

HABITABILITY CONSTRAINTS/OBJECTIVES FOR A MARS MANNED MISSION: INTERNAL ARCHITECTURE CONSIDERATIONS

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ABSTRACT

It is generally accepted that high quality internal environment shall strongly support crew's adaptation and acceptance to situation of long isolation and confinement. Thus, this paper is an attempt to determine to which extent the resulting stress corresponding to the anticipated duration of a trip to Mars (1 and a half years to 2 and a half years) could be decreased when internal architecture of the spacecraft is properly designed.

It is assumed that artificial gravity shall be available on board the Mars spacecraft. This will of course have a strong impact on internal architecture as far as a 1-g oriented design will become mandatory, at least in certain inhabited parts of the spacecraft.

The review of usual Habitability functions is performed according to the peculiarities of such an extremely long mission. A particular attention is paid to communications issues and the need for privacy.

The second step of the paper addresses internal architecture issues through zoning analyses. Common, Service and Personal zones need to be adapted to the constraints associated with the extremely long duration of the mission. Furthermore, due to the nature of the mission itself (relative autonomy, communication problems, monotony) and the type of selected crew (personalities, group structure) the implementation of a "fourth zone", so-called "recreational" zone, seems to be needed. This zoning analysis is then translated into some internal architecture proposals, which are discussed and illustrated.

This paper is concluded by a reflection on habitability and recommendations on volumetric requirements. Some ideas to validate proposed habitability items through simulation are also discussed.

INTRODUCTION

This paper is an attempt to make architectural recommendations for a spacecraft supposed to fly an early Mars exploratory mission.

It is not the purpose here to provide solutions for a complete system but rather to propose hints for the internal spacecraft architecture in order to decrease as much as possible the stress for the crew associated with such a long period of confinement.

Ideas generated or suggested in this paper could be considered as possible architectural inputs after engineers will have agreed on the overall spacecraft envelope.

STARTING HYPOTHESIS, LIMITATION

The foreseeable durations for Mars first exploratory mission range from 1.5 to 2.5 years. In our hypothesis a crew of 6 astronauts (possibly 3 couples) is considered (11). They will live in a confined environment where water would be fully recycled and breathable oxygen generated from carbon dioxide.

It is also assumed that food will be stored on board but small quantities might be produced (lettuce, algae...). However, this production of fresh food would remain anecdotal with respect to overall nutrition issue.

The environment would remain constant for the crew which means that no seasons would be simulated on board for instance.

The crew will remain operational during the whole mission, hence no hibernation is considered during the Mars transit.

An artificial gravity (TBD g) would support crew's health in addition the countermeasures programme.

This provision for artificial gravity will probably make the design of all hardware and equipments on board the Mars spaceship more complex because they will have to work both in 0 and partial g environments.

Finally as far as the spacecraft will have to accommodate and international crew, the 5th to 95th percentile of the world population (from the Japanese female to the American male) will be taken into consideration for its internal design.

REVIEW OF HABITABILITY FUNCTIONS

* Food and Galley

Apart the nutrition aspects, food will be a major opportunity in day time for the crew to meet together. Then, the food and galley hardware should be designed to enhance group cohesion as much as possible.

Galley and wardroom should be located in a dedicated area of the common zone. All facilities to manage prepare and handle food available on board as well as the food which could be produced should be part of the galley. With respect to the food management a pantry type approach is highly desirable as far as it multiplies the number of possible meals to be prepared by the crew during this long mission.

* Hygiene

Mainly due to the number of crew (6 astronauts) and the duration of the mission, the hygiene function should be split between various areas. Namely 2 toilets and 2 whole/partial body cleaning areas seem to be the minimum baseline to be implemented on board. This mainly to avoid congestion and improve living standards. Other hygiene functions such as refreshment oral hygiene could be located in the individual cabins. The reuse of clothes, dishes cutlery is desirable. A laundry and a dishwasher should therefore be implemented. This, mainly to reduce mass and waste and second to relieve the crew of these fastidious tasks.

Automation is a requirement but on the other hand a good accessibility to all these equipments are needed mainly in case of repair and maintenance.

* Physical exercise and recreation

At the present time a very tough countermeasure programme (2 hours per day) is carried out by the Russian astronauts on board the MIR space station for missions lasting up to 1 year. We hardly imagine that a crew of 6 will be able to cope with such a programme for a mission which could last up to 2.5 years. That is why artificial gravity is proposed in a sense that it could significantly reduce the daily duration of training and the type of countermeasure exercises.

What is proposed here is to try to combine physical exercises with training. This training might concern the rehearsal of Mars surface activities for instance in a simulator located in the common zone: Once donned in his space suit, one astronaut could repeat all kind of experiments (building, exploration, maintenance, piloting) he would be supposed to do on Mars. But other kind of trainings or sports would be also possible: climbing, skiing or tennis....

For extreme long duration missions, long periods of exercise are rapidly becoming boring. A possible solution to reduce this boredom, is to associate exercise with training tasks, but also with recreation activities to sustain motivation.

For training purposes, a potential concept might be the rehearsal of Mars surface activities: The duration of the cruise flight requires that high level of performances be maintained until the landing on the surface, thus simulators could be used to ensure required capabilities. A Mars partial gravity can be implemented during the in-bound trip for the crew to get used to it. Such simulators, as conceptualised in figure 1, are further developments of actual "all-glance" cockpits military and commercial jets cockpits simulators. For example, if an EVA Surface suit is introduced inside the dome, rehearsals of activities such as site preparation, construction, maintenance, exploration could be performed. Reconfiguration of such simulators could be used also for Surface Vehicle piloting. Furthermore such simulators located in the common zone could be linked together,

if there are several of them on-board, in a network and provide interactive training between crewmembers. For recreational purposes associated with exercise, one can also imagine sports being simulated either alone: running track or golf and tennis in interaction with a on-board or ground partner. (Delays in communication shall be assessed). One can easily imagine the advantages of such devices!

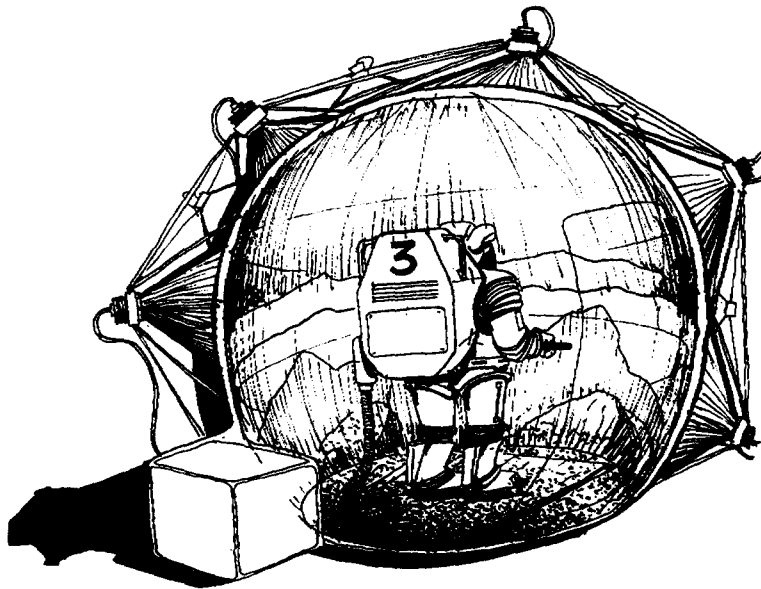


Figure 1 Training facilities

* Medical Support

We recommend, in addition to the use of expert systems and the support of the medical ground team, a crew medical officer (CMO) which could be preferably a medical doctor. However each crew member will have a minimum medical background (mainly for safety reasons).

But, the Mars spaceship cannot be a "flying intensive care unit". The problem is to design a realistic medical system which could cope with the most likely spontaneous illness or accident. The very tight screening during the crew selection should aim at decreasing the medical risks during the mission.

On an architectural standpoint, the most seeable medical facilities are:

- the "Shield room" (radiation protection in case of solar flare).
- the hyperbaric facility (decompression sickness).

* Privacy

Privacy is of the outmost importance for psychological reasons in the case of extended human space flights. Hence, privacy calls for acceptable volume requirements.

Only few studies have investigated acceptable thresholds with respect to volumetric requirements. (Free volume estimation FRASER-NASA CR 1084, 1968).

In addition it is difficult to compare these data related to volumetric requirements for a space station orbiting in LEO with those needed for a manned spacecraft designed for an interplanetary trip and which requires therefore much more autonomy.

However we recommend to consider skylab volumetric requirement (gross volume about 100 m³/man) as a minimum working hypothesis. The determination of minimum volumetrical requirements for long periods could be an area to be investigated and consolidated through simulation experiments. Table 1 summarises data from previous space flights habitable volumes.

Table 1 Data on habitable volumes

Mission	Crew size	Mission duration days	estimated gross volume m ³	gross volume/ man m ³
Saluyt-Soyuz	2 + visiting crew	175	91	45
Soyuz-MIR + Kvant 1	2 + visiting crew	366	130	65
Skylab-Apollo	3	84	300	100
Orbiter/Spacelab	7	7	140	20

Due to the role played by the group leader in such a mission to maintain group cohesiveness, one recommends to provide him with a larger cabin than the rest of the crew.

A possible concept for a double crew quarter is illustrated in figure 2. A very important point is the fact that all habitable volume of the spacecraft shall be usable either in 0-g or partial gravity during rendez-vous or orbit insertion and manoeuvres. Therefore provisions for handles, objects restraints shall also be provided. Furnitures shall also be used in either status of gravity, this being an interesting challenge for the architects and designers. Limited hygiene functions such as grooming, hands and face washing shall also be provided. Partitions shall also be used to provide variety and internal space appropriation, but also to help reduce conflicts between crewmembers. Personal storage will also be a problem due to the huge amount of items to be brought in and out.

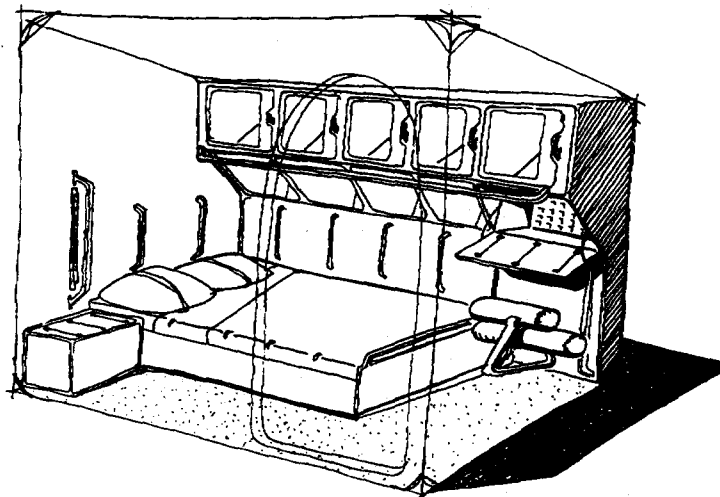


Figure 2 Example of double crew quarter

* Communications

The "recreational zone" should offer a particularly great support on that issue. The purpose and the need for this recreational zone is detailed further in this paper. However from this zone the crew could have a group communication with the ground. The use of an "Hologramme/3D screen is suggested because making communication more living and attractive than a normal TV set screen. If needed this zone could be partitioned and used for more private types of communications (with family, psychologist, medical doctor etc...).

It has to be recalled that communication between ground and crew will be delayed (some minutes) due to the far distance of the spacecraft from Earth. This will imply some training to get used with it and to optimise the transmission of info between crew and ground. For instance the use of asynchronous communication hardware (fax, electronic mail) could be preferred when oral communication is not necessary.

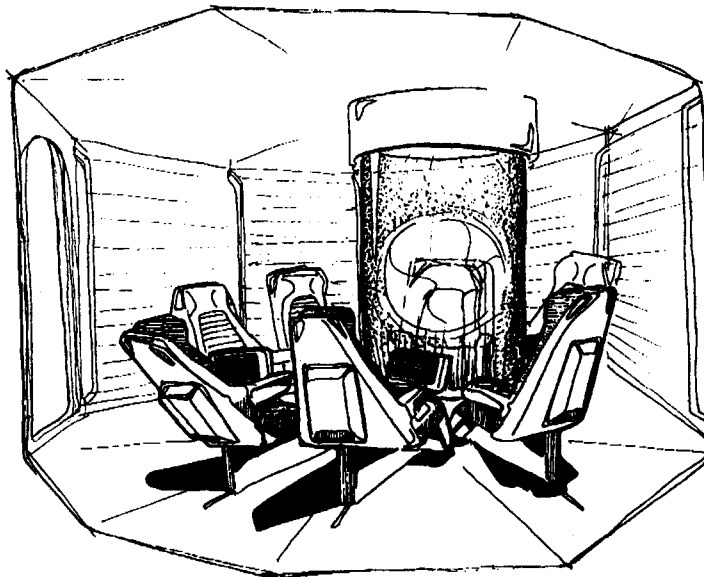


Figure 3 Communication room (recreational and command)

3 Proposal for architectural design

Human habitat are generally described by 3 functional zones:

- Common zone: where functions such as hygiene, health care, physical exercises, waste/trash management, wardroom, galley, communication, refuge can be performed.
- Service zone: Which has more a function associated with control, maintenance of the spacecraft, and other kind of workshop activities.
- Private zone: Which is namely represented by crew's cabins.

In addition for a Mars exploratory mission, this zoning analysis seems not enough particularly when considering the importance to maintain group cohesiveness for a long period of time. Even if the crew can meet during the meal periods in the Common zone an area where the crew could meet together more freely and less formally seems necessary. One proposes to call this fourth zone "recreational zone".

CONCLUSION

The habitability of a Mars spacecraft should be improved from the present concepts with the introduction of a 4th habitable zone so called "recreational zone".

When designing the spacecraft the importance for privacy dictated by the duration of the mission and the need for crew highest autonomy and cohesiveness should not be forgotten. It is premature to provide accurate figure of minimum volume requirements but it could be reasonable to consider Skylab data as a starting working hypotheses (gross volume per man about 100m³).

This recreational zone and these volumetric requirements should be further studied through a simulation programme: for instance a crew of 6 could be locked in an habitability test bed for several months simulating life and activities as foreseeable during the Mars transit.

Finally the lessons learnt from lunar outposts could bring new valuable inputs not only in areas such as psychology, medicine but also architecture.

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