Acta Astronautica 96 (2014) 138–150

Contents lists available at ScienceDirect

Acta Astronautica

journal homepage: www.elsevier.com/locate/actaastro

Greenhouses and their humanizing synergies

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ARTICLE INFO

Article history:
Received 5 February 2013
Received in revised form
22 November 2013
Accepted 23 November 2013
Available online 1 December 2013

Keywords:
Greenhouse design
Habitat integration
Mobile Plant Cultivation Subsystem
Plant–human relationship
Habitability

ABSTRACT

Greenhouses in space will require advanced technical systems of automatic watering, soilless cultivation, artificial lighting, and computerized observation of plants. Functions discussed for plants in space habitats include physical/health requirements and human psychology, social cohesion, as well as the complex sensorial benefits of plants for humans. The authors consider the role of plants in long-term space missions historically since 1971 (Salyut 1) and propose a set of priorities to be considered within the design requirements for greenhouses and constructed environments given a range of benefits associated with plant–human relationships. They cite recent research into the use of greenhouses in extreme environments to reveal the relative importance of greenhouses for people living in isolated locations. Additionally, they put forward hypotheses about where greenhouses might factor into several strata of human health. In a recent design-in-use study of astronauts' experiences in space habitats discussed in *Architecture for Astronauts* (Springer Press 2011) it was found that besides the basic advantages for life support there are clearly additional “side benefits” for habitability and physical wellbeing, and thus long-term mission success. The authors have composed several key theses regarding the need to promote plant–human relationships in space, including areas where synergy and symbiosis occur. They cite new comprehensive research into the early US Space Program to reveal where programmatic requirements could be added to space architecture to increase the less quantifiable benefits to astronauts of art, recreation, and poetic engagement with their existential condition of estrangement from the planet. Specifically in terms of the technological requirements, the authors propose the integration of a new greenhouse subsystem component into space greenhouses—the Mobile Plant Cultivation Subsystem—a portable, personal greenhouse that can be integrated functionally into future greenhouse constructions in space.

1. Introduction

On Earth, plants grow in different forms according to their natural environment. In extreme environments technology has to substitute for the Earth's natural conditions in order to allow plants to grow. One of the best-known and so-far largest endeavors of creating an artificial and closed-ecological biosphere is the Biosphere 2 project in Arizona. In the longest mission, eight people spent 2 years living in the sealed ecosystem. Reported problems include troubles with CO_2 and oxygen levels leading to an unbalanced fauna and flora; participants also experienced hunger and interpersonal conflicts [1]. The Biosphere 2

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http://dx.doi.org/10.1016/j.actaastro.2013.11.031

experiment eventually failed, but results and experiences are still considered relevant for studies on possible future agriculture systems, as well as their importance and effects in isolated environments and beyond Earth [2].

Artificial biospheres and greenhouses will be essential for future human space exploration. As space missions become longer, more arduous, or remote bases for long-term habitation on the Moon or Mars are designed, the effects of micro-gravity, as well as how well different plants grow in space and what kind of light they need are among the many technical issues to be discovered [3]. In addition, near-future missions to the Moon offer a great potential for testing and evaluating those delicate systems.

Besides the technical and scientific challenges, the "human system" becomes equally important. This paper deals mainly with the plant–human relationship in space. It provides a short overview of the history of technical greenhouses in space, highlighting aspects that are related to the humanizing aspects of such systems for sterile, technical environments such as a spaceship, leading to the proposal of an additional greenhouse sub-system component.

The key issues presented confirm the need for personal greenhouse systems. These require technical integration into communal greenhouse projects for the wellbeing of the whole community in future human space habitats.

2. Greenhouses and gardening in space: a history of systems and benefits

Salyut 1 (launched April 1971) was the first space station that implemented a greenhouse—it was named *Oasis*. Since then, plant growth facilities were implemented in the later Salyut stations 4 (1974), Salyut 6 (1976) and Salyut 7 (1982); on Mir (in the module KRISTALL launched in 1990); and on the International Space Station. The US space laboratory Skylab (launched March 1973) only had an educational experiment with space grown rice seeds [4].

Table 1 details the greenhouse facilities that have been used on-board particular space stations.

A number of experiments with seeds and plants have been conducted, with the first plants carried to space in 1960 with Sputnik 4 ([5] p. 3). However the first space-grown vegetables were reportedly eaten in 1975 onboard Salyut 4. During their mission the cosmonauts Vitali Sevastyanov and Pyotr Klimuk were given permission to eat some of the onion tubers [10].

The first successful life-cycle from seed planted in orbit to flowering plant to producing new seeds was conducted in the growth chamber *Phyton* on Salyut 7 ([9] p. 177).

2.1. The first individual greenhouses

Very early during the Salyut missions, astronauts experimented with plants and "designed" their own little greenhouses. Robert Zimmerman writes that Salyut 6 cosmonaut Valery Ryumin "had a green thumb" and "turned the space station into a veritable jungle by growing [plants] in empty film cassettes, equipment casings, and food containers hung everywhere on the station's walls." ([11] p. 3).

Salyut 6 and 7 cosmonauts even had multiple choices of greenhouses. Valentin Lebedev stayed 211 days onboard the Salyut 7 station and during his long-term stay he planted peas in *Oasis*, Arabidopsis in the *Fiton*, lettuce in the *Biogravistat*, tomatoes and coriander in the *Malakhit* and onions in a *Vazon* ([12] p. 169; [13]).

Based on the many experiments with greenhouses, the Soviets recognized very early the psychological benefits of

Table 1
Overview of greenhouse facilities used in space stations.
Sources: [5–9]

Small Plant Growth Facilities onboard SALYUT (1, 4, 6, 7) and MIR
Oasis 1 (Salyut 1): first plant growth system
Oasis 1M (Salyut 4): improved water metering system
Oasis 1AM (Salyut 6): designed for long duration missions
Oasis 1A (Salyut 7): advanced lighting system
Malachite (Salyut 6): ornamental plant culture system to provide psychological comfort
Fiton (Salyut 6): greenhouse for onions and radish
Svetoblock (Salyut 6): plant system that could be mounted to a light in the cabin
Svetoblock-M (Mir) *Svetoblock-S Svetoblock-G Svet* (Mir): first joint Russian-US experiment
Magnetogravistat (Salyut 7, Mir): greenhouse for wheat and flax
Biogravistat (Salyut 7): greenhouse for lettuce
Vazon (Salyut 6, 7 and Mir): system for the cultivation of bulbous plants without artificial lighting
Phyton (Salyut 7): miniature growths system, first seed to flower produced on orbit.
Small Plant Growth Facilities onboard STS and ISS
Plant Growth Unit – PGU (STS): plant growth unit that fitted into a mid-deck locker on the Space Shuttle
Plant Growth Facility – PGF (STS): improved lighting and control system
Astroculture System (STS, Mir): closed chamber
Advanced Astroculture System (ISS): student-designed experiment and commercial payload
Plant Generic Bioprocessing Apparatus – PGBA (STS): included fluorescent lighting
Biomass Production System – BPS (STS): developed for long duration missions
LADA (ISS): modular type system
MagISStra, Veggie and AstroGarden: as described below.