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LESSON LEARNED FROM SPACE HAB FOR DISASTER MANAGEMENT LAB: SPIN-IN/OUT OF TECHNOLOGY AND KNOWLEDGE FOR DISASTER MANAGEMENT FACILITY

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ABSTRACT

The purpose of this paper is to discuss the development and evaluation of a new disaster management facility concept from Space to Earth. Habitats would be designed to be easy to develop, maintain, and reconfigure, while taking a holistic approach to hazard protection and psychological health as well as applying innovative technology from smart textile material to the communication. This paper focuses particularly on building habitats that are affordable, maintainable, expandable, mobile, and self-sustaining. Concepts that are issues both for Space (spin-in knowledge from Earth to Space) and Earth (spin-off knowledge from Space to Earth) are included in this study. In particular this paper takes a systematic approach to minimising both external hazards of extreme environments and internal vulnerabilities with a multidisciplinary methodology. It considers the transfer of knowledge from a specific set of habitat designs for early Deep Space missions, and the application of those lessons to small habitats on Earth used in the context of extreme environments, such as in a disaster facility.

I. INTRODUCTION

The question that approaches this paper is: How to create an environment of permanent cross-fertilisation between Space and Earth? The idea is to establish a mission simulation facility where innovations can be tested for extreme scenarios with very similar needs as in Space, in order to allow such innovations to be transferred to Space and vice versa [1]. Specifically, this considers bidirectional technology transfer between space mission design and a disaster response system for conventional use in situations such as earthquakes. (Schlacht et al., 2012)[1].

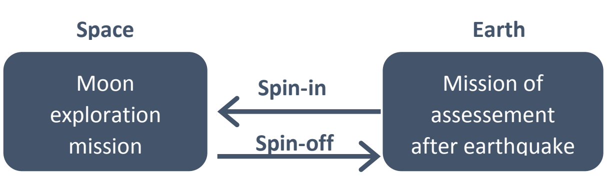

Figure 1: Cross-fertilisation between Space and Earth (©Schlacht 2014)

II. OBJECTIVES

Habitability is considered as the "usability of the environment" (Blume Novak, 2000)[2]; in other terms, as defined by the major space agencies, it is the "quality of life" (ASI, CSA, ESA, NASA, NASDA; 1999)[3] in an environment in order to optimise performance, safety and comfort (Schlacht, 2012[4]; Schlacht et.al, 2012[5]).

This project focuses on the concept of a simulation facility to simulate mission on extreme environment on space and earth in order to spin-in/spin-off[6] innovation in habitats.

The main goal is to test the degree of habitability within spin-in/spin-off innovations.

Also important goal are the achievement of innovation for:

- Increase of safety, efficiency and performance for operation in extreme environment conditions
- Optimised use of resources and autonomy for water, energy and communication
- Smart remote operations
- Development of a safe, self-sustainable, smart habitat and lab concept with high-tech, green and social development content.

III. SCENARIOS

The context of application is an off-grid minimum habitat for two persons. In this context, two key scenarios have been selected:

1. SPACE: Moon exploration
2. EARTH: Earthquake aid assessment

Figure 2: Exohab1 configuration (©3Develop & Schlacht 2014)

These scenarios have been selected in order to create a platform of technological fertilization both for Space and Earth applications. Technology and know-how solutions tested for Earth off-grid habitats will be available to be transferred to Space off-grid habitats with similar scenarios. Other possible scenarios are: 3. self-sustainable habitat, 4. nuclear or radioactivity disaster management, 5. Antarctica expedition. However in particular the 1. Moon and 2. Earthquake scenarios share the same needs:

- No access to local infrastructure for energy/water/communication
- Need for protection from the dangerous environment surrounding
- Need for safety and connection with a local control centre

IV. FINAL UTILIZATION

Assessments of geological and medical safety are example investigations that may be carried inside the habitat in those scenarios. This kind of final utilization allows maximum compatibility for the transfer of technologies between Moon geological exploration and earthquake geological assessment.
The Moon scenario is based on the experience of simulation facilities such as the Mars Desert Research Station[7,8], considering also the fact that at the moment, no such facility exists in Europe.

The second scenario considers the need for field support right after a geological disaster, specifically following an earthquake, when there is no deep knowledge of the event and field specialists are called to assess the type of support needed[9].

Figure 3: Exohab1 on the Moon (©3Develop & Schlacht 2014)

Figure 4: Exohab1 in Earthquake (©3Develop & Schlacht 2014)

In both cases, the habitat is off-grid; in other words, it needs to be autonomous in terms of communication and resource supplies (water, energy). Also, it is located inside a geological disaster that may be described as an extreme and unknown environment where particular safety procedures are needed in order to successfully perform the geological mission.

V. FURTHER APPLICATIONS SCENARIOS

1. Self-sustainable habitat

The transfer of innovation will also work "from and to" common Earth environments to allow acquiring and producing new applications “for and from” common life contexts on Earth as well. Self-sustainable contexts of living were chosen as contexts with a lot of similar problems (e.g., recycling of resources vs. off-grid), and as a consequence, the possibility of transferring problem solutions. In the “state of the art”, there is an increasing demand for innovation in self-sustainable habitats that may be realised with Space spin-offs. In parallel, new technologies developed for self-sustainable environments offer the potential for innovation spin-ins to Space (Karga and Schlacht, 2012[10]).

2. Nuclear or radioactive disaster management

Possible implementations that have been considered include, for example, application of the facility in a radioactive context. In this case, one possibility would be the application of an insulation system based on the Space technology of radiation shielding using micro cavities filled with highly pressurised gas[11].

3. Antarctic expedition

Other possible implementations may be considered, such as a scenario of application of the facility in other extreme contexts such as in Iceland, Artic or Antarctic expedition taking as an example the Concordia research station.

I. FACILITY DESCRIPTION

Target: The facility must support geological fieldwork of two persons for two weeks.

Off-grid: Disaster may create break-down of water, communication, and electricity access, contamination and infrastructure damage. The facility must be able to simulate off-grid connection in terms of water, energy and communication.

Portability: The facility must be mobile directly (similar to a camper) or transportable. If the vehicle falls within the dimensions of a shipping container, that will improve transport options and lower transport costs.

Requirement: The habitats would be designed to be easy to develop, have low maintenance requirements, and be easy to reconfigure. Special attention would be given to textiles, flexible materials, innovative products, flexible interior design and system design, while taking a holistic approach to hazard protection and psychological health.

Figure 5: Exohab1 off-grid and sustainable (©3Develop & Schlacht 2014)

Figure 6: Exohab1 in nuclear disaster (©3Develop & Schlacht 2014)

Figure 7: Exohab1 in Antartica (©3Develop & Schlacht 2014)

Figure 8: Exohab1 movibility (©3Develop & Schlacht 2014)

<u>Control Centre</u>: To support long-range communication and local communication with the crews in the area.

<u>Facility</u>: A container structure organised for the support of habitability tests, with:

- Laboratory: A laboratory area may be required, as well as a small workshop, or a common work space that can be configured to any of the roles as needed.
- Medical treatment area: It must be possible to respond to medical emergencies with minimal outside support.
- EVA preparation (airlock) and EVA suits/helmets.
- Bathroom
- Living space: To support meal preparation, sleep and personal activities.

<u>Storage area</u>: A container structure to be used as support for the test facility.

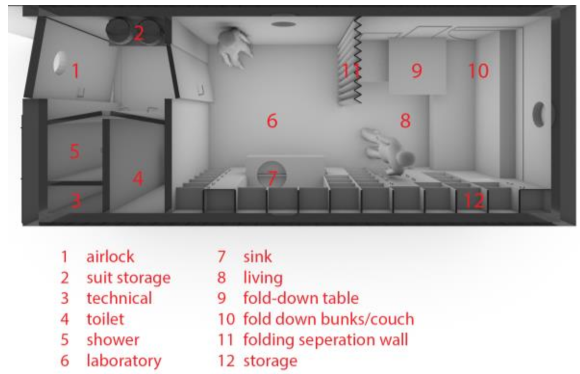

Figure 9,10: (up) Exohab1 partition & (down) sections (©3Develop&Schlacht 2014)

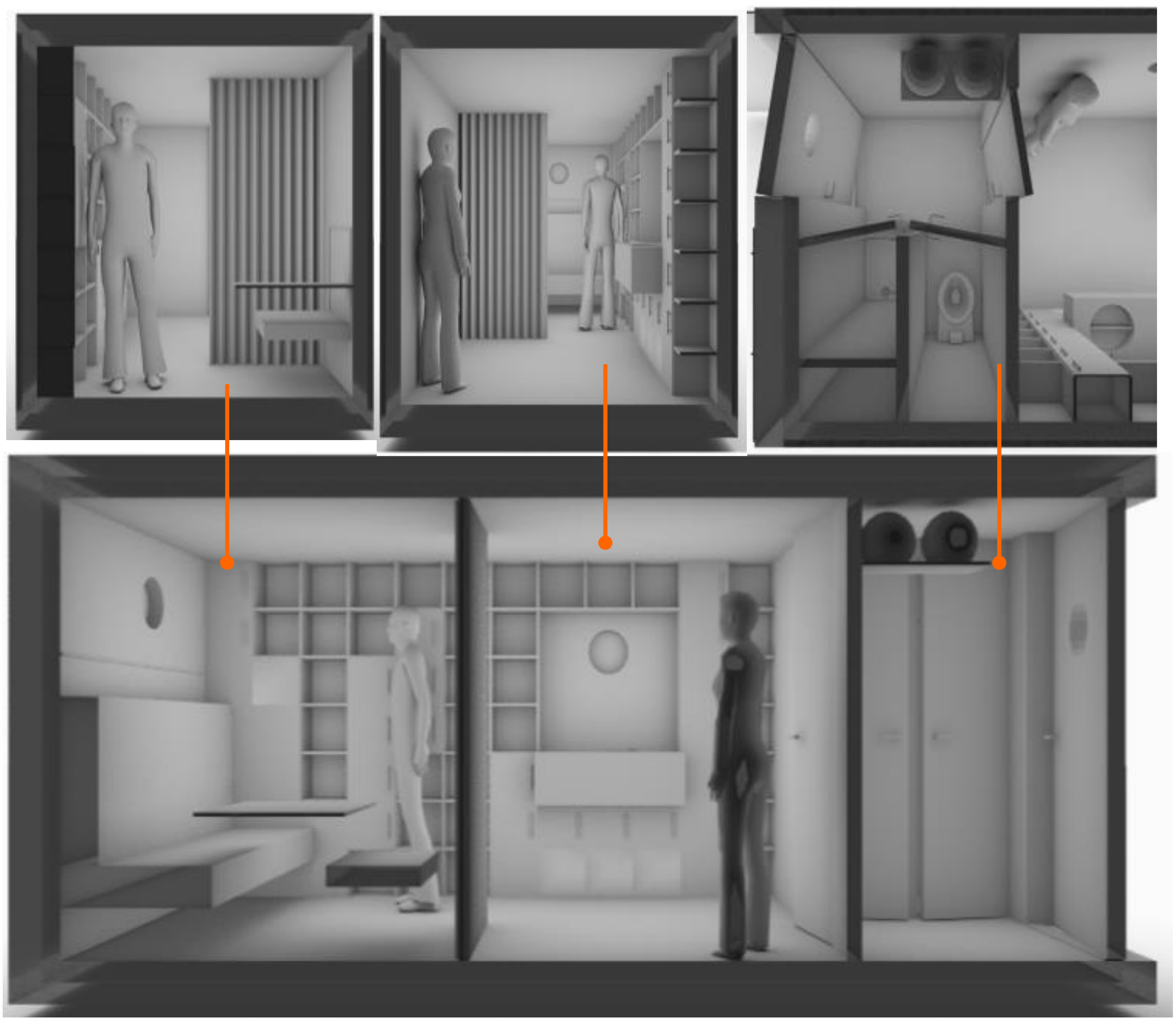

Figure 10: EVA equipment (Schlacht 2014)

Equipment: The equipment is selected within the mission model, but would require testing within the given scenario. Equipment would always be provided for work outside the shelter.

II. INNOVATION AND TRANSFER OF TECHNOLOGY & KNOW HOW

The technologies applied in Exohab1 aim to increase habitat autonomy in terms of resources, communication, and safety. Water, energy, and communications are the main areas of focus. The habitat system is supposed to be as regenerative as possible to reach maximum autonomy. This technology will refer to the improvement of the ISS's space habitat system. In particular, to the Environmental Control and Life Support System (ECLSS) recycled wastewater, including water from air humidity condensation and urine, that is converted into "drinking water" (NASA, 2010 p. 8212).

Not only the technology will be tested and transferred from and to space, but also the knowledge and the research done by the human factors, ergonomics, design, psychology as well as architecture disciplines. Indeed the configuration of ExoHab1 is exactly the same configuration as that of a module from the International Space Station: Self-sufficient Module + Communication System + Control Centre.

III. UTILIZATION

This project will start by providing a bench technology for testing the technology/knowledge spin-in and spin-off from entities that work for space and outside the space sector. The habitat will be used to test procedures and technologies for living and working in extreme environments. The goal of this phase will be the finalisation and optimisation of the habitat (minimum space, time and costs). Moreover, during the test period the candidate will build a network and acquire the capability to address Exohab1 for large organisations, such as aid agencies that need to work in disaster environments.

SPACE BENEFITS	EARTH BENEFITS
GOAL Easy-to-build test bench for **Space technology transfer**	**GOAL** facility for **operations in extreme environment**
IMPACT Create awareness on space technology utilisation, e.g. sustainability	**IMPACT** Manage disasters quickly and safely
APPLICATION Private companies that like to expand their technology application	**APPLICATION** Agencies and governments that provide disaster management

Table 1: Space/Earth benefits (©Schlacht 2014)

TEST (Bench Technology): Operational habitat for testing and researching the application of space technology and knowledge for Earth use.
USE: Facility for operations during disasters. Providing the Extreme Operational Habitat to disaster management organisations for disasters requiring minimum space, time and costs, which can be quickly set up immediately after a disaster as a safe location from where to operate in autonomy from, for example, contaminated areas.

IV. PROCEDURES OF UTILISATION

- Persons interested in researching geological procedures for extreme environments are selected for a campaign with different missions.
- During the two weeks of the mission simulation, the two selected persons will utilise the technology to be tested and will perform the simulation of an extreme geological investigation.
- A control team will support the mission from the control centre, also verifying the testing of the technologies.

Mission simulation activities:

1. Mission preparation: will be organised via web conference meetings, with a strict schedule to be selected.
2. Mission start: The two field specialists will organise the facility, structuring the interior configuration according to their needs.
3. Mission development: The specialists will live and perform activities following the simulation procedures relative to the selected scenario.

In the first and the second scenario, the activity will be mainly geological. IVA (intra-vehicular activity) will be the same, with a structured schedule, control centre support and limited resources (e.g., limited water, food, energy). EVA (extra-vehicular activity) will be performed strictly with the simulation of helmet, oxygen and gloves in the first scenario, and also in the second scenario where air/environmental contamination caused by an earthquake will be simulated.

4. Mission conclusion: A debriefing evaluating the habitability level will be performed (on the basis of the habitability debriefing tested on mission simulations at MDRS from 2010 to 2013), paying particular attention to the technology and the geological procedures tested. Focus discussion group at the end of the mission, the facility needs to be left clean for the start of the next mission simulation.

V. POTENTIAL TECHNOLOGY TO BE TESTED

It has been verified that the inventions coming out of small company with strong innovation have great potential for application in the two main scenarios selected: geological missions in Space and geological assessment of earthquakes. As a consequence, strong interest was expressed mostly by this kind of companies in the possibility to test their products at the proposed facility, also considering expansion of the application in the context of the spin-in and spin-off concept. A testing application has been verified by using MDRS (Mars Desert Research Station) with the VEA MEA low-band communication system. The system has shown innovative application possibilities during the simulation of a geological investigation on the Moon and during a geological disaster on Earth.

Figure 11: Geological investigation during EVA at MDRS (© Schlacht 2010)

VI. CONCEPT EXCELLENCE & COMPETITIVENESS

This project has also social implications that bring excellences and competitiveness.
In particular:

- It increases awareness of the relevance of Space research and technology
- It supports scientific research in bio-geo-science, human factors and medical investigations.
- It has an economic application: the facility can be rented or sold for applications in confined habitats
- It has a social application: refugee and disaster habitats, prisons, and other social aspects of life in Space can be applied to the way institutions and groups organise themselves (decision making, social support, etc.)
- It has an environmental application: off-grid technology may be useful for sustainability by adapting principles and technologies to balance the impact of human habitats on the environment

VII. SCIENTIFIC CONTRIBUTION

Exohab1 emerged as a result of many years of activities by the Extreme-Design research group (Exohab0, MDRS Campaign, Workshops, …). Extreme-Design was founded in 2007 by the Dr. Irene Lia Schlacht as a non-profit research and development group. It connects different professionals from different universities (Politecnico di Milano, Utah Institute of Technology, Technische Universitaet Berlin, Universita’ di Torino) and companies, who are working on improving living and working conditions in extreme environments[13].

Within a team of multidisciplinary field experts, Dr. Schlacht is coordinating the project

development based on her knowledge acquired in the past:
- Crew member in Space mission simulation at MDRS (Mars Desert Research Station) in 2010
- Habitability experiment coordination in Space mission simulations in 2010 [14, 15], 2011 [16], 2012[17,18], 2013
- Participation as crew member in microgravity mission[19] and Mars mission simulation[20].
- Different publications about Space habitability, such as Moon Settlement in 2010[21] and Space Habitability in 2012 [22]
- Test at ESTEC from 2009 in cooperation with ILEWG
- Workshops (e.g., Workshop on Human Behaviour and Performance in Analogue Environments and Simulations (ESTEC 7-8.12.2009[23]; SSDW 2009[24])
- Development of the first self-sufficient habitat facility concept at DLR (German Space Agency, 2011[25])
- Doctoral research done by the researcher in 2007-2011 on Habitability for Space[26].

The main activity of Dr. Schlacht is: the construction of the facility and the performance of habitability tests.

Figure 12: Dr. Irene Lia Schlacht during EVA at MDRS (©Schlacht 2010)

VIII. EUROPEAN RESEARCH BENEFITS & INTERNATIONAL COOPERATION

This research entails great benefits for European research development:
- Attracting international researchers to Europe
- Building a sound intra-European network of cooperation between different institutions
- Supporting a network of European and international institutions (Technische Universität Berlin, Università di Torino, and Politecnico di Milano) and extending to the ESTEC, VU Amsterdam and ILEWG field research network.
- Developing European facilities for training young experts in multinational teams
- Producing strong visibility due to cooperative publications in professional journals and conferences.
- Appling different and multidisciplinary knowledge from an international team of specialists located in different entities (Mars Society, ILEWG, ESA, VU Amsterdam, and Eindhoven University of Technology)
- Creating the best research and development condition for the project success.

IX. SUMMARY (PRESENTED ON THE POSTER)

Earthquakes, floods, cyclones as well as human made disasters are all hazards which kill thousands of people and destroy billions of euros of infrastructures every year[27]. The rapid growth of the world's population and its increased concentration often in hazardous environments[28] has escalated both the frequency and severity of disasters[29]. As it has been underlined by the European Commission (EU) in 201130, this situation is increased by poor or no budgetary allocation for disaster assessment and management[31]. To face the problem the EU has been encouraging funding to support development of adequate technology[32]. As pointed out by the ABS head of catastrophes management, what is needed is an immediate and safe access to experts for in-situ disaster assessment and management that at the moment is performed without equipment and without possibility for a safe in-situ working location[33].

Exohab1 is an Extreme Operation Habitat based on Space Technology for immediate disaster assessment and management. It is a safe, self-sufficient, smart shell to support geological and medical experts with equipment for immediate and in-situ assessment.

Disaster may create break-down of water, communication, and electricity access, contamination and infrastructure damage. Thanks to the space technology and know-how transfer, Exohab1 is able to support experts for operation in very devastated and extreme environments. In particular, the space technologies used, focus on energy, communication, and water self-sufficiency applied for the optimized autonomy of the

International Space Station: the habitat that is undoubtedly suited for the most extreme environments.

Finally under the EU guideline and the needs pointed out by disaster management associations, Exohab1 provide a key innovative step providing a sound disaster assessment with immediate and equipped in-situ disaster screening, optimizing the specialists' safety and performance. Moreover it is business planned to supports the maximum feasibility with minimum cost, time, and space.

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Figure 13: Exohab1 in Rotterdam (©3Develop & Schlacht 2014)

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