The NASA CELSS Program

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OVERVIEW

The NASA Controlled Ecological Life Support System (CELSS) program was initiated in 1978 by the Life Sciences Division, Office of Space Science and Applications (OSSA), with the premise that NASA's goals would eventually include extended-duration missions with sizable crews requiring capabilities beyond the ability of conventional life support technology. Currently, as mission duration and crew size increase, the mass and volume required for consumable life support supplies also increase linearly. Under these circumstances the logistics arrangements and associated costs for life support resupply will adversely affect the ability of NASA to conduct long-duration missions. A solution to the problem is to develop technology for the recycling of life support supplies from wastes. The CELSS concept is based upon the integration of biological and physico-chemical processes to construct a system which will produce food, potable water and a breathable atmosphere from metabolic and other wastes, in a stable and reliable manner. A central feature of a CELSS is the use of green plant photosynthesis to produce food, with the resulting production of oxygen and potable water, and the removal of carbon dioxide.

The development of an operational CELSS will provide economic, psychological and mission operations benefits. For long-duration missions, such as permanent lunar or Mars bases, where logistics supply is very costly or impractical, the development of a full integrated bioregenerative life support system will be enabling. As the duration of future manned space missions increases, a cross-over point is reached where it will be more economical to provide life support supplies by the recycling of metabolic and hygiene wastes than to incur the repeating costs of resupply. In-situ regeneration of life support consumables will protect the mission from unpredictable and potentially disastrous interruptions in the logistics train.

The development of bioregenerative life support systems should be viewed as a key enabling step in NASA's ability to support humans for long durations in space. Such a system will have economic benefits, radically lowering costs of mission life support, mission operations benefits by substantially reducing the need for consumables that must be resupplied or brought along, and psychological and health benefits, by providing astronauts with a dependable supply of fresh food from a self-contained system.

TECHNICAL APPROACH

The general approach to CELSS research and development activities is to accomplish successive stages of prototype system development, based upon and supported by appropriate ground-based and flight experiments, so that the development of operational space systems can begin soon after the turn of the century. A CELSS can be viewed as an integrated set of biological and physico-chemical subsystems, functioning through processes of regeneration of recycling to sustain human life.

These major subsystems include:

1. Biomass production (plant and secondary animal production)
2. Biomass processing (food production from biomass)
3. Water purification
4. Air revitalization
5. Solid waste processing
6. System monitoring and control

These subsystems are interactive and interdependent. Research needs include both ground-based and flight studies that range from determining the environmental requirements for optimal plant productivity and the effects of micro-gravity on plant growth, to the problems inherent in the development of the technology required for the recycling of human and plant wastes. The development of these subsystems, their integration, and the characterization of mission-specific CELSS variants will be carried out by a series of projects as described below.

PROGRAM DESCRIPTION

The CELSS program is structured around six major elements, each of which represents a major area of science and technology research and development. These elements are:

1. Research Program

A continuing program to develop advanced component technologies for CELSS projects and provide scientific support for the development of biologically-based processors. Activities include the development of physical-chemical waste processing techniques, food processing scale-down, and development of advanced lighting systems.

2. Systems Integration and Control

Directed at the design, development, testing and evaluation of models and laboratory- scale experimental systems bearing on CELSS system monitoring, control and behavior. Activities include the development of system and process models, and an interactive program of systems testing under laboratory conditions.

3. Breadboard Project

Ground-based project at the Kennedy Space Center which will determine if lab-scale plant growth, food production and waste processing techniques can be successful when tested at an operational scale. Does not include humans in the system. The completion of the Breadboard Project will be a major step in the demonstration of CELSS feasibility.

4. Human-rated Test Facility

Ground-based project which will provide a full-scale test of a complete CELSS, including all biological and physical chemical systems and crew interfaces. Based upon current and anticipated experience with the Breadboard Project and planned to be operational in the middle 1990's.

5. Advanced Mission Concept Studies

Directed at developing mission specific options for CELSS applications for the suite of potential future manned missions such as lunar and Mars bases.

6. Space Flight Experiments

A program for determining the productivity, adaptability and stability of food crop plants and their supporting systems in a microgravity or reduced-gravity environment.