HYBRID LIFE SUPPORT SYSTEM TECHNOLOGY DEMONSTRATIONS. R.C. Morrow[1], J.P. Wetzel[1], and R.C. Richter[1]. [1]Sierra Nevada Corporation, 1212 Fourier Drive, Madison, WI 53717 (robert.morrow@sncorp.com), (john.wetzel@sncorp.com), (Robert.richter@sncorp.com).

Hybrid Life Support Systems (HLSS) integrate biological components with physical-chemical components to increase system closure while reducing power and mass in space habitats. SNC is working to develop precursor plant growth components for HLSS, with a plan to evolve the technology developed for smaller International Space Station (ISS) systems into large, standalone systems that can provide significant levels of supplemental food production. This phased approach transitions plant growth technologies from ground-based development, to component and subsystem testing, to mission testing of subscale and full-scale system technologies. This provides a point of departure for transition of these technologies into larger integrated ground and flight testbeds to allow validation of system function and reliability prior to demonstration in a long-duration Low Earth Orbit (LEO) or cis-lunar environment in preparation for Mars transit missions. Plant growth systems first flew in space in the 1960s, and plant payloads since that time have emphasized fundamental gravitational biology research and the capability of plants to play a role in human life support. As part of this process, component technologies for plant growth in reduced gravity have been developed and refined, and testing of subsystems and systems on a small scale have been conducted on the ISS. A renewed emphasis on flight-testing early precursors to plant-based life-support has begun through the development of small-scale crop production systems such as the Veggie units currently growing edible crop plants on ISS. Efforts are now oriented to evolve these precursor crop-production units to larger growing systems that may become components of a HLSS for deep space use. One current effort is the GreenWall modular garden system developed to meet the requirements of NASA's Exploration Life Support (ELS) salad crop architecture. Demonstration flights with this system would advance the Technology Readiness Level (TRL) of plant support technologies for space applications, validate scaled-up current space-based plant growth system technologies to levels appropriate for life support applications, and generate data to understand bioregenerative systems operating in the space environment. These technology demonstrations would also clarify challenges of hybrid life support by demonstrating configurations that adhere to real-life space vehicle and space operational constraints, and provide data necessary to better evaluate hybrid architectures for different mission scenarios.

SNC proposes to demonstrate a scaled-up microgravity compatible plant growth system and to validate the integration between plant chamber and ECLSS systems, primarily atmospheric composition control and water recovery components. Potential technology demonstration test parameters include:

- Microgravity food production on a scale sufficient to impact crew diet
- Impacts on vehicle atmosphere control systems
- Alternative low ESM nutrient delivery systems
- Biological system reliability
- Plant physiological responses in microgravity
- Radiation shielding potential
- Interface dynamics between biological & physical/chemical life support subsystems
- Plant culture protocols in µg
- Salad crop production protocols
- Microbial food safety
- Role of plant systems in improving human habitability in space
- Operational and crop protocols to accommodate dormant, uncrewed habitat phases

Test durations of 30 days or more would allow testing with crops like leafy greens and radishes. Longer test durations would enable testing with fruiting crops or testing of alternative cropping protocols such as "cut and come again". Test profiles could include sequential harvests and plantings, or the continued harvests of the same plant over time. The GreenWall unit operation would be initiated and the payload would operate on an automated growing cycle (lighting, water and nutrient delivery) with minimal crew oversight. Experiment data would be obtained through imaging and data communicated to the ground daily for analysis. At crop maturity plants would be harvested by the crew with an option for consumption. Some plant tissue would be frozen for return to ground for detailed analysis. Inedible plant tissue or unused tissue would be packed as trash for disposal. In addition to operational and performance data on HLSS, these tests would enhance the quality of the crews' habitation during these missions by providing food augmentation, producing fresh food for nutritional and psychological benefits, while providing a potential radiation shelter. One current Greenwall module has 0.74 m^2 of growing area and a volume of 0.9m^3 (1.2m L x 0.6m H x 0.6m W), with a mass of 43kg and a max power draw of 530W. For scaling purposes, plant systems for conducting HLSS research in LEO or cis-lunar space would require approximately a power density of 716W/m^2 and a mass density of 58kg/m^2.