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Architectural design for space tourism

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Abstract

The paper describes the main issues for the design of an appropriately planned habitat for tourists in space.

Due study and analysis of the environment of space stations (ISS, MIR, Skylab) delineate positive and negative aspects of architectonical design. Analysis of the features of architectonical design for touristic needs and verification of suitability with design for space habitat.

Space tourism environment must offer a high degree of comfort and suggest correct behavior of the tourists. This is intended for the single person as well as for the group. Two main aspects of architectural planning will be needed: the design of the private sphere and the design of the public sphere.

To define the appearance of environment there should be paid attention to some main elements like the materiality of surfaces used; the main shapes of areas and the degree of flexibility and adaptability of the environment to specific needs.

Keywords: Space; Habitat; Tourists; Environment; Architecture; Design

1. Introduction

1.1. Background: on the journey, on the travel group, and on planning

A healthy adult can adjust to the conditions of weightlessness very rapidly, usually in the course of 3–4 days [1], this makes it possible for tourists to experience outer space.

Whereas the suitability of astronauts, cosmonauts, and taikonauts for space missions was decided after a rigorous selection process [2] and they were then trained [3] for the missions for about 3 years [4], including a "group training" [5], future space tourists will depart with no selection process and little training. For this reason, space stations will have to be planned for a high degree of user-friendliness and comfort [6]. The thesis of this paper is that an integrated architectonic planning of space habitats that make a comfortable, user-friendly "home" in space possible can compensate for deficits caused by lack of training and can promote group cohesion.

2. Methods

2.1. Analysis of the space stations built up to now. Possibilities of adjustment for tourist use

2.1.1. Salyut

The first Russian space station, Salyut, had a volume of 90 m^3, which during the mission corresponded to ca. 30 m^3 per person, but which was used for only very short stays [7]. Such spartan dimensions and outfitting

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make it unsuitable as a model for a space station for tourists.

2.1.2. MIR

The MIR station complex [8] had a volume of $372\,m^3$. The three crewpersons had $124\,m^3$ of space each.

According to the reports on their experience acceptance of the MIR space station's habitability varied, especially between the Russians and the Americans: "…the former were less happy with their interpersonal environment than the latter" [9]. This has to do with cultural background and with the composition and experience of the Russian crew [10].

Purely in terms of architecture, the interior of the MIR appeared very chaotic, due to the unsurveyability of the luggage and the visibility of the technology. "They really have a situation where the inventory management got out of control, and Ryumin thinks it happened at about the three-year point, and the crews have been struggling since then" [11]. The analysis of the interior of the space station led planners to take some aspects of design into account: coloration serves orientation in interior of the station. The ceiling, floor, and walls had different colors [12].

The design was suited to the long-term missions of the well-prepared Russian cosmonauts. The visible and accessible technological infrastructure gave the adept cosmonauts security, because it enabled a high degree of control of the station. As Shannon Lucid reported in her Scientific American article "Six Months on MIR" [13], "The cosmonauts typically spent most of their day maintaining MIR's systems… and they could fix everything".

This kind of design for the interior is not suitable for tourist purposes. The lack of a luggage organization system, which leads to a chaotic appearance in the interior and takes up a lot of space, is burdensome. The visible presence of the technology is a danger, because the inexperienced tourists could damage it or use it improperly.

2.1.3. Skylab

The US space station Skylab had a volume of $283\,m^3$. Skylab had less stored luggage than the MIR and thus had more available space. Despite the generous provision of space, the interior of the station was not very comfortable.

The design aspect entered into the planning in a very late phase. Designers who analyzed the station found a need for improvement in many areas [14].

The grating structure present everywhere to serve for flexible fixating was too transparent as a room divider in the orbital workshop, and it was not used everywhere for fixation, but only in those places where it was needed to use equipment.

The excessive interior diameter of the station led to the situation of the astronauts "hanging" in space and hindered movement.

The possibilities that weightlessness opens up were not adequately deepened. In this sense, the design was coherent: it gives the impression that the astronauts move as if they were on earth, by fixating their feet on the grating [15]. Only in the cabins, where the sleeping bags fixated vertically on the "wall" in order to save space, weightlessness was taken into account.

2.1.4. ISS

The ISS was planned from the beginning with a design that aimed to compensate for the deficits and enhance the advantages of the precursory stations Skylab and MIR. Its volume is $425\,m^3$ (as of December 2006)—ca. $142\,m^3$ per person for a small crew of three persons or $63\,m^3$ per person for a crew of seven. Like the MIR, the station is built up of modules.

An important design improvement was the use of racks in the basic facility; they provide space for luggage, supplies, and experiments. The technological infrastructure is mostly invisible. The principle of rack arrangement makes it possible to use the space fully in all three dimensions.

One of the critical aspects is that the rack storage system is not adequate to store all the materials. The use of visible fixations for materials that do not fit in the racks gives the station's clear design a provisional appearance. There should be no loose material on a space station for tourists.

Also critical is the monotony of the forms in the habitable space on the ISS. The interior—$2\,m \times 2\,m$—seems like a corridor [16], and spatial subdivision and sequence is lacking. This could lead to conflicts with an untrained crew. The rack system could be varied so that, with the same basic grid, protuberances and swellings in the interior could make a differentiated design possible and also be useful for storing pieces that have been loose until now.

2.2. Examples of spatial planning that could be adapted for space stations and that are currently found in the planning of tourist habitats (the criteria are volumes, design, quality, and organization)

An exemplary high quality of habitability for touristic needs is found on yachts, cruise ships, and passenger airplanes.

2.2.1. Yacht

The yacht is one of the most interesting examples of designing with “minimal space”. With a habitable volume of ca. $5\,m^3$ per person, examples of interior space design can be found with a high degree of multifunctionality and a well-considered, cozy ambience. Yachts are particularly interesting in comparison with other minimal-space tourist facilities because they are used with a certain degree of confinement. Multifunctionality is achieved by the design of the fixed interior furnishings. Generally, the standard design of the interior of a yacht is a comfortable living area. The arrangement can be transformed in an easily managed way to fit requirements: from bedroom to kitchen, dining room, or work room. What is problematical about the yacht’s design is the special public space of the deck, which cannot be created on space stations.

2.2.2. Transatlantic cruise ships

Cruise ships display great variability in the design of their leisure areas. This helps avoid boredom and is especially important where passengers are forced to live in a confined space. Cruise ships are an example of diversity in limited space.

2.2.3. Luxury passenger airplanes [17]

Good examples of the development of the design of interiors [18] are passenger planes [19] like the Airbus [20] A 380 [21] and the Boeing 787 Dreamliner [22]. The luxury class, in particular, offers travelers a high degree of comfort. Socializing areas with lively design, the use of light effects, and comfortable furniture have given this means of transportation a high quality of design and transformed it into a place for fun and entertainment.

3. Results

3.1. Architect contribute to the quality of a stay in space

Architecture [23] can influence the experience [24] and use of space [25].

This is a great opportunity that should be used for designing space stations for tourists. The role of the architect in designing a space station is to plan a comfortable, functional, and “aesthetically pleasing” living space. The use of the habitat for tourists should be “natural” and unmistakable.

3.2. Building blocks: pleasing, comfortable, functional [26]. Criteria for defining public and private areas

Living together on space stations should be as pleasant and harmonious as possible for all participants. This means that the basic rules of our society should have a corresponding spatial framework [27], also on space stations [28]. In our society and in earlier societies [29], the architectonic planning of the space where people spend time has often been characterized by a clear subdivision of space for the individual and of space for the group [30]. In the past and today, the architect has given special design to the spaces for societal life [31]. But private space has been left up to the individual, who built for himself in accordance with his own wishes and financial means [32].

In public space, the group must be represented as the subject of planning. In private space, the individual must be able to find himself [33]. “Overwintering” experience [34] in Antarctica [35] has shown that private space is important for the human psyche.

3.2.1. Private

The cabin is the only possible private space on the space station into which a person can withdraw. It must be able to fulfill the role of a private “refuge”. For this reason, the basic form of the volume, materiality, color, and illumination must be carefully selected [36]. The space for the private cabin will be very small on space stations, so that more space can be devoted to the shared spaces. A spherical or cocoon-shaped cabin seems larger and permits better use of the volume available (see Fig. 1). Private cabins should be designed to fulfill the following functions: a room for sleeping and resting; a private work room; a room for communicating with friends and relatives on earth; a room for listening to music and watching videos with comfortable seating “restraints”.

The form of the private cabin (see Fig. 2) should be as controllable as possible (in principle, the form, color (see CROMOS) [37], light, and acoustics should all be adjustable) to increase the individual’s acceptance of the room [38].

3.2.2. Public

Public space should be designed with the goals of promoting socializing and of avoiding conflict situations. Conflicts produced by the environment can be avoided by means of studies of the *functionality* of room design in terms of the assignment and sequence of spaces (see Fig. 3), taking the ergonomics of weightlessness [39] into consideration.

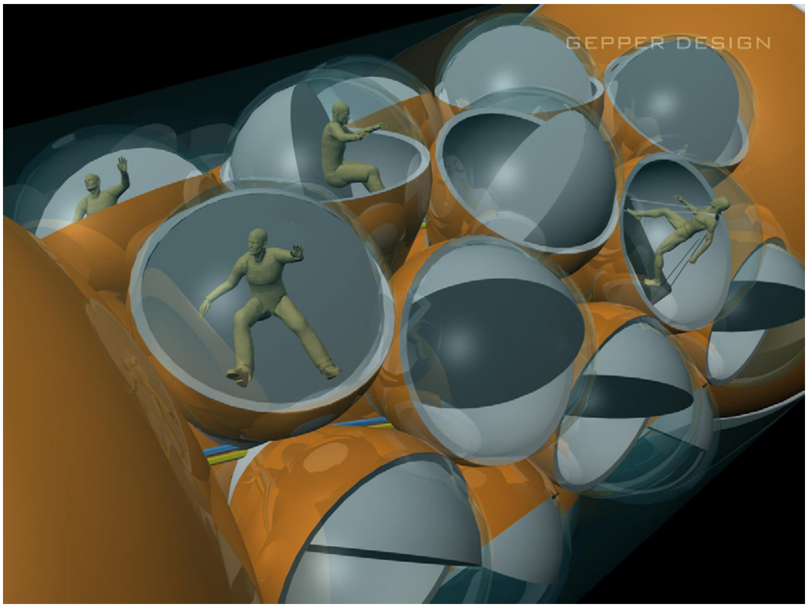

Fig. 1. Student: Gepper (2006), multifunctional private cabin design, "tourist spaceship space-eye", TU Darmstadt.

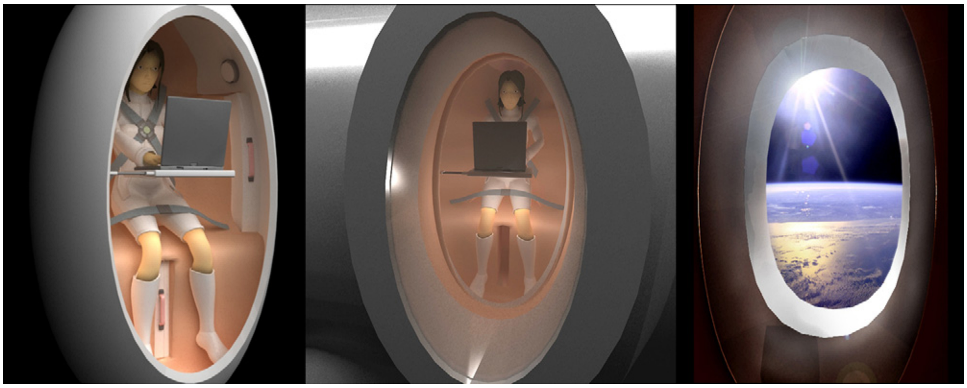

Fig. 2. Students: Bachowski, Nazarov, Valdivieso (2007), mini private cabin design, "moon bus. MIR interior redesign", TU Darmstadt.

To avoid problems created by the surroundings and conflicts between persons moving and persons involved in an activity, areas for movement and transit must be designed to fit their function. The planning of the areas for carrying out all activities [40] should be developed in accordance with the changed ergonomic conditions of weightlessness. The space should be designed to make sizes and dimensions (volume contours) ergonomic; this also applies to the organization of the storage space and the locations of activities. The room for storing materials and instruments should be planned carefully so that the user can take everything in at a glance (see Fig. 4). The interior size of the space, ideally on two of the three axes, is determined by the limitations of motion [41] in microgravity.

It is more difficult to conceive the design of an environment that promotes socializing and represents life in the community, with which both the individual and the group can identify, and in which the individual and the group feel at ease [42].

A difficulty for planning is the limited possibilities offered by the spaceship's interior. Exclusion of the exterior space as an element of architectonic planning places greater demands on the design of the spaceship.

Fig. 3. Students: Bachowski, Nazarov, Valdivieso (2007), public space design, "moon bus. MIR interior redesign", TU Darmstadt.

On the earth, interrelation with the landscape creates an additional quality for all inhabitable constructions [43]. Quantity and quality are the primary characteristics that are essential for the spatial definition of public and private areas for the group and the individual, respectively. The quantity must accord with the kind of activities.

Quality defines the degree of convenience, comfort, and aesthetics to be found in the design of the functionally defined areas. Quality appeals to people's senses. In design, it is determined by several factors: spatial proportions, spatial form, and spatial sequence, surface consistency and color, light and light temperature (see Fig. 5).

3.3. Dimensions

The size of the spaceship is generally determined by the mass that can currently be launched into space. The larger a station, the easier it is to plan its architecture. Dimensions that can be expanded at will, permit the planning of great diversity, which more closely approximates our living situation on Earth [44].

This can be seen in the examples of some course work by students at the Technical University of Darmstadt (see Fig. 6).

For planning a tourist space station in the near future, the size of the stations ISS and MIR should be considered realistic dimensions.

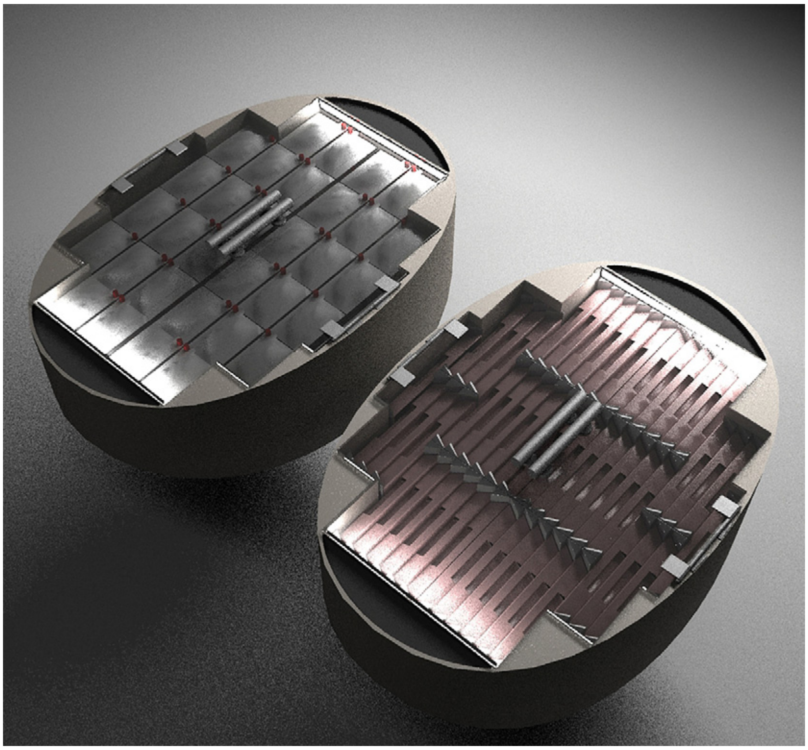

Fig. 4. Students: Bachowski, Nazarov, Valdivieso (2007), stowage design, “moon bus. MIR interior redesign”, TU Darmstadt.

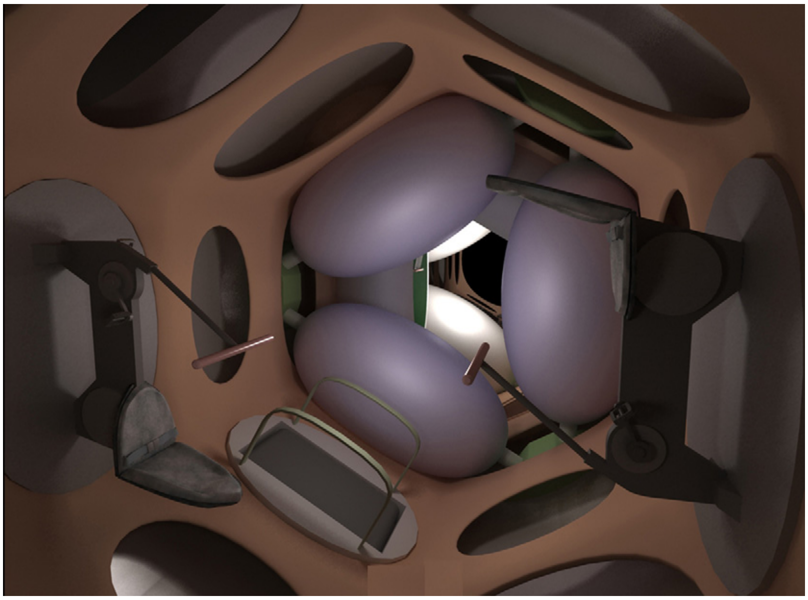

Fig. 5. Students: Bachowski, Nazarov, Valdivieso (2007), training area and private cabins design, “moon bus. MIR interior redesign”, TU Darmstadt.

Possibilities to produce variability, even if the circumference remains the same (taking the ISS as an example), can result from the variable designing of the size and form of the interior hull (see Fig. 7), by the use of different surface structure, and by coloration and light.

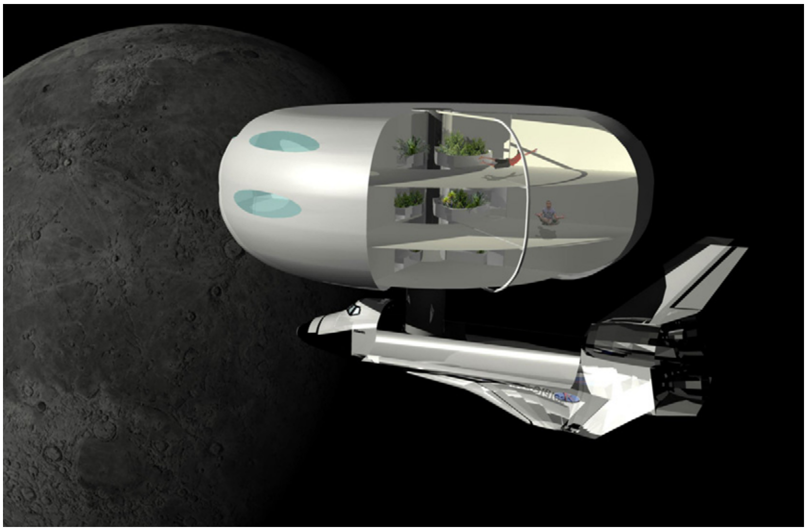

Fig. 6. Student: Paffrath (2005), section view, “lunar orbiter inflate base”, TU Darmstadt.

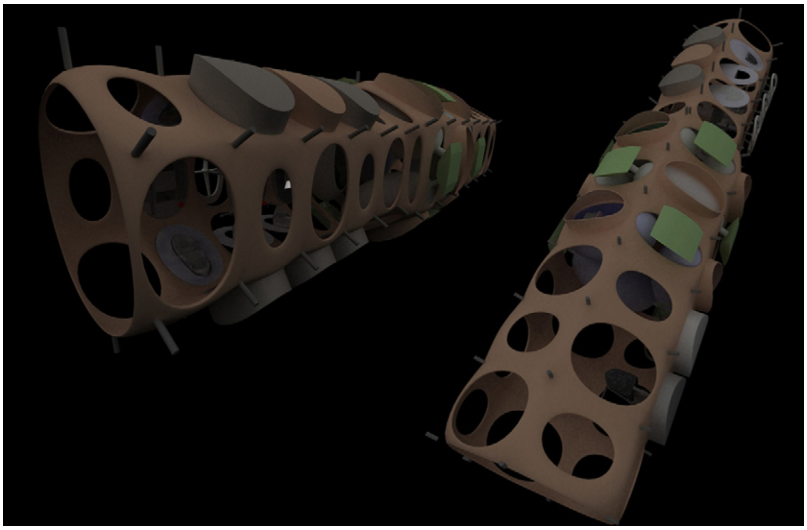

Fig. 7. Students: Bachowski, Nazarov, Valdivieso (2007), interior flexible structure design, “moon bus. MIR interior redesign”, TU Darmstadt.

The designing of light and the controlling of the space station’s light temperature can simulate the natural rhythm of day and night and accompany the people as they carry out their activities. The effect of light on people’s feeling of well-being [45] cannot be neglected when planning space stations for tourists.

4. Conclusions

Architectonic planning of space stations for tourists should take place in a very early phase of a project. To achieve a high degree of quality, activities for the tourists’ stay in space should be planned very precisely, similarly to how a mission is designed for scientific purposes. The number of tourists and the accompanying crew, the number of days on the station, a list of all materials that need to be brought and the proper dimensioning, the kind of activities (see Fig. 8) and the equipment necessary for them, along with the volumes and dimensions of the space station, are the information essential for a high quality of planning for a tourist space station. Floors, walls, and ceilings should be used as interchangeable storage spaces for changeable furnishings (like on yachts). Arranging things in

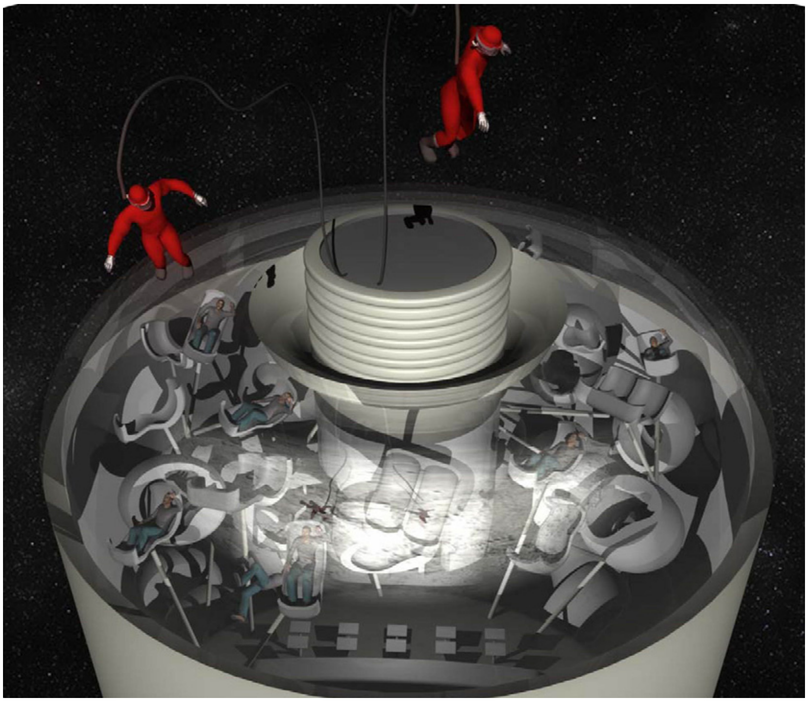

Fig. 8. Students: Ostholt, Paffrath (2006), leisure area, "lunar orbiter tourist station", TU Darmstadt.

accordance with function and an orderly appearance make it possible to use the containers for luggage and technology as design elements in the rooms. Special attention should be given to the room for flux and the room for permanence to minimize conflict and stress.

In Messerschmid's definition of "human factors" [46], ergonomics and habitability are the essential factors contributing to the architectonic design of space stations. If a space station is used for tourists, habitability is the essential factor, while ergonomics [47] should find new application in designing leisure activities.

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