Habitat Design Workshop 2005

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Abstract

The Habitat Design Workshop 2005 has been conceived by the *MoonMars Working Group* with the support of the European Space Agency (ESA –ESATEC) that hosted the workshop from 2nd to 10th April 2005 in The Netherlands. The MoonMars Working Group is an undergraduate and postgraduate led programme of interactive, international and trans-disciplinary projects, which aims to get undergraduates and young professional actively involved in *Moon and Mars* projects, workshop and other related events.
The Habitat Design Workshop 2005 is the first workshop focused on interdisciplinary interaction in the develop of human habitat for Moon, Mars and Phobos (satellite of Mars). Thirty students and young professionals from disciplines such as engineering, medicine, physics, architecture and industrial design were selected to participate at this workshop.
This paper presents the methods, process and outcomes of the design workshop. We conclude with evaluating this type of interactive workshop and its impact on developing the skills needed for the next generation space workforce.

Introduction

To go away from Earth orbit and enable human exploration of the Moon, Mars and beyond, means that we must understand the complex interactions between humans and their environment. Human-human interactions in a confined environment as well as the technological and logistic complexities involved in space missions has to be deeply investigated.

The idea of the Habitat Design Workshop was that bringing these disciplines together during the first concept development phase is advantageous since the design is still fluid and many constraints have not been imposed yet. Of course a concurrent approach throughout the design process would not be pertinent. However in concept development phase, over a short period of time, certain obstacles that would have arisen much later in the design process can be avoided or mitigated.

Aside from traditional space mission design and analysis using subsystems such as thermal control, launch mass, power, navigation, communication etc. other fields such as Human-machine interfaces, gravitational influence on perception, psychological effects due to isolation, change in perceptions of taste, colour, observations of patterns etc. The human component of space exploration complicates the issue of space design and thus calls for new approaches to the space mission design process.

Design a human habitat: past experiences

In past human space flight missions, the characteristics of the inhabited environment were strongly driven by engineering requirements. Although the efforts of engineers were focussed on making all parts, of a system or project, work together in the most efficient and economical way, many facets of human inhabited space systems were missing, leading to problems later on when the system, i.e. an orbital station, was used.
For example, living and working in the confined environments provided by the space stations MIR and Salyut still remain challenging problems for a human being's life in space. Moreover the

satisfaction of requirements, such as safety and reliability, does not assure an adequate habitat, both form and function need to be considered, especially when considering the extension of the space mission duration.

In the past little attention was given to human factors due, on the one hand, to the available technologies that did not allow a more comfortable habitat, on the other hand to the mental attitude driving the design approach (space systems design originated from the military driven programmes following traditions of military design). In the earlier period, in fact, most of the astronauts were coming from the airforce, and were trained to bear extreme environments over short periods of time.

From Salyut to the ISS we have seen an increasing number of non-military users (inhabitants) of orbital stations and increasingly from many different fields of scientific research. Many of these experts receive only a short period of training in how to deal with, and work in, an extreme environment. For effective use of such space stations, habitability is becoming more relevant. However it is evident that all efforts spent on improving habitability aspects of the ISS where focused after the main configuration definition.

Fig. 01 Sergei Krikalev on board of Mir Space Station

Fig.02 International Space Station

The realised space habitat designs up to now feature the classic tin-can elements which are defined by the form and size of the payload bays of the launchers. This means that professionals such as architects, industrial designers and those involved with ergonomics start from the already defined architecture of the space module, with little chance to modify it.
Also, there are certain inputs which are not currently included in the design of habitats, such as biomedical specialists, social psychologist etc. They too have to work with an already defined module. This has consequences on the effectiveness of the space mission which is dependent on the efficiency of the crew, and if these human habitability issues are to be effectively overcome they must not be integrated into a design after the fact.

Design a future human habitat

With future human exploration missions beyond Earth orbit, and the subsequent increase of mission duration, habitability will become an even stronger aspect. Defining the habitat for a lunar or Martian base is a complex task, which involves numerous disciplines. Habitability cannot be considered as a project independent from the main module architecture definition to be integrated in the design process later on.

With the term *habitat* we commonly mean the set of physical and chemical factors that characterise the environment in which a species lives. But if we broaden the definition of habitat, we can indicate the environment congenial to human needs. This second definition fits better with our design approach.

Habitats can be considered as the result (or best compromise) of the relation between human beings and technologies, by technologies we mean the technologies related to each subsystem that achieves the mission, from launch to survival in extreme environment (to returning to Earth). Propulsion systems, landing systems, radiation shielding, thermal control, telecom systems, on board data handling system, life support systems etc. are all strongly linked to the technological part of the design and they are integrated into the requirements and constraints definitions of the habitat. At the same time these technologies and the correlated subsystems are influenced by the extreme environment conditions.

The human being is a complex system in itself. Providing life support and radiation protection is not sufficient to assure optimal habitability conditions for long duration missions. A human being has to live and work in, and often with, the habitat. Life entails satisfying physiological and psychological needs (for example providing food, adequate solutions for sleep, privacy, intellectual and social stimuli, mechanisms of de-stressing).

A designer must assure the ability of carrying out the scientific experiments and the maintenance of the operational condition of the module. In reality, these two large groups of activities are not separated, but linked together in an environment with limited volume, and so these activities must be carried out in the same place or at the same time.

Designing a habitat for a space mission means to intertwine these two main groups of activities (living and working) with the rest of the environment: this leads to the human-machine interaction and human–human interaction.

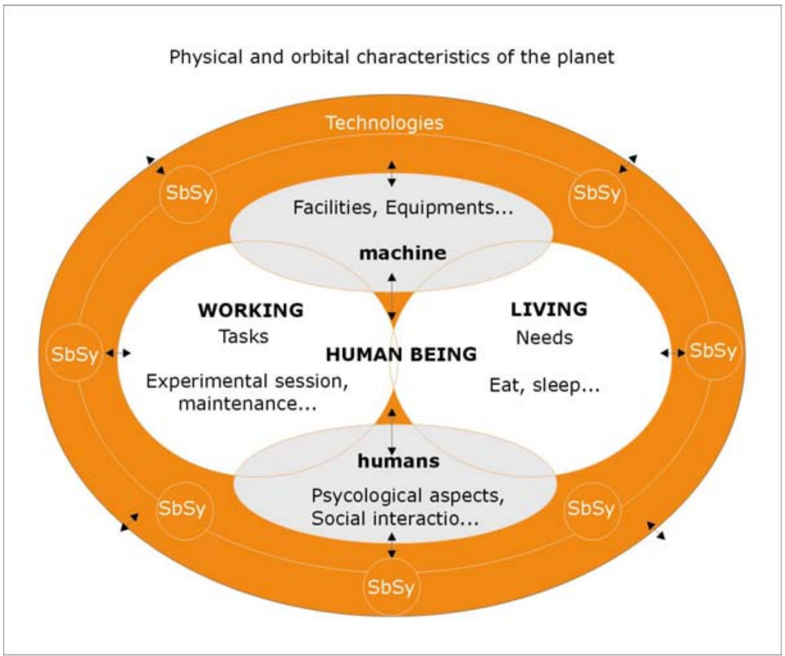

Fig.03 Scheme of the relations of human being in he habitat

During design of human mission the human being can be considered as a payload that imposes requirements for volume, safety and other types of support.

"An other way to look at the crewmember is as a system, comparable to other (hardware) systems. The human has sensors (eyes, ears, touch), mechanical actuators (finger, arm, legs), self propulsion (walking) and an on board processor (brain). The human also has requirement for maintenance (sleep, hygiene), fuel or power (food and water) and a particular type of operating environment (oxygen, temperature)" [4].

This way of considering the human being (and his relation with machines and other human beings in the environment) increases the complexity of the design process and again calling for broadening the design process to include non-traditional disciplines in the very early stages of human space mission design.

Design Approach of the Workshop

The concurrent design strategy presently used by ESA, has already demonstrated its validity in the sharing of data and knowledge during the design process with a relevant reduction of time and cost.

The definition of Concurrent Engineering that ESA has adopted for their Concurrent Design Facility is: *"Concurrent Engineering (CE) is a systematic approach to integrated product development that emphasises the response to customer expectations. It embodies team values of co-operation, trust and sharing in such a manner that decision-making is by consensus, involving all perspectives in parallel, from the beginning of the product life-cycle."*

The design approach to be used in the Habitat Design Workshop 2005 is a concurrent approach shared by selected participants (with different disciplinary backgrounds and different nationalities reflecting the member states of the European Space Agency) during all phases of the habitat definition.

The composition of the disciplines the organisers of the Habitat Design Workshop decided on included: engineering, space science, architecture, industrial design, ergonomics, medicine and psychology.

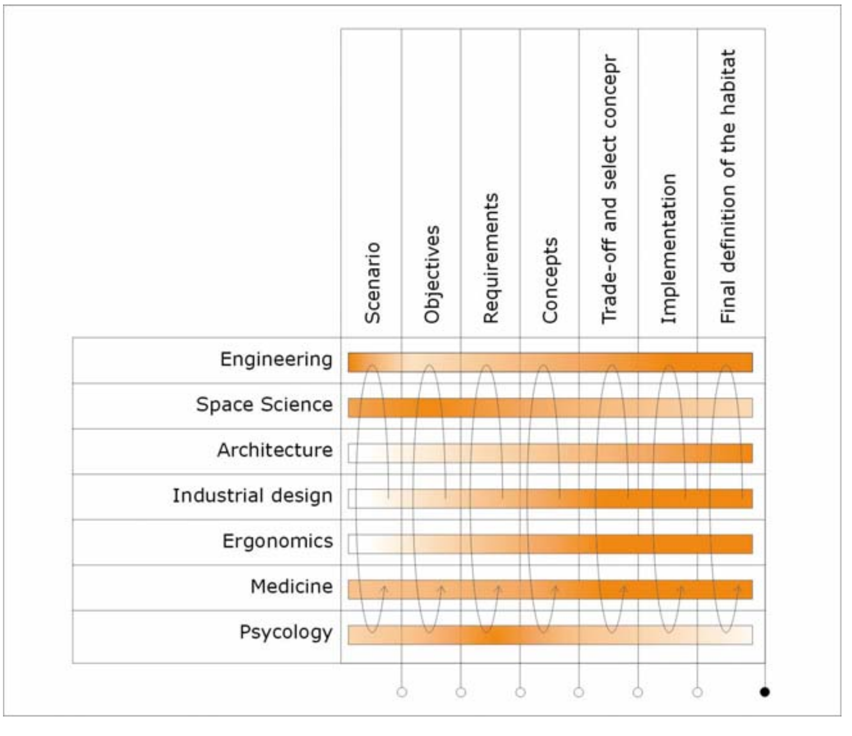

Fig. 04 Scheme of the design approach

The design process in which they were involved simultaneously was composed by different steps:

- Choose the scenario
- Definition of objectives of the mission
- Definition the requirements of the mission and the functional requirements
- Propose different preliminary concepts for the chosen scenario
- Make trade-offs between the concepts and select one idea
- Implementation
- Final design result of the habitat

Process of the workshop

Participants were selected one month before the beginning of the workshop by mean of Curriculum Vitae and Short Portfolio.

Providing pre-workshop reading material was necessary to assure a minimum (or starting) level of knowledge and to increase the communication level of the group (due to the short duration of the workshop).
The workshop focused heavily on interaction, both between student-expert (via presentation and informal discussions) and between student-student (bringing different nationalities together as well as various disciplines).

The lectures made by experts during workshop time were useful for this purpose. The participants attended lectures on space science, life science, system engineering, mission analysis and architectural concept design.

Fig.05 partecipants attende the lecture

Fig.06 Location of the workshop: height Bay of the Erasmus Building of the ESA-ESTEC in Noordwijk (The Netherlands)

Fig. 07 Mars 2 group during a working section

Fig. 08 Participants searching information on line on the ex control room

Although the organisation team suggested a few mission scenarios from were to stating, a challenging phase for each group was to define the scenario. This was due to the fact that it was the first step, so the first attempts at communication between different people, from different disciplines, with different social backgrounds, different cultures and different psychological characteristics.

Each group got the access to a computer room in order to find data for their project. A series of books focused on specific mattes related to the workshop were provided by the organization. Dedicated meeting point with computers and whiteboard were provided by ESA.

An almost daily session of group reviews was scheduled which allowed for a step by step look at the development of the design projects. This was helpful to motivate the design process and minimise delays by cross comparison and discussion (between the different design teams).

Each group defined the objectives of the mission and starting from this point defined the characteristics of the major subsystems (power, life support system, radiation protection, dust removal, telecommunication…) needed to achieve the mission. Concurrently the main objectives of the mission also lead to characterisation of the functional distribution of the inner volume as well as the interior configuration.

The workshop culminated in the students presentation of concept design of a first generation Lunar Habitat, Martian Habitat and Phobos outpost.
The final presentations demonstrated that the multidisciplinary team was able to collaborate and define the concept keeping into account all the aspects and the related subsystems that define a habitat for human exploration.

Workshop Design Outcome

From the design point of view most of the designs venture deeply into the problems related to habitability and there is a good correspondence between the objectives and the final concept design. Most teams managed, even in the short time allotted, to define the internal layout.
Each team defined the objectives of the mission and starting from this point each team defined the characteristics of the major subsystems (power, life support system, radiation protection, dust removal, telecommunication…) required to achieve the mission. At the same time the main objective of the mission also lead to characterisation of the functional distribution of the inner volume and the interior configuration.

Project Mars 1

The proposed habitat will have a cylindrical shape and will consist of three parts: semi-spherical aluminium end caps, an aluminium cylindrical middle part and a cylindrical part made from locally produced glass. The semi-spherical end caps and the aluminium middle part will be launched from Earth and contain all equipment, interfaces and docking ports. The cylindrical glass part will consist of a number of cylindrical segments that are made from the regolith.

Mars 1 differentiates itself by the concept of processing glass on the Martian surface. In this case to use ISRU is not simply a requirement of optimising the mission in terms of transferable cargo. By designing the habitat structure using glass also answers a human demand of having to see outside and could reduce the psychological effect due to the confined and dark environment of a typical habitat. It also allowed expansion using a reusable mould to extend the habitable volume of the base. This main characteristic of the design is the result of a cooperation of different disciplines from the earliest steps of the design process.

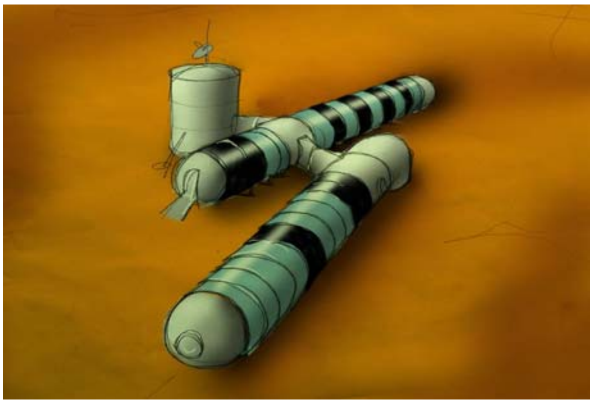

Fig.09 External view of Mars base

Fig.10 Internal view of Mars base with glass elements

Project Mars 2

Group mars 2 proposed an expandable core unit for the exploration of Mars. The core unit is designed to allow for easy expansion in a variety of ways.
The bjectives of the mission are:
getting the crew to Mars and back because discovery, curiosity, adventure and achievement remain significant driving forces for the manned exploration of space; to carry out human studies on the psychological and physiological aspects of long duration space flight; to provide a comfortable and safe living and working environment for the astronauts;
Landing site selected is the equatorial region in favour of a polar alternative and the data is between 2030 and 2035

Mars 2 was characterised since the beginning by good communication between its members. They clearly defined the scenario, the requirements and the main subsystems. This team placed particular emphasis on the psychological requirements of the internal configuration of the space. The final habitat was well described by 3D modelling, which comprised a first study of the internal configuration. Their proposed way of expanding the main module is quite original.

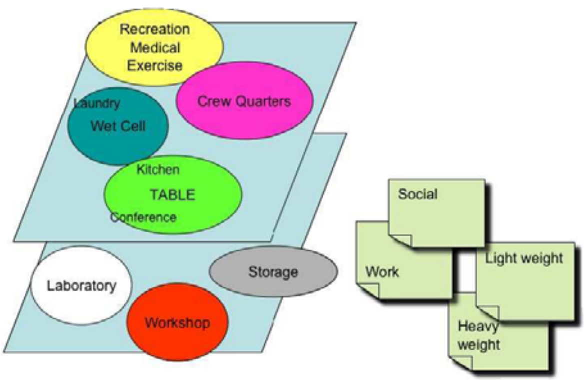

Fig.11 Internal layout and functional areas distribution.

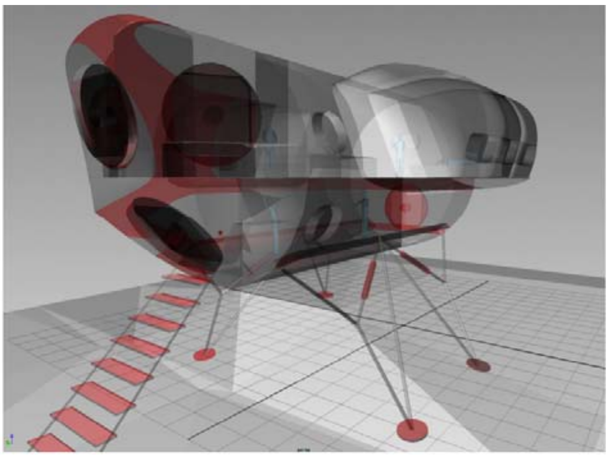

Fig.12 Transparent view of the habitat with the inflatable deployed

Project Moon 1

The first of a series of missions to place a permanent base for humans on the Moon within 10 years. Minimal mission duration of 3 months and using a minimum number of launches.
The objectives are: Exploration, Biology (obtain knowledge about living and working in a hostile environment) and human factors (Psychological aspects of ‘space living’; reduced gravity, micro societies, isolation, dependency). Further Cultural, Educational and Outreach is a second objective: To develop and extend the interest in space flight and science among the population.

For the first time a significant amount of crew time will be assigned in the mission schedule to communicating the experience of living on the Moon to the people back on Earth.

Moon 1 was characterised by objectives strongly related to cultural exploration, educational and outreach. Their inflatable, asymmetrical shell design paid particular attention to habitability issues.

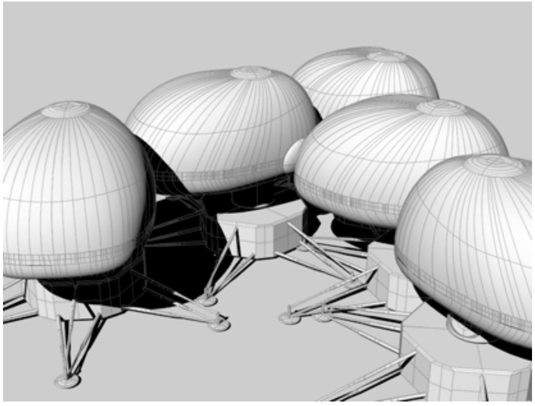
Fig. 13 Frame modules

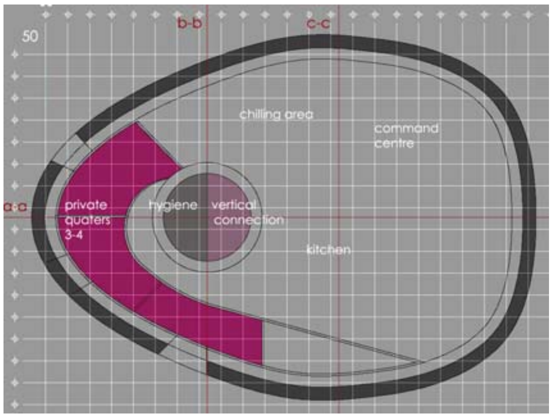

Fig. 14 Frame module internal layout

Project Moon 2

The design scenario chosen was based on the establishment of a permanent human presence on the moon.
As a result, the design scenario was expanded to include the following points:

- Begin design and testing in the near future (~ 2025-2030).
- Enable a crew of 6 to live and work on the moon.
- Establish a flexible habitat capable of expansion to accommodate a wide range of activities, including scientific research, engineering, education, art, philosophy and guests from any background to allow the sharing of this resource.

Moon 2 proposed a simple but smart concept. The cube solution (being similar to earth habitability system) offers a very different way to live in a moon base. The cubic concept has two main applications: one is that of habitat and one is as radiation protection bricks. Addressing these two issues with one solution is quite innovative.

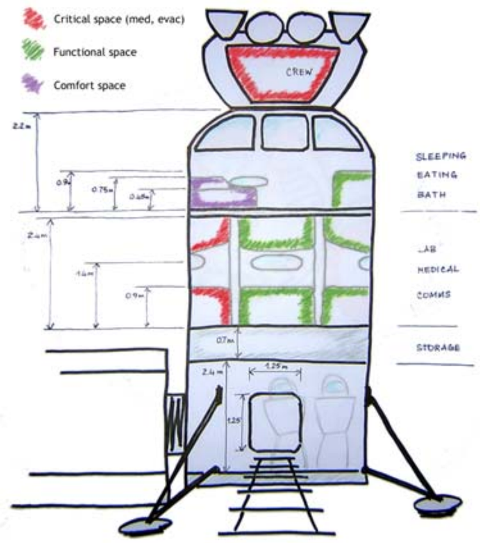

Fig.14 Short term habitat cross section

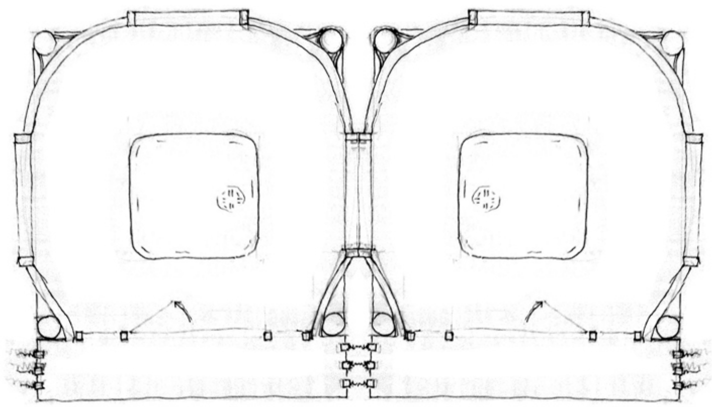
Fig.15 Joined habitat modules

Group Phobos

The scenario for this project is a scientific base on Phobos with the following objectives:

- to research the origin of Phobos and the composition of the body
- to develop techniques for ISRU of asteroidal bodies
- to telecommand rovers and aerial explorers on Mars in real time
- to study long term micro-gravity effects on the human body

Team Phobos experienced some difficulties with getting started as a few dominant personalities from very different disciplines and with very different languages clashed on matters related to the design process and to which issues priority should be given. Fortunately, the team members managed to overcome this problem and present a result that had a number of original features. Such as the use of very large plasma screens as virtual windows or open ceilings with the ability to display any vista or provide a user interface. A short arm centrifuge to combat the problems of gravity's absence was incorporated in the design as well. The entire habitat was to be powered by a nuclear reactor some distance transferring the power via laser transmission. The Phobos group impressed the organisation team near the end of their design process as compromises where made between the clashing personalities which shows the professionalism of the team members

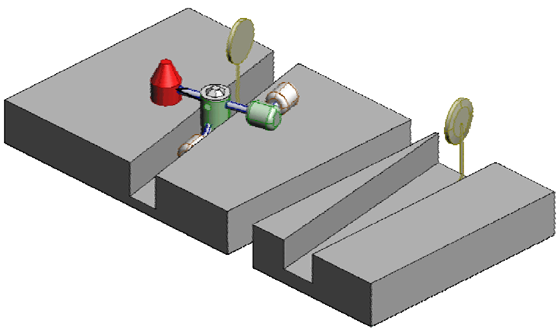

Fig.16 Final configuration of the Phobos base

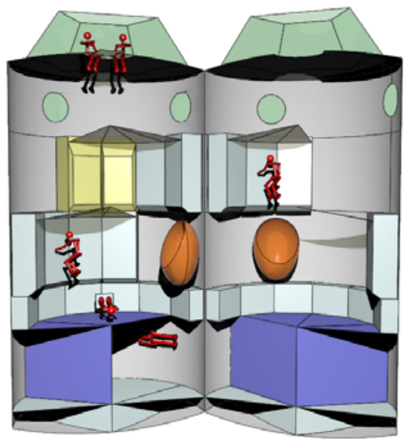

Fig.17 Internal configuration of the main habitat module

Conclusions

The Aurora Habitat Design Workshop 2005 was organised by a group of highly motivated PhD candidates, post-graduate students and young professionals in cooperation with the European Space Agency to achieve the following goals:

- Use, learn about, discover in practice the multidisciplinary design process
- Find novel and innovative habitat designs concepts
- Bring together space enthusiastic post-graduate students and young professionals on the verge of their careers to exchange knowledge, experiences and achieve a synergy thought and execution.

After spending an intensive week with thirty participants, ten organisers and various experts, working together to achieve the best results, some conclusions can be reached about this workshop, its underlying philosophy, its implementation, its success and on how to proceed.

Since the target was to develop a concept of an exploration habitat taking into account what was required from different disciplines, the methodological approach used was appropriate.

The first challenge to overcome was the collaboration of people from different countries and different disciplines given the relatively short time frame of the workshop, one week.

Providing pre-workshop reading material proved very important to assure a minimum homogeneous level of knowledge of the participants with different backgrounds. Expert lectures during workshop itself reinforced the reading material along with the workshop ethos of providing as much opportunity for interaction with the experts as possible.

Adopting a basic methodology for the design process to be shared by different disciplines was very important: define objectives and scenario, select the requirements, define the concept of habitat, implementation and conclusion. This methodological approach was useful because it bears strong similarity to basic scientific methodology. This is the most common approach used by all different disciplines, which come from our natural approach to problem solving.

While all different disciplines did adopt this basic methodology, its implementation did vary substantially. Engineering/science likes to build its design or solution to a problem one step at a time arriving at a linearly arguable and justifiable result, whereas architecture and design likes to skip ahead to the end result and move back and forward. Without worrying so much about the detailed nature of the problem/constraints, allowing for testing of many paths to the end result.

Some problems in the definition of requirements where however signalled, due to the complexity of the project. Complexity (in addition to the multidisciplinary aspect) is the second challenge that characterises this workshop.

The proposed design approach was concurrent in the sense that all disciplines involved were able to contribute to the design at the same time with the same weight in every step of the process. However some skills became spontaneously predominant in some specific phases of the process: For example, it was a general and recognised fact that the first decisions were mainly based on science and engineering, leaving the designers unsure of their role in the first 2 days. Once mass constraints and the purpose of the habitat were decided, however, the engineers satisfied themselves with merely constraining the design to fairing size and mass possibilities. Psychological issues were strongly involved during requirement definition while design played the major role during the following phase where all requirements were synthesised in a visualized concept of the habitat. The speed and details of drawings and 3-D models that the architects and (industrial) designers were capable of amazed both other participants and organisers alike. Working together taught the participants a great deal of respect for the other disciplines that will be useful for the rest of their lives. The continuous presence of all disciplines during the whole process, however, yielded a development of the design from all perspectives.

Although a few scenarios had been suggested, a third challenge of the workshop was to define the scenarios. This was due to it being the very first step of the design process, hence the first attempt of communication between different people with different characteristics, different values, various approaches to problem solving and different cultures.

Scheduling almost daily sessions of public step- by step reviews of the designs was helpful in avoiding delays, verifying the design process and to allow mutual comparison between the groups.

The decision of the organisers to not interfere in the decision making process of the teams was positive in order to obtain fresh and innovative concepts.

All final results show that the multidisciplinary team was able to collaborate and define the concept keeping into account all the aspects and the related subsystem that play a role when defining a habitat for human exploration.

The 2005 Aurora Habitat Design Workshop was a great success, yielding original and innovative designs, exchanging knowledge and experience between people who would ordinarily never meet professionally and taking these new inputs back to their respective fields of expertise. The network of people established during this workshop can only grow with more such endeavours spreading this type of design methodology throughout the various industries, until one day this network is these industries.

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