Concept House ①

Towards customised industrial housing

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The Universal House
An Outlook to Space-Age Housing

Andreas Vogler
Architect (dipl. Arch ETH), Architecture and Vision, Munich, Germany.
andreas@architectureandvision.com

Abstract

Sending Humans to long-duration space missions like Mars, is imposing radical challenges to the way we look at the human habitat. We have to build a complete machine for living, which will support all hard and soft requirements of human life under extreme conditions with minimum space and minimum energy use. This requires light-weight mobile structures, autonomous and interactive environmental systems. Similar trends can be found in terrestrial architecture, where the house eventually could become, through technology, a more active part of the planetary ecosystem.

Keywords: Space Habitats, Extreme Environment, Mobile Architecture, Autonomous Systems, Psychology

1. Introduction

„If our designs for private houses are to be correct, we must at the outset take note of the countries and climates in which they are built."

Vitruvius, de architectura 6.1.1, ca 27 bc

"The Earth is the cradle of humanity, but one can not live in a cradle forever!"

Konstantin E. Tsiolkovsky, 1911

The space-age has made fundamental impacts on our understanding and perception of our home planet Earth. The first images from the Earth seen from space, especially as the "blue marble" taken by the 1968 circumlunar Apollo 8 team, showed us the preciousness of this blue planet with its thin atmosphere in the vast dark vacuum of space (figure 1). These images helped a growing understanding of the limitation of resources and the understanding of the Earth as a living system. This was first postulated by James Lovelock in the early 1970s in his 'Gaia'-Hypothesis.[1] The interesting point in this hypothesis is, that favourable conditions like average temperatures of 15°C and atmospheric oxygen content of about 20%, were not provided for life to happen, but actually established by life and maintained by it. Without life it is assumed the Earth would have an average temperature of about 240-340°C and an atmosphere consisting of 98% carbondioxide [1]. The architect has been aware of the influence of the environment on the architecture as much as the profession has learned by failures in the early industrial cities in the 19th century as well as in the

[1] The Gaia-Hypothesis was named after the Greek goddess of the Earth. As much as it was praised by the esoteric movement at the time, it was rejected by the sciences, whether geophysics, chemistry, geology, or biology, which believed they said all that there was to say about the Earth. Dubbed under ‚Earth System Sciences' and ‚Astrobiology', today there is a clearer scientific understanding of the interaction of life and its environment.

social housing programs of the 1960s, where the influence of the architecture on the environment has been ignored. We know today, also by satellite data, that the tremendous growth of our cities and the sub-urban sprawl is counteracting on our environment dramatically. It was Buckminster Fuller [2] who pointed out that the Earth should in fact be regarded as a spaceship. (Figure 1 and 2).

Fig. 1. The Earth is our home. A wonderful large scale macro architecture with dynamic systems. Images taken from the Galileo Mission in 1991. Credit: NASA

Fig. 2. The astronaut suit is representing a micro architecture, allowing the human being to live 8 hours in free space. Credit: NASA

What we face, when designing a space habitat is, that we have to build a ship, which handles speeds of 30'000 km/h and more, provides all life-support functions like fresh air, drinking water, food, environmental control and deals with our metabolic off-products like the system Earth does in a recycling way. Further, the longer the mission the greater the need to compensate for the lack of our social life and psychological experience. Leaving the gravity of Earth demands great energy and requires minimal volume, minimal mass and minimal energy systems for spacecrafts.

Thus, a space habitat can be characterized as

- Mobile
- Autonomous
- Interactive

Although there are still many unknowns on how the human being will adapt to long-duration spaceflight and how the design of space habitats will evolve, it is claimed here, that the space habitat is the prototype of an 'universal home'. It has to be able to offer in one way or another all basic functions, which we usually get for free on our home planet. It thus forms an 'archetype' of architecture[2]. The world is incorporated into the spacecraft.

There are actually clear trends in terrestrial architecture, which point into the same direction of mobile, autonomous and interactive homes. There is a tendency, that houses will incorporate all systems to be independent from the environment. The

[2] Archetype is not understood temporally of what has been first, but as the general concept of a minimal optimized system for the human being to 'live' (not just survive) in the most extreme environment of space. Today's spaceships are still far from that optimum.

viewpoint from space architecture should help to clarify some aspects of the human habitat in its most extreme condition and hopefully help start a new practical and theoretical discussion about the human being and the self-made environment in the space-age. Thus, outlining an outlook for future concept houses, not deriving from the past, but heading into the future.

2. The Space Habitat

Space Habitats are the most challenging of extreme environment habitats. As new human missions to the Moon and eventually to Mars in the time-frame of the next 20-30 years are realistically discussed by the Space Agencies, we just start to realize, what challenge this is for the human being. And although architecture is one of the oldest professions, we do know little about the implications and countermeasures of sending a crew of six in a 8m diameter tin can for two years to Mars, as current mission plans are proposing [3]. Three main characteristics of future space habitats will be 1.) Mobility, 2.) Autonomy and 3.) Interactivity[3]. These will eventually impact our understanding of the terrestrial habitat, which is infact also a 'space habitat', just on a planet with more favorable conditions, than the ones around us.

2.1 Mobility

Space habitats are vehicles, even if their final specification is a surface habitat. They need to leave the gravity field of Earth travel through space and land on another planet. The mobility has major implications and restrictions on its construction, dimensions and mass. The space shuttle (figure 3) can fly 24'400 kg to Low Earth Orbit with a fairing of 4.7 m diameter and a length of 18.6 m. The whole International Space Station (figure 4) is build up on these launch dimensions and mass. The average speed of the station is 28'000 km/h. To fly one kilogram of mass into Low Earth Orbit costs currently USD 20'000. If you price the 3.5 kg of potable water, the 0.62 kg of solid food and the 0.84 kg of oxygen needed per day per astronaut [4], you start to realize how valuable resources in space are. When you have to bring everything from 'home', you start to look at your home differently.

Fig. 3. The Space Shuttle is the 'truck' for the orbital construction site. Credit: NASA

Fig. 4. Each part of the International Space Station has to be delivered by the Space Shuttle or the Russian Proton

[3] Further important characteristics, which are not included for this essay are radiation protection and pressure vessel structures.

Rocket. Credit: NASA

For surface habitats, these restrictions, lead to discussions and research of how to use in-situ resources (ISRU) to produce energy or to build domes and shelters against radiation with regolith, how the local material on a celestial body is called.

2.2 Autonomy

Up to these days spaceflight is still dependant on resupplies from Earth. The International Space Station ISS is resupplied, by the Automatic Transfer Vehicle ATV, which brings consumables like water, food and oxygen and is filled up with waste before burning during re-entry into Earth's atmosphere. To go beyond the Earth's orbit, autonomous closed-loop systems will be necessary. There are several research programs moving in this direction. Space simulations are planned or have been conducted like the chamber experiment at NASA-JSC (figure 5). The primary goal of the Lunar-Mars Life Support Test Project (LMLSTP), conducted from 1995 through 1997 at the NASA Johnson Space Center, was to test an integrated, closed-loop system that employed biological and physicochemical techniques for water recycling, waste processing, and air revitalization for human habitation. As an analogue environment for long-duration missions, the conditions of isolation and confinement enabled studies of human factors, medical sciences (both physiology and psychology), and crew training. The results of these studies provide a wealth of important data not just for Space Shuttle and ISS missions into space, also other missions in extreme environments here on Earth. The longest simulation was done by a crew of 4 for 90 days, using wheat to re-vitalize the air and a bioreactor for the water recycling process, which used microbes to clean-up the water. An incinerator was used in the solid waste processing system to turn crew fecal matter into ash and gaseous carbon dioxide products for reuse by the wheat [5].

These systems will have to become light-weight with a minimum power usage in future. The astronaut of the future will likely be a 'bionaut' as well, living in symbiosis with controlled plant and bacteria systems on smallest space (figure 6).

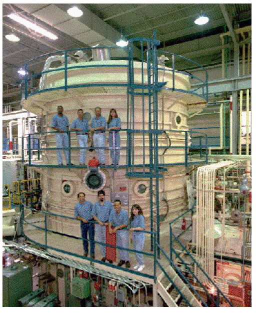

Fig. 5. In this 6m diameter vacuum chamber, NASA tested autonomous life support systems for up to 90 days. Credit: NASA

Fig. 6. Plants provide oxygen, clean water and provide food. They are also supporting the crew psychology. They are an important factor in spaceflight. Credit: NASA

2.3 Interactivity

The astronaut will be forced to live in a closed interactivity with the spacecraft. Technical systems will monitor the environment, but will also need to be maintained by the astronaut (figure 7). Housekeeping is a major task in small spaces, even more so in weightlessness. More than that on a long-duration spaceflight the sensory deprivation will be a major psychological problem. Once the terrestrial orbit is left, there will be no day and night cycles, no clouds moving, just black space with a bright sun and distance stars and planets. The systems and interior design of a space habitat will have to provide countermeasures for that [6]. They will have to allow the astronaut to reconfigure the interior as well as to provide active sensory stimulation by the use of light, acoustics, odours and materials (Figure 8). Real-time communication with Earth will impossible, when a signal from Mars to Earth takes 20 minutes one way. A personal conversation robot may also become an important device for expression problems outside the crew community. The most extreme environment may actually be our inner self.

Fig. 7. The Zvezda Module of the International Space Station is the main Habitation Module at the moment. In the foreground you see the dining table. Credit: NASA

Fig. 8 Mars Habitat Crew Quarter design concept by TU Munich. The Crew Quarter contains a interchangeable modular storage system. The light can be adjusted by computer in colour, intensity and distribution. Credit: TU Munich

3. The Universal House

"Who said pleasure is not useful?"

Charles Eames

In the 18th century Abbé Laugier derived the 'Urhütte' (Primitive Hut) from a natural timber construction (figure 9). The looks of the building were dominated by its structure. Le Corbusier separated construction and appearance of the house in his five points of architecture establishing the Maison Domino as the 'primitive hut'. The looks of the building were dominated by its function. Today, without any deeper theoretical discussion nor vision the looks sometimes seem to be fairly independent from anything, maybe from the last update of the Nurbs modeling software. Space Habitats have to develop their own aesthetics under the laws of nature and limited resources (figure 19). They are highly optimized complex structures, they form the 'primitive hut' of the space-age, a universal house, which works on Earth as well as on any other celestial body. A next step to the concept house of the future may be a more research based optimization of the production, the advanced environmental requirements of the house and the interior needs of the inhabitant. Thus a modern house could evolve, leaving behind the iconic discussion, and rather develop like a modern industrial product, where design is more than styling, but systems integration.

If we just consider the three characteristics mentioned for space habitats, it shows us astonishingly known concepts, but also provides an outlook towards space-age housing, which can be defined as the scientific understanding of architecture as the technical interface between the human being and its environment. The architectural understanding of technology does include aesthetics and pleasure as functional needs of the human being.

Fig. 9. In 1753 the Abbé Laugier introduced the primitive hut as an embodiment of classic principles in his "Essai sur l'architecture". The primitive hut, four tree trunks supporting a rude pitched roof, became the natural origin of architecture.

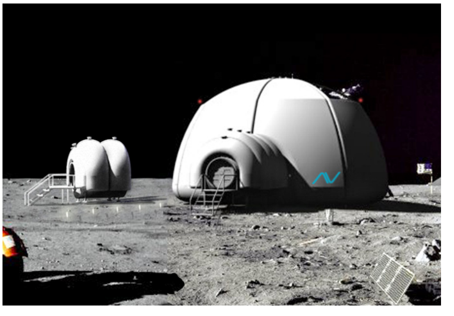

Fig. 10 The inflatable Moon Base by Architecture and Vision, is shaped by minimum transport volume and atmospheric pressure after deployment. A pure, rational structural form, as postulated by Laugier's primitive hut. Credit: Architecture and Vision.

3.1 Mobility

Mobility in architecture is not a new concept. Nomadic tents are likely to be the oldest and lightest structures ever built and date back to 25'000 years. But also the most impressive transport logistics started with architecture. The Cheops pyramid built 2530 BC, consists of about 2.3 million stones, 2.5 tonnes each and transported from quarries around 1000 km distant. Nevertheless, the reality on some modern building sites, does not seem much more advanced since then and the level of prefabrication is still relatively low. The requirement of mobility is driving construction to lighter, compact and modular structures and is an important element of the industrial production of houses. Mobility comes together with prefabrication. An important advocate of mobile building is Richard Horden [7][8], who continues to blur the boundary between vehicle and architecture and thus working on the aesthetic and technical language of these small-scale structures (figure 11). Extreme environment building like in the mountains also requires different solutions. The short available building time during summer and the transport by helicopter require a high degree of prefabrication and a modular design, which is taking into account weight limits and flight dynamics (figure 12)

Fig. 11. Skihaus by Richard Horden. A small light-weight mountain hut, which can be transported by helicopter.

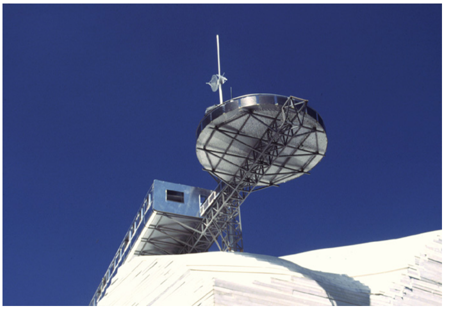

Fig. 12 Design for a high altitude weather station in the Swiss Alps. Credit: Andreas Vogler

3.2 Autonomy

The traditional farmhouse has been fairly autonomous, based on a in-situ resource utilization, providing food from crops and animals and fire wood from the forest (figure 13). With the growth of the cities and the building up of modern infrastructure this concept has been lost. Most buildings are fully dependant on supply of water, electricity and heating energy. With the oil crisis in the 1970s a better insulation of houses and the use of solar energy started to reduce the energy need of houses. Steady improvements in materials and building technologies led to the passive house standard, making active heating redundant. Although the zero energy house is not economic yet, the industry developed a drive and the market of houses is a potential mass market. The Fraunhofer Institute recently predicted a substantially growing market on passive houses in the next 10 to 15 years [9]. There is a clear trend of houses becoming self-sufficient again (figure 14).

Fig. 13. Traditional farm-house in the Austrian Alps. Credit: Petra Gruber.

Fig. 14 Competition design for a autonomous mountain hut. Credit: Architecture and Vision.

3.2.1 One Step Beyond: Houses are improving the environment

The reduction of the energy use of building and their self-sufficiency is an honorable objective, but regarding the expected development of the world's climate, this may not be enough. Buildings of the future should not only visually improve the environment, but also clean the air, collect water and produce energy and fresh vegetable for our daily needs. Now this may sound romantic, but is actually challenging our continuing romantic understanding of nature. The NASA BioHome project employed inhouse plants for wastewater treatment, harvesting drinking water, crop growth and air purification [10]. A more compact vertical arrangement of plants, supported by robots and LED lights can become the 'green lung' of a house. The house would become the technological equivalent of the tree, actively cleaning the air around it.

3.2.2 Another Step Beyond: Water for the World

As we get excited by technological possibilities, we shall not forget that according to UN reports 1.1 billion people don't have direct access to drinking water (figure 15) and 2.4 billion don't have access to basic sanitation. Developing countries often do not have the means for extensive infrastructure. Mobile and low energy water recovery systems can help to improve the situation and maybe allow a technology jump as it happened with the mobile phone. The insufficient infrastructure in landlines was suddenly redundant in many developing countries by the growing market of the mobile phone. Analog to the mobile phone market the large housing market of the wealthy countries can help to make a cheap mass product in the future out of a now expensive technology (figure 16).

Fig. 15. According to UN about 50% of the world's drinking water is carried on women's heads.

Fig. 16. Mobile Eco Units powered by solar energy can provide safe sanitation. Credit: Architecture and Vision

3.1 Interactivity

In the last century all formerly public events have also been privatized and integrated into the home. The radio brought the concert hall, the TV the Cinema, the washing machine the former washing house etc. This century will start with the integration of data systems and the interactivity of the house and the user.

Further technology movements are directed towards the networked 'Smart Home' and household robots, making the home a fully interactive 'machine for living', as it has been postulated as early as in the 1920s by Le Corbusier and others. But as alienation and social isolation of the individual is increasing in the modern mass society, these 'toys' become more than just an electronic servant. They become objects of affection. The Sony QRIO and the Honda Asimo robot (figure 17) recognize your face, can dance and walk and offer social skills. 'Cocooning' is a recent and growing trend for making the home the main center of one's private life. The home has to increasingly serve for the 'grounding' of one's senses. A growing in-house wellness market is reflecting this. 'Home' is the cradle of ones privacy and psychological health. Like in a space habitat, the terrestrial home will increasingly offer countermeasure against exhaustion, boredom and loneliness.

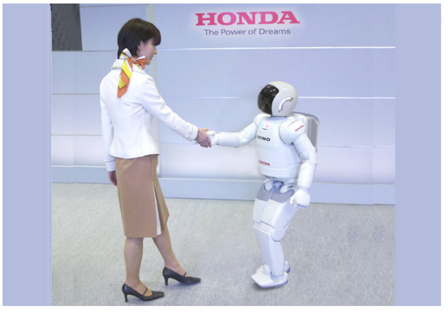

Fig. 17. The Honda Asimo robot shows social skills and interacts with the people around. Credit: Honda

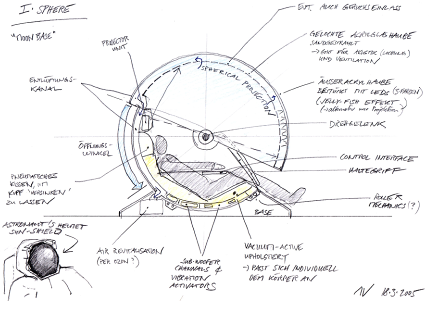

Fig. 18 Multiple sensory environments will provide power-relaxation in future. Credit: Architecture and Vision.

3. Results and Discussion

The comparison of the space habitat and the existing trends in terrestrial architecture show that the Universal House is more and more developing towards a fully technically controlled environment, a machine for living. What is a requirement for a space habitat – incorporating everything needed inside – becomes an evolutionary trend in the terrestrial home. This is going that far, that not only the physical comfort of the inhabitant will be maintained, but also the psychological comfort. Now this is happening at a time, where machines become invisible and technology gets smaller and smaller, but also friendlier and less frightening than it has been before. Embedded systems will allow the architect to work in a new dimension with space, light and material. The requirement for mobility in aerospace creates lightest structures and new materials, which provide highly compact spaces for living. Buildings have been becoming lighter and lighter through history. Modern buildings employ light-weight materials, saving transport mass and grey energy. It is a clear technology development: lighter, smaller more efficient, or 'Touch the Earth lightly'.

Autonomous building systems are needed for spaceflight and face an increasing market potential in the housing segment. First buildings are built using vacuum toilets, a system known from aerospace and trains. These use five times less water and are gravity independent, providing more flexibility in design. These systems will also create a new relation to resources and nature. Inhouse gardens complement their technical and psychological functionality. Buildings in future will be able to not just to reduce their own energy and consumables need, but actively clean the environment and provide energy.

An interactive environment in the space habitat will allow the environment to adapt to the activities of the astronauts, but also to countermeasure against sensory deprivation. The smart house development is exploring similar steps. The research from spaceflight will also affect the leisure industry and vice versa. There is a need for people for 'power relaxation', 'resetting' after a working day. Much of the leisure time of modern people is used by inefficient relaxation. The future house will be able to react to the moods of the inhabitant and to be pro-active about it.

Nevertheless, the construction industry is lacking a lot of innovation found in other industries. Whereas the Aerospace industry is leading in research, it is especially the automotive industry, which is leading in production. A similar approach to houses can only be found in Japan. In USA and Europe the standard house factory is basically a building site put under a industrial shed, with builders crawling on their knees over timber structure, cutting insulation material and hammering nails into panels. But neither in Japan nor anywhere else the prefabrication of houses is reaching a substantially higher market share than 15% in average. The majority of houses are built by local companies with 2-10 employees. There are different reasons for this, which need to be understood. Although production is a major key to lower costs and rise quality, mass production is not the only key as well as low costs is not the only market. In the US, where manufactured housing mostly supplied the lower end of the market, the industry had a severe drop with the current housing boom, where the market shifted to the mid-range and luxury segment. Different in Japan, where industrial housing industries where able to maintain their market share throughout the sharp recession on the market. Japanese industrial manufacturers where always focusing on the mid-range and high-end market, offering quality and life-time warranty for their products. The evolution of the new home will neither happen by marketing studies, production technologies nor design alone, it only can happen by a interaction of all elements of this complex system. And, it only will happen, if we keep on challenging our preconceptions of the home.

Fig. 19. Mercury House II is a concept house by Architecture and Vision introducing mobility, pro-active environmental systems and interactive, robot-supported environments. Credit: Architecture and Vision.

3. Conclusion

Long-duration Human Spaceflight requires a full symbiosis of the crew and its spaceship, which will have to provide a 'whole world' for them. This 'micro world' development can similarly be detected in the terrestrial house, where increasing building technology and smart systems make the house and its inhabitants more and more independent. As architects we need to keep up with these developments and help shape them to increase the quality of our lives and our environment. Concept houses play a crucial role in this development, since these technologies are initially expensive and we need to use them to understand them. But also the concept of 'home' needs to be questioned rigorously. If we observe the reality of house building as it happens everyday, it seems, that we have never been as far away from a truly modern architecture as today. But maybe the house of the future is not evolving from the mass market, but rather from a niche market, where it develops its identity and is ready, when the generic perception of the house is changing as the way we view our world is continuously changing.

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