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SELF-SUFFICIENT AND SUSTAINABLE TECHNOLOGY FOR HABITAT SYSTEMS FROM SPACE TO EARTH

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ABSTRACT

In Space habitats, many factors such as the high cost of material transportation have been pushing the research of closed-loop applications towards the regenerative life support system approach from both a physiological and a psychological perspective. Today, the increase in population and pollution as well as the global economic instability make autonomous production of food and energy a need for megacities, too. Almost since its beginning, settlement in Space has been conceived as "green" for survival reasons. Plants produce oxygen and consume CO_2, while humans do the opposite. Therefore, there is the need to support each other. Moreover, there is the psychological factor, which applies to both cities and Space. It is important for humans to experience the cycle of life through the cycle of plants. The current Space research on life support systems is based on the work of microorganisms, vegetables and humans (e.g. MELliSSA) and has many similarities with the systems that are being developed for food and energy production in cities. The problems are basically the same, though they are much more extreme in Space (e.g. production of food, water, energy, heating, oxygen… and processing of human outputs - urine/feces- , rubbish, …). The Extreme-Design research group has been dealing with the psycho-physiological habitability of autonomous habitats in extreme environments since 2007, and has been working from 2009 in the EuroMoonMars ILEWG campaign at the Mars Desert Research Station simulation facility and has collaborated from 2011 in the project of Valentina Karga, "Machine for Sustainable Living". This paper addresses similarities and differences between Space and Earth applications and proposes the exchange of information and technologies. Building such a system for cities could help experience how it would be to live in a similar system in Space, while we could adapt systems that have been designed for life support in Space to Earth applications.

Keywords: self-sufficient system, architecture, sustainability, technology/know-how transfer, MELiSSA.

1. INTRODUCTION

This research focuses on the know-how and technology transfer from Space to Earth for closed-loop and self-sufficient systems.
Since the onset of Space exploration in the 1950s and 1960s, there has been interest in survival under extreme conditions and, as a consequence, in how to produce primary resources.
There was a need to rethink the domestic space that astronauts would inhabit not just as shelter but as a system of "total circular resource regeneration" (Kallipoliti, 2011, p. *27)* which later got the name Life Support System. The concept of the perfect closed loop has been a dream for architects ever since; not only in Space but also on Earth. The idea of a house that recycles everything is not new for humankind. Before people developed cities and manufactured products, they used to produce everything themselves and made use of everything in their homesteads. However, in parallel with Space research, the idea became conceptually more concrete, and for the first time it was seen as a hybrid system that follows both nature and technology. Throughout history, there are examples of transferring systems that were developed for Space to Earth[1], while we cannot deny that the research about potential migration to outer Space is also about reinventing a new way of living; the best occasion to do that would be in a totally new land, where even the climate does not follow the rules we all know.
From modernism until today, architecture has been treated as a pure empty shelter; bio-waste is better put out of our sight. What we can learn from these examples is that the act of inhabitation cannot be separated from the physiology of ingestion and excretion; an idea strongly linked with the false existence of the constructed notion of waste: in the ecosphere[2], waste does not exist. Matter is simply

[1] "These applications, transferred from technologies used in Life Support System for Spacecraft, sold a considerable number of units in the United States under the label Grumman's Integrated Household System" (Kallipoliti, 2011, *p.29*).
[2] Oxford British and World English online dictionary (2012): "Ecosphere (noun): the biosphere of the Earth or other planet, especially when the interaction between the living and non-living components is emphasized".

transformed. Dead organic matter becomes earth and from there life is generated again[3].
The paper reviews historic and contemporary examples of terrestrial and extra-terrestrial life support attempts trying to detect and advance the know-how exchange between the two areas and also between different disciplines.
The authors are: Valentina Karga, an architect who is researching self-sufficient habitation, and Irene Lia Schlacht, a researcher specializing in human factors and habitability applied to Space.
In this paper, the two authors also present their direct experience with designing, building and living in habitats oriented towards self-sufficiency for both Space mission simulations and Earth environments.

2. FROM SPACE TO EARTH

2.1 The historic example of Graham Caine

There have been several attempts of knowledge transfer from Space to Earth. One example is the one of architect Graham Caine and his Eco-House in 1972 in South London. “It not only looked like a spaceship but also functioned as one” (Kallipoliti, 2012, *p. 86*). He lived there for two years with his family until he was asked to demolish it. The attempt was successful since the system functioned perfectly. Lydia Kallipoliti in her essay “Return to Earth; feedback houses” describes it: “The Eco-House was a fully functional integrated system that converted human waste into methane for cooking, as well as maintained a hydroponic greenhouse with radishes, tomatoes and even bananas” (Kallipoliti, 2011, *pp. 32-33)*. Caine was studying biology as well as chemosynthesis and Life Support from NASA publications. He was interested in creating a life support system for Earth. In his diagram (Fig.2), he depicts himself in the middle of the cycle doing the act of excretion, cooking and monitoring the machines at the same time and we understand that he realized that the most essential thing for the system to function is the human input. The architect, therefore, “was an indispensable biological part of the house, connected to it in a diagram where excretion becomes a vital constituent of the system’s sustenance.” (Kallipoliti, 2011, *pp. 32-33).*
Caine did not have access to the technology of a life support system for Space available at that time, and with very minimal funding from his school, the Architectural Association, he achieved the know-how transfer from Space to Earth translating high-tech into low-tech and simulating a more biological rather than physic-chemical life support system.
His system was made up of different interconnected processes. Process A, Digester: treatment of organic matter and liquid waste to produce methane. Process B, Oxygenation: creation of the required oxygen by photosynthesizing algae. Process C, Hydroponic plant culture: growing crops and plants by recycling human and vegetable matter. Process D, Secondary digester: decomposition of algae also producing methane. Process E, Water filtration: rain water is used for drinking after active carbon filtration of petrol pollution with active carbon is used for drinking; if purification is not sufficient, it is recycled to be used for domestic purposes. Process F, Gas collection: guided methane production to be used for cooking purposes (Kallipoliti, 2012b).

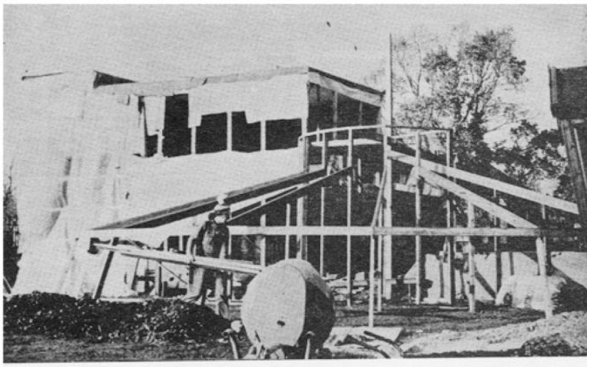

Fig. 1: Graham Caine’s Eco-house from Kallipoliti, *2012, p. 97*

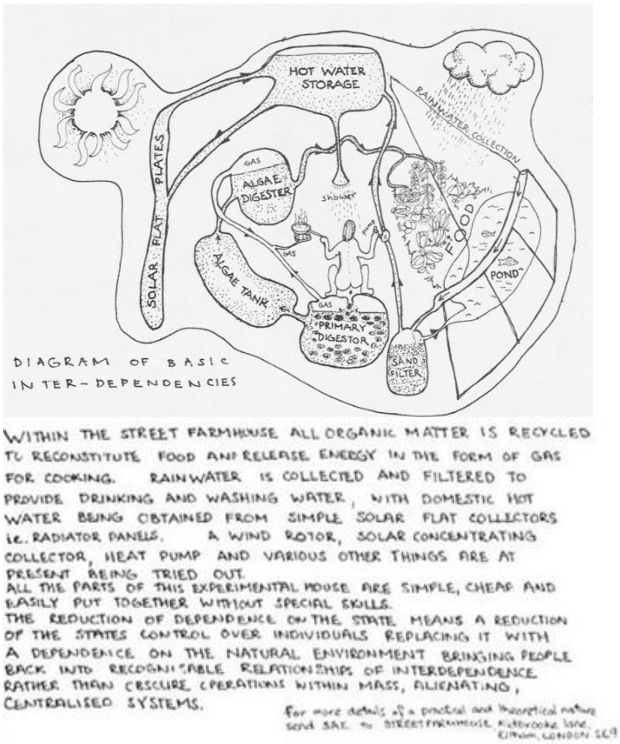

Fig. 2: Graham Caine’s diagram for the Eco-house from Kallipoliti, *2012, p. 97*

2.2 The MELiSSA loop

One of the approaches of the current research on Life Support and regenerative systems for Space application is that of MELiSSA (Micro-Ecological Life Support System Alternative). The MELiSSA loop replicates the rules of an aquatic ecosystem and is based on the work of micro-organisms, vegetables and humans.
There is a striking similarity between the Eco-House and the bio-regenerative system of MELiSSA. In both

[3] “ Life is always a product of the decomposition of life” (Bataille, 1986, p.55)

approaches, the goal of converting all output back to input is achieved by regenerating food from the human feces. On the homepage of MELiSSA we read: “The driving element of MELiSSA is the recovering of food, water and oxygen from waste (feces, urea), carbon dioxide and minerals (MERGEAY 1988). Based on the principle of an "aquatic" ecosystem, MELiSSA is comprised of 5 compartments colonized respectively by thermophilic anoxygenic bacteria, photohererotrophic bacteria, nitrifying bacteria, photosynthetic bacteria, higher plants, and the crew.” ESA (2007) The attempt to treat human feces is actually the innovation of the MELiSSA loop: “MELiSSA goes further than other recycling systems used on Mir or the International Space Station, which purify water and recycle exhaled carbon dioxide but do not attempt to recycle organic waste for food production.” ESA (2007)

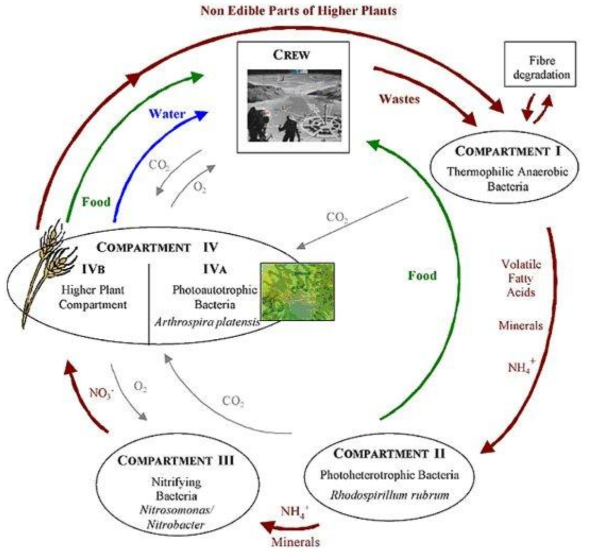

Fig.3: MELiSSA *loop (Poughon et al. 2009)*

The Eco-house functioned in a similar way. As we see in Caine’s diagram (Fig.2), the Eco-House was based on a series of digesters (primary digester and algae digester) for the treatment of human waste, which was eventually purified and used in food production. In the cycle an aquatic eco-system was integrated that “acted on the fringe of the cycle as a heat sink, like an extra water storage tank and a source of protein”. (Kallipoliti, 2012, *p. 97*).

2.1 <u>The FLaSH project</u>

FLaSH is an interdisciplinary DLR study of a terrestrial Facility of Laboratories for Sustainable Habitation.

A project is under development to create a closed-loop environment for terrestrial and Space applications.

There are two approaches that need to be implemented in future sustainable habitats: the usage of recycling technologies in order to gain closed-loop processes and the primary production of resource materials with In Situ Resource Utilization (ISRU) principles. Various products like higher plants (e.g. vegetables, fruits, crops), animal husbandry (e.g. fishery, insects), fuel gases (e.g. hydrogen, oxygen), building materials (e.g. structural and isolation materials), but also consumables (e.g. clothes) as well as base maintaining services (e.g. water or waste recycling) and power supply will be provided and, where applicable, recycled in such a system. Although the theory of a completely closed-loop habitat has been the subject of many research campaigns, the practical implementation and realization within a real habitat still needs to be established (Quantiust et al., 2012a).

The first DLR habitat design workshop was held at DLR's Concurrent Engineering Facility (CEF) of the Institute of Space Systems. “By the help of domains such as Air, Water, Waste, Greenhouse, Animal, Food Processing, Human Factors, Living, Sickbay, ISRU, Workshop, Design and Configuration, a scenario of selected habitat modules with input and output relationships has been set up” (Quantiust et al., 2012b, p.1).

The system consists of twelve modules, which are linked together via a connecting passage through locks. The modules are arranged in a circle around a dome-shaped agglomeration. With this arrangement, all modules are distributed with the same distance from the center of the system (see Figure 4), (Quantiust et al., 2012b, p. 5).

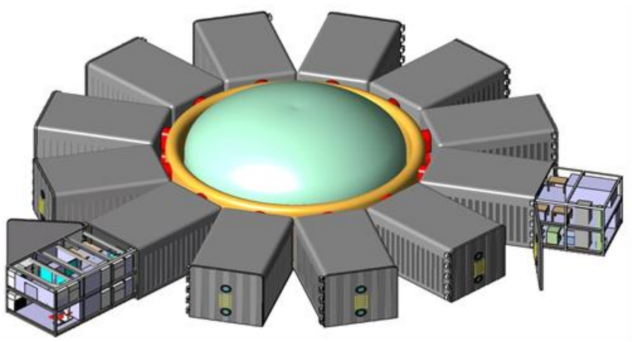

Fig.4: Overall layout of the Habitat Module Complex

In such a closed environment, “Isolation and user-system interaction are some of the many human factors challenges that strongly affect the level of habitability” … and consequently human performance, safety, and well-being” (Quantiust et al., 2012b, *p. 3*). As a means for dealing with these needs, the FLaSH study, with the support of Irene Lia Schlacht as a Human Factors specialist, incorporated human factors principles already in the preliminary design phase.

The human factors specialist was responsible for coordinating the study team in the support of essential factors regarding the needs of humans. The main issues were the following:

• Safety and quality of life (e. g. health, performance, privacy, motivation)

• Human system interactions (e. g. system usability and work load in normal and emergency situations)

• Psycho-physiological, operational, socio-cultural and ethical factors (e.g. anthropometric, nutrient, ergo-nomic, and ethical requirements) (Quantiust et al., 2012b, *p. 3*).

Unlike the previous project, the FLaSH study tried to achieve complete autonomy of the system with a closed-loop environment. However, the structure still resembled the project of Graham Caine, having instead of module 1, 2, 3… the various process components A, B, C... In both systems, the human is the main component that must be carefully dealt with to maintain the difficult system equilibrium. As mentioned by the human factors specialist, there are many interaction factors; however, the physiological factors are those that influence the other modules or processes more (Table 5).

Table 1. Physiological output factors (Quantiust et al., 2012b, *p. 4*).

Output per day per person	***Applied***	***Crew of 8***
Carbon dioxide kg	1	8
Water kg (Res-Perspiration)	1.83	14.64
Waste water	6.8	54.4
Feces (100 g; 350 g)	0.253	2.024
Urine	1.63	13.04
Flush water x 4 times a day	2.5	10
Dirty clothes per week kg	6	48
Grey water washing machine per day		7.13

3. SELF-SUFFICIENCY

In recent decades, Graham Caine and the idea of applying the life support knowledge from Space to Earth was forgotten. However, with the appearance of the notion of sustainability, people are again developing an interest in self-sufficiency and not only in cases of isolation. Sustainability and self-sufficiency are two different ideas, though very strongly linked together. On Earth, in most cases, we have built networks that make the distribution of goods possible for the entire planet. However, we have come to the point that this logic is being questioned. It would make more sense if each city or even housing unit were more autonomous and could produce some of its own food and energy. In that case, less energy would be required for the transportation of goods. Moreover, if more people became part-time workers and part-time producers, it would be possible to solve the problem of unemployment. The ones who now work full time would give half of their working hours to the unemployed while both would produce part-time part of their food. There is one big question though: In the way our cities are built there is not enough space, light, air quality, water and, depending on the climate, not the proper temperature. Having this in mind, the goal of achieving self-sufficiency in cities could be compared to the goal of achieving self-sufficiency in Space.
An environmental control and life support system has two functions that support each other: "It provides the input resources required for humans and other biological species in this habitat and it processes human and other outputs and wastes" (ESA, 2003, *p.127*). Extra-terrestrial applications require more inputs. In Space, normal elements like oxygen and air pressure need to be produced artificially. On Earth, you can usually concentrate on other primary resources like heating, water and energy. In both cases, food is one of the primary needs. The production of food is related to the study of Space colonies; on Earth, it is associated with the concept of Urban Farming (see appendix). Space Farming and Urban Farming, as well as the processing of waste in Space and in cities could belong to the same logic.
In this section, examples of research into self-sufficient systems that could apply to both Space and Earth are presented.

3.1 Mars Desert Research Station (MDRS)

The MDRS is a terrestrial settlement in Utah, which simulates a base on Mars. Regenerating life in the desert and on Mars is not so different.
A Space mission simulation in an extreme environment like the desert is very close both conceptually and practically to reality. A fusion of reality, rules and identification give the simulation results credibility.
At MDRS, "every two weeks exchanging crews of six members come to the station to perform a new mission to establish the knowledge and the equipment necessary for future successful planetary exploration viewed also from a Human Factors perspective" (Schlacht, et al., 2010, p. 1). The crews are isolated from the world community for two weeks while experiencing the problems and the life of a real space mission (Table 1).

Table 1: Habitability debriefing MDRS mission 2011 (Schlacht et al., 2012)

Crew 113	Problem	Solution
Operational IVA	Space design, e.g. small quarters, cold environment, low air quality	Better <u>layout,</u> e.g. increase private <u>storage</u> area, insulation, plants to produce oxygen
Social	<u>Communication</u> barrier caused by dominance of French language group	Avoid cultural dominance with mixed crew
Cultural and physical	Food according to American culture	Increase variability of <u>food</u> and nutritional level, e.g. with more <u>Nutella</u>

As members of the ESA-ILWEG campaign, Irene Lia Schlacht (in 2010) and Valentina Karga (in 2012) were fascinated by the fact that research for both terrestrial and extra-terrestrial closed-loop systems can merge into one in this particular example. The climate of a cold desert contains some of the most difficult characteristics to be solved on Earth (very hot or very cold, drought) and the closest we can get to how we imagine the climate on Mars. In addition, the fact of

the isolation and total lack of resources demands an approach oriented more towards self-sufficiency.
Having this in mind, after a brainstorming coordinated by Valentina Karga in 2012, the crew developed plans for how to improve the MDRS simulation by implementing more low-cost custom-made systems that are already being used on Earth.

Fig. 1: Solar cooking at MDRS

Sufficient photovoltaic panels could cover the needs of the Hab and the ATVs, which should then become electric. A solar cooker could save electric energy in this sunny climate. Rainwater could be collected from the roof and, if combined with a sand-algae filter, could become drinkable. The crew uses a dry toilet. Both liquid and solid waste are fermented anaerobically separately and become compost to be used in the green Hab to grow edible plants. All organic waste becomes compost as well. In a next step, the urine could be treated in order to become potable water again. Water, which is used in the kitchen and the shower, could be purified in order to be used again.

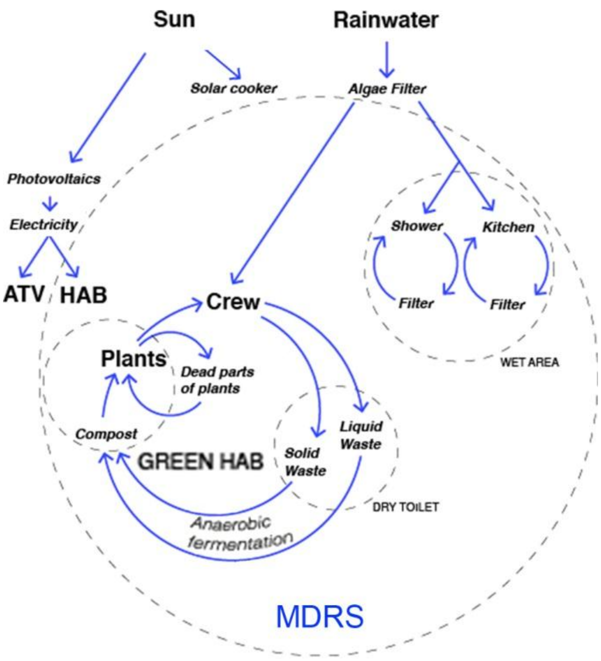

Fig. 2: Brainstorming for developing MDRS self-sufficiency (2012)

3.2 The Southbase, CLUI

Fig.3: The Southbase (Image from http://fopnews.wordpress.com/2010/06/, Retr. date: 09/03/12*)*

Another contemporary example of what a life support system for Earth could look like is the Southbase in Wendover, Utah. It is a residency facility for artists from the Center for Land Use Interpretation built by the architecture-art collective Simparch. What is interesting about the Southbase is that it is an experiment of regenerating life from scratch in a dead place, such as the desert. They use photovoltaic panels for electricity, to run refrigerators, lights, heaters, and other equipment. They have a rainwater collector and a greywater treatment facility, and for waste management they use a compost toilet from where they generate soil in order to create plant life and "link the end and the beginning of the life cycle" (Center for Land Use Interpretation). The system is called Clean Livin' because it "is cycling the waste generated by its users back into the system" (Center for Land Use Interpretation).

3.3 Machine For Sustainable Living

"Machine for sustainable living" (Karga, 2010; Karga, in press) is a system that converts a house into a small energy production plant. It is not a product but a manual for a Do It Yourself (DIY) product that can be adapted to needs, budget, time and climate. It is an assemblage of a rainwater collector, an aquaponic system, a biogas digestor, photovoltaics, a solar cooker, a solar heat panel, an algae photo-bioreactor and a biodiesel processor. When all these systems are combined together in a "nothing is wasted" concept, they could produce a semi-closed loop system with the only inputs being solar energy, rainwater and human (energy and outputs).

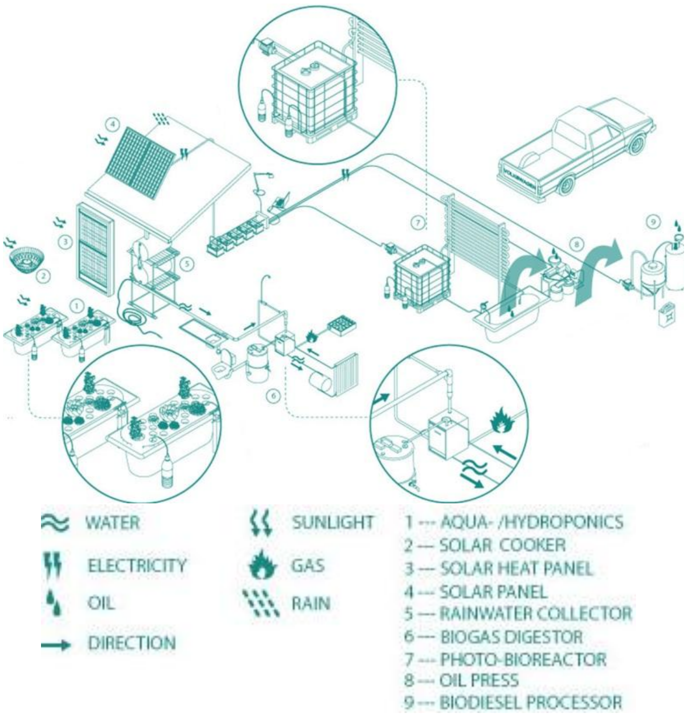

Fig. 4: Machine for sustainable living

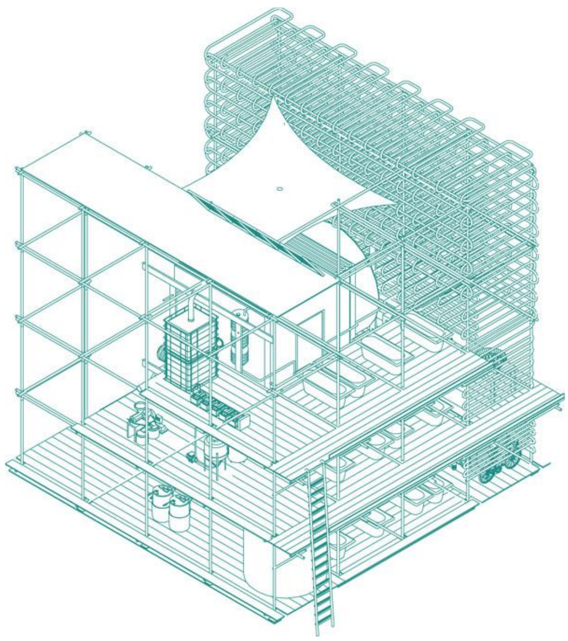

Fig. 5: Active Sustainable Chamber

The Active Sustainable Chamber is an extreme application of the manual in a totally self-sufficient one-person habitat. Its main feature is excessive economy. The user utilizes the water through a hierarchy system of value until it has evaporated. Moreover, through simple chemical processes, it produces useful goods from useless waste, while producing no waste, since everything is re-used. The appearance of the system seems complicated, but consists of humble materials. It is an assembly of used items, garbage, cables, pipes and fluids of changing purity, transparency and clotting interfering or cooperating with the building. One could describe it as a concentrated version of the complexity of gathering the goods of modern life.

The dwelling can be seen as an element for survival, and like water and fuel, must be used sparingly. The unit is a box of $10m^2$, its dimensions being 3.5m x 3.5m x 3.5m with a volume of $43m^3$. Despite its humble size, it does not lack the functionality and comfort of a regular dwelling, as the box can be rotated around its horizontal axis, and this rotation alters the layout and use of the space. Each sidewall becomes floor, back wall and roof, carrying such uses as a bed, table, bench and openings. The residence is known as the 'washing machine-like house'.

3.4 Berlin Farm Lab

Fig. 6: Aquaponic system outdoors in summer and indoors in winter

The Berlin Farm Lab is an application of "Machine for sustainable living" to fit one person's requirements. Valentina Karga is building a small prototype using herself as the center of the experiment (just as Caine did as well). Her aim is to cover her personal needs in terms of food and energy for a certain period of time, adapting the system to her own lifestyle, needs, and budget in the city and climate of Berlin. So far an aquaponic system of 600l has been built, which is mobile and can be used indoors in the winter and outdoors in the summer.

She has also created $15m^2$ of garden, where she grew a variety of 20 vegetables and herbs, according to square foot gardening and companion planting.
For cooking, a solar cooker is used on sunny days, while on non-sunny days, biogas from the biogas digester is used. If there is a lack of biogas, a rocket stove is used, which is a fuel-efficient stove that burns wood leftovers from the garden. For waste management she uses a compost toilet that converts human waste to fertile Earth for next year's cultivation.
Moreover, there is a rainwater collector for watering the garden and washing the dishes. Next year she is planning to complete the system with solar cells and a water purification system.

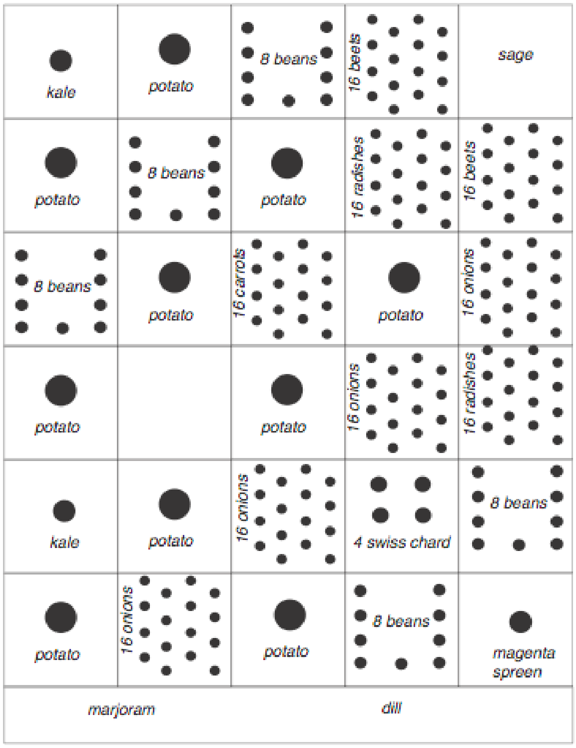

Fig. 7: Companion planting and square foot gardening diagram

Fig. 8: Anaerobic fermentation unit (biogas digester), production of food and compost toilet unit.

The Berlin Farm Lab was tested for the first time as a self-sufficient system to live in from August 15 to September 15, 2012 by Valentina Karga. She then spent 30 days surviving strictly on what the system produced daily from the morning until sunset. All daily meals, activities, time, weight, human waste and psychological state were documented.
She exchanged her surplus of vegetables for goods she could not produce herself. People would bring rice, flour, sugar and in exchange get potatoes, wild spinach, or fresh herbs in the amounts they considered a fair exchange. This particular experiment also had a socio-economic character, involving people in experiencing and learning about different ways to live.

Valentina Karga's experience was not easy; she had to face difficulties and learn from the system. Here are some of her notes on her physical health status during the experiment: *"The first days I felt hungry. I was only eating potatoes mainly with vegetables. After people brought me flour and I could make at least flat bread, my hunger disappeared. Around the middle, people started bringing me homemade cookies and cake and chocolate. They brought me yeast and I make my own bread, which made me feel really full. In my suggestions I didn't ask for milk and meat, but in a few cases people brought me. At day 15th I already had all the basic supplies to make whatever I wanted. I lost almost 4 kilos to that point which I then immediately gained back. At day 15th I had my period. Usually I suffer from a lot of pain and I need painkillers, but this time I didn't need any. The pain was bearable and I also had a bit of bearable headache. Usually I suffer from headaches often, but this month I only had it once. I drank mint or lemon balm tea almost every day".*

With the support of Irene Schlacht, she also investigated the human factors difficulties she faced by applying the debriefing technique developed by the Extreme-Design group to investigate the habitability of self-sufficient systems in Space (Table.1). This process also involves the idea of know-how transfer from Space to Earth.

Table 1: Habitability debriefing Berlin Farm Lab 2012

A. OPERATIONAL FACTORS
A.1 Fish died: The aquaponic system worked steadily for a month and then I left for one week to visit my family in Greece. That week there was a water leak and nobody was there to solve it. Almost all the water was out and the fish died. Some friends of mine went once to feed the fish and they saw the sad event but it was already too late. At the end all the water was out and the fish died.
A.2 Cooking difficulties: It was taking always too long to light up the rocket stove and once it was on I had to be constantly there to feed the fire.
A. 3 Eating only from the system requires perseverance: I had to plan my food and cooking ahead. (see also C.1 *Social Isolation*)
A. 4 Sleeping far from the system was inconvenient: I had to drive there every morning to go to the toilet.
B PSYCHOLOGICAL FACTORS
B.1 Feeling of oppression: I felt healthier and I was eating better. However, sometimes I felt oppressed by how much time I was spending on my nutrition.
B.2 Privacy matter: Sometimes I felt a bit that my personal life was invaded and people interpreted my research in ways I am not sure that I like.
C SOCIAL AND CULTURAL FACTORS
C.1 Social isolation: I felt a bit distanced from my friends and partner because of my restrictions; I couldn't go to all social events including meals that we were invited to.
C.2 Popularity: People really got interested in the project and it became a much more social space than I had expected.
C.3 Networking: I met many new people.
D ENVIRONMENTAL FACTORS
D.1 Weather dependency: It was not always sunny to use the solar cooker.
D.2 Weather complications: On rainy days it was hard to use the rocket stove.
D.3 Influence of the weather on the system maintenance: It was rainy enough so I didn't have to water the plants much. (I didn't water them once in the month of the experiment, so that reduced working hours). The tomatoes got a disease

from too much rain.
E. PHYSIOLOGICAL FACTORS
E.1 Medication not needed: Usually I suffer from unbearable pain during my periods and I use painkillers. This time I couldn't use them because they would go into my urine and then in my next year's soil. Nevertheless, the pain this time was much more bearable and I managed without painkillers. My diet was very healthy and I was drinking lots of lemon balm tea.
F. SOLUTION TO THE MAIN PROBLEM
F.1 A trained support person: Someone has to be constantly there. If I need to ever leave again I should find someone who is responsible and really teach him how live there.

The results of the debriefing were quite interesting. During the 30 days of Valentina Karga's experiment living only with the Berlin Farm Lab system, a strong interconnection between the system and the environment emerged, e.g. when it rained, she had more difficulties to cook with the rocket stove. She also had no alternatives because she could not use the solar cooker. On the other hand, she gained more time as she did not need to water the plants. Also the interdependency between the person and the system came out really clearly in the fact that she could not take any medication because those would pollute the soil. From a socio-cultural perspective, the issues were both isolation from her previous social circle and new networking, as well as a privacy problem. As a conclusion, this study clearly shows the relevance of considering the human-machine-environment interconnection in self-sufficient systems.

4. CONCLUSION

In conclusion, this is what is happening on Earth right now: Some people, motivated by different factors, from Space exploration to the ecological and economic crisis, have been developing self-sufficient systems to live in. In particular, Space research in this sector may be used as an example to start rethinking the way we live in cities and transform our dwellings into small food and energy production stations, aiming at a zero footprint. What has changed since the 1960s is the combination of the growing pressure of the ecological crisis and the availability of the Internet; the latter has led to an awareness of alternative models of habitation and resources and has helped to spread technical knowledge. For the first time, people are building by themselves what the industry does not yet offer. The so-called Maker subculture has also been growing under the pressure of the economic crisis, since 2008.

We believe that the next step could be to expand the interest in self-sufficiency and create a platform for the exchange of know-how between terrestrial and extra-terrestrial applications, not only regarding technical information but also life experience. In that way, we could eventually create a new reality regarding the perception of waste and resources. Apart from that, there are still many questions to be answered: What kind of lifestyle would emerge by living in such a system, which kind of people would be interested to inhabit it, would people have enough time for intellectual discourse apart from working for sustaining themselves, and so on. From our experience in living in habitats that simulate, or to a certain extent have achieved, self-sufficiency, there is a contradiction regarding the feeling of freedom; being autonomous comes with the idea of being less enslaved to the global system. However, a self-sufficient system is still a system in which the feeling of being oppressed might be even greater due to its micro-scale and concentrated complexity. By creating functioning closed-loop habitats on Earth and experimenting with different scales of this model, we could investigate many aspects and these results could apply also to Space research.

4.1 Future possibilities

Considering the current stream from ESA, DLR and ILEWG on high-tech transfer from Space to domestic environments, the authors in cooperation with the Extreme-Design research group are developing the design for the MINI Hab (Schlacht et al., 2012b). The project, which is based on previous research of Berlin Farm Lab, MDRS research and the FLaSH study (Quantius et al., 2012 a,b), aims at creating a mini self-sufficient habitat system based on technology and know-how transfer. Unlike the agencies' projects, which are always too expensive to be accessible by the general public, the goal will be to increase the feasibility of self-sufficient habitat projects. To do this, we need to reduce the cost, the time, and the volume of such habitats to the minimum needed, while still considering the human requirements for living in them: the habitability requirements. Only in this way will the high-tech applied in Space also be transferable and accessible for Earth application in the near future (Schlacht et al., 2012).

We are faced with habitat problems in our everyday common reality, too, e.g. in megacities with their exploding populations and their need for room and resources; when catastrophes occur; as a consequence of limited access to resources; as well as for scientific research or tourism in isolated contexts that require self-sufficiency (Schlacht, 2012; Quantius et al., 2012 a,b; Karga & Schlacht, 2012). Moreover, such habitats are also interesting for environmentally sensitive people who want to experience living with self-sufficient technology.

Those are the reasons why the expensive high-tech technology should be transferred in order to be accessible for the benefit of the Earth population of both trained and common[4] people (ESA, 2002).

APPENDIXES

Urban Farming

[4] Designing the interaction with trained and selected users, such as astronauts, is a different approach than applying a "design for all" for common people. As a consequence, the need has emerged for integrating the design right from the start of the technology transfer process in order to support interaction with common users.

In modernistic architecture and urbanism, a city's green space is formed by big parks with trees and non-edible plants. Agriculture has traditionally been limited to the countryside. Today more and more people and communities are creating edible gardens in the city. However, urban farming is not a new phenomenon. Allotment gardens were found in Germany in the early 19th century as a response to poverty and food insecurity. Victory gardens were used during WWI and WWII in the US, UK and Canada to reduce pressure on food production, which had to support the war effort.

On the other hand, today the countryside is not excluded from what is happening in the city thanks to the Internet. "Inhabiting the countryside, today, does not preclude participation in global developments, thanks to electronic communication networks" (Gannisi, Kotionis, 2010, *p. 17*). In this way, the boundaries between city and countryside are merging reciprocally.

Urban farming has many advantages. First of all, there is an educational aspect. New generations that have no family in the countryside can experience how food grows and learn to evaluate the quality of homegrown food. Then there is a sustainable aspect; if we grow our food locally in our neighborhood, we don't need to spend energy on transportation. Finally, there is a psychological aspect. It is very important for the human being to see every year the cycle of life repeating itself, from beginning to end, through the plants in the garden[5].

Many people in the United States started producing their own food and energy after losing their jobs during the economic crisis. This phenomenon is called "the urban homestead" or "living off the grid". For the same reasons, they started building their own systems with low-cost, locally available materials instead of buying materials, and developed a do-it-yourself culture. The Internet helped to spread knowledge.

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[5] Herman Hesse writes: "I sow my small garden with lettuce, Reseda and cardamom, I fertilize them with the leftovers of the previous generation, go back to it in my thoughts and think in advance of the generations of the plants that will follow. I accept, like any other human being, this so well organized life cycle as something self-evident and, really, very beautiful". (Hesse, 1952, p. 14)

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