STRUCTURAL AND PSYCHOLOGICAL PLANNING ASPECTS OF A HABITAT MODULE FOR LONG TERM HUMAN SPACE MISSIONS AND PLANETARY HABITAT

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Introduction: The travel time for a spacecraft from Earth to Moon may be as low as a few days, or a week. To the Moon it is economical to transport and replace personnel, tools and infrastructure. It is significant, that while the Lunar day and night is 2 weeks each, during this the Earth and the Sun may be constantly or frequently visible. This has a significant psychological impact on the people working on planetary bases. Furthermore the possibility of returning to Earth can be achieved at any time without great complications, and the duration of the return trip is only a few days. To the Lunar surface, transporting human personnel and technological infra structure can be achieved economically in a multi-step multi-missionapproach, as outlined by previous mission concepts (e.g. Orion).

Background: The search and results of previous long term human missions on MIR and ISS revealed the profound importance of the sight of Earth on the human psyche, along with the constant reassurance of a potential rapid return to the surface. [1]
The travel time from Earth to Mars, depending on the relative phases of the orbits, may take at least six to nine months, and a longer time to stay thereafter. Immediate resupply or return from such journey is not possible, therefore the mission must be designed as a long term expedition standing on its own for the full duration. Delivering the technological infrastructure is more difficult compared to the case of the Moon. The most essential tools and supplies have to be sent preceding or along with the human crew, possibly on the same spacecraft.

Detailed discussion: During the expedition to Mars, we have to take into considerations the local surface conditions. The Sun is visible, but appears smaller than seen from Earth and with an orange tint. The entirety of the Martian surface is solid ground, with regions of frozen dust-covered water or CO2 ice. The Martian day-night cycle is only slightly different from the terrestrial: 1 Martian day (sol) is 24 hours and 40 minutes.
There is an atmosphere and wind, however the surface pressure is very low (only 0.00628 atm). There are seasonal variations with warmer and colder periods depending on the solar irradiation and geographical location, and surface temperatures fluctuate between approximately -170 C to +20 C. Mars does not have a planetary magnetic field, and it's surface gravity is only 1/3 of Earth [3].
The Martian surface conditions strongly influence and determine the technical requirements of long term human expeditions and habitation, and the relevant human psychological factors.
The view of the Martian surface is a red-orange, barren, rocky or mountainous range. Similar regions on Earth are only found in remote, loosely populated areas. Due to the thin atmosphere and the lack of planetary magnetic field, at the surface, solar irradiation and cosmic ray background is much stronger than on Earth, which also affects human outposts.

Technical aspects: The spacecraft has to provide for the requirements of long duration travel, and the technical circumstances of long term human habitation on the surface. For both of these cases the minimal needs of human habitation must be met: e.g. air and water supply and re-circulation, sleep, food, waste disposal and re-circulation [2]. Some related requirements are a reliable long term power source, communication capabilities both with the home base on Earth and among the crew. Furthermore the eventual vehicles and infrastructure for mobility and construction on the Martian surface should also be included. For the activities on the Martian surface only those tools are available which were brought from Earth. Local materials could be made use of at later stages via In Situ Resource Utilization (ISRU), where using in situ materials with technologies brought from Earth. .

Fig. 1.: Earth viewed from the ISS cupola module. The vicinity of home and the possibility of safe return is expected to have a strong psychological impact.
Credit: Koichi Wakata / NASA ISS038-E-000246

Psychological aspects: Long duration interplanetary travel taking several months is expected to put a considerable, and hard to predict psychological strain and stress on the mission crew. This stress can be reduced to manageable levels by the appropriate design of the habitat module.
Even the most thorough study is facing difficulty in predicting how long duration interplanetary travel affects the human psyche, as so far all analyses and experiments were conducted on, or in direct close vicinity of Earth. During these experiments there was always a possibility and a robust timescale for returning back to Earth, and Earth was visible for almost the entire duration of the stay in space. The importance of this latter point is emphasized by the fact that a vast majority of spontaneous photographs taken by astronauts are aimed at Earth. [1]
The crew of previous missions were thus not detached from Earth even as they left physically, it's image and the predictable possibility of return was always there. The crew of submarines face a similar challenge when carrying out missions requiring them to stay submerged for extended periods of time, however in fullness they are also not detached from Earth, the possibility of return is always open.
To manage the above outlined potentialities, it is important for the crew to stay in a psychological and sociological environment similar to Earth, where stresses and conflicts could be resolved through conventional means, in more familiar settings. Furthermore the mission crew will have to stay together as a team for a very long time, and accomplish complicated tasks requiring their full cooperation.

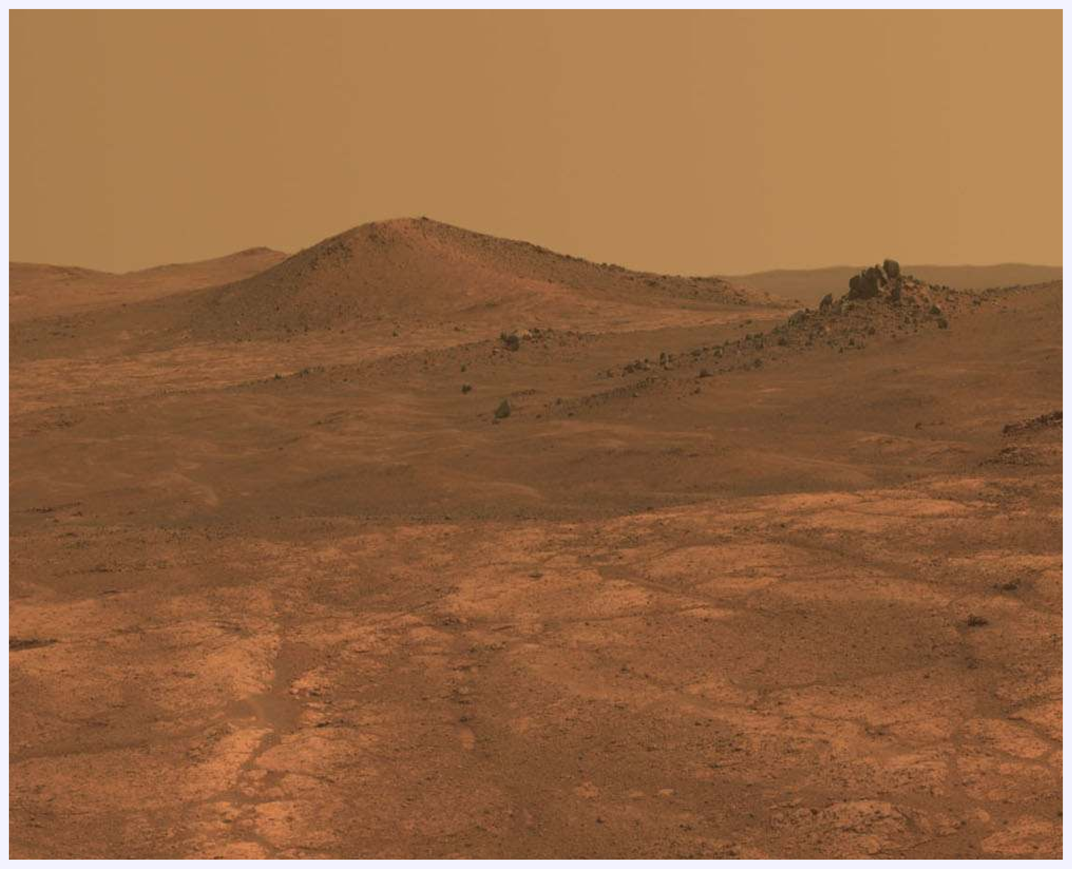

Fig. 2.: The Martian surface as seen by the Opportunity rover near the Spirit of St. Louis crater.
Credit: NASA/JPL-Caltech/Cornell Univ./Arizona State Univ.

The essence of our proposal: In the case of Mars it can be economical to construct the spacecraft in a way to be usable for not only the journey to Mars, but also to serve as the initial, or longer term surface outpost for human activities. For landing such structure on the surface a propulsive landing system could be used, similar in concept and design to the sky crane used in the NASA Curiosity mission. Naturally, for landing significantly larger payloads further developments are required in propulsive landing systems.
Long term human space missions, and planetary expeditions pose interconnected technological and psychological requirements and considerations. The habitation module must be designed to optimize structural and technological requirements, but simultaneously, it also has to provide for the psychological needs of the crew on long term human missions, allowing for unplanned events and contingencies during the expedition. These are the two aspects which should be reconciled in a single spacecraft.

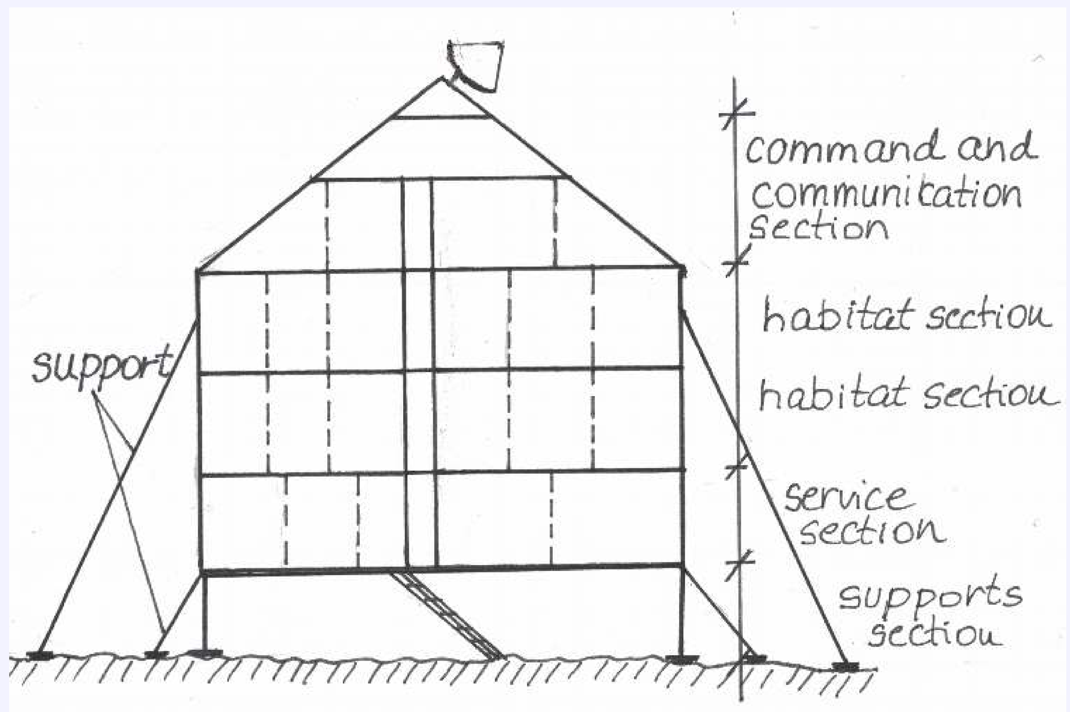

Fig.2. Cross section of a possible planetary surface habitat module for long travel and planetary habitat
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The design of the habitat module: It's structure and interior arrangement can be very beneficial in resolving, or potentially preempting the above outlined potential conflicts and problems. One important factor is to provide private space for each crew-member to retreat and separate from the common areas, which requires the appropriate design of the spacecraft and habitat module.
A space where all crew is present at the same time is also required. This would be used to define and discuss common tasks and aims, to hold scientific presentations and discussions, cultural events and leisure activities. Participation should not be mandatory in all of these programs, such that individuals have the freedom to choose to fully or partially retreat into their personal space.

Fig. 3.: Typical interior environment of a space habitat, in this case the Destiny laboratory of the ISS.
Credit: Reid Wiseman / NASA ISS040-E-104127

Feasibility study: In a possible concrete realization for applicable for 8-16-32 people, with multiple floors. Command and control facilities on the top with single or multiple sections. Below this a large common space or room, which allows for all personnel to be present at the same time. This is used to give a sense of community as well. Below this are individual rooms, joined with smaller spaces or rooms sized to fit the common activity or meeting of 3-4 people. Here the meetings or common meals of smaller groups is possible, where not everyone have to be present.
The technical design can be cylindrical or polygonal in cross-section, which is chosen to provide structural integrity during landing and during the surface stay. For the propulsive landing, the 3-4 landing legs could be placed at the bottom of the structure to dampen the touchdown, and which can be adjusted to level the superstructure in the presence of an uneven landing site.
These landing legs at the same time define a protected space under the station, which can be used as a storage area for vehicles and other technical tools and devices. Furthermore the legs provide a large and adjustable separation from the surface. The transportation of personnel and tools or vehicles between the surface and the habitat module can be done via expandable stairs, elevators or cranes.

References: [1] Psychology of Space Exploration, Edited by Douglas A. Vakoch, Washington, DC 2011, NASA SP-2011-4411, [2] T. P. Varga et al. Assembly and installation concept... 46. LPSC 2015 # 1357, [3] Bérczi et al.: Space research and Technology, Published by ELTE Space Research Group © 2007,