MARS GREENHOUSE EXPERIMENT MODULE, AN EXPERIMENT TO GROW FLOWERS ON MARS. T. K. MacCallum[1], J.E. Poynter[1], and C. P. McKay[2], [1] Paragon Space Development Corp. 810 E. 47th St, #104, Tucson, AZ 85713; [2] NASA Ames Research Center, Mail Stop 245-3, Moffett Field, CA 94035.

Introduction: NASA has entered a new phase of in-depth exploration of the planets where robotic exploration of the Solar System is focusing on in-situ missions that pave the way for human exploration. Creating a human presence on Mars will require specialized knowledge and experience concerning the Martian environment and validated technologies that will provide life-supporting consumables. An understanding of the response of terrestrial organisms to the Martian environment with respect to potential deleterious effects on crew health and changes to biological processes will be paramount.

In response to these challenges an innovative self-contained flight experiment is proposed, which is designed to assess the biocompatibility of the Martian environment by germinating seeds and following their growth through to flowering. The experiment, dubbed Mars Greenhouse Experiment Module (Mars GEM), will be accomplished in a sealed pressurized growth chamber or "Mars Greenhouse". Seeds will be grown in Martian soil and the Mars Greenhouse will provide ultraviolet-radiation protected, thermal-controlled environment for plant growth that actively controls the CO2 (required nutrient) and O2 (generated by the plants) levels in the chamber.

The simple, but visually dramatic demonstration of the potential to grow a plant in a man-made environment on the surface of Mars should establish a strong connection between current robotic missions and future human habitation on Mars.

The Objectives and Significant Aspects: The experimental goal is to determine the biocompatibility of the Martian environment such as the atmosphere and regolith. This is to be accomplished by studying the stress sustained by an Earth organism (an angiosperm) grown in Martian soil and possibly Martian CO2 and water during germination, growth and production of flowers. Such an experiment will determine if exposure has deleterious effects or results in fundamental changes to biological processes. A second objective is to ignite public interest in the exploration and possible future colonization of Mars and elsewhere in the solar system.

NASA has a long tradition of flying technology demonstration missions. Once a technology has been tested on Earth it is important that we gain technical and psychological reassurance by demonstrating that something works on Mars. Pathfinder was such a mission. A module capable of growing plants from seed is a biological demonstration mission similar to plans to test physical/chemical oxygen production from atmospheric carbon dioxide on Mars.

There are many reasons to send flowers to Mars. It would be highly symbolic. These plants would be the first organisms from Earth to grow, live and die on another world. They would be true biological pioneers, an important step for life from Earth as it begins its expansion beyond the planet of origin. More practically, a plant growth module would test the toxicity of the Martian environment in a very direct way. If Martian CO2 and water are used, the experiment would demonstrate the use of Martian atmosphere components in a greenhouse. These are essential steps toward a full-scale greenhouse to support a human base. The growth of a plant in the Martian environment would help alleviate concerns about dangerously contaminating the Earth by the return of Martian samples by showing that the soil and atmosphere are compatible with life. In all these respects a plant growth module would be a first biological precursor to human exploration of another planet.

The Technical Feasibility: Due to planetary protection requirements and the inherent constraints imposed by a pressurized growth chamber, the plant life support system must be completely materially closed. Paragon Space Development Corporation has performed design studies including plant requirement definition, thermal analysis, regolith collection and dissemination, nutrient and water delivery, seed delivery, CO2 and O2 measurement and control, and pressure control. The chamber and subsystems have undergone preliminary design studies and all parameters (mass, size, electrical power, data etc.) can be met using a growth chamber that can be supported as an instrument package on a Mars-01 type lander. The chamber weighs approximately 3.5 Kg, is 17 cm wide by 19 cm high by 25 cm long, and uses less than 16 W-hrs during operational hours. No power is required during the darkness of night.

Planetary protection issues have been studied in depth to ensure that designs meet all criteria for eliminating the risk of contamination of the Martian surface with Earth borne life. The planetary protection guidelines do not explicitly prevent the controlled transport of biological materials to Mars and the use of biological materials in controlled experiments aboard spacecraft. The seeds of the plants would be treated in such a way as to minimize the risk of transport of bacteria. In addition, the sealed chamber is sterilized prior to transportation and treated with high levels of antibiotics and antifungal agents during the experiment. At the completion of the experiment the entire chamber is sterilized to ensure that no microbial life has survived and that all bacteria have been eradicated. Growing a flower on Mars would not contaminate the planet or compromise any future scientific study of the planet.

The plant proposed for the experiment is *Arabidopsis thaliana*, which is used extensively in laboratory gene expression and physiology studies. Thus a large body of knowledge exists with regards to its requirements and propagation. Phenotypes are available that have low light intensity requirements, dwarf plant sizes, short inflorescence, with 45 days to flowering and senescence. The plant will be selected and possibly genetically manipulated to tolerate elevated levels of free-radicals expected in Martian soil and thus can serve as a biosensor for measuring oxidative stress. Further genetic engineering can be performed using Green Fluorescing Protein whereby each plant can indicate the presence or absence of specific stress factors such as toxic levels of metals, high salinity etc. The plants' growth and flowering would be monitored using the lander camera and a camera internal to the growth chamber.

The vessel has an antechamber with a door to the Martian atmosphere to allow the planting bed to be filled with Martian regolith. Once the exterior door is sealed the chamber is pressurized and the soil hydrated before being moved into the greenhouse. Current designs use only that portion of the atmosphere that enters the antechamber from the Martian atmosphere while the door is open. Further design studies need to be performed to determine whether all the CO2 and water used in the experiment can be derived from the Martian atmosphere while conforming to the power and mass limitations of a mars lander.

The greenhouse is constructed with a combination of transparent aerogel and phase change material. A thermal model has been made which shows that the proposed method of heat storage and release maintains the temperature within requirements without the need for a powered heat source at night.

Through 6 years of in-depth work in the field of closed biological systems and biological systems made for space use, Paragon has developed innovative concepts for CO2 and O2 control. These systems allow for an entirely sealed growth chamber with small volume requirements, and reduce the amount of gases required for delivery to the plants from pressurized canisters. An atomic level model has been made that tracks the movements of carbon, hydrogen and oxygen within the system. The model demonstrates the need for daily release of CO2 and nightly storage of CO2 due to plant metabolic processes, which the Paragon system accomplishes with no moving parts and low energy requirements. No energy is required at night for O2 storage.

Summary: For most of us life is the reason that Mars is interesting. We go to Mars to search for the possibility of life early in Martian history when that planet had water and to determine if Mars may be a home for life in the future.

The proposed Mars Green House Experiment Module is conceived to provide important scientific data and to validate exploration technology as a precursor to human missions. The experiment provides for an exceptional opportunity for public education and outreach. It is technically feasible and the maturity of design studies show that a Mars GEM could be used to send life to Mars on the next lander.

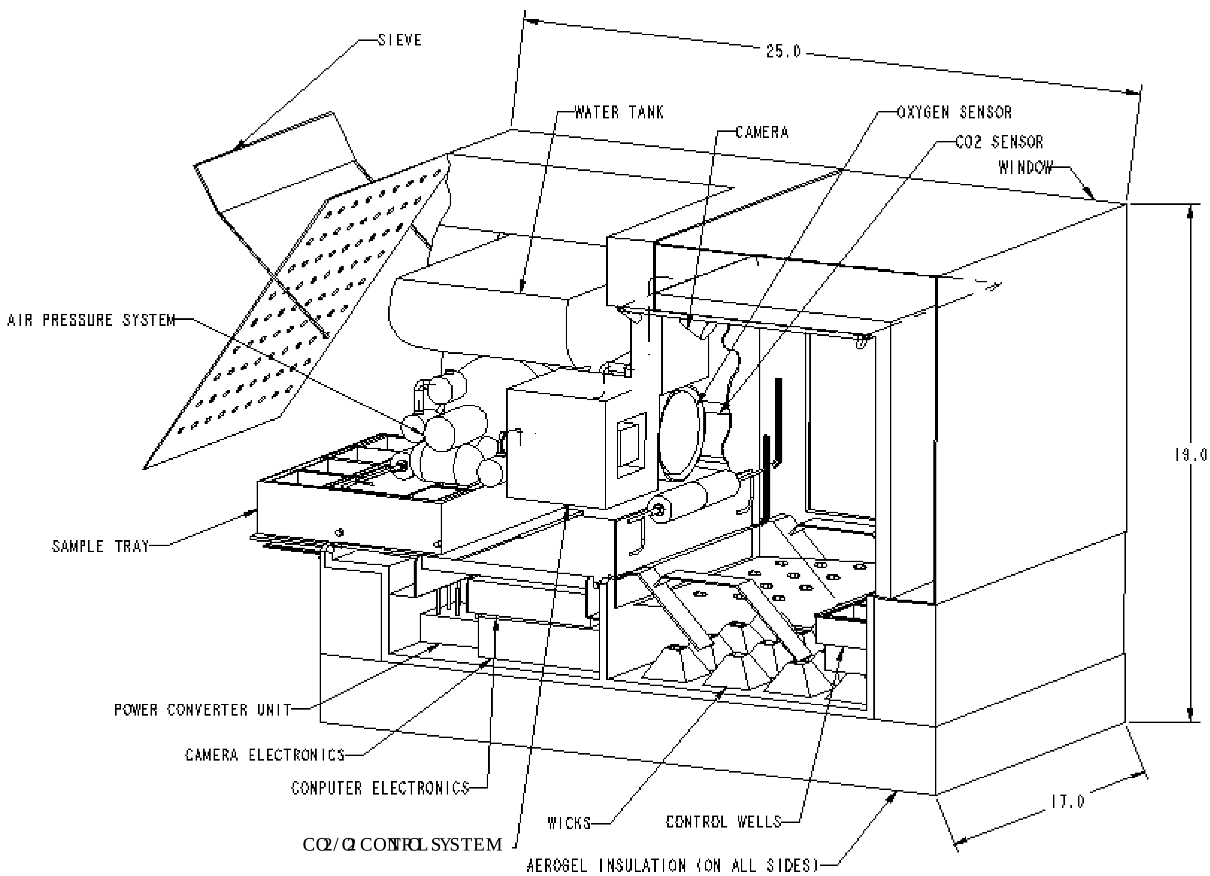

Figure 1. Mars GEM Design Concept