CELSS SCIENCE NEEDS

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Introduction

In the development of a Controlled Ecological Life Support System (CELSS) it is periodically useful to review the project to identify those areas that are most in need of research. This paper is my own view of what is necessary to accomplish in CELSS science. It is not intended to be definitive, but to be an heuristic tool to focus attention on outstanding questions. Any list of this sort is sure to have omissions, and mine is no exception, though it is reasonable to expect that a list of science questions will continue to evolve as some of those questions are answered and while new areas of interest are being uncovered.

Despite the evident difficulties, I propose the following list of areas where further investigation is needed before we can build a workable CELSS. To make these suggestions more concrete, each of them is numbered to correspond to specific portions of the CELSS that is diagrammed in Figure 1. Each of the numbered areas will be affected by the research in question. In the spirit of this paper the details of Figure 1 are not meant to represent the final design of a CELSS. In fact, the schematic shown does not even reflect my own current thinking on that subject. Nevertheless, I hope it will be a useful "straw man" for the purpose intended.

CELSS Science Needs

Biological Sciences

Ecology

1. Investigate the dynamical behavior of the system, and adjust the design to minimize buffer sizes, while assuring system stability and safe operation.

2. Develop and characterize a benign microbial community to enhance plant growth, and to provide protection against plant pathogens.

Genetics

3. Provide novel cultivars that will increase yields within a small volume. Select plants that will be able to thrive at less than one gravity.

Plant Pathology

4. Develop prevention and control measures for potential plant pathogens.

Plant Physiology

5. Characterize optimal growth needs of crop plants useful for a CELSS.

6. Develop control methods for crop plants (control growth, transpiration, etc.).

7. Characterize the gas exchange capacity of crop plants under different growth regimes, and during different phases of the plant's life cycle.

8. Explore the use of transpiration water as drinking water under the full range of growth regimes envisioned.

9. Characterize the production of secondary compounds by crop plants under the growth regimes envisioned.

10. Evaluate the potential for mixed-crop and continuous-harvest systems under CELSS constraints.

11. Develop a method to orient crop species in micro-G.

Medical Sciences

Nutrition Science

12. Fully define human nutritional requirements, and determine the extent that they can be met by a CELSS.

13. Characterize the waste materials produced by humans on a CELSS-compatible diet.

Human Physiology/Space Physiology

14. Characterize human metabolic activity and gas physiology in the micro-G environment over a long-duration mission.

Toxicology

15. Characterize the long-term effects of exposure to low levels of plant secondary compounds.

Computer Science

Artificial Intelligence/Robotics

16. Develop the capability for remote monitoring and control of plants and algae.

17. Develop the capability for automated harvesting, with quality assurance and food preservation needs being met.

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Cybernetics

18. Develop methods for overall system control and failure analysis, perhaps by integrating a computational model of the system with the system itself.

Chemistry

Analytical Chemistry

19. Develop monitoring capabilities for the nutrient solutions and waste streams.

20. Develop monitoring capabilities for mixed-gas streams.

21. Develop capabilities to monitor small quantities of plant secondary compounds and potential toxins in real time.

Physical Chemistry

22. Develop appropriate models to predict the behavior of nutrients in solution.

23. Develop appropriate models to predict the behavior of mixed-gas streams.

24. Develop a method for separation and storage of nutrients from the waste stream.

25. Optimize gas-separation methods to match CELSS power and volume constraints.

26. Develop methods for control of nutrient solutions in the growth chambers.

Materials Chemistry

27. Develop processes for the small-scale handling of plant by-products.

Waste Chemistry

28. Perfect techniques for physical-chemical waste treatment.

29. Investigate hybrid waste-treatment techniques (to include the use of genetically engineered microbes to detoxify waste).

30. Develop specific techniques to remove low-level toxins and plant secondary compounds from both liquids and gases.

Physics

Fluid Dynamics

31. Develop systems for mixed-gas storage in micro-G.

32. Develop methods for mixing the algal-growth media and controlling the waste-processing streams in micro-G.

Optics

33. Develop an optimized system to provide photosynthetically active light to the growth chambers.

Solid-State/Atomic Physics

34. Determine the most efficient way to provide the radiation shielding necessary to protect the system from long-term damage and performance degradation.