

# Distributive Life Support Testing

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## Abstract

### Distributive Life Support Testing:

Presently, the National Aeronautics and Space Administration (NASA) research indicates that Closed Ecological Life Support Systems (CELSS) cannot achieve a payback on a mass basis until after 15 years mission length, based on current technology. There are well documented reasons to expect that this number (15 years) can be reduced by investigation of specific hardware problems. However, because of NASA's mission profile based priorities this result may deny CELSS the research funding required to develop the science behind "go to stay" scenarios. This would make a "flags and footprints"-based life support system the inevitable NASA research priority. Also, this means that if truly long-term life support (go to stay) is to be competitively developed past the theoretical phase, then organizations like the Mars Society may play a key role. Three areas where this is particularly true are:

- Development of a broad and flexible body of knowledge (database) in the use of appropriate hardware and techniques related to long term life support systems that are likely to be overlooked or receive insufficient funding at NASA.
- Development of a broad interdisciplinary group of knowledgeable and competent researchers on the model of the backyard astronomers involved in Near Earth Asteroid (NEA) research.
- Development of an open ended forum organization (coop or working group) among Mars Society members to act as a working group and information point of contact for independent researchers in CELSS.

There are five specific areas of CELSS-related research in which any committed Mars Society (or other space Active organization) member could make real and valuable contributions to the state of the art. These areas are:

- Advanced water treatment technology process validation
- Composting and digester technology process validation
- Applied greenhouse and hydroponic controls and CELSS integration
- Extremeophile (lichen and microorganism) culture
- Inflatable structure and waste treatment (solid and wastewater) system field testing in extreme environments

This paper is primarily dedicated to the serious examination of meaningful garage and backyard science opportunities in the above five areas, and ends with an encouragement for Mars Society members and their counterparts in other space development oriented organizations that are interested in these areas to come together in an active research coop.

## Introduction

Current National Aeronautics and Space Administration (NASA) Closed Ecological Life Support Systems (CELSS) utilizing vascular plants have long projected mass payback time projections. Studies at NASA Ames Research Center (ARC) relating to probable time to payback based on power considerations indicates a 15 year payback (Flynn and Borchers)<sup>1</sup> for CELSS mass and energy requirements (based on 1997 state of the art). This exceeds all reasonable mission planning in length, and indicates that CELSS is a reasonable life support system only for permanent basing. This study also indicated that mass payback time could be greatly reduced with targeted research. However, based on NASA's current Low Earth Orbit (LEO) focus for the foreseeable future, large scale funding for CELSS will remain difficult. This situation will mean that the coordination efforts and direct research efforts of Non-Governmental Organizations (NGOs) like the Mars Society can play a critical role in forming and promoting these technologies.

### **Flight Hardware vs. Base / Community Infrastructure**

One of the primary difficulties associated with CELSS development is the different, and sometimes contradictory, goals of in space (transit) and surface life support systems (Cohen).<sup>2</sup> Interplanetary transit habitations have no in-situ resources for use, or to defray lifting mass costs in construction. Radiation and zero gravity add design requirements (and thus mass) to the transit habitat that are not required on the surface. The difference between transit and surface can be summed up as the difference between aerospace life support and base infrastructure. NASA, over a period of 40 years, has provided an excellent knowledge base for CELSS as short- to medium-term life support, but a permanent human presence on Mars (or any other planetary body other than Earth) requires getting off life support quickly and moving to a form of CELSS that is a base and/or community infrastructure. This transition should start at touchdown of the first manned mission.

Base and community infrastructures in extreme environments on Earth have been and are being used as analog test beds. Amundsen-Scott South Pole Station has been a subject of cooperative research in this area (Flynn et al).<sup>3,4</sup> It is likely that infrastructure engineering in the Antarctica, at sea on submarines, and in various sanitary applications in the Arctic and in high altitude settings has equal application to planetary habitats as does NASA CELSS research to date. Due to the environmental impact constraints being placed on Antarctica, Arctic, and high altitude recreational, scientific and recreational support service development, it is likely that sanitary / environmental engineering and technology development in the private sector has out-stripped NASA planetary CELSS research in critical areas. The Mars Society and other NGOs (National Space Society, Planetary Society, etc.) could play a fundamental and important roll in developing planetary habitat technology and system architecture by leveraging this private sector engineering.

### **A Model For NGO Coops For CELSS Research**

Coops in the Mars Society already exist in the form of working groups. The Mars Society Technical Working Group (MSTWG) and the Green CELSS Task Force (Green CELSS) are organized to facilitate discussion of these issues. In order to leverage these and other similar groups three basic organizational goals should be pursued.

- Develop a broad and flexible body of knowledge (database) in the use of appropriate hardware and techniques related to long term life support systems that are likely to be overlooked or not receive insufficient funding at NASA.
- Develop a broad interdisciplinary group of knowledgeable and competent researchers on the model of the backyard astronomers involved in Near Earth Asteroid (NEA) research.
- Develop an open-ended forum organization (coop or working group) among Mars Society members to act as a working group and information point of contact for independent researchers in CELSS.

MSTWG has started the process. However, work in all three areas is needed to develop a coop while maintaining an open and welcoming atmosphere. Potential hobby and craftsmen participants are as essential as research engineers and scientist if off-the-shelf leverage and broad analog environment testing is to be effective. MSTWG has been developed to provide this welcoming atmosphere that is essential. A high level dialogue on addressing the above three areas of development could leverage current Mars Society efforts. This dialogue should include specific recommendations for productive research.

### **Specific Research Opportunities**

The next step is to develop specific research projects with a high potential of payback that can be undertaken by MSTWG members that are not affiliated with NASA or any other large supporting groups. Also, these research efforts should be organized so that members with practical skill can play a real and legitimate roll. There are five specific areas of CELSS related research in which any committed Space Active NGO member could make real and valuable contributions to the state of the art. These areas are:

- Advanced water treatment technology process validation
- Composting and digester technology process validation
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### **Advanced Water Treatment Technology Process Validation**

Public water systems and private wells throughout the United State and the world are experiencing ever-increasing difficulty achieving basic drinking water quality standards. This is as true for ordinary urban residences as well as residences of what are traditionally thought of as “underdeveloped” areas. Serious consideration is being given to a more distributive system approach to both municipal water and wastewater systems. This would mean the development and wide application of small water and wastewater treatment technologies at the city block or in-house level. Many of these small systems resemble CELSS relevant hardware. The present market for this hardware is the under sink or whole-house water treatment system for the concerned citizen. Because these water quality degradations effect the personal security of individual Mars Society (or other space NGO) members, the development of a database for members to receive free information on these technologies and services from qualified experts relating to their effectivity would provide a basis for advanced off-the-self water treatment technology process validation. Highly CELSS compatible water treatment technologies could be selected, studied, improved, and eventually fully validated for CELSS use using Space Active NGO homes while simultaneously providing a valuable membership benefit for these organizations.

### **Composting and Digester Technology Process Validation**

Composting and digester technology process validation offers a similar opportunity to water treatment, but more in a hobbyist role. Composting is already central to the organic gardening culture. Special products are available in the form of garden composters, composting toilets, snail farms, and dog feces composers, among many other examples. The Green CELSS coop appears to be highly leveraged in this area, based on current e-mail traffic. Better coordination among this group and the avid gardeners, trade craftsmen, and engineering professionals in the space NGOs could develop into an excellent and rigorous test program. Also, zero emission incineration units could also be investigated (Fisher et al).<sup>5</sup>

### **Applied Greenhouse and Hydroponic Controls and CELSS Integration**

NASA Ames Research Center has published excellent work on CELSS system control for systems using off-the-self hardware (Bates and Bubenheim).<sup>6</sup> Extensive text references on the plant physiological parameters are available to help set hydroponic systems control start points (Hashimoto et al)<sup>7</sup> and environmental physics (Monteith).<sup>8</sup> Simply repeating CELSS experiments on new plants provides an expanded database of plants with tested metabolic performance. Every plant will have a different set of performance curves or metabolic envelope. A valid plant test cell can be made out of an old refrigerator. With some instruction any reasonably capable hydroponic gardener can define all the relevant performance curves presently available for wheat, lettuce, and a few other selected crops tested extensively by NASA and the Russian Space Agency.

### **Extremeophile (Lichen and Microorganism) Culture**

For people who live in “horticulturally challenged” areas, Extremeophile culture is often a hobby. Cactus and succulent gardening is quite popular. If this type of unique gardening could be extended to lichen, air pollinated Arctic vascular plants, and some alga then culturing unique and useful strains could be developed.

### **Inflatable Structure and Waste Treatment (Solid And Wastewater) System Field Testing In Extreme Environments**

The ultimate testing of CELSS technologies and system architectures could be conducted by volunteer fabrication and test teams in extreme but accessible locations. Some of the best and most accessible locations may be dry, high altitude locations in the western US. Promising water treatment and composting technologies could be offered to the mountain resort community or the Park Service as novel solutions for responsible environmental stewards operating in these delicate environments. Greenhouse technologies are a part of life for avid gardeners who are fortunate enough live in these areas. Members that fall into this category should be encouraged to participate in CELSS research. Greenhouse specific HVAC systems can be actively compared to life support related control parameters using standard deign texts (ASHAE).<sup>9</sup>

The ultimate goal of the development project is to produce CELSS related technology that is lightweight, compact and simple to activate and/or assemble. A program of adventure tourism to test maturing equipment (inflatable structures and waste handling equipment) would have direct research and development value. It would also unite “outward bound” hobbyists in an extreme sport that leads to a social coop as well as a research coop. One location of interest is the White Mountains of Western Nevada and Eastern California. These are dry desert mountains with large areas of alpine desert (similar to Arctic desert) between 10,000 and 14,500 feet in altitude. It is also home to the Ancient Bristlecone Pine Forest and some spectacular and lightly populated wilderness areas that are accessible by road. Depending on the specific technology, other locations of equal recreational value may be recommended.

### Conclusions

This paper is intended to start a real dialog on developing a research agenda for Space Active NGO members to pursue. The suggestions voiced in this paper provide for a rewarding and inclusive approach to this research. The ideas in this paper are certainly not the only way to do this, but they may present a solid starting point. What is most important is that a program be developed that offers real people real opportunities to contribute and reap the rewards of contributing. This paper offers solid suggestions on how to get started, both organizationally and in terms of technical directions that may prove rewarding.

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