SHEE, Self-Deployable Habitat for Extreme Environments

1-page summary

Self-Deployable **H**abitat for **E**xtreme **E**nvironments (SHEE) is a three-year project developed under the European Commission's Seventh Framework Programme Space between January 2013 – December 2015. SHEE is the first deployable habitat simulator to be designed and constructed in Europe and is now available to the larger research community for conducting simulations.

Distinctive features of the SHEE project include its easy transportability with a standard flatbed truck and its capacity to automatically deploy – increasing the size of the habitat and usable space to accomodate a crew of two persons. The habitat is outfitted with interior furnishings permitting different usage and activity by crew members; including sleeping cabins, a work area, a multi-functional common area, hygiene compartment and small workshop. The habitat Environmental Control and Life Support System (ECLSS) can sustain a two-person crew for two weeks. It is anticipated that elements of the SHEE design will find practical applications in any hostile environment requiring human presence, on or off the Earth.

The habitat is ideal for conducting scientific research on the affects of confinement and for testing space-related systems and technologies.

Partners collaborating on this project:

- International Space University – FRANCE (coordinator)
- LIQUIFER Systems Group GmbH – AUSTRIA
- Space Applications Services N.V. – BELGIUM
- Institute of Technology, University of Tartu – ESTONIA
- Compagnie Maritime d'Expertises S.A. – FRANCE
- Sobriety s.r.o. – CZECH REPUBLIC
- Space Innovations, s.r.o. – CZECH REPUBLIC

SHEE, Self-Deployable Habitat for Extreme Environments

General Information

SHEE is a test-bed for terrestrial simulations of extreme environments with possibility to be deployed in space analogue environment or laboratory conditions. The habitat is available starting by 2016 to interested parties conducting mission simulations in analogue sites.

The main objective of SHEE was the effective integration of architecture and robotics for autonomous deployment of a self-sufficient habitat. To integrate human labour into construction on the lunar or Martian surface or disaster zones on earth is very risky, complex and costly. Self-deployable, autonomous habitats will mitigate construction safety risks, reduce costs and require minimal infrastructural systems and machinery. SHEE also represents a architectural principles for near term human space exploration.

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. Based on these parameters, a design concept was chosen which would be fully developed during the course of the project.

Construction

Structurally, the design of SHEE is a loadbearing, monohull structure with six deployable appendages (referred to as petals, i.e. deployable compartments). 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 both informed the preliminary design of the habitat as well as validate design hypotheses along the way. Analysis of the structure took into account different load cases, for a range of different scenarios. The final structural verification of SHEE showed a positive Margin of Safety for all cases analysed.

The self-supporting structure of the mail hull is made of stiffened sandwich panels (60 mm thickness) of fiberglass facings with a core of foam material. The main hull was manufactured in two halves and attach to one another by means of an equatorial metallic flange. The petals were manufactured using the same principle as the main hull. 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.

Deployment

The deployment of the habitat consists of rotary motions that are driven from a central axis. The system was selected mainly because of the availability of commercially off the shelf components. The drives are compact and are located in the floor and ceiling compartments.

In total, six petals automatically deploy from within the main body of the habitat. The six petals are divided equally into two groups and are symmetrically aligned on the central axis within the stowed habitat.

SHEE deployed and folded configurations; *credit: SHEE Consortium, photo: Bruno Stubenrauch, 2015*

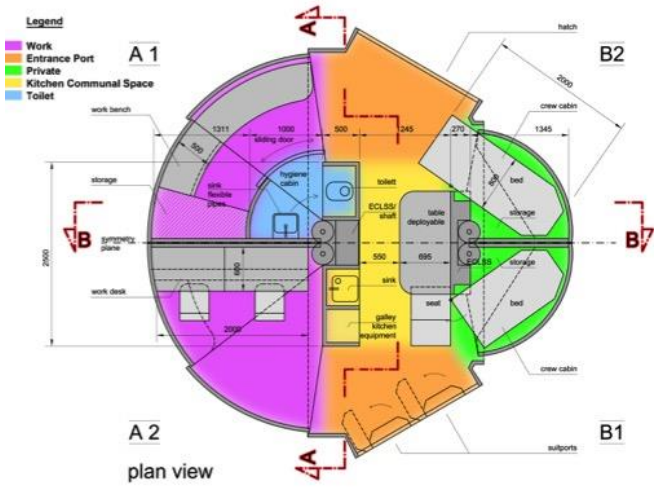
Deployment of the petals is synchronized, so that identically dimensioned petals on either side of the axis are paired together during actuation. Each petal in the set has an individual gearbox, but the same motor drives the set. The actuation is done by 2 x 800 W electric motors running on 24 V DC powered by battery or from the 3 phase grid. The position of the petals is tracked using a rotary encoder located directly on the pivot axis.

Inflatable seals fill the gaps between the moving petals and the main hull. The seals are fully inflated after the habitat is deployed. The seals must be deflated using a vacuum pump during their motion.

Interior

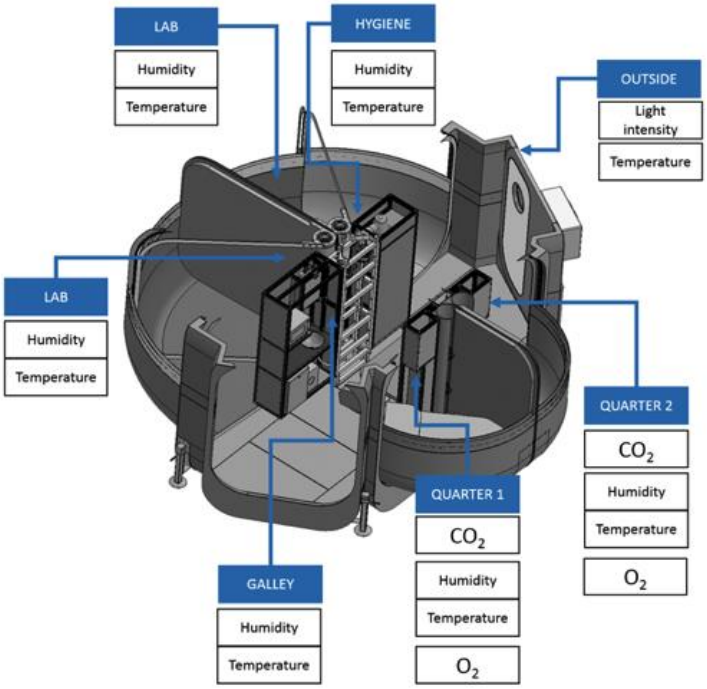
The overall inhabitable volume was based on current NASA/ESA studies suggesting between 20-25m³/person for a two-person crew for short duration mission. Within the SHEE interior volume of approx. 50m^3, it was determined that the habitat could accommodate:

- Galley for food storage, food preparation and disposal,
- Hygiene facility including whole body cleansing, defecation, urinating, first aid kit, medicine box,
- Crew quarters for individual use,
- Working area, work bench,
- Access airlock with a window



Final baseline concept; *credit: SHEE Consortium, visualization: LIQUIFER Systems Group, 2013*

ECLSS components are provided in the form of modular racks, which can be replaced by other functional elements if needed. The kitchen rack of SHEE includes items that enable the astronauts to prepare and store food such as a microwave oven, refrigerator and a dehydration unit to reduce the food's size and recover water out if it. A hygiene rack includes a toilet (gravity based) and a sink for personal hygiene. The 'monitoring and ventilation rack' is comprised of two small racks and includes the environmental monitoring system of SHEE, the air conditioning and two ventilation units.



SHEE life support systems location and measurements; *credit: SHEE Consortium, visualisation: COMEX, 2014*

In addition to the rack components, the interior furnishings of the SHEE habitat are modular and can be modified depending on the specific needs of a mission as well. Internal furnishing can be fastened to the rigid exterior structural shell at hard contact points by means of insertion and threading. A “virtual window” was integrated to change the colour of light within the habitat.

(top) left: Galley, right: Crew quarter (bottom) left: workspace / work bench, center: hygiene facility, right: access airlock door with window; *credit: SHEE Consortium, photo: LSG, 2015*

Transportability and availability

The SHEE test-bed is a unique structure developed by a European consortium of industry and research institutions to serve the international research community for habitation simulation tests. SHEE was developed to be easily transported by land, sea and air. It is the only easily transportable habitat simulator on the global market.

The Self-deployable Habitat for Extreme Environments is now open to the scientific community and is commercially available for research.

To fully understand the SHEE design and its capability a researcher's user manual will be provided to guide in science preparation and planning prior to SHEE utilization. Between October 2015 and December 2015 the SHEE habitat went through testing in a laboratory environment.

Thorough investigation in three fields included:

- Exterior testing including repeated deployment and stowing operations
- Interior testing
- Logistics and set-up issues

Testing of the habitat was broadly separated into two phases:
1) functional testing to the designed, built and integrated systems of the habitat and 2) user-based testing of the experience and operations of the habitat.

Transport by truck with trailer - 20ft ISO container size cargo, *credit: SHEE Consortium, photo: COMEX, 2015*