sup> of growing area and most of the subsystems are designed to be gravity independent for operation. The testbed provides temperature, humidity, CO<sub>2</sub> control, and nutrient solution control. Root zones currently use aeroponics but are modular so alternative technologies can be tested. Lighting is provided by red, blue and white LEDs. Each module has individual control of light level, photoperiod and light quality. The system also has a mechanism for capturing transpired water. Astro Garden was configured to meet the NASA Exploration Life Support Salad Crop Diet production requirements.



**Figure 1. Astro Garden system with nine growing modules and three atmospheric control, fluid system, and electronics modules.**

## 2. Unique Plant Responses.

Nothing to report.

## 3. Accomplishment Summaries.

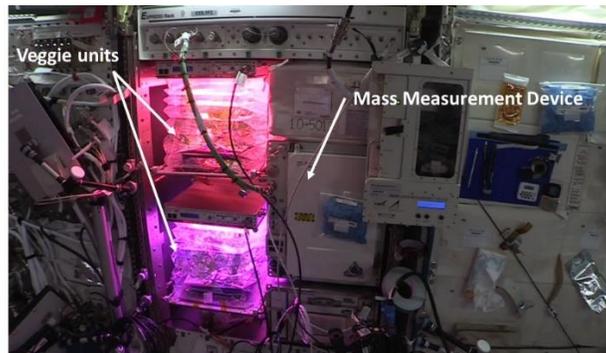
### Hybrid Life Support Systems- Plant Culture Units

Sierra Space is continuing work on the development of Exploration Life Support Salad Crop production as an early stage implementation of hybrid life support systems (combination of bioregenerative and physical-chemical life support technologies). Current efforts include development of aeroponic and nutrient film hydroponic (soilless) systems and variable plant spacing systems for use in the space environment. This continues our efforts to develop advanced subsystems (e.g. LED lighting, porous interface transpiration recovery) that significantly reduce the mass, power, and volume of microgravity plant production.

Our current efforts included a series of parabolic flights investigating aeroponic and nutrient film systems for use in microgravity, and a technology demonstration experiment for the ISS called the Exposed Roots On Orbit Test System (XROOTS) to look at these same parameters in long duration microgravity. We are preparing the XROOTS payload for flight in early 2022.

### Space Biology

Sierra Space continues to work with the Kennedy Space Center to support the two Veggie plant growth systems and the Mass Measurement Device (for support of animal and plant sciences) currently operating on the ISS (Figure 2).



**Figure 2. Image of the two Sierra Space Veggie plant growth units and the Sierra Space Mass Measurement Device on the ISS.**

The Advanced Plant Habitat (APH) that Sierra Space fabricated for the Kennedy Space Center is operating on the ISS to support a wide range of microgravity plant research. This system is the largest plant growth system put in space to date. We are currently providing engineering support to APH as it continues operations on the ISS (Figure 3).



**Figure 3. Radish plants growing inside the Advanced Plant Habitat on ISS (NASA image ss064e013129 Dec. 20, 2020).**

### Environmental Control & Life Support Systems

#### ***LIFE™ (Large Integrated Flexible Environment) Habitat***

Sierra Space continues to work with commercial partners for development of human Life Support and Thermal Control systems for space habitats. Sierra Space has moved their full-scale mockup of its LIFE module (shown in Figure 4) to NASA Kennedy Space Center. This system is being designed to support a 1,100-day mission and is currently part an effort to develop a large commercial space station (Figure 5).



**Figure 4. Sierra Space LIFE module mockup. Left-view of inflatable structure. Center and Right-Interior views of habitat.**



**Figure 5. LIFE modules as part of commercial Orbital Reef Space Station development.**

#### **4. Impact Statements**

- Sierra Space is working toward development of hybrid life support systems for space applications, integrating biological and physical/chemical technologies.
- Sierra Space is advancing the technology of controlled environment systems to meet the performance and quality needs of long duration space applications. Some of this technology may be transferable and scalable to terrestrial protected agriculture systems.
- Sierra Space continues to develop LED lighting configurations and control strategies for plant and human habitat lighting applications to provide increased lighting system utility for aerospace and gravitational biology applications.
- Sierra Space continues to use its space biology controlled environment work and human life support work to spark interest in high school and college students in controlled environment technology and STEM.

#### **5. Published Written Works.**

Morrow, R., J. Wetzel, and C. Loyd. 2019. Expanded Set of Criteria for Life Support Comparative Assessment. 49th ICES, paper 2019-07-07.

Moffatt, S., R. Morrow, and J. Wetzel. 2019. Astro Garden Aeroponic Plant Growth System Design Evolution. 49th International Conference on Environmental Systems, 2019-07-07

#### **6. Scientific and Outreach Oral Presentations.**

Morrow, R.C. 2021. Light for life: Innovative Approach for Future Food Production in Space. ISHS Light 2021, Invited keynote speaker.

Wetzel, J. P., R.C. Morrow, and J. Valania. 2021. Space Research Applications for Large-scale Habitat. *ASGSR Annual Conference (Abstract)*.

Morrow, R.C., J.P. Wetzel, and S. Moffatt. 2021. Astro Garden Salad Crop Production System Demonstration Testing. *ASGSR Annual Conference (Abstract)*.

Morrow, R.C., J.P. Wetzel, G. Tellez, and S. Moffatt. 2019. Astro Garden large-scale microgravity crop growth system. *ASGSR Annual Conference (Abstract)*.

#### **7. Other relevant accomplishments, news and activities.**

Sierra Space is a new company being transitioned from the Space Systems Group of Sierra Nevada Corporation as of June 1, 2021. The Sierra Space group that was originally the small business ORBITEC continues to operate in facilities located in Madison, Middleton, and Baraboo Wisconsin.

#### **8. Websites:**

Sierra Space <https://sierraspace.com>