THE SHEE PROJECT
SELF-DEPLOYABLE HABITAT FOR EXTREME ENVIRNOMENT TEST-BED FOR ANALOG SIMULATIONS

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Abstract

The Self-deployable Habitat for Extreme Environments (SHEE) project (www.shee.eu) is developing a test bed to evaluate the potential of changeable-geometry architectures in both space and terrestrial environments. Funded by the European Commission under an FP7 contract, the three year development program which started in 2013 will produce a habitat test-bed to simulate deployment mechanisms, life support systems and aspects of habitability. The usability evaluations will support guidelines for future habitats. When completed habitat test-bed will support a two person crew for analog missions of up to two weeks in duration. The system will provide the power, life support, hygiene, waste storage and treatment, and consumables necessary for the mission. The design phase has now concluded and the manufacturing is progressing. SHEE will be the first transportable and a unique space habitat simualtion facility in Europe. By being foldable and deployable, it can be transported to various analogue sites in Europe and elsewhere. It will demonstrate key technologies needed for future rigid deployable space structures. The presentation will show the architecture of SHEE, its simulation possibilities and give an outlook on possible missions in the future.

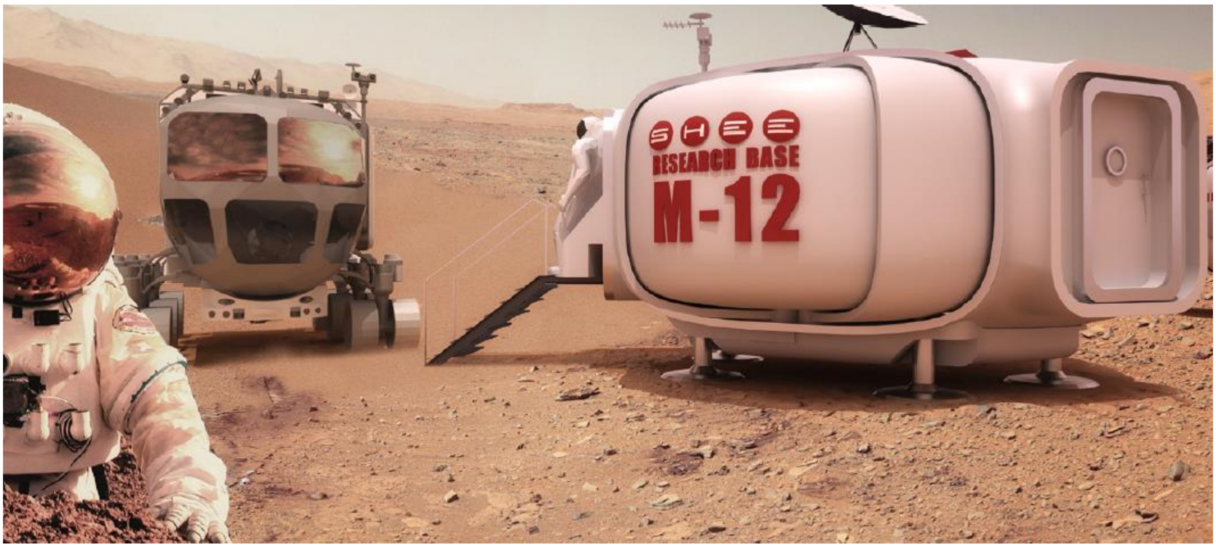

Figure 1: Artist's view of the SHEE research base module on Mars with NASA Space Exploration vehicle at the background.

Introduction: A space habitat simulator in Europe

Human labor for the construction of infrastructure, such as habitat modules on the lunar or Martian surface or any other extreme environment is very risky and complex. To mitigate drawbacks of human construction activity, it is an imperative to apply *autonomous* construction methods. Self-deployable, autonomous habitats represent a possible solution for extreme environments without infrastructure and heavy machinery. Such habitats will mitigate construction safety risks and also reduce costs of setting up research bases on Earths most extreme environments or future human outposts in space.

The SHEE design utilizes rigid deployable segments to create a large, portable habitat environment suitable for use in both terrestrial and extra-terrestrial hostile environments and provides a feasible solution for near term human space exploration. The results of the SHEE project will be applicable in both space and terrestrial conditions, such as in extreme environments on Earth or during disaster mitigation.

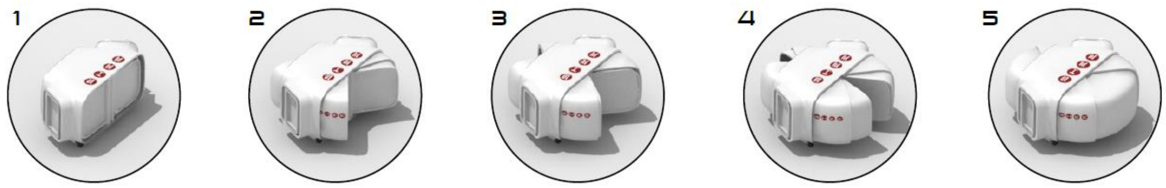

Figure 2: Deployment of SHEE from folded configuration (1) to operational configuration (5).

The design driver for SHEE was cost efficiency and a high ratio of deployed versus packed volume [1]. A further important factor is the level of simulation fidelity or, in other words, functional similarity between the simulator/analogue system and the real system to be used in space or on Earth. SHEE has been designed to be i) easily transportable on road to analogue sites for space mission simulations and ii) to fit into the capsule of a launcher such as ARIANE-5 for future missions on Moon or Mars [2].

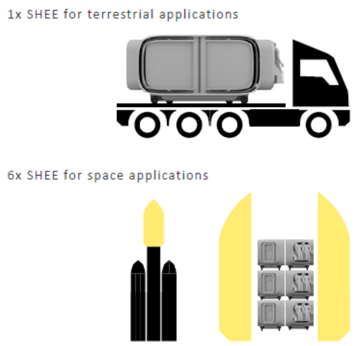

Figure 3: Transport options for SHEE: (top) on road by lorry or (bottom) inside an ARIANE-5 launcher.

This paper presents the aspects of SHEE including the design characteristics, habitat operations and deployment and its applicability in space and terrestrial research. SHEE will be made available upon its construction in 2015 to the scientific community as habitat base for confinement or EVA simulations, and hardware tests on analogue sites.

Architecture and design of the SHEE concept

When designing equipment for extreme environments it is frequently necessary to test such systems in an environment that mimics some characteristics of the final destination. Such analogue environments provide engineers with the opportunity to increase the technology readiness level of their development without the added expense, complexity and constraints of deploying it in the real environmental conditions. Analogues have been used since the dawn of the space industry. During the American Apollo program, every piece of equipment was tested in the most Moon-like environments to be found on Earth to increase the chances it would sustain lunar conditions.

The first SHEE habitat is an analog habitat that will be used to demonstrate the feasibility of rigid deployable habitats as well as to gain experience on the operation of such habitat in a variety of analogue sites. It is developed to provide a mission base for a crew of two persons in extreme terrestrial environments. Apart from providing living and working spaces inside the habitat for the two "*SHEEonauts"*, it features thermal protection and regulation mechanisms to sustain temperatures ranging from -10°C to +40°C, water and waste management systems and air revitalization systems (the Life Support System – LSS- is not working on a closed-loop configuration, the CO2 scrubbers used are sufficient treat the air inside SHEE for 24 hours with two crew members).

Figure 4 gives an overall view on the architecture of SHEE, including its living and working spaces, hygiene facility and EVA suit ports.

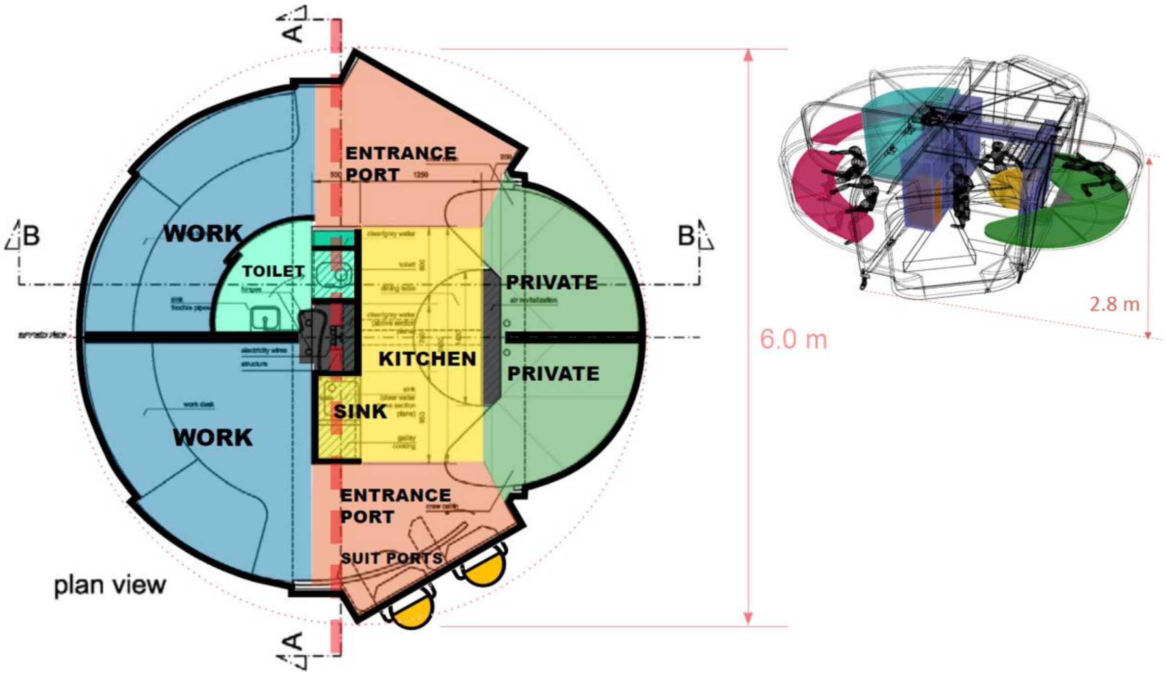

Figure 4: Living zones inside SHEE and main dimensions (deployed).

The habitable volume for a two person crew is suggested to range between 20 to 25 m³/person according to current NASA/ESA standards. SHEE has an internal volume of around 45m³. The habitat is composed of five functional areas:

- Crew entrance port and suit ports (for two suits)
- Private/Sleeping areas (2 sections)
- Work area and Laboratory area
- Hygiene facility
- Galley with kitchen and storage spaces

All elements need to comply with the design philosophy of a fully functional habitat that can be deployed and folded for transport. The crew is supposed to enter the habitat only with water, food and any scientific equipment needed for the mission. All the internal furnishing and life support elements that are needed are installed inside the (folded) habitat. The sections for working, hygiene and private spaces can be refurnished in order to be used as greenhouses, laboratories, medical station or other functions.

The architecture allows to combine several habitats with each other (see Figure 6 and 7) where a "*SHEE-village*" includes modules that serve as living base, laboratories with greenhouses or medical stations.

SHEE will be an ideal module for space analogue research or base for missions to extreme environments: Self-containing and autonomous it can be transported to various spots and serve various purposes.

Figure 5: SHEE as base for polar research

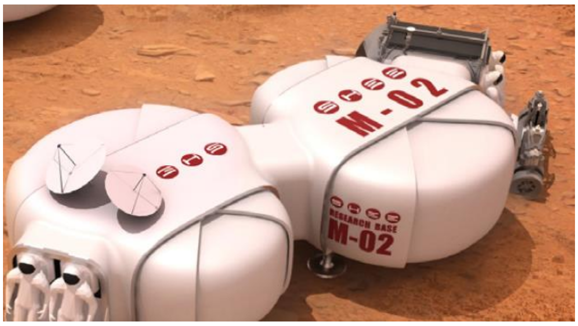

Figure 6: The habitats are conceived to be combinable

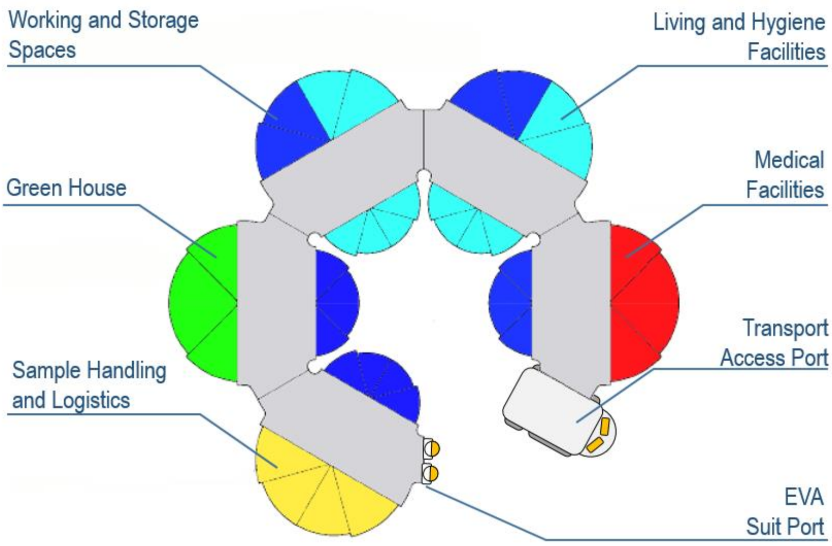

Figure 7: SHEE modules combined for a research base

<u>The deployment and repack requirement</u>

Based on an autonomous deployment/repack mechanism, SHEE has two configurations (Figure 8):

- The packed configuration: For transportation, lifting relocation and general transport purposes.
- The deployed configuration: For operation purposes.

The habitat deploys its petals in a rotational sliding sense. The terrestrial analogue test-bed includes a sealing system to protect the habitat against dust intrusion. The hull of the habitat is comprised of a composite shell structural metallic beam and plates. Its overall weight is estimated at below 6 tons, including the internal elements. The fabrication of the habitat is ongoing at the edition of this manuscript at University of Tartu in Estonia. It will be delivered to COMEX, Marseilles beginning of 2015 for the integration of the Environmental Control and Life Support System (ECLSS) and the internal furniture.

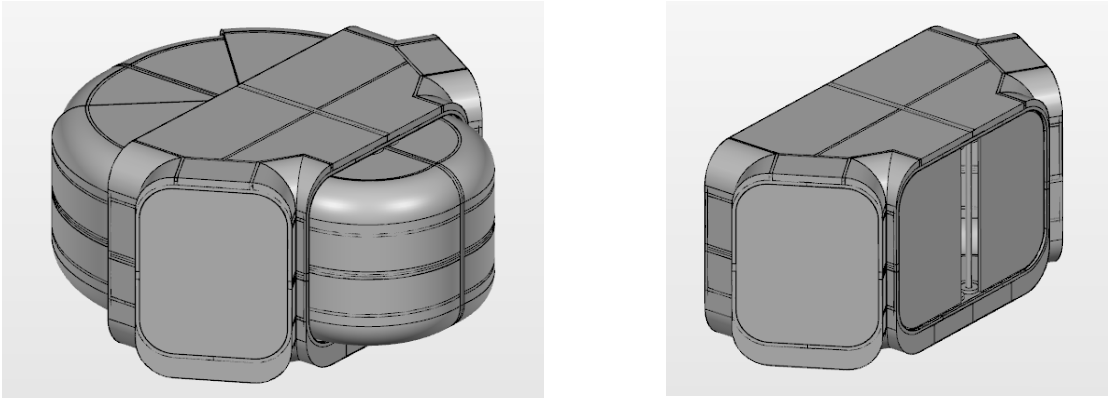

Figure 8: (left) SHEE deployed and (right) packed configurations

Interior furnishing layout

The interior layout represents an optimized design solution fulfilling all the requirements for a deployable structure. It provides a positioning and balancing of loads keeping the centre of gravity close to the ground and to the centre of the SHEE habitat in its deployed state. The interior furnishing is transformable to allow a high level of functionality and space using optimization and ergonomics (see Figure 4 and 7). It provides numerous possibilities to rearrange the interior according to alternative mission requirements. The virtual model of SHEE can be visited through the project website at the link http://www.shee.eu/build/build_web.html.

The Environmental Control and Life Support System

The ECLSS subsystem ensures the biological autonomy of the crew while isolated on a planetary surface or during an analog simulation mission. The objective is to have a partially regenerative system that can serve to train crewmembers in the use of such equipment and to serve as a potential test platform for future design and test of closed-loop ECLSS for long duration space missions. The power systems provides necessary autonomy for deployment and system initiation. However SHEE is not energy self-sufficient and requires an external power source for recharging its 600Ah batteries.

Following data can be stated for the ECLSS and Power System of SHEE:

- *Capacity: 2 people for 1 day closed loop / 2 weeks open loop*
- *Drinkable water:, grey water and black water storage*
- *CO_2 scrubbers for a closed loop system autonomy of 24:00h*
- *Automated monitoring of atmospheric parameters (O2, CO2, temperature, hygrometry rate)*
- *LSS racks: the hygiene facilities rack, kitchen facilities rack and monitoring & air management rack are foreseen to be removable to allow interchange with another if needed (e.g. a lab rack).*
- *Power (grid): 10 kW*
- *600 Ah rechargeable battery (fuel cell - optional)*
- *Output 24 V (DC), 200 V (AC)*

Towards a European space analogue habitat

The SHEE habitat will provide significant background for further development and evolution of extra-terrestrial habitable structures. The folding capability of the habitat will allow interdisciplinary research and tests of various technologies in different analogues in Europe and worldwide. SHEE has been designed in order to be easily transportable –due to its folding mechanism- and is open to the international research community for space analogue research.

The SHEE project is a European Commission project funded under the Framework Programme 7. The authors of this manuscript would like to express their thanks to the European Commission.

References

[1] Doule, O., Imhof, B., Hoheneder, W., Ransom, S., Waclavicek, R., Kull, P., Aabloo, A., Weiss, P., Taillebot, V., Gardette, B., Gobert, T., Gancet, J., Letier, P., Rodriguez, G., Salini, J., Nelson, J., Welch, Ch., Gajdos, P., Sevcik, D. (2014) Self-deployable Habitat for Extreme Environments – Universal Platform for Analog Research, AIAA Space Forum 2014, San Diego, August 4-7, USA.

[2] Doule, O., Imhof, B., Hohender, W., Aablo, A., Welch, C., Šálený, V., Ilzkovitz, M., Gancet, J. & Weiss, P. (2013). Self-deployable Habitat for Extreme Environments - Innovative Architecture Test-bed for Terrestrial and Space Applications, 64th International Astronautical Congress, Beijing, China.