Executive Study

Self-Deployable Habitat for Extreme Environments (SHEE)

Europe's first transportable space analogue habitat

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Europe’s first transportable space analogue habitat

credit:
SHEE Consortium,
visualisation: LIQUIFER
Systems Group / Space
Innovations (SPIN) 2014
/ 2016

Background image: courtesy
of NASA

SELF-DEPLOYABLE HABITAT FOR
EXTREME ENVIRONMENTS

CONTENTS

Executive Summary of the SHEE project 7

Extreme Environments 8

Project Introduction 13

Detailed Description 18

SHEE features 24

Analysis and Validation 31

SHEE transport information 34

Future of Europe’s first space analogue habitat 35

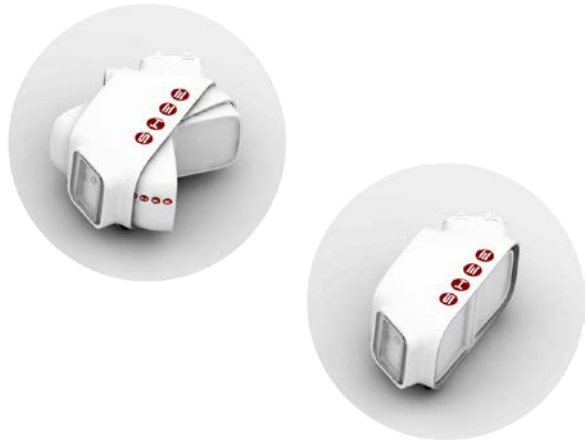
Consortium members 38

Description of image:
Multiple stage deployment process of SHEE from stowed to fully-deployed configuration. (early concept study)

credit:
SHEE Consortium,
visualisations: Space
Innovations (SPIN) 2014

Executive Summary

The Self-Deployable Habitat for Extreme Environments (SHEE) is a transportable habitat testbed demonstrating technology for human habitation in hostile environments both on Earth and in space.
SHEE is autonomously deployable, requiring no human interaction in setup. Each SHEE module provides support for two crew members for a mission of at least two weeks in duration. Multiple SHEE modules can be linked together to build a “SHEE village” permitting the expansion of crew size, length of the mission or programmatic capabilities of the base.
SHEE represents three years of research and development work by seven European companies and institutions and was funded under the European Commission Framework 7 Programme.
As of January 2016, SHEE has been declared functionally complete and is available for use by scientists and engineers in analogue missions. In April of 2016, SHEE will participate in its first analogue mission scenario in Rio Tinto, Spain as part of the MOONWALK, FP-7 project.



Extreme Environments

There are many extreme environments on both the surface of the Earth and in space where humans cannot operate for extended periods without support. These environments represent extremes in temperature, pressure, radiation, alkalinity, salinity, humidity or other environmental factors that are hostile to human life. While inhospitable to humans, extreme environments present many activities that may warrant a human presence.

Resources

As the most easily accessed resources on our planet are either claimed or in the process of being exploited, places that were once considered too expensive to access are now being re-evaluated for their natural wealth. Evaluation and exploitation of these regions can put personnel at risk if a safe staging area is not provided.

credits from top to bottom:

Wikipedia, González Videla Antarctic Base

Wikipedia, Atacama Desert, Paranal Observatory

Wikipedia, Tadrart Acacus desert (Sahara), western Libya

Wikipedia, Liberian tropical forest

Wikipedia, Atacama Desert, Chilean Andes, home to the ESO/NAOJ/NRAO ALMA

Disaster Relief

Disaster zones, both natural and man-made, frequently pose risks to first responders and relief personnel. One of the first tasks of responding personnel is to establish a safe staging area, which can be difficult when facing environmental hazards and lack of fundamental infrastructure.

Science / Space Analogues

Some scientists frequently enter extreme environments to conduct experiments or maintain data collection apparatus. Other experiments in preparation for future spaceflight (known as analogue simulations) place human subjects in extreme environments that closely resemble the operational environments on the Moon or Mars.

credits from top to bottom:

Wikipedia, Disaster area 2004 Tsunami, Meulaboh, Sumatra, Indonesia

Wikipedia, Atacama Desert, Paranal Observatory

Wikipedia, The DEWLINE site at Point Lay, Alaska

Wikipedia, Mars Desert Research Station (MDRS)

Wikipedia, Tundra, Kongsfjorden, Spitsbergen

credit:
SHEE Consortium,
visualisations: Space
Innovations (SPIN) 2014

Background image (top):
Devastation after Tsunami in
Rikuzentakata, Iwate, Japan,
credit: Mitsukuni Sato

Bottom: SHEE habitat with
NASA Exploration Vehicle

Construction of safe staging areas in an extreme environment can be incredibly costly, time consuming and exposes personnel to the extreme environment for extended periods during the construction. Existing solutions such as tent cities or Jamesway huts are either too fragile or take too long to construct for many environments. Tent cities, while providing basic protection from the elements, lack integrated hygiene facilities or power generation necessary for longer term habitation.

Description of images:
SHEE is visualized singularly or in clusters in areas of both natural / human-made disasters and in extreme environments for research purposes. The habitat can be adapted for different purposes, providing shelter, medical facilities and scientific laboratories.

credit:
SHEE Consortium,
visualisations: Space
Innovations (SPIN) 2014

Background image (top):
Ishinomaki Miyagi tsunamic,
Japan, credit: Relief20.com

Background image (middle):
credit: NYdaily.com

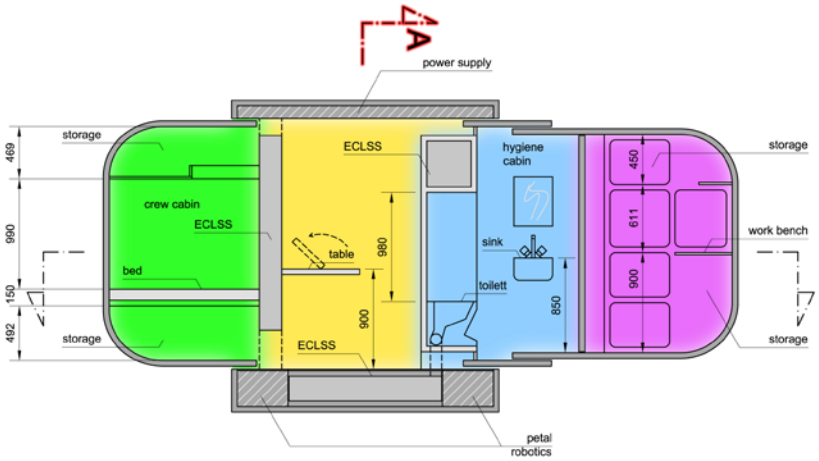
Description of images:
SHEE Deployment
Multiple stage deployment process of SHEE from stowed to fully-deployed configuration.

credit:
SHEE Consortium,
photos: Bruno Stubenrauch
2015

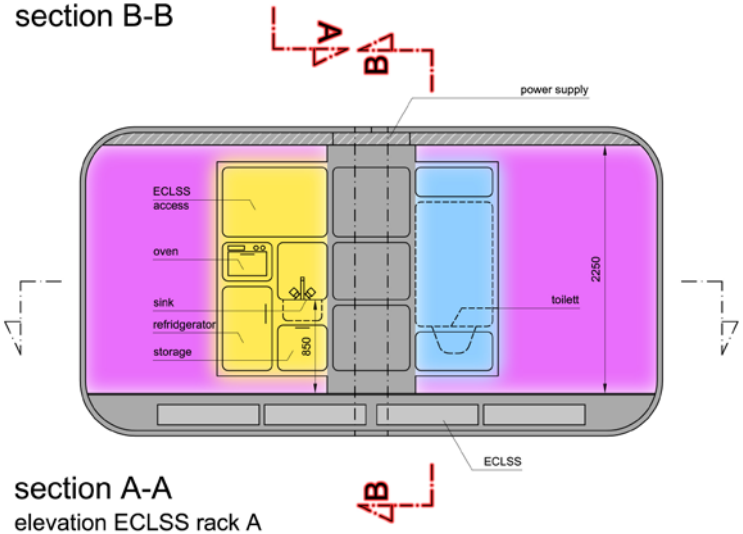
Project Introduction

The Self-Deployable Habitat for Extreme Environments (SHEE) was a three-year research and development project conducted under the European Commission Framework 7 Program. The goal of SHEE was to examine how design principles from both terrestrial robotics and space habitat design could be integrated to form a self-sufficient habitat that suited the requirements for extreme environments both on and off the Earth.

In the beginning, different concepts for the design and configuration of the habitat were devised and trade-off criteria were weighted. Priorities that rated highest were deployment simplicity, structural simplicity, deployed/stowed ratio and structural robustness.



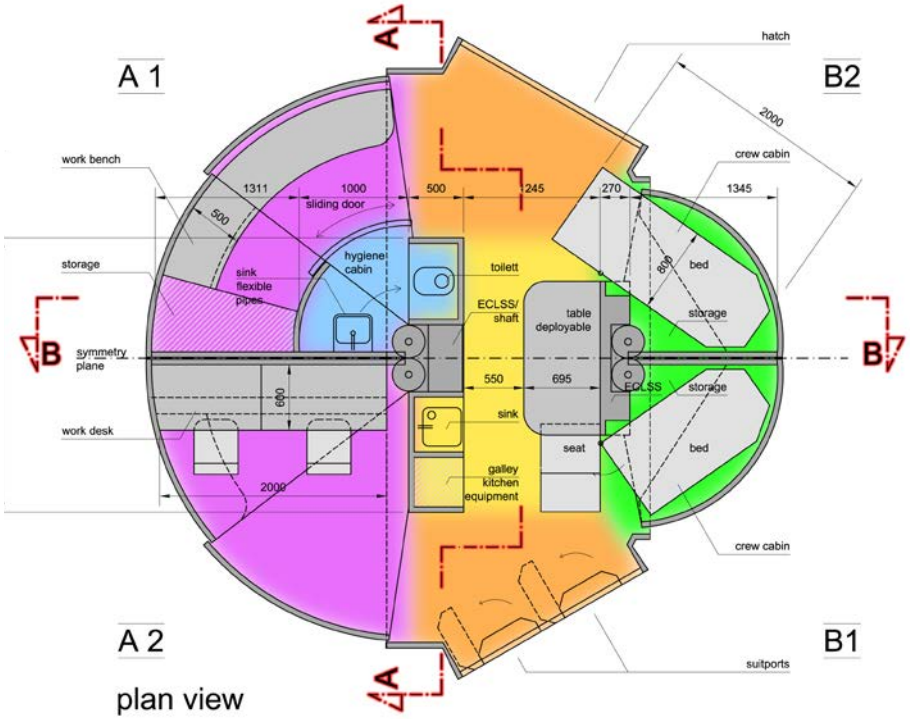
section B-B



section A-A
elevation ECLSS rack A

Legend

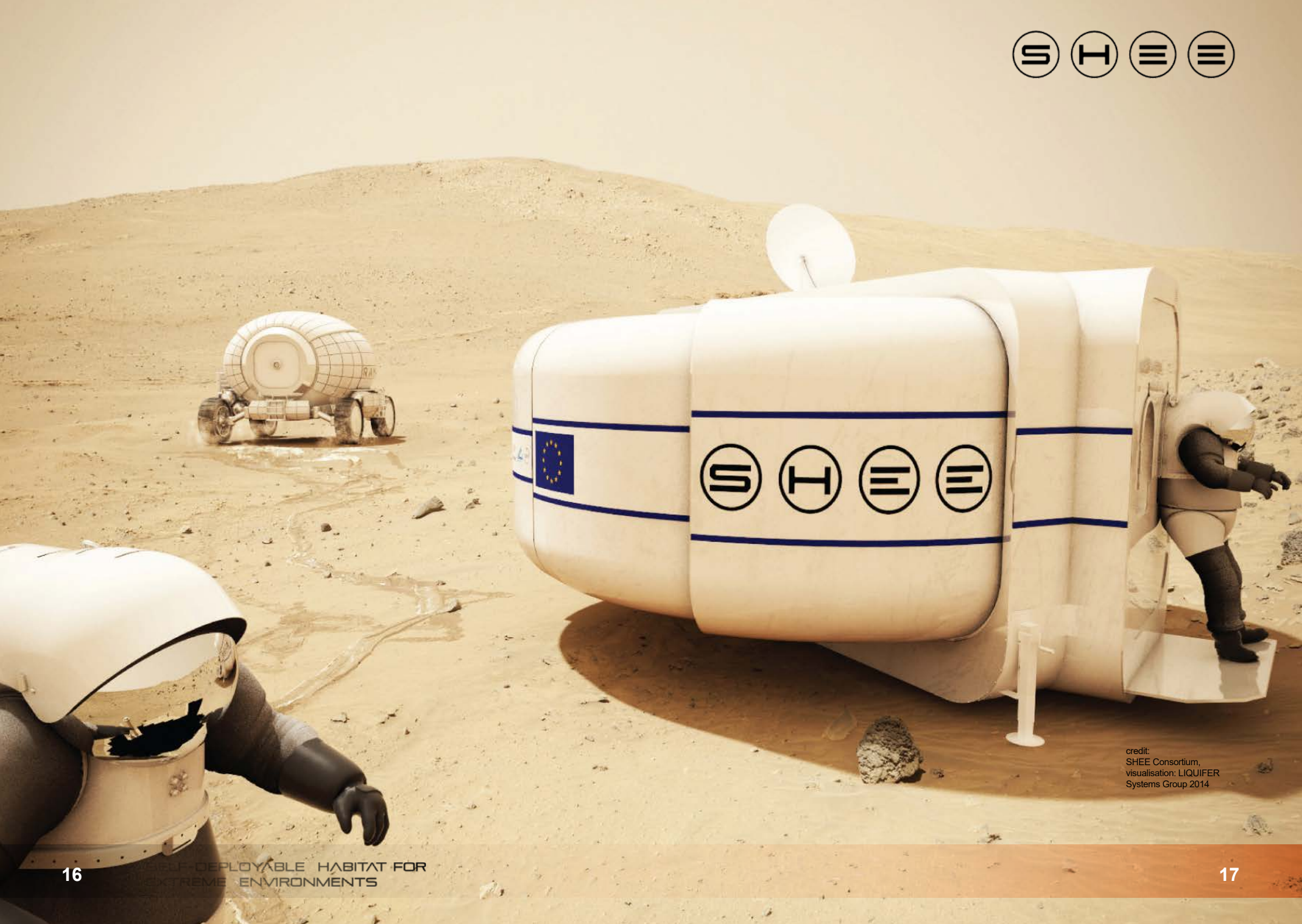
- **Work**
- **Entrance Port**
- **Private**
- **Kitchen Communal Space**
- **Toilet**



plan view

Basic requirements were set for a habitat that would provide:

- For the needs of two personnel for missions of up to two weeks in duration
- Fully functional staterooms, kitchen, hygiene facility, workshop and meeting areas
- Autonomous deployment and semi-autonomous packing
- Environmental control and monitoring system sized for both arctic and desert environments
- Support for suit-port style entry and egress
- Transportable via common place infrastructure
- Modularity to support different mission needs (laboratory, greenhouse, medical station, etc.)



credit:
SHEE Consortium,
visualisation: LIQUIFER
Systems Group 2014

Detailed Description

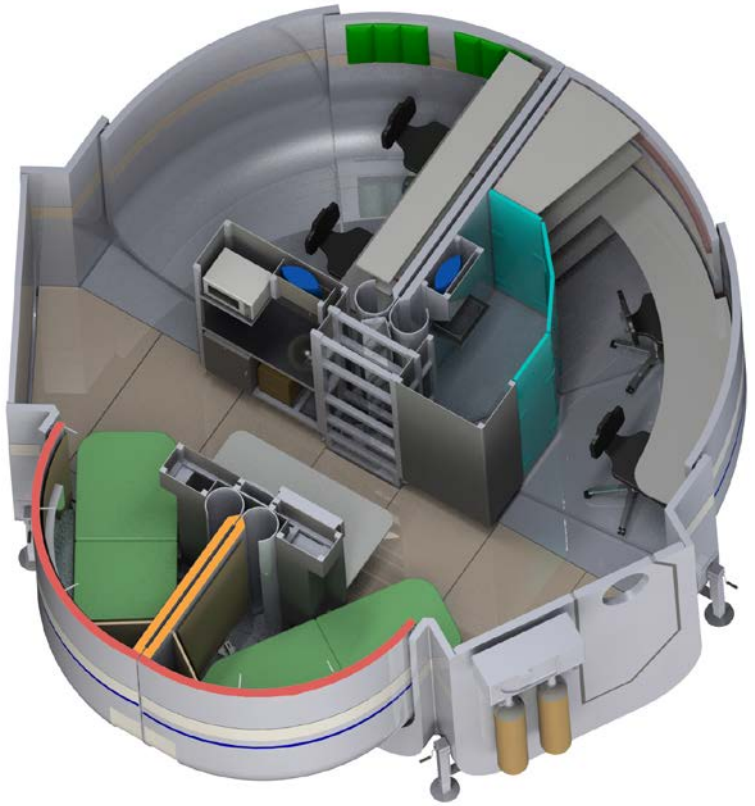
Construction of the SHEE prototype was completed in December of 2015. As delivered the SHEE habitat is unique among analogue habitats in that it is designed from the beginning to be transportable, allowing for each unit to be used multiple times and in multiple locations.

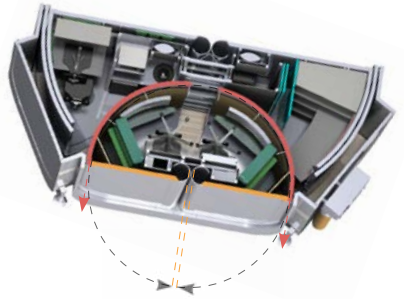
Structurally SHEE is composed of a central loadbearing structure with six “petals” that deploy radially outward. The central structure utilizes aluminium structures for the floor and the rims as well as self-supporting composite shells from fiberglass sandwiching a foam core. Each of the petals rotate radially out from the central structure and like the central structure are made of fiberglass foam core shells. Sealing between petals is provided by inflatable rubber seals.

As outfitted, the SHEE prototype has six fully equipped modular “zones” including two staterooms, kitchen, hygiene facility, workspace and workshop/laboratory. All furnishings and subsystems within these modules have been designed to be packed for transportation in approximately fifteen minutes, while maximizing the usability of the available volume.

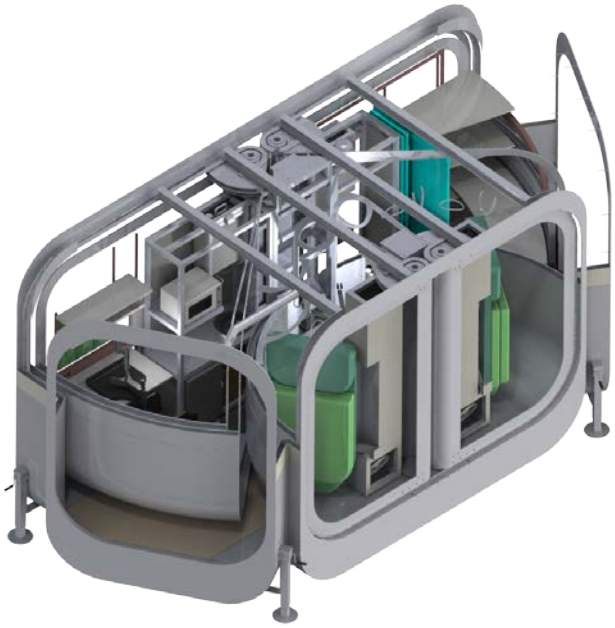
Description of images:
Section cut through exterior hull showing the stowed and fully deployed configuration of the interior with and without furnishings.

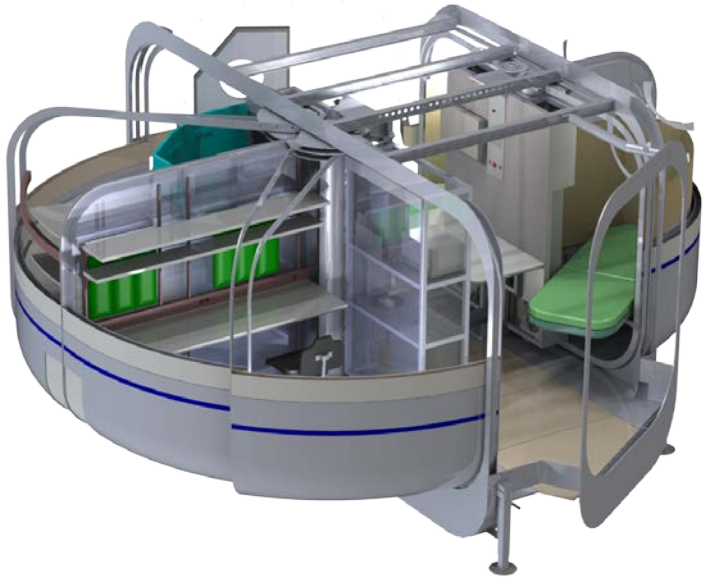
credit:
SHEE Consortium,
visualisations: Sobriety 2015

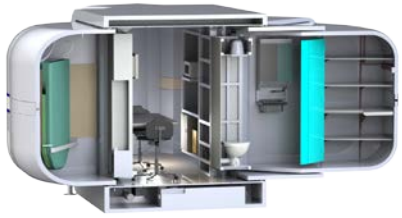




All equipment and furnishings within the SHEE is modular by design, allowing for easy modification to accommodate the specific needs of individual analogue missions. Beyond the modules delivered with the prototype habitat, SHEE designers envisage future modules being developed as first aid facilities, science laboratories or even greenhouses.







Description of images:
Section cut showing the stowed and fully deployed configuration of the interior with furnishings.

credit:
SHEE Consortium,
visualisations: Sobriety 2015

SHEE Fast Facts

Packed dimensions:
5.9 m length x 2.4 m width x 2.8 m height

Deployed dimensions:
5.9 m length x 6.5 m width x 2.8 m height

Deployed volume: 50m3
Habitat floor area: 28m2

Mass: 5,500 kg

SHEE Structure

The manufacturing method as well as the materials used to construct the structural components of the SHEE habitat are similar to those used in the boating and yachting industries for composite hulls.

Stiffness and strength criteria were verified (for stowed and deployed configurations) using Safety Factors and recommendations from Industrial standards NASA-GSFC-STD-7000A-1 and MIL-STD-810F.

Structural verification performed by means of Finite Element Analysis (FEA) using PTC Creo® simulate software both informed the preliminary design of the habitat as well as validated design hypotheses along the way. Analysis of the structure took into account different load cases, for a range of different scenarios.

credits:
SHEE Consortium,
photos:

top three photos, credit:
University of Tartu 2014

bottom photo, credit:
COMEX 2015

Description of images:
Building of the SHEE exterior hull at the University of Tartu, Estonia.

credit:
SHEE Consortium,
photo: University of
Tartu 2014

The main hull was manufactured in two halves and attached to one another by means of an equatorial metallic flange. The petals were manufactured using the same principle as the main hull with a thickness of 60 mm. Exterior surfaces of all components have a fireproof gel coat; and the core material is a thermo-plastic honeycomb filled with closed cell thermoplastic foam. The benefits of the core material are two fold; both inhibiting the rip propagation, like honeycombs, and providing superior heat and noise insulation, like foam cores.

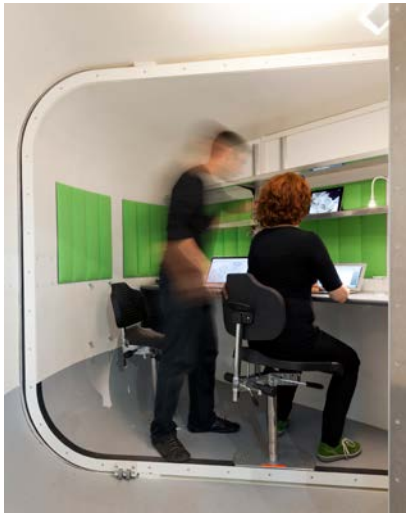
SHEE features

Staterooms
Each SHEE module features 2 staterooms, accommodating one analogue astronaut each. Privacy curtains and sound absorption are available to provide a measure of personal space.

Kitchenette
SHEE is outfitted with a kitchenette for meal preparation including a sink, refrigerator, microwave oven, electric kettle, espresso machine and waste dehydrator.

Meeting Space
The centre of the habitat is allocated to a dedicated meeting space where the crew can conduct meetings or eat their meals while easily monitoring the display screens for the habitat subsystems.

Workspace
The workspace is located in one of the larger sections of the habitat and is equipped with a desk and adjustable shelving. It accommodates two people and provides sound absorbing panels with a soft colourful textile surface.



Description of image above:
View into kitchenette and meeting space.

credit:
SHEE Consortium,
photos: Bruno Stubenrauch
2015

Hygiene Facility
Essential hygiene needs are provided for with a toilet, sink and mirror behind a foldable privacy wall. To conserve water and more accurately simulate conditions in a spaceflight environment SHEE does not possess a shower. Bathing is achieved using no-rinse shampoo, wet wipes, or wet towels depending on the simulation protocols. The toilet is positioned in the non-deployable rack.

Workshop / Laboratory
SHEE has a fully functional space dedicated to workshop and laboratory work. During testing of the habitat this workspace served as an assembly space for a parabolic flight payload.

Suitport
Ingress and Egress from SHEE modules during simulation is envisioned using suitport style spacesuits. While the SHEE does not come with its own suitport suites, interchangeable “blanks” on one wall of the SHEE provide for easy mounting of third party suitports.

credits:
top photo:
SHEE Consortium,
photos: COMEX 2015

middle photo:
SHEE Consortium,
photos: Bruno Stubenrauch
2015

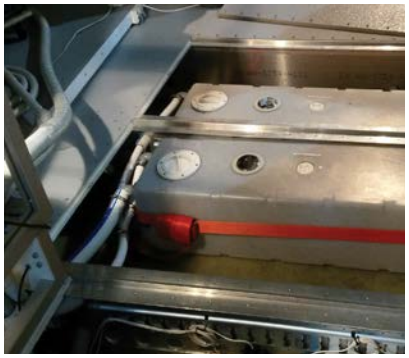
bottom:
SHEE Consortium,
visualisation: LIQUIFER
Systems Group 2015

Description of image above:
View into multi-functional space; hygiene facility and Workshop / Laboratory. The partition wall is made from a translucent material and can separate the two functions of hygiene facility and Workshop / Laboratory.

credit:
SHEE Consortium,
photo: Bruno Stubenrauch
2015

Closed Water and Waste Storage
Many hostile environments of interest to scientists are sensitive or protected ecosystems. SHEE stores all waste generated by the crew internally including both household and excremental without the need for exterior infrastructure.

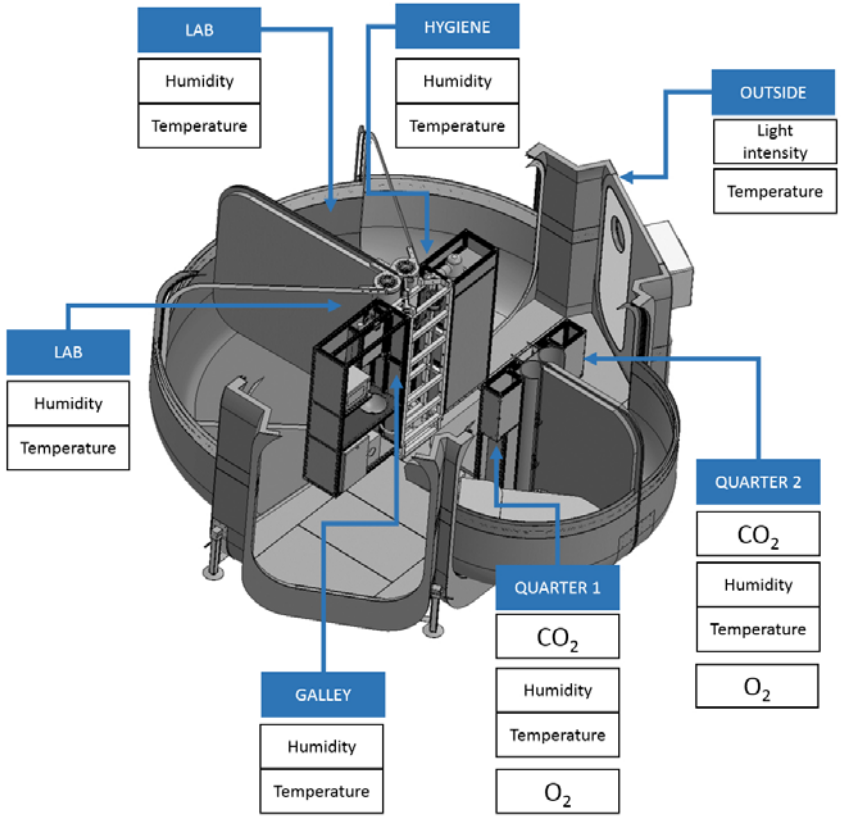
Environmental Control and Monitoring System
SHEE autonomously monitors a variety of internal and external environmental parameters and provides alerts to the crew when measurements fall outside of acceptable boundaries.



Description of images:
Top: water tanks under the SHEE floor panels
Bottom: control panel and buttoms for the Environmental control and monitoring system

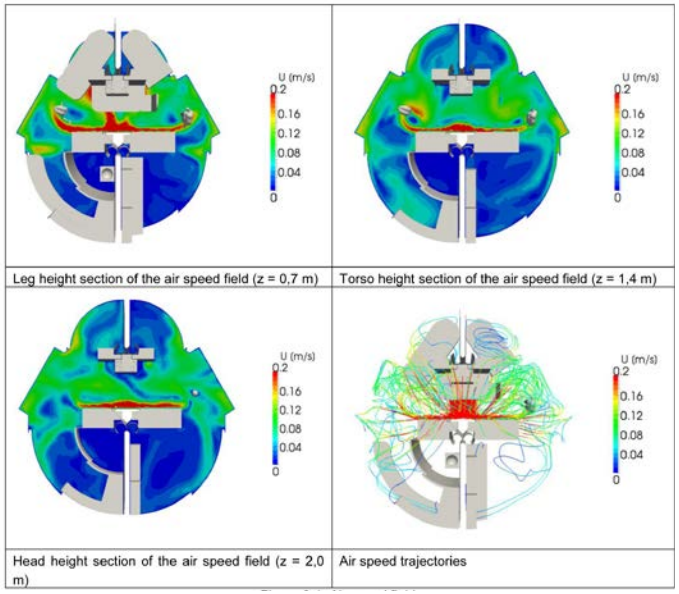
credits:
top:
SHEE Consortium,
photos: COMEX 2015

bottom:
SHEE Consortium,
photo: Bruno Stubenrauch 2015

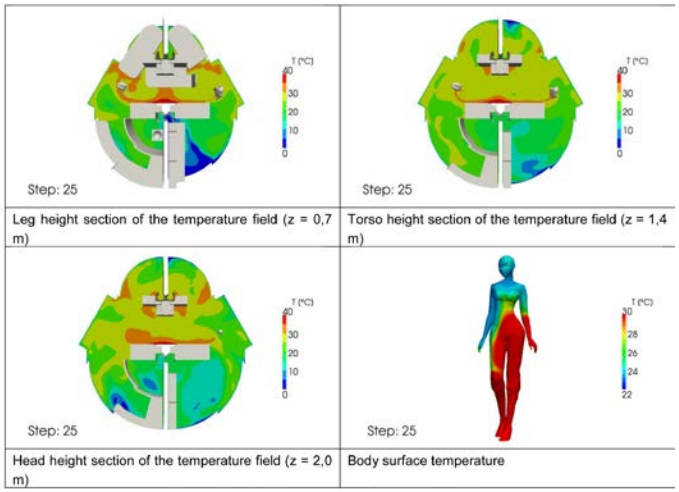


Description of image:
SHEE life support systems and environmental measurements

credit:
SHEE Consortium,
visualisation: COMEX 2014



Description of image:
Air speed fields in the habitat



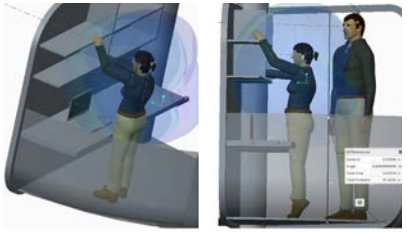
Description of image:
Field of temperature inside the habitat - Moon Cold Case

credit:
SHEE Consortium,
visualisation: Sobriety 2014

Analysis and Validation

The SHEE prototype underwent an extensive testing campaign from August through December of 2015. During this time the prototype was tested to ensure the functionality of deployment and all subsystems and identify areas for future improvement of the design.

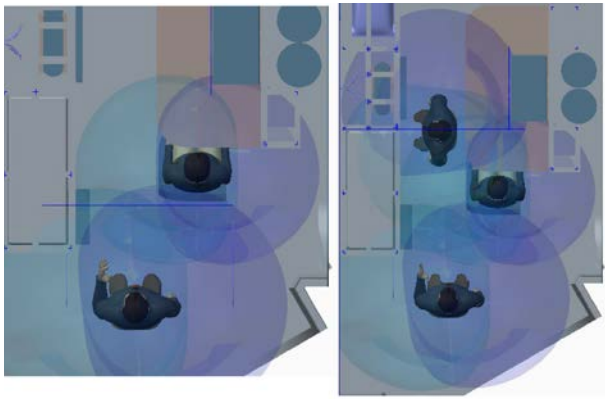
SHEE was found to comply well with all pre-existing models and simulations. Ergonomically the habitat performed better than expected, with all test subjects rating the habitat as comfortable and easy to use.



Description of images:
Top: Reachability of CAESAR Netherlands Female 5 percentile in work space (left) Normal standing posture; (right) Feet raised standing posture

Middle: Sitting posture

Bottom: Crew interference in meeting space



credit:
SHEE Consortium,
visualisation: Space Applications Services 2014

credit:
SHEE Consortium,
visualisations: Space
Innovations (SPIN) 2014

SHEE habitat with NASA
Exploration Vehicle in the
background

SHEE transport information

Unique among analogue habitats, the SHEE has been designed from the very start with terrestrial transportation infrastructure in mind. SHEE may be transported using a simple flatbed trailer and crane.

As of the completion of the development contract in December of 2015 the habitat has been transported commercially four times.

Future of Europe's first space analogue habitat

In September of 2015, SHEE participated in the German Space Day at the European Astronaut Centre in Cologne. During the exhibition the general public and staff from ESA and ESTEC visited the habitat and provided feedback on the design. Overall the habitat was well received by both the general public and researchers alike.

credits:
opposite page top:
SHEE Consortium,
photo: COMEX 2015

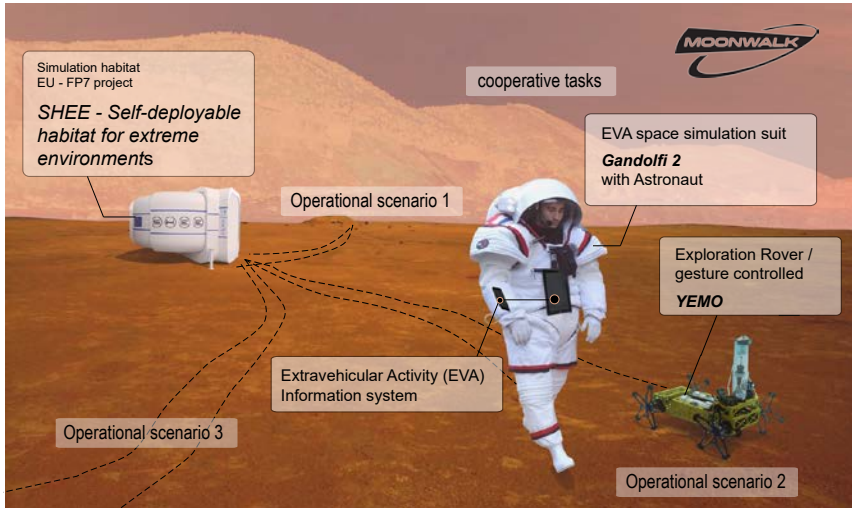
opposite page bottom:
SHEE Consortium,
photo: International Space University (ISU)

this page:
SHEE Consortium,
photo: International Space University (ISU) , 2015

The first SHEE research excursion will be in April of 2016, as part of the European Commission FP-7 Project called MOONWALK. SHEE will provide logistical support to the analogue astronauts and researchers in studies on the interaction between humans and robots in lunar and Martian exploration scenarios.

Description of image:
Digramme of the MOONWALK Mars simulation elements in Rio Tinto, Spain

credit:
MOONWALK Consortium, visualisation: LIQUIFER Systems Group 2016



From the beginning the SHEE prototype has only been seen as the first step in a larger production programme. For missions requiring more than two occupants, multiple SHEE units could be built and linked together to form a "SHEE village."

After three years of development the SHEE prototype has been successfully completed and is now available for use by European researchers, educators and exhibitions as the first transportable European space analogue habitat.

Description of image:
Consortium partners and EC representatives at the International Space University final SHEE presentation, 2015

credit:
SHEE Consortium, photo: International Space University (ISU) 2015

International Space University

The International Space University is a private non-profit educational enterprise offering graduate level interdisciplinary space studies programs in an international and intercultural environment and promoting the peaceful uses of outer space for the betterment of humanity.

LIQUIFER Systems Group

LIQUIFER Systems Group is a transdisciplinary platform engaged in innovative research and product development with focus on the positive synergies between Earth and Space. LIQUIFER Systems Group comprises architecture and design, human factors, systems engineering, robotics and exploration science.

Space Applications Services

Space Applications Services NV is an independent Belgian space technology company, founded in 1987, whose aim is to develop innovative systems, solutions and products for the aerospace markets as well as related industries.

The University of Tartu

The University of Tartu (UT) was founded in 1632 by the Swedish King Gustavus Adolphus. UT is Estonia's leading centre of research and training. It preserves the culture of the Estonian people and spearheads the country's reputation in research and provision of higher education. UT includes nine faculties and four colleges.

COMEX

COMEX was created in 1961 and became a pioneer in deep-diving operations specialized in engineering solutions for extreme environments and diving operations. Its business activities include: hyperbaric/ hypobaric testing and engineering for ocean and aerospace applications, Oceanographic research and neutral buoyancy testing for equipment and EVA.

Sobriety

Sobriety s.r.o was established in 2002 and as a provider of numerical simulations specializing on Computational Fluid Dynamics and Finite Element Method calculations (aerodynamics, thermodynamics, thermo-mechanics and mechanics). Sobriety also delivers Information Technology (IT) application services in areas of IT engineering and testing support.

Space Innovations

Space Innovations (SPIN) founded in 2011 is a research and design studio focused on human system integration in extreme environments on Earth and in space. SPIN's activities include topics of architecture sustainability, autonomy, environmental integration, cognitive engineering, education and outreach.

This booklet was prepared as a part of the dissemination activities in the SHEE project.

For more information regarding the SHEE project, please contact the Project Coordinator or your local SHEE Consortium partner:

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www.shee.eu

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