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MASH

Deployable Emergency Shelter on Mars

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MASH
Deployable Emergency Shelter on Mars
DESIGN STUDIO 2012/13

**Department for
Building Construction
and Design – HB2**
Institute of Architecture and Design
Vienna University of Technology

MASH - Deployable Emergency Shelter on Mars

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Content


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The Design Studio

25 students of the Vienna University of Technology worked in groups on different concepts for a deployable and portable emergency shelter for Mars that finally resulted in one common project.

The Studio Approach

Sandra Häuplik-Meusburger & Polina Petrova

Introduction

Mars surface infrastructure as anticipated for future human missions includes habitation, rover and infrastructure facilities. Exposure of an unprotected human body to the harsh Martian environment, caused for example by malfunction of the space suit or the life support system, can result in serious health damage or even in sudden death.

With regards to potential Extra-Vehicular Activities (EVA) due to science explorations and related safety issues to be performed on Mars, we recommend an additional crew support element. The primary feature of such an element shall be a portable and deployable shelter which can be employed in the event of an emergency that would require immediate action and where return to the base / rover is not possible in due time.

Objective and Design Task

The shelter shall be compactly packed, lightweight and be carried by one astronaut, similar to a "rucksack" or "suitcase" typology. It shall be easy to deploy and accommodate up to two astronauts wearing space suits, e.g. one injured astronaut and one helper astronaut.

It shall temporarily provide a breathable atmosphere for a minimum duration of up to 48h until rescue arrives (rover, other astronaut) or immediate emergency ceases (successful first aid, change of conditions).

Furthermore, deployment of a portable shelter will prolong EVA activities on Mars missions. Astronauts could possibly stay in the shelter overnight (if required for an experiment for example) or use it to take a short break either planned or due to an unexpected issue.

The Studio

During the 2012 winter term 25 students in the Master of Architecture program developed a series of emergency shelter design concepts.

Based on our design brief for the deployable shelter we assigned the students to three research groups:

(1) *Activity-based spatial Analysis:* This group analyzed the relationship between the required human activities during emergency situation and potential architectural solutions.
(2) *Deployable Structures:* Students in this group concentrated on potential structure typologies for the shelter and related materials.
(3) *Specific Features:* This research includes selected interesting ideas and partial solutions for potential challenges of the specific environment.

At the same time, students developed their ideas into initial concepts. Following extensive reviews by the project team and our external experts the most promising concepts were chosen for further development and the first big-scale-models were built.

In total three prototypes were developed and tested. The second prototype was tested with the suit tester during the Dress Rehearsal Meeting in Innsbruck. The final prototype was transported to Morocco to be tested within the OEWF Mars Analog Field Simulation between 01. - 28. February 2013.

Along the design process, we have evaluated the shelter concept concerning its usability, functionality and adaptability.

The structure of the booklet follows the work process.

Further information:

MARS - NASA explores the red planet
http://www.nasa.gov/Mars

Morocco Mars Analog Simulation
http://www.oewf.org

Department Hochbau 2 Publications
http://www.hb2.tuwien.ac.at/shop

Project Team

Vienna UT

Project Lead

Dr.-Ing. Sandra
Häuplik-Meusburger

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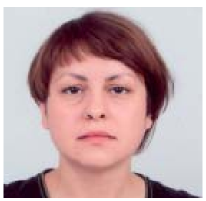
Expertise: Architecture and Habitability in extreme environment, adaptable and flexible habitation design



DI. Polina
Petrova

INSTRUCTOR
Ass.Prof. Department HB2
Expertise: deployable space frames and freeform deployable structures

DI. San-Hwan
Lu

INSTRUCTOR
Ass.Prof. Department HB2
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Extended Team

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Dr. Chan Sivanesan, Intern, Crew Medical Support Office (HSO-UM), European Astronaut Centre (EAC)

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DI Irmgard Derschmidt

Consultants for the AOUDA space suit:
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Daniel Föger, Analog astronaut, OEWF, Physics Student

Simonauts TU-Student team:
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OEWF Analog Astronauts:
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Florian Mathias Aigner


Ottokar Benesch


Tzvetan Dineff


Nico Flieger


Daniel Galonja


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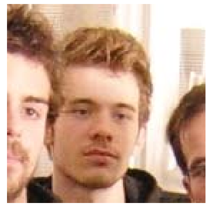
Katarina Josipovic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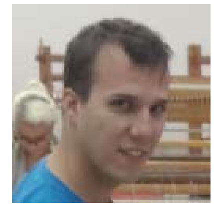
Zuzana Kerekretyova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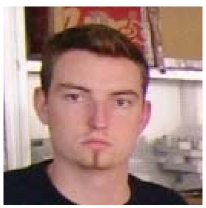
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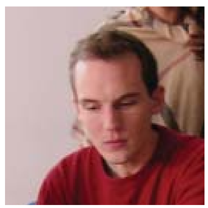
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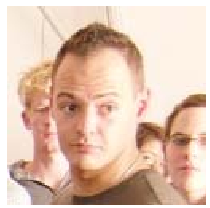
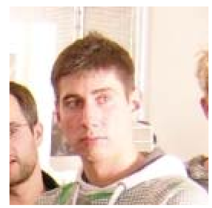

Markus Mitrovits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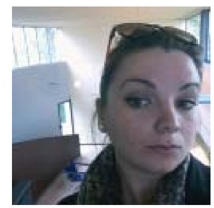
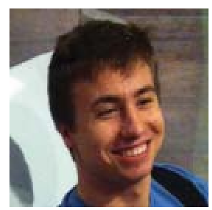
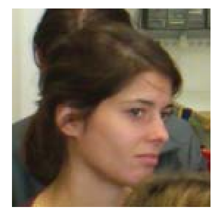

Aida Mulic


Alexander Nanu


Josef Öhreneder


Tanja Pavlovic


Marcin Puchalski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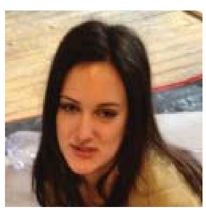
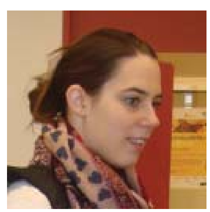
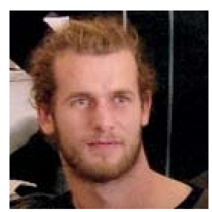
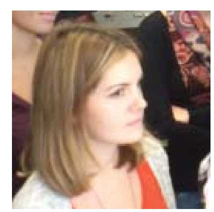
Markus Scherz


Nina Tica


Stéphanie Toussaint


Kristoffer Stefan


Kristina Zodl

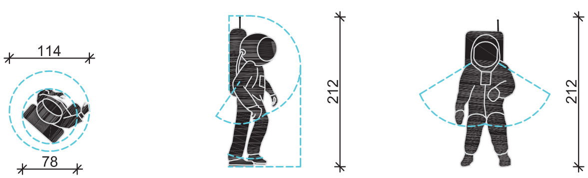
Research

Based on the preliminary design brief for the deployable shelter students worked in groups on relevant research topics.

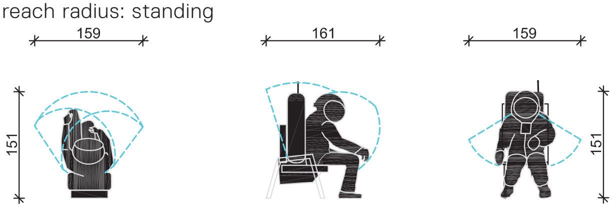
Activity-based spatial Analysis

Research

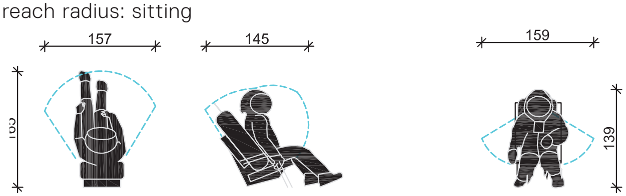
The students analyzed the spatial requirements for two astronauts based on spatial maneuverability, human activities and interaction. The aim was to define the minimal space envelope necessary for the emergency shelter.
This requires the specification of typical emergency scenarios which can be expected during Extra-Vehicular Activities (EVA) on Mars.
Combinations of different emergency situations were analyzed regarding spatial requirements for the recovery (rescue) activities and the feasibility of these scenarios. This is strongly related to other design criteria like the maximum size and weight possible to be carried by one astronaut.



reach radius: standing

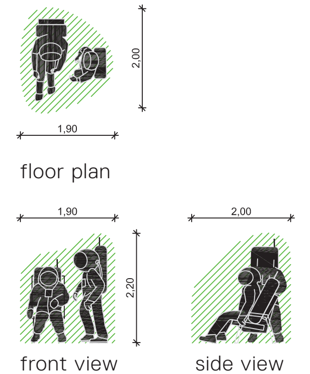


reach radius: sitting



reach radius: relaxed sitting

MUST - SHOULD - COULD



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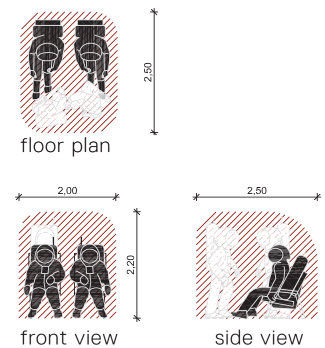
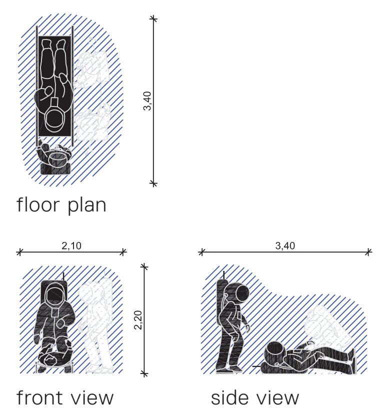


MUST - SHOULD - COULD




floorplan
front view
side view
1,45
3,00
2,20
floorplan
front view
side view
2,00
1,80
floorplan
front view
side view
1,45
2,60
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front view
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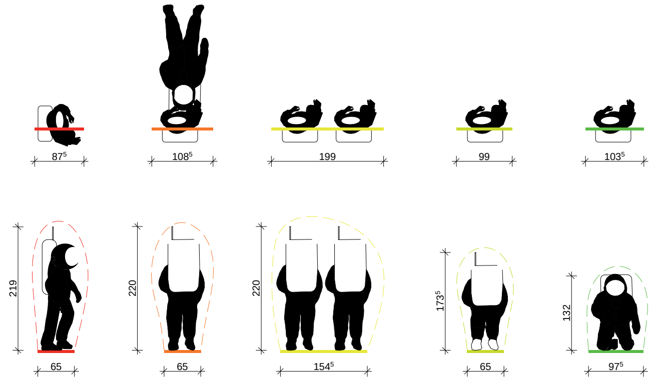
2,70
2,00
1,80
floorplan
front view
side view
3,40
1,45
2,20
floorplan
front view
side view
2,70
2,00
2,20

2D and 3D diagrams, analog simulations performed by the students as well as some inputs from the Aouda Spacesuit-Tester were carried out and analyzed during this research. The evaluation then served as a basis for the definition of possible scenarios using the shelter and for roughly determining shelter size.



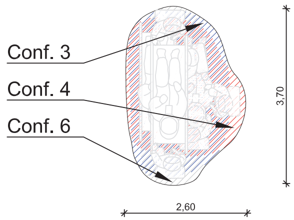
Analysis for entering the shelter

Movement analysis

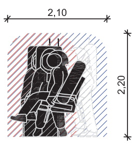
Activity-based analysis with the Aouda-Spacesuit

Evaluation

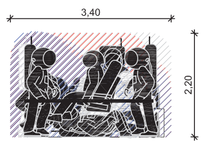
Combination 1:
all configurations



floorplan

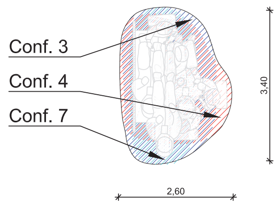


front view

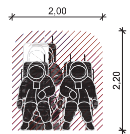


side view

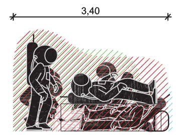
Combination 2:
all configurations
without transport



floorplan

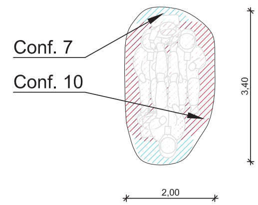


front view

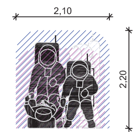


side view

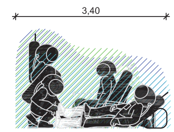
Combination 3:
all configurations
without transport
without lying on „bed“



floorplan

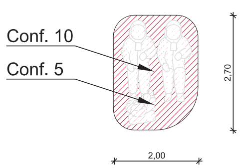


front view

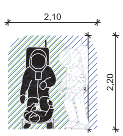


side view

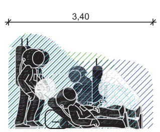
Combination 4:
without transport
without lying on „bed“
without removing suite



floorplan

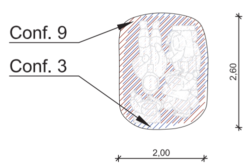


front view

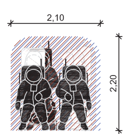


side view

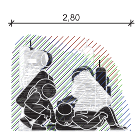
Combination 5:
only sitting and
crouching



floorplan

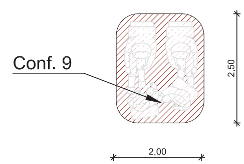


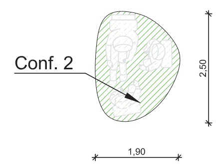
front view



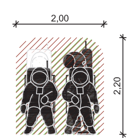
side view

Combination 6:
only sitting





floorplan



front view

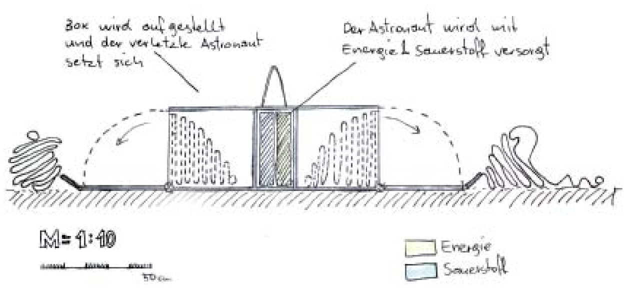
side view

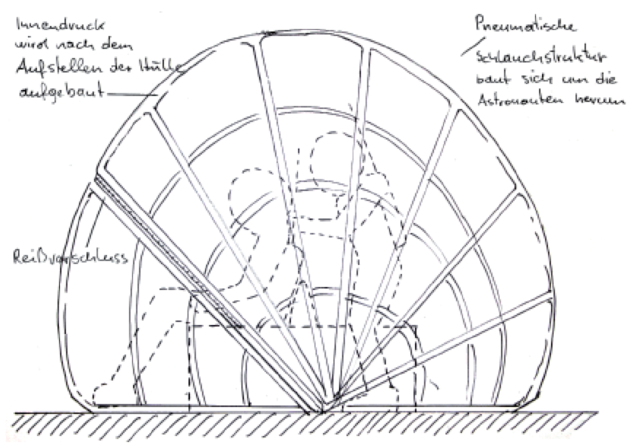
Deployable Structures

Research

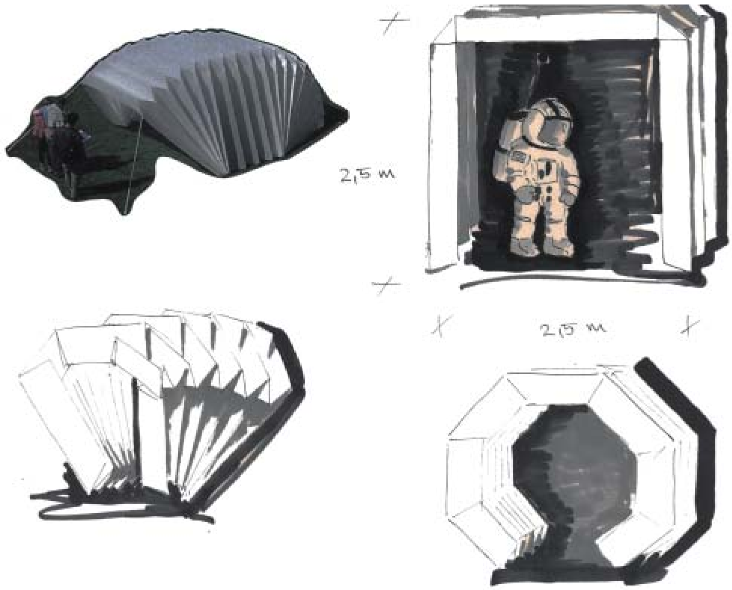
An important feature of the emergency shelter is its compactly packed lightweight structure that allows it to be carried by one astronaut, similar to a “rucksack” or “suitcase” typology. On the other hand it should accommodate up to two astronauts (with space suits) when deployed by expanding to five times its initial size. In case of an emergency requiring immediate action it should be fast and easy to deploy by the uninjured astronaut.

These special features implicate a wide range of challenges and require an analytical study of different typologies of deployable structures. The students analyzed different deployable systems like pneumatic systems, deployable bar and surface structures, hanging films and bells. Basic kinematic concepts were worked out and specific case studies were simulated. All systems were evaluated in regards to design criteria like weight, stability, handling and reusability. The research which was carried out brought critical reflections to light and furthermore serves as a basis for future experiments with the ideas and techniques that were revealed.

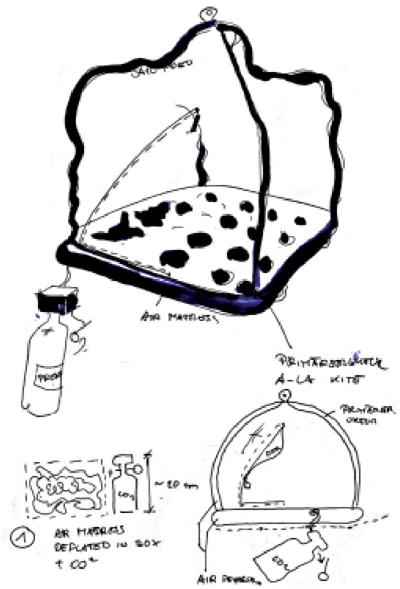




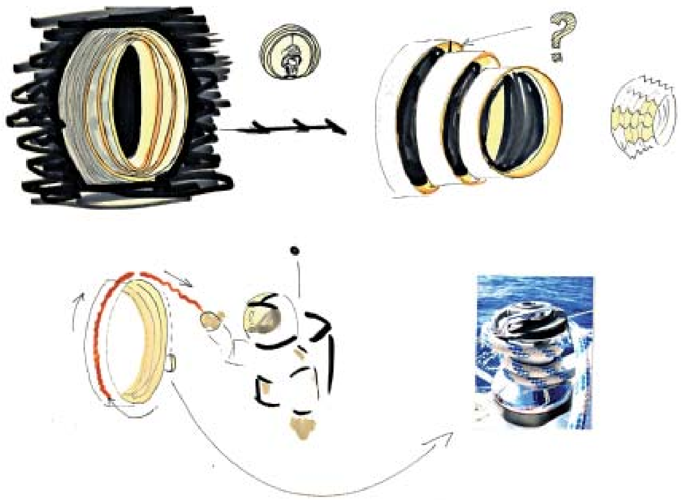
Mixed system: mechanic, pneumatic



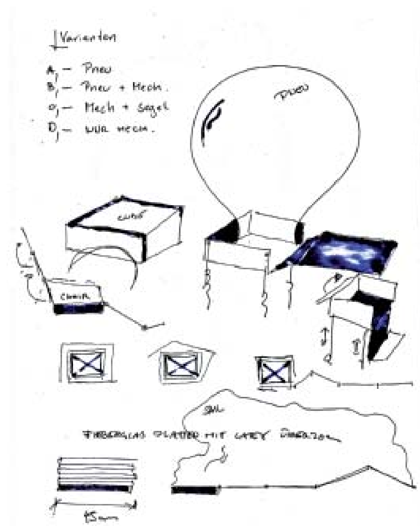
Surface folding system



Pneumatic system



Telescopic system

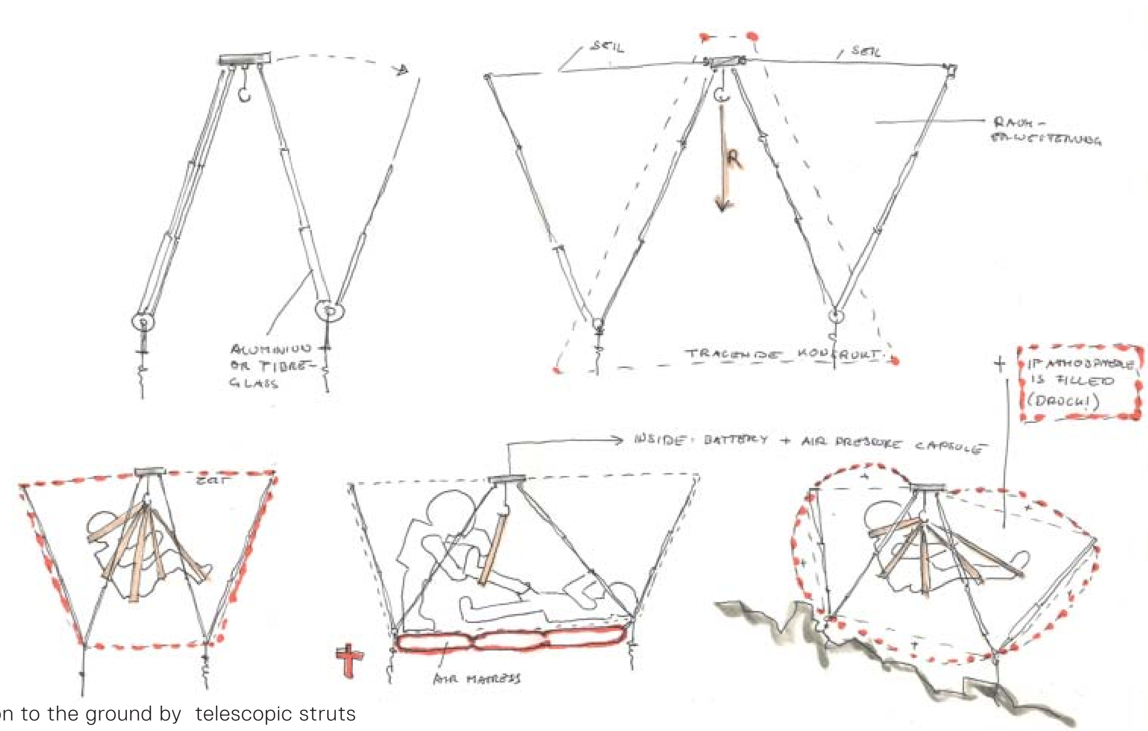


Mixed system: mechanic, pneumatic

Specific Features

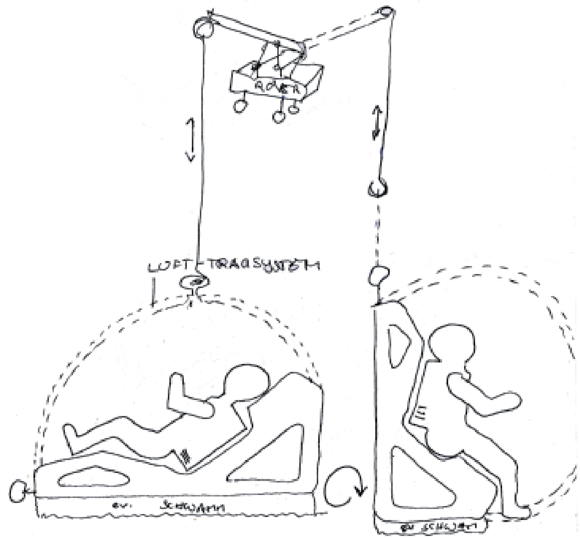
Research

In addition to the study of deployable structures, capable of only changing size and volume, some other features of the shelter like functional and topographical adaptability were explored by another group of students. In this research the topic of Mars topography and the required design features to withstand this surface were tested. In comparison to known earth surface typologies, the Mars surface most closely resembles Earth's rocky surfaces. Therefore the shelter should have adaptable parts at the bottom, e.g. telescopic feet. In this manner, the adjustment to the surface does not have to be all at once. By adjusting the telescopic elements leveling could be achieved on uneven surfaces.
Another possible solution could be pneumatic elements in the form of spheres or tubes on the bottom of the shelter. These would be separately inflatable, thus enabling height adjustments in relation to the uneven terrain surface. To increase stability, adjustable pneumatic "thorns" can be added to the underside of the membrane to stabilize the shelter on the uneven Mars surface.



Adaptation to the ground by telescopic struts

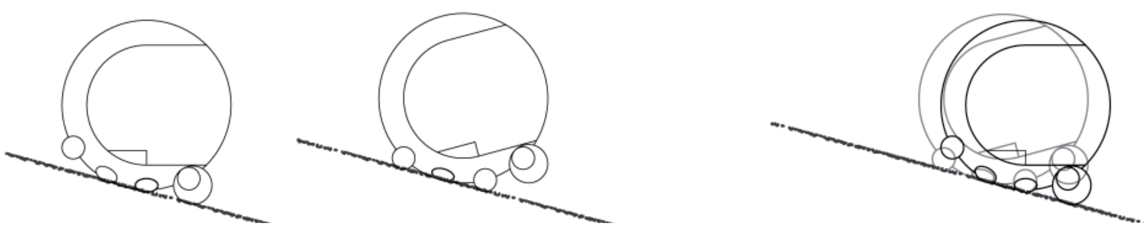
Another important topic was the adaptability of the shelter in regard to functional requirements. Students also focused their research on the adaptability of the structure through changing its shape, which allows manifold different human activities to take place within its confines without increasing the volume of the structure. Different mechanical devices to control the shape of the structure consisting of either rigid foldable frame elements, pneumatic muscles or cables, were tested and evaluated with focus on usability and simplicity.



Functional adaptability

point support / pads

linear support / hoses



Adaption to the ground surface by double-layered pads with connected external-chamber

Workshop Austrian Space Forum

29th - 30th October, Innsbruck

The team visited the OEWF office in Innsbruck (Austrian Space Forum) to get relevant technical and user-related information about their analog spacesuit AOUDA to incorporate that into the shelter´s design process.

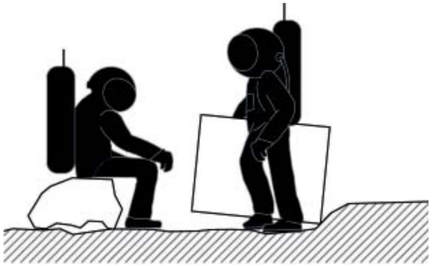
Day 1: Dr. Gernot Grömer, OEWF's chairman, gave a presentation on Mars' atmosphere and available materials and machines. At AOUDA spacesuit lab, a demonstration on how the spacesuit is put on was given. All of the students were able to try on gloves and do exercises, such as tying shoelaces or operating walkie-talkies.

Day 2: The group did role playing to better understand the astronauts' needs on Mars and what different alterations of the design would mean to the users. Furthermore, equipment such as a mini rover was demonstrated. The group got to try everything themselves, to once again see things from the analog astronauts' perspective.

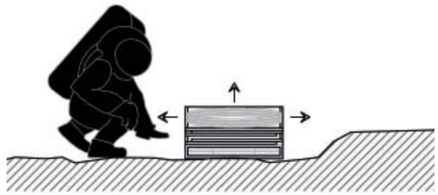
Design Concepts

Several concepts were developed by the students in multiple design stages. The further progress of the design project Mars and its prototypes is on the basis of the concept *„res[C]ue me“ (page 51)* .

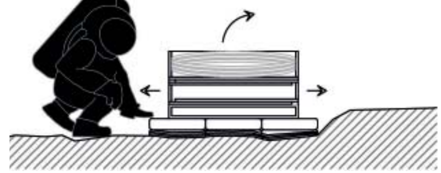
Deployment of the Spiral



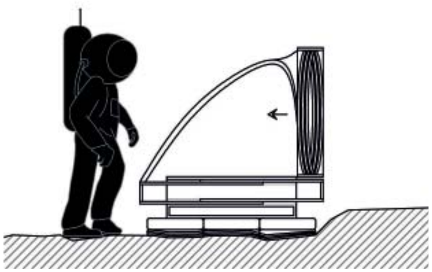
1. The shelter is packed into a "suitcase".



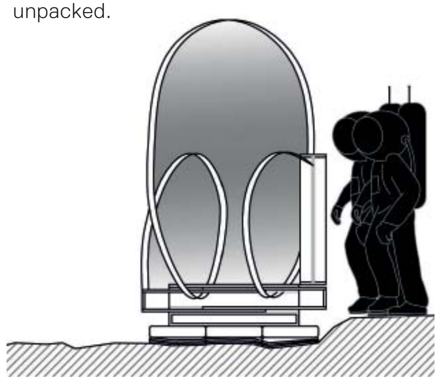
2. The suitcase is placed on the ground and unpacked.



3. The floor is inflated.



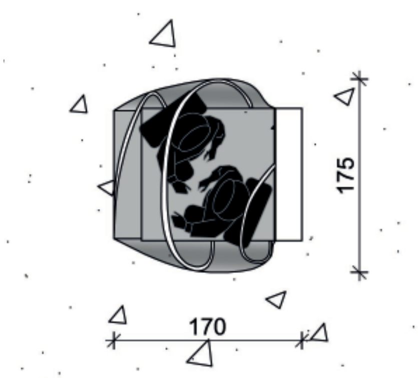
4. The spiral starts to inflate.



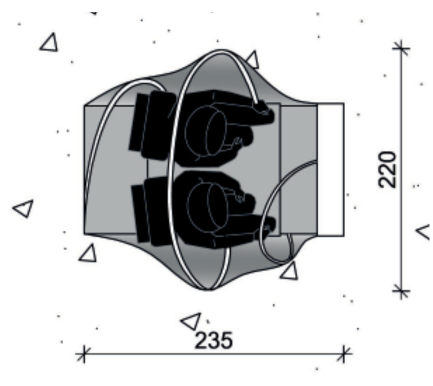
5. The spiral is inflated to the first stage. Astronauts enter the shelter.

6. Astronauts sit in the shelter. They can adapt the size of the shelter to the needed state.

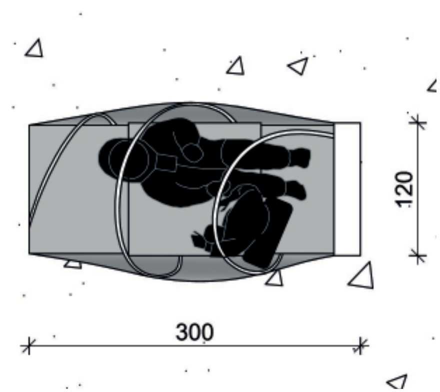
Adaption of the Shelter



state 1



state 2



state 3

Spiral System

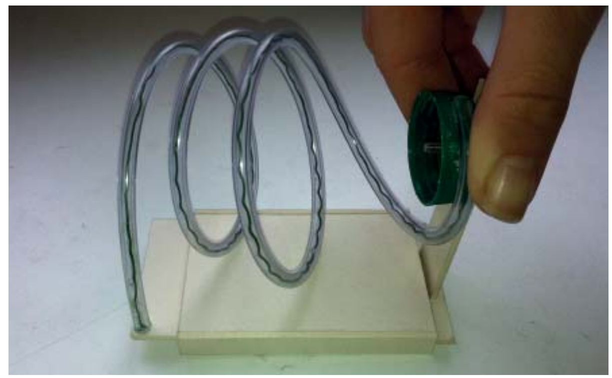
As an inspiration for the emergency shelter design we took the spiral. It is a flexible form that can easily change its size in both directions. Both length and height depend on the required form.
We studied the behavior of a spiral under the influence of various forces and developed the following concept: The shelter´s deployability, collapsibility and flexibility is based on simple screwing and stretching of the spiral, which serves as the main structural element. It is a pneumatic tube made of airtight silnylon fabric. Depending on the air pressure inside this tube, the spiral´s density as well as shelter size can be controlled.

State 1: The state with the biggest height and the smallest length - both astronauts can stand inside the shelter
State 2: A state between 1 and 3 - both astronauts are able to sit in the shelter
State 3: The state with the largest length - the astronauts are able to lie and kneel

The skin of the shelter is made out of multilayered stretchy fabric. It consists of an airtight inner membrane (Silnylon) and a midlayer - a strong fabric woven from Panox and Vectra fibers. On the outside the skin is coated with aluminum that protects the shelter from radiation.
The skin is flexibly connected to the spiral and can move around it. This movement is provided by stripes (made from the same material as the inner membrane) welded onto the inner side of the skin pulling over the spiral. The biggest advantage is that the size of the emergency shelter can be adjusted even when astronauts are already inside.

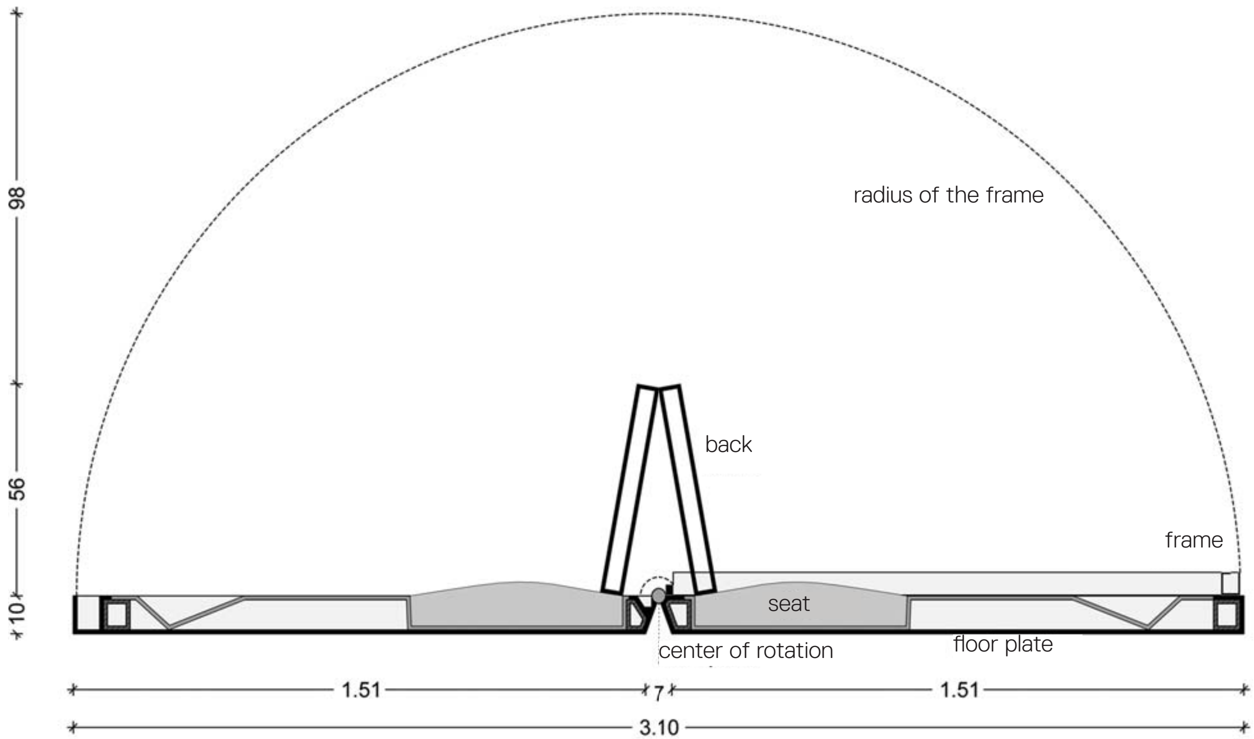
Zuzana Kerekrétyová, Rene Mathe, Markus Mitrovits

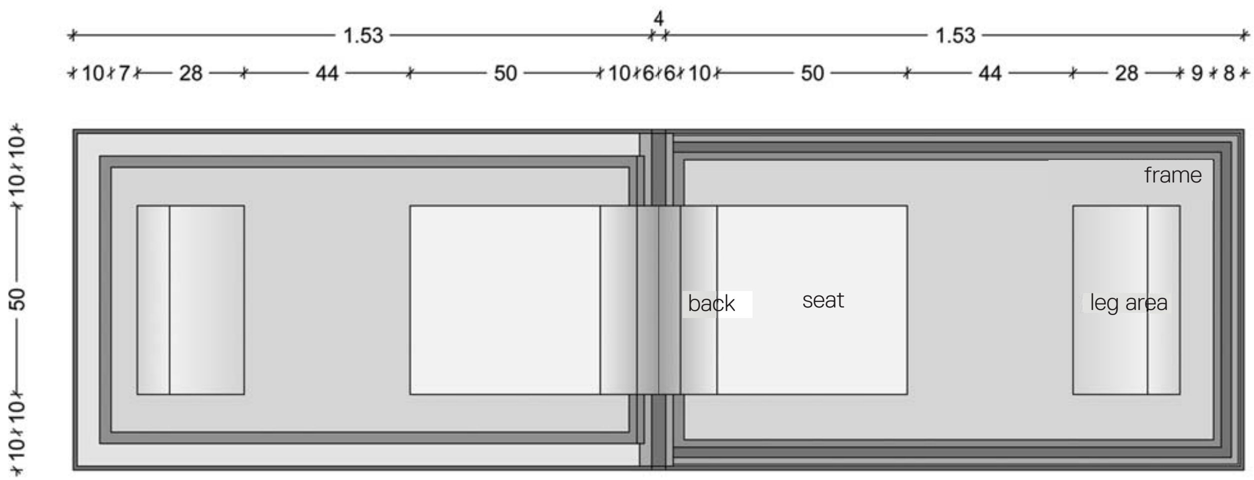
State 1



State 2

State 3


98
56
10
radius of the frame
back
frame
seat
center of rotation
floor plate
1.51
7
1.51
3.10


1.53
4
1.53
10 7 28 44 50 10 6 6 10 50 44 28 9 8
10 10
50
10 10
frame
back
seat
leg area

Emergency Case

An important task during the development of the "*Emergency Case*" was to cover all possible scenarios. First priority was energy and oxygen support as well as stable positioning of the astronaut. Another necessary part of the development was an airproof shell, which could be inflated in case of emergency to provide atmospheric pressure and enough space to give first aid.

The deployment of the "*Emergency Case*" is conceived in a way that could fulfill the different requirements depending on their priority. To provide the most important functions - supply and positioning - the case only has to be opened. The shell can be closed to protect from radiation. In case of a damaged spacesuit or heavy injuries the shell can be inflated with 0,6 bar to guarantee survival.

The "*Emergency Case*" can easily be carried by one astronaut. It is made out of a solid, scratch resistant material since the outer part serves as the base for the shelter.

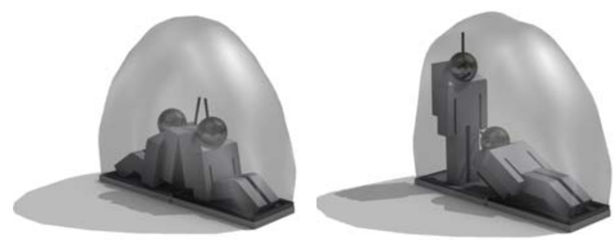
When the case is opened, the surface measures 310 x 90cm. It is only 10cm high to easily place an injured astronaut on top of it. Two back rests with integrated oxygen and energy supply can be pulled out.

The frame is assembled on the same axis as the bottom plates. It folds and pulls the cover over the astronauts. This shell can be inflated so the astronauts have the ability to move.

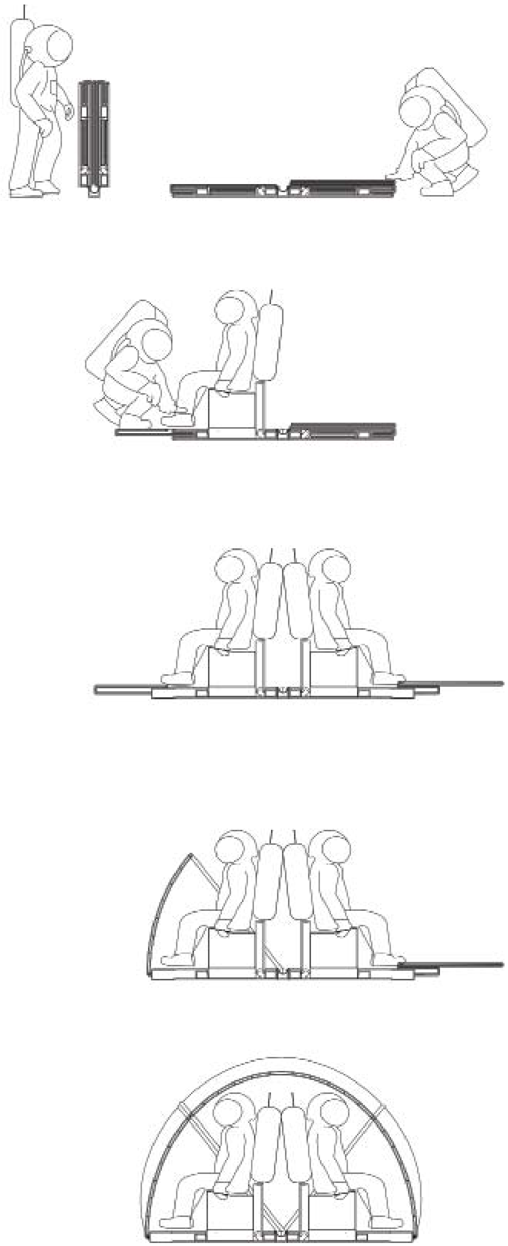
Nikolas Karhan, Markus Scherz

Deployment

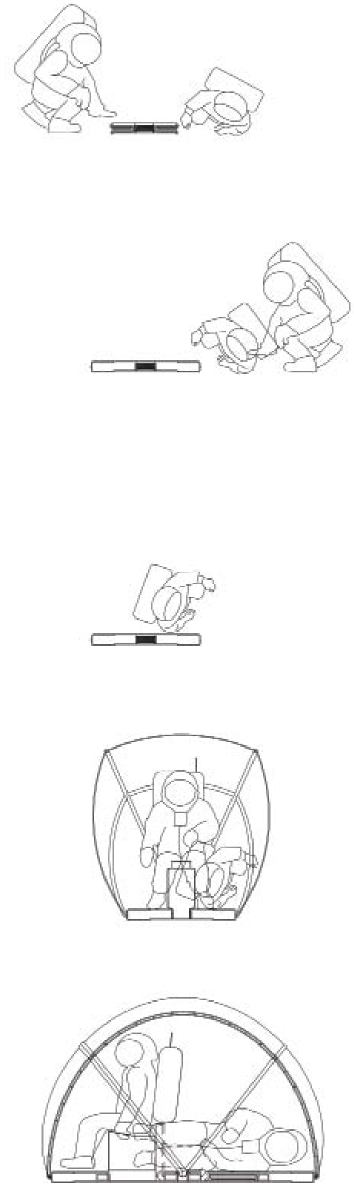
State 1



State 2



Deployment procedure with one sitting injured astronaut



Deployment procedure with one lying injured astronaut

Deployable Stretch Shelter

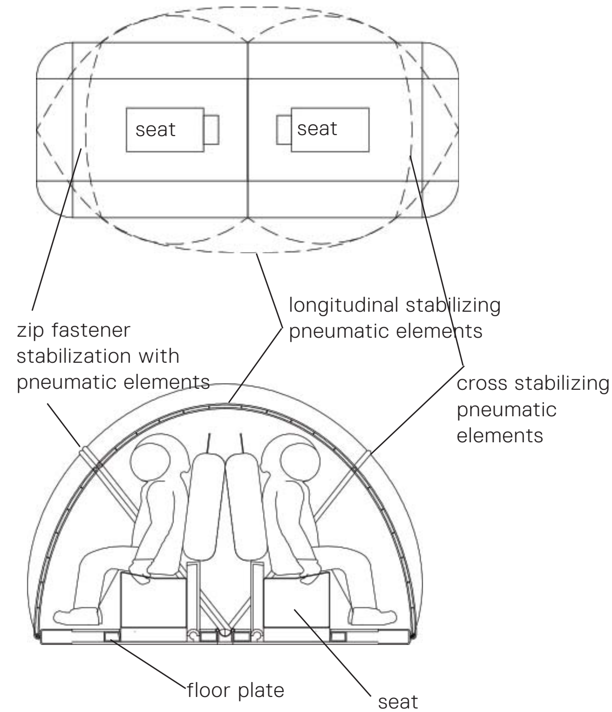
In the folded state, the shelter resembles a portable suitcase. Opening the case deploys a solid surface panel (made of carbon composite or Keflar-fabric and silicone, protected by open-weave textile Nextel). The pneu is located between the inner and the exterior carbon shell.

The process of folding the pneumatic floor and exterior-wall elements is facilitated by the Mars atmosphere. Floor and walls are separately inflatable. Thus, the floor can be first used as a „scoop-stretcher“ and later on as a shelter. The expandable floor allows the astronauts to carry out a number of complex tasks. The shelter can be adjusted in height, so that both astronauts can stand. Other possible positions include lying back to back or one astronaut lying with the second one sitting next to him.

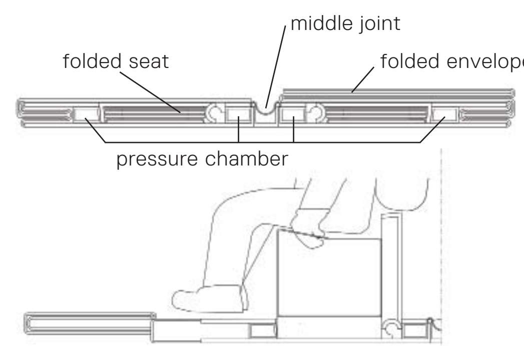
The backrest (place for the backpack while sitting) is popped out of the bottom plate and locks in the upright position. After it locks, the seat cushion is deployed, which allows for a seating-area of 30x40cm.

Josef Öhreneder

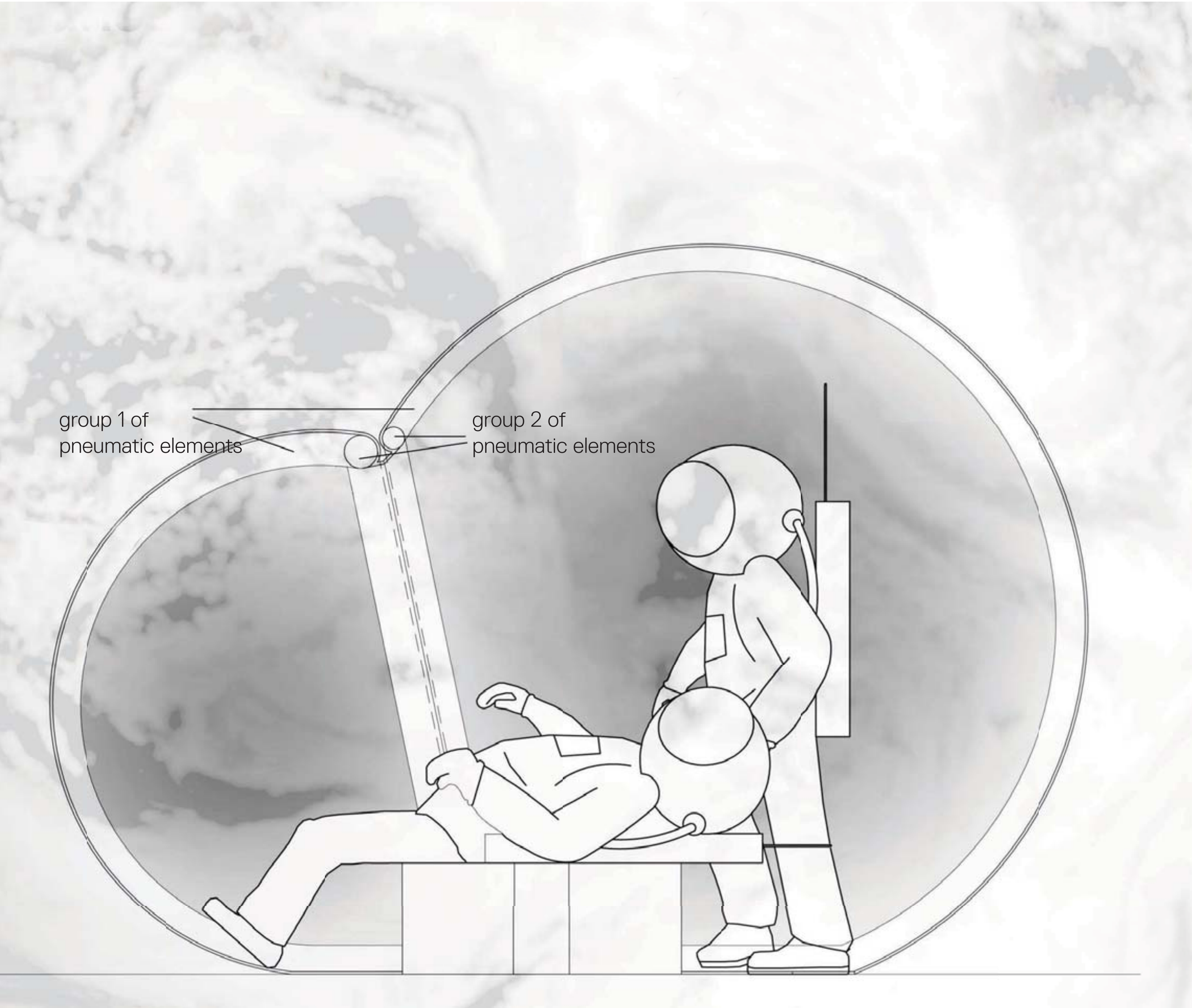
Top view



Longitudinal section



Detailed section through the floor plate


group 1 of
pneumatic elements
group 2 of
pneumatic elements
Section

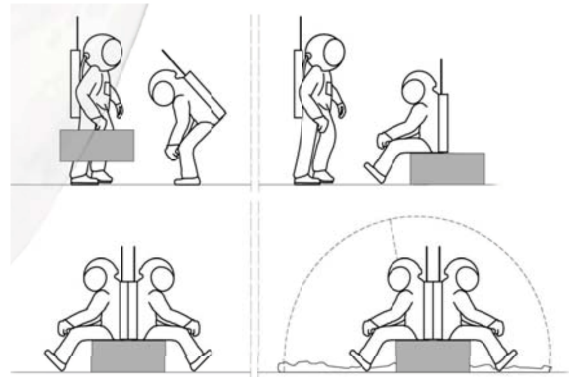
2planets2people

The packed shelter is 40x40x100cm and can be used as a seat for two people. The astronauts sit back to back connected to an oxygen and energy supply.

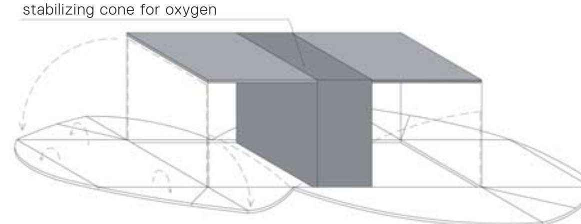
The envelope is deployed by using pneumatic elements. A first group of pneumatic elements form a stable ring (Fg. Section). Using air pressure, a second group of pneumatic elements positions the ring diagonally across one of the astronauts, so he can close the zipper between the elements of the first group. Once an enclosed space is provided, inner pressure is built up.

The great advantage of this design is that one astronaut can attend to his injured teammate from all sides without restrictions to treat and stabilize him. Afterwards he can also take a seat and then start the deployment procedure. Now the shelter deploys around the two astronauts, with the smaller sphere providing a protected space for the injured astronaut while the larger one is spacious enough for the second astronaut allowing standing, squatting and sitting activities.

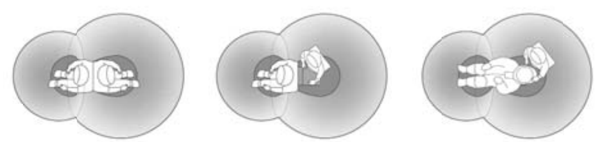
Nikolaus Gutscher, Benjamin Mrowetz, Stéphanie Toussaint



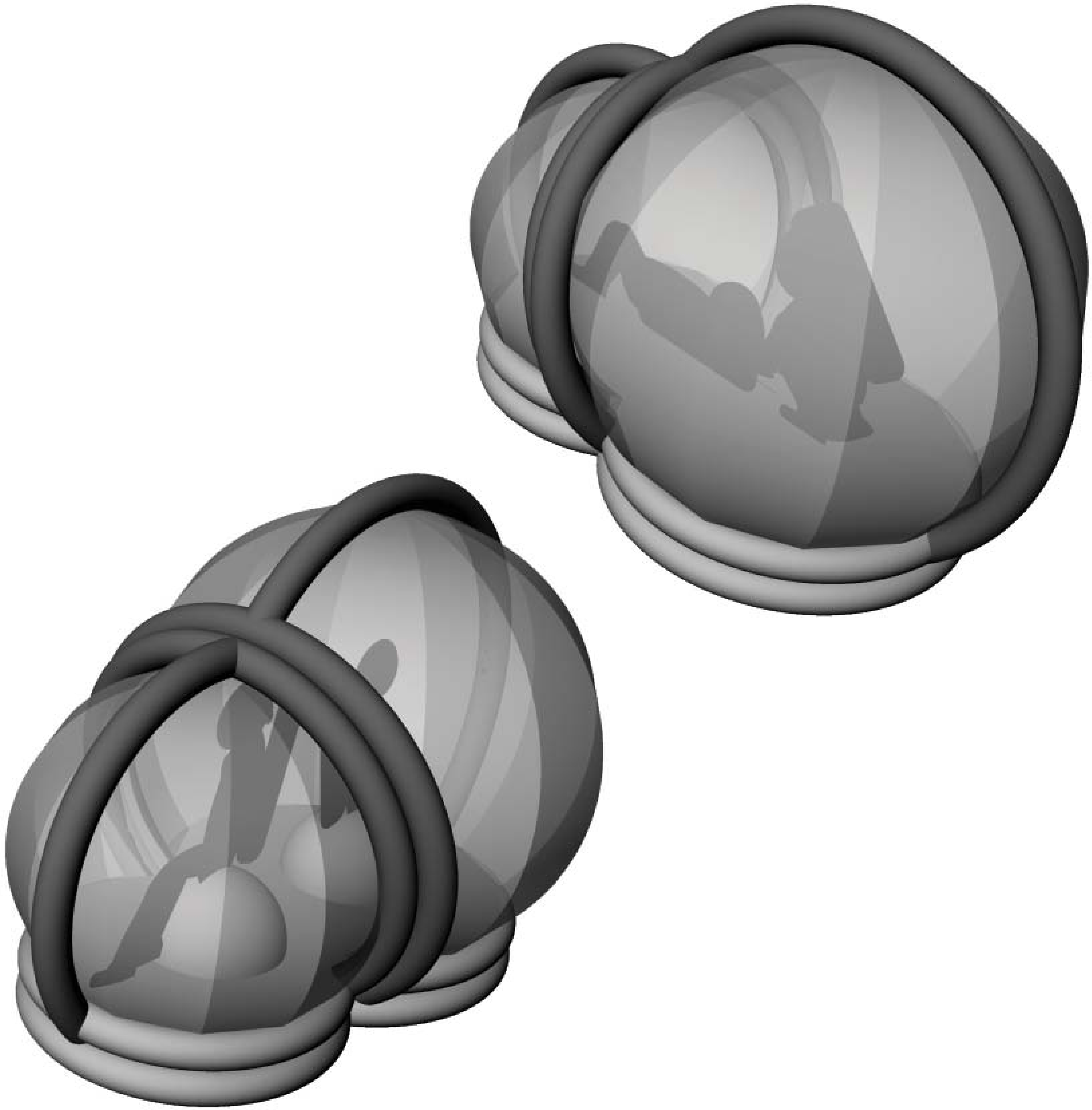
Deployment 2planets2people



Structure of the box



Scenarios: sitting/sitting, sitting/standing, lying-standing



Sitting (left) and lying (right) position

2planets2people 2.0

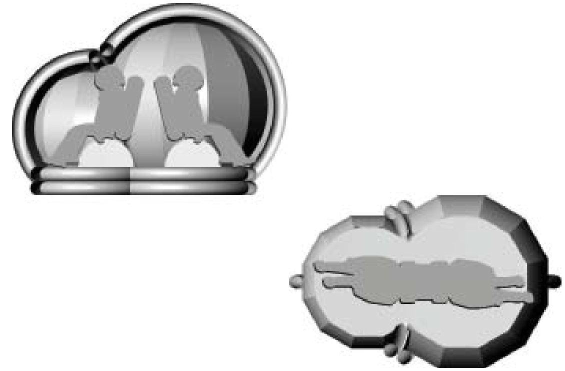
This project is a further development of 2planets2people. The object of the suitcase is not implemented here. In this case, the floor and the seats comprise of inflatable pressure elements.

By reducing the solid components, the pack size can vary and therefore be more convenient and space-optimized.

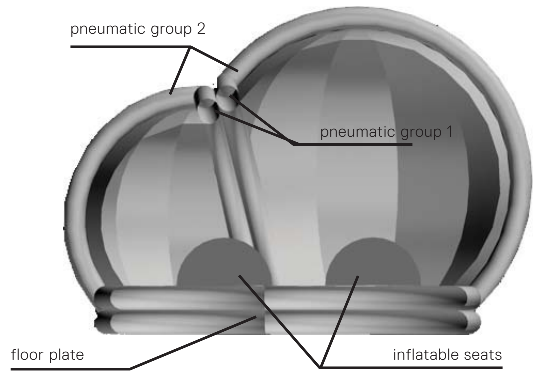
The envelope consists of pneumatic element group 1 and group 2, which provide structural stability, and of a membrane connected to one of the pneumatic groups, which is the necessary interface between the interior and the exterior atmosphere on Mars.

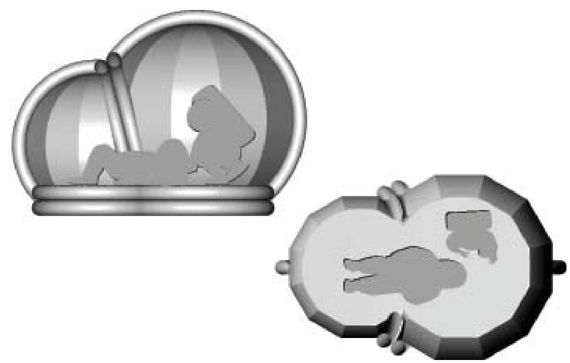
The floor plate consist of a two-layer system. The lower layer can be adjusted to the ground by using four individually controllable chambers up to a maximum unevenness of 20cm. This allows it to adapt to a wide range of surfaces, thus expanding the potential scope of the shelter. The upper layer above serves as a base panel for the astronauts. Usage scenarios range from standing to lying while seats can be unfolded from sub-floor chambers. These adaptable seats provide a greater range of usages for the interior space. For example two astronauts could wait for help while lying down. It is also possible to optimize the prone position of an injured astronaut to avoid unnecessary pain.

Nikolaus Gutscher, Josef Öhreneder

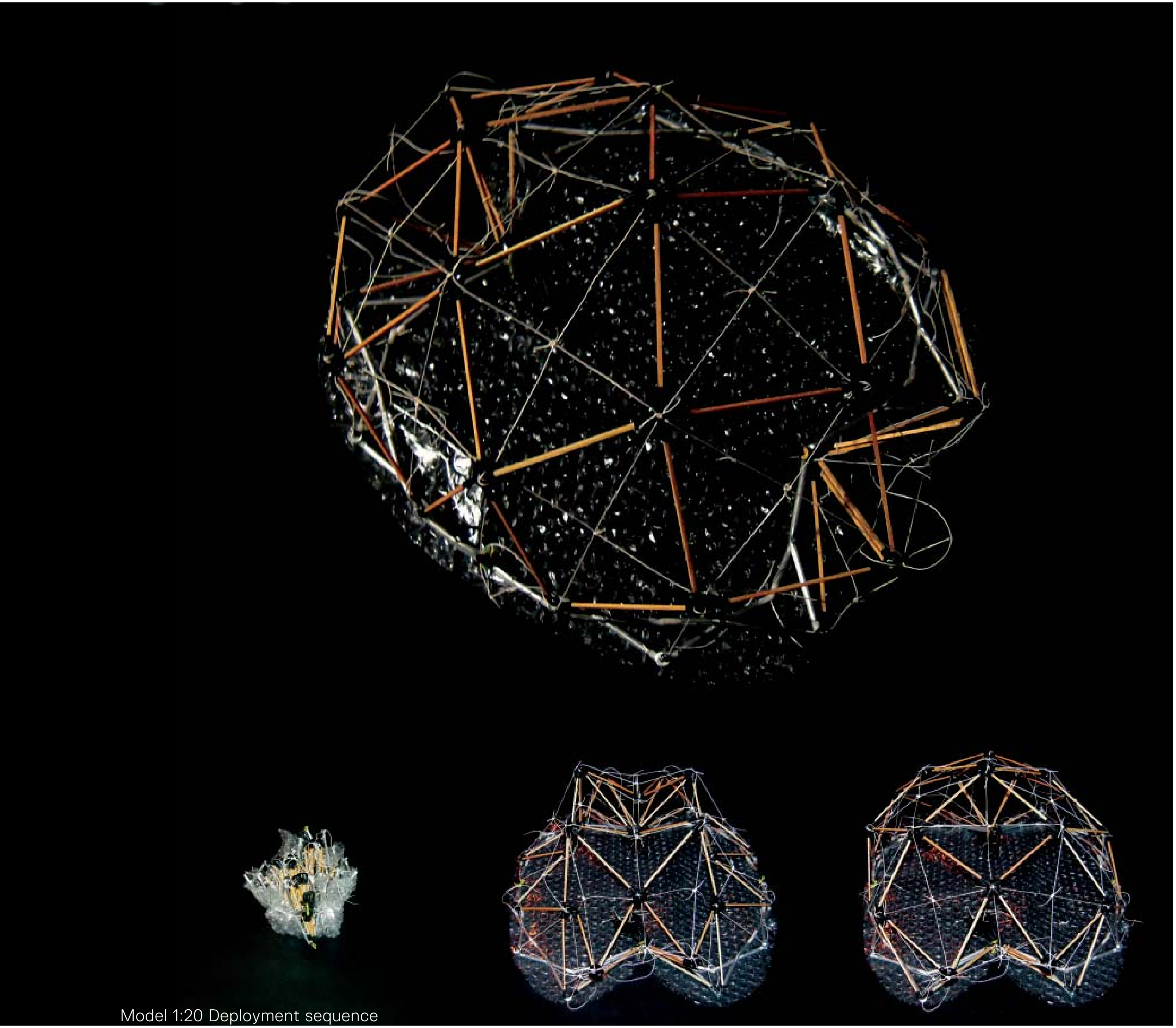


Section and floor plan: astronauts wait sitting





Section and floor plan: treatment of the injured astronaut



Model 1:20 Deployment sequence

Deployable Shelter

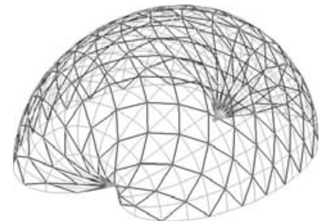
This structural concept is based on an interaction of different folding techniques with the aim of compactability and ease of deployment. The support structure is arranged radially and forms rhombuses of different angles but with constant side length which allows it to be folded completely by pushing out or pulling in half of the nodes.

For strutting the rim of the structure four scissor-like arcs are connected. By folding them, each arc is bended 90 °. This, as a whole, generates a movement in three dimensions. The scissors form a box embedding the roof structure.The whole shelter is deployed automatically while inflating by the internal pressure. Once set up, the structure maintains its shape even in case of pressure loss.

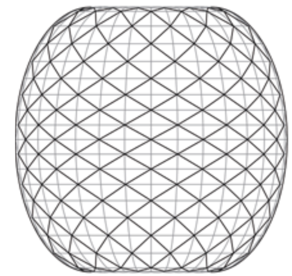
Functionally, the structure can be used in several different ways depending on the scenario. By opening the „poles“, the shelter can be entered from the front. The structural adaption is generated by activating two of the rim arcs. A two-chamber airlock-system is suggested for the entrance.

Additionally, instead of unfolding the structure simultaneously it can also be opened sideways. Adding a hatch on the bottom would allow a person lying on the ground to enter the shelter.

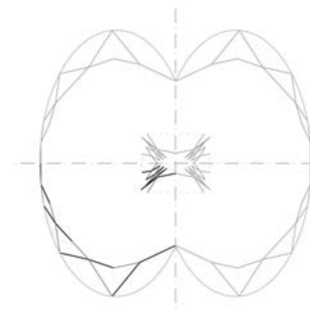
The same folding process also provides the ability to adapt the structure to uneven terrain.



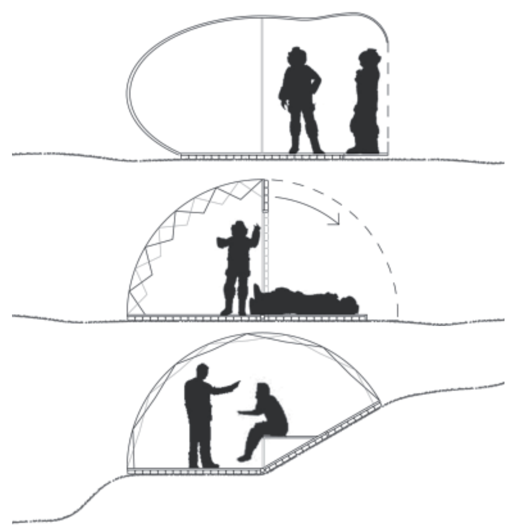
Axonometric view



Top view

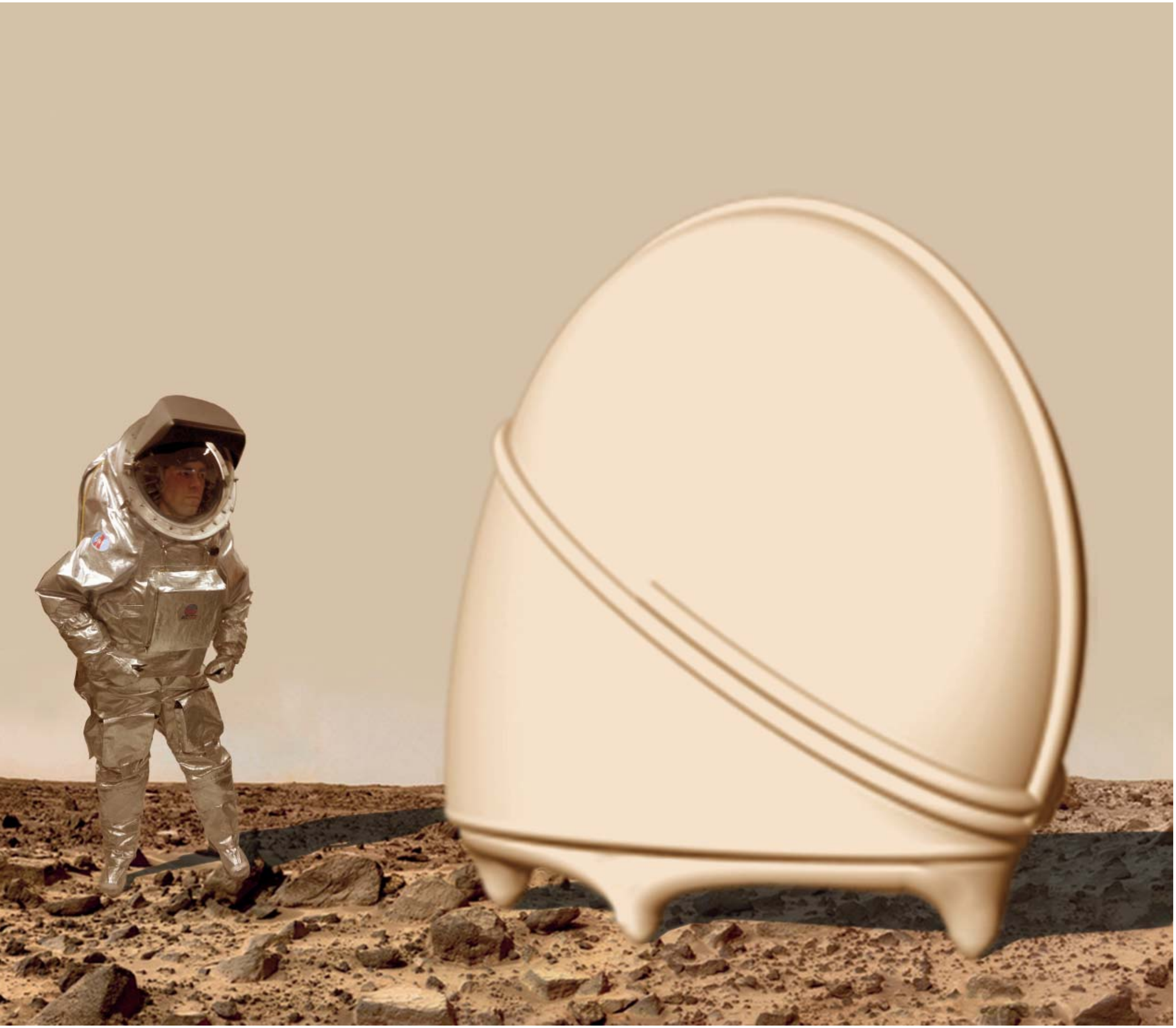


Floor structure



Adaptability of the shelter according to scenario

Kristoffer Stefan



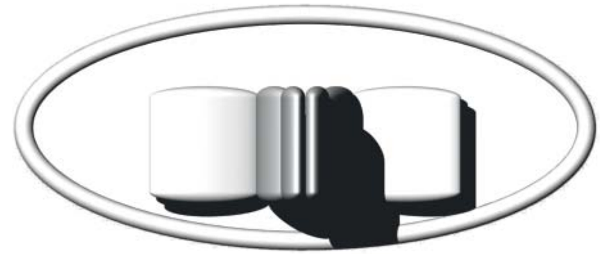
Air Support

The „air support“ is rolled up like a sleeping pad and has a pack size of 40 x 40 x 100 cm. It consists of a neoprene case and pops up using pneumatic hoses. The floor of the shelter is stabilized by 0.6 cm thick aluminum pipes, so that the astronauts have a solid base.

The „air support“ has six separate air chamber systems:
A pneumatic ring (1) forms the primary structure and stabilizes the floor together with the aluminum tubes. Four separately inflatable pneumatic supports (5) can be adapted to various terrain conditions by changing the air pressure inside and stabilizing the pneumatic ring against extension from the inner atmosphere. A roof structure, composed of bezel (2), clip (3) and a pneumatic closing element (4), controls the air inlet through the valves between the pneumatic element. Only after the bezel and the clip are sufficiently pressurized, air gets into the closing pneu and closes thereby the air support.

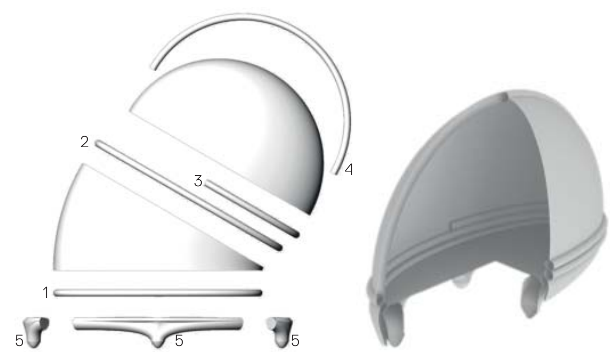
Different inflation-scenarios create a variety of functional utilizations:
- Barrow/bridge: pneumatic ring and side pneumatic „feet“ are deployed
- Bench: pneumatic ring and supporting pneumatic „feet“ are inflated
- Emergency shelter: all pneumatic structures are inflated, minimal volume of the structure
- Emergency shelter: all pneumatic structures are inflated, additional membrane structure is opened: maximal volume of the structure

Benjamin Mrowetz, Stéphanie Toussaint

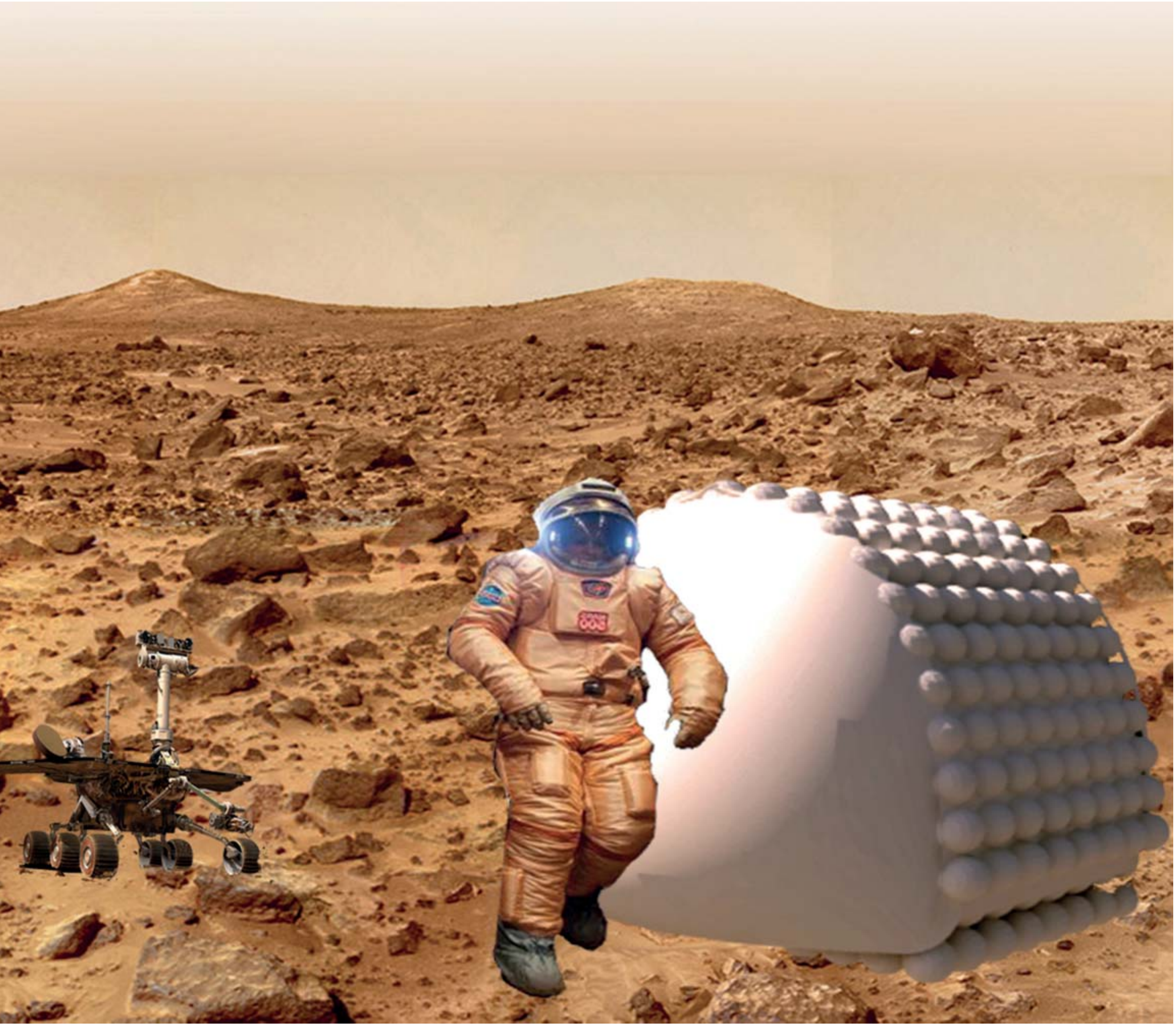


Plan: barrow

Sections: deployed shelter: minimal and maximal volume



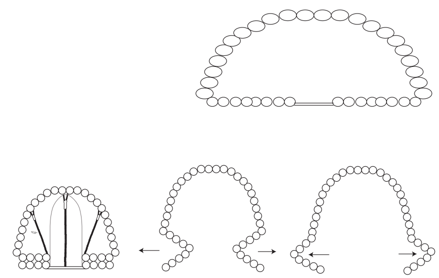
Section, structural elements



Bubbles

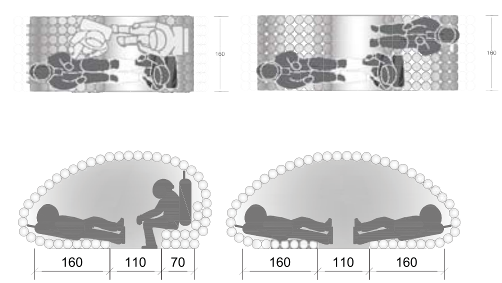
The design `Bubbles´ is a preliminary concept for a transformable shelter. It consists of a continuous envelope made of `bubble-like´ pneumatic cushions. Parts of the shelter can be inflated according to the needs of the astronauts.

Pressurizing the shelter causes the outer shell to expand to its maximum voule. The pneumatic system for the bottom of the shelter allows adjustment to the uneven surface thus helping stabilizing the shelter.



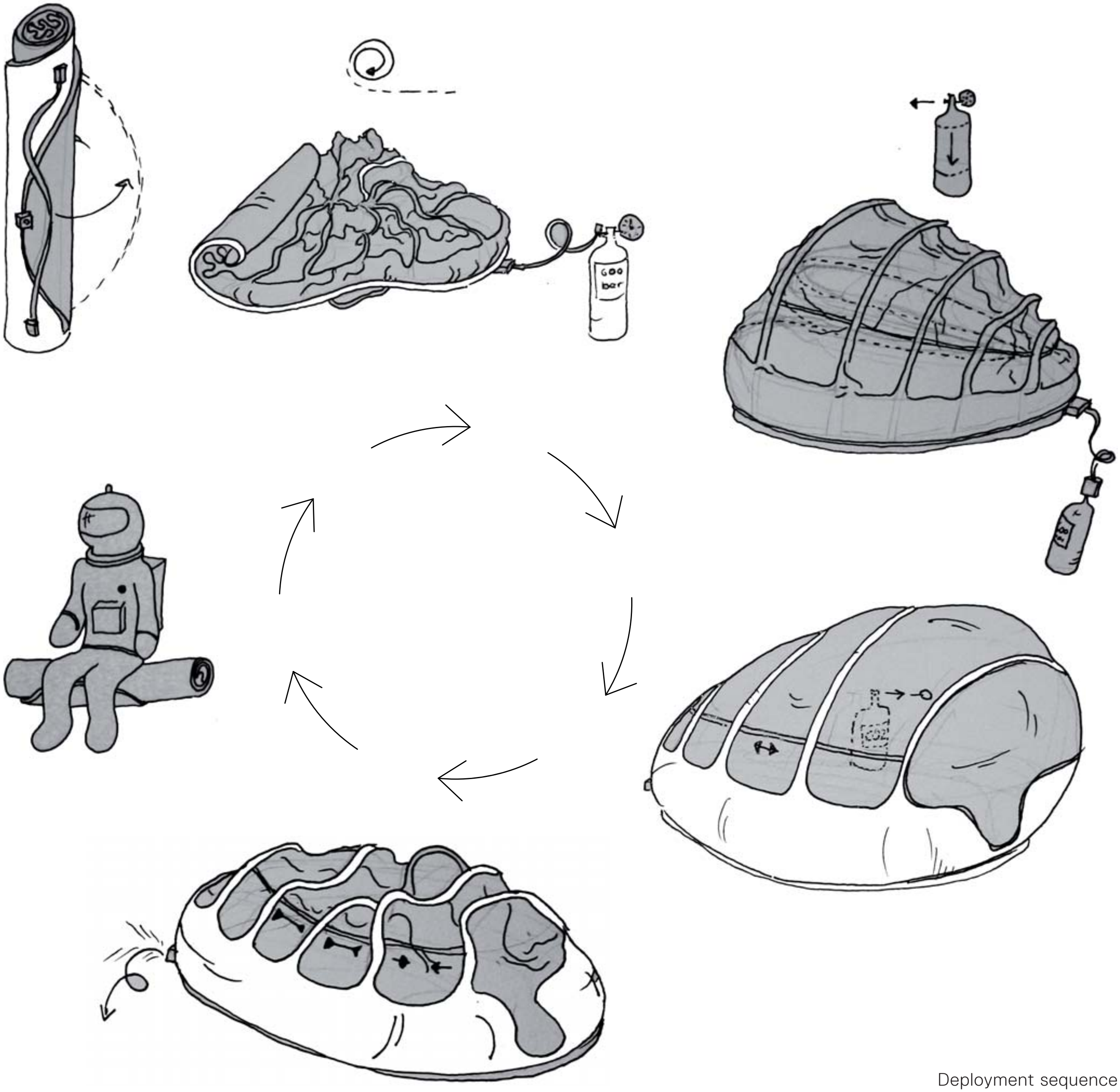
The deployment process

Adaptability according functions



Section, Floor plan

Katarina Josipovic, Aida Mulic, Tajana Pavlovic, Nina Tica

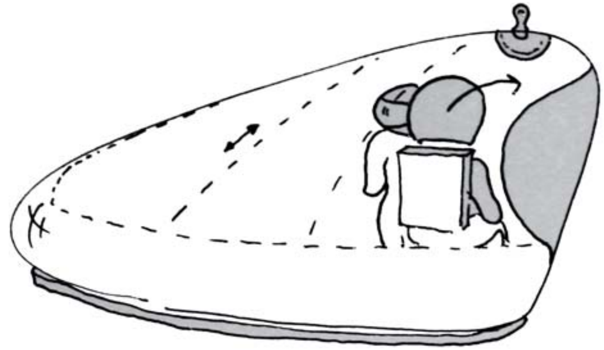


Deployment sequence

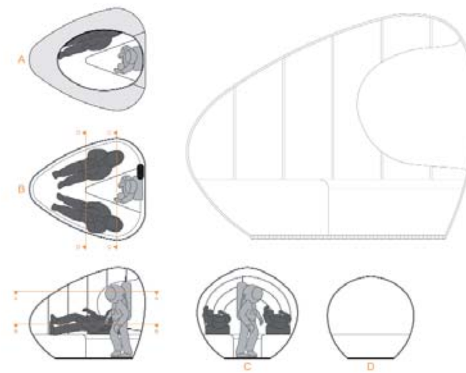
Pneu

This design concept refers to the fact that the parts of the emergency shelters in direct contact with the Mars surface must have different properties than the rest of the habitat.
A foam rubber mat was chosen for the floor of the shelter as it provides sufficient insulation.

It can be rolled into a compact bundle. The membrane of the shell and all other auxiliary parts of the structure are rolled inside the rubber mat. Its shell is a pneumatic structure which is inflated automatically after the floor mat unrolls.



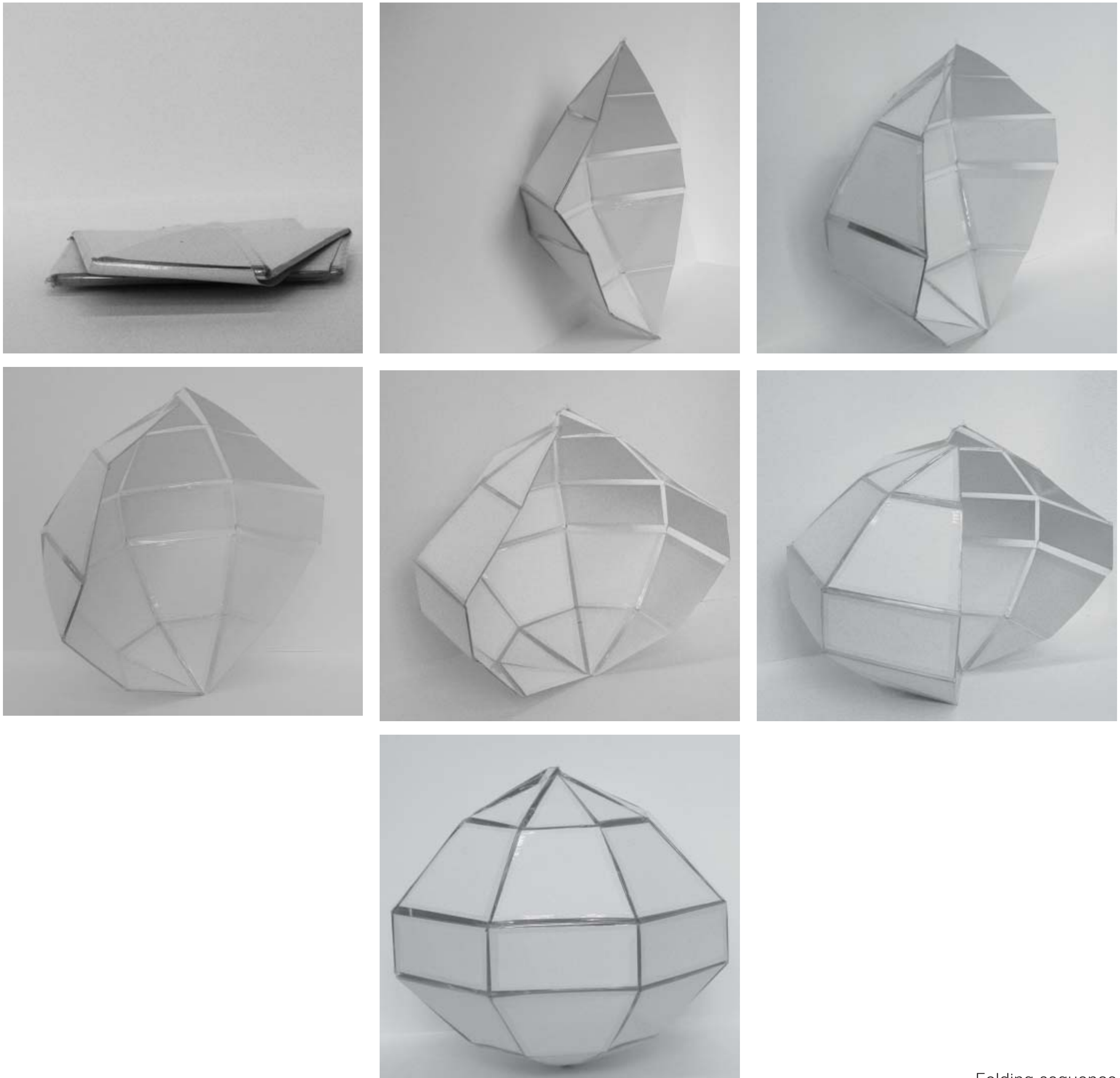
Concept , elevation



Sections: functional scenarios

Outer shell

Florian Aigner, Alexander Nanu, Kristina Zodl



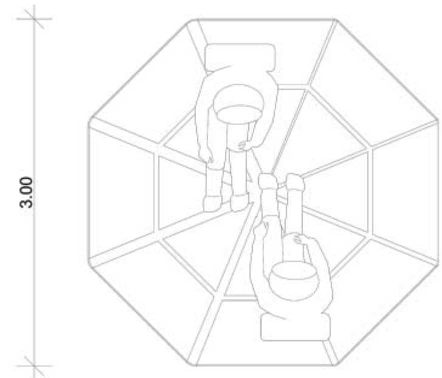
Folding sequence

Foldable Sphere

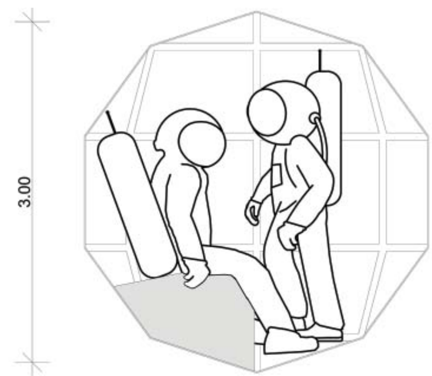
FOLDABLE SYSTEM
- the chance for technical failure is reduced by a simple folding system
- the deployment requires only the strength of one astronaut
- the direction of folding is determined by the rigid plates and therefore easy to handle
- minimal dimensioned in the folded state
- for technical and physical reasons the hemisphere is the optimal form for the shelter:
- it is the optimal shape which is formed by the pressure difference between the atmosphere inside and the outside pressure

CONSTRUCTION
- the system is composed of hinged rigid plates and can be folded and unfolded very easily
- astronauts enter the shelter before it is fully deployed
- the plates can also double as additional radiation protection

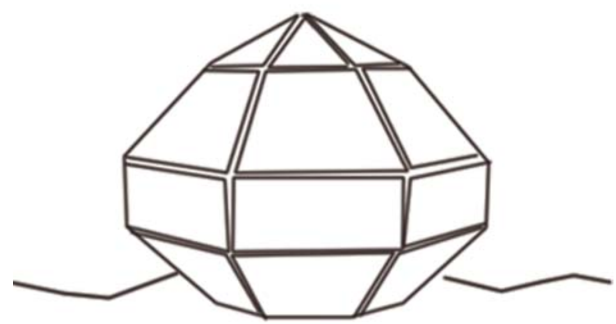
TERRAIN ADAPTATION
- the floor plates consist of smaller plates which are linked together by a membrane to provide adaptability smaller terrain differences
- the floor membrane additionally can inflate itself to adjust to larger terrain differences



Floor plan



Section



Deployed State

Tzvetan Dineff, Kathrin Rainer

Model

Scenarios

injured astronaut is lying
rescuer is sitting

injured astronaut is lying
rescuer is standing

injured astronaut is sitting
rescuer is standing

Jumper System

Rescue: [1] In case of less severe incidents, such as dizziness or panic attack, the shelter is entered through the side entrance. [2] For severe incidents such as pain caused by fractures, the shelter is opened on the bottom and raised to the side. The injured person may now be rolled up to the „second" floor of the shelter. The rescuer then closes the floor again and enters the shelter through the side entrance.

Transport: To prevent cracks and other damage the shelter is kept in a shock-proof „tire". This is towed behind and thus enables the use of both hands. In addition it can be used as seating option.

Shelter assembly: The big advantage of this design lies in its assembly. Once the „tire" is opened the shelter can be removed quickly out of the safety container. In the folded state, this structure is under tension, which leads to an immediate unfolding.

Shelter dismantling: Through proper folding the shelter can be put back into its original position and stowed. For this purpose it is sufficient to pull on a cord.

Structure: Two highly elastic and resistant fiberglass rods hold the constructin in its tension state. The shell consists of a pressure and a sun protection layer.

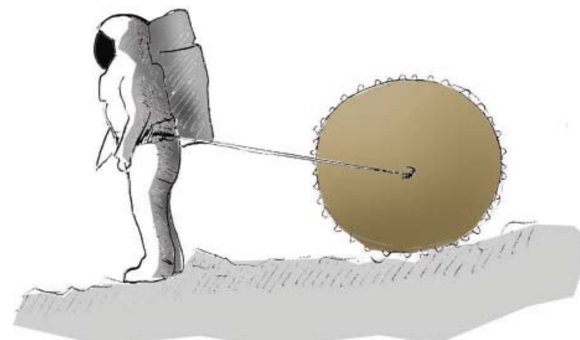
Floor layer: This part comes into direct contact with the surface of Mars, and therefore has to be very resistant.

Thomas Kropatschek, Marcin Puchalski

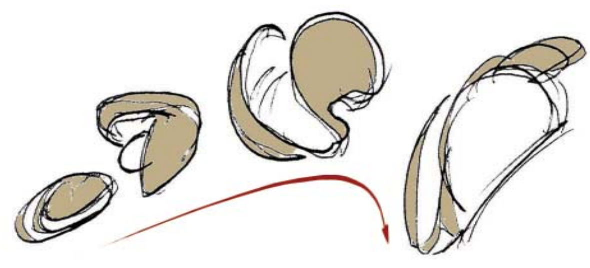
[1]

[2]

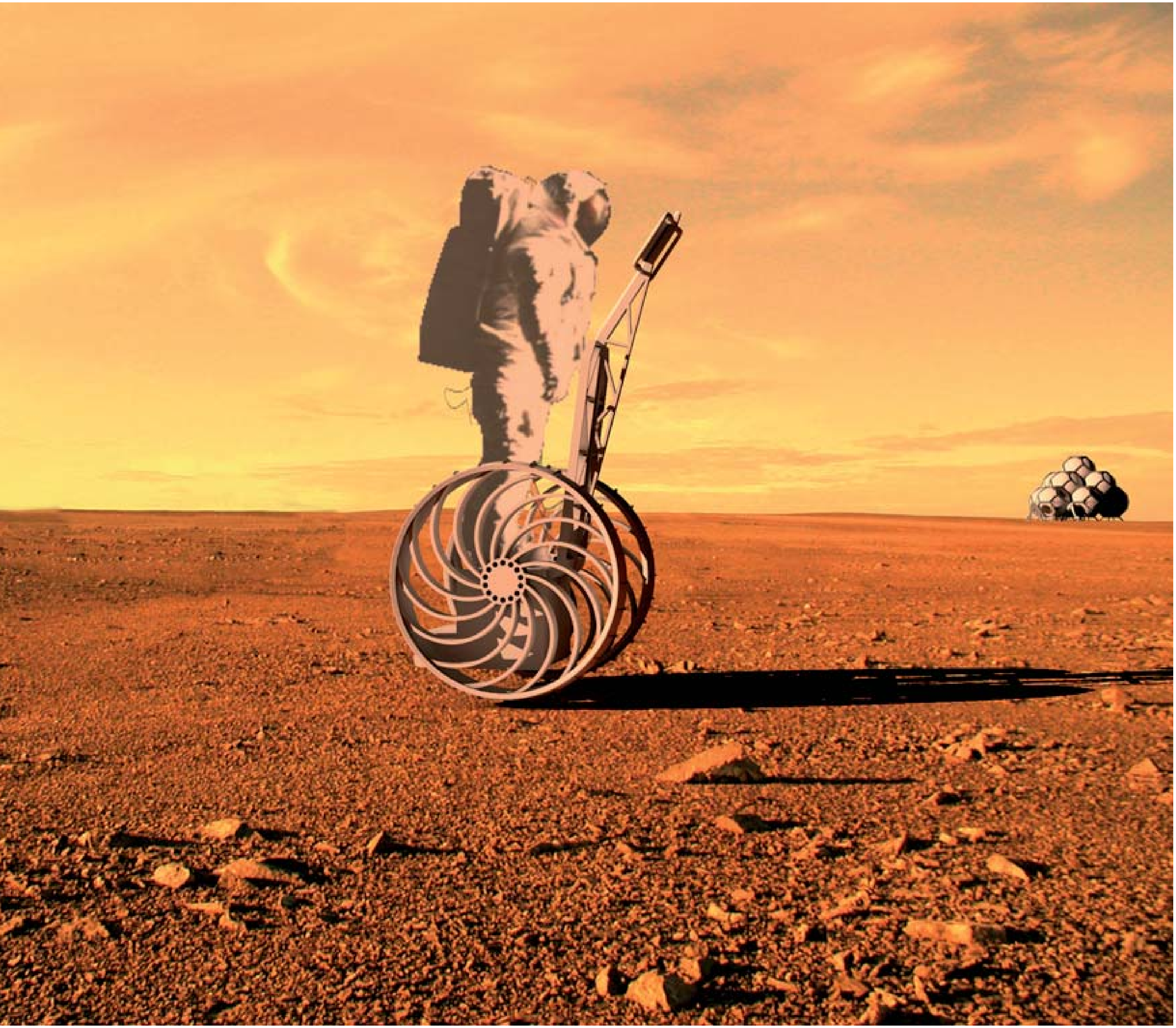
Rescue 1 - through side entrance
Rescue 2 - through bottom entrance



Transport - shock-proof tire towed behind



Shelter assembly - opening procedure [shelter jumps up]



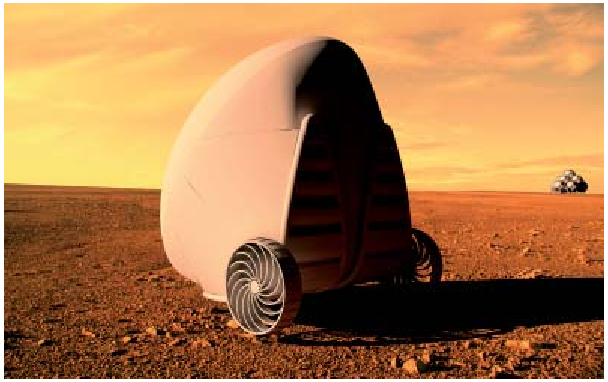
HTV-Shelter

The design concept is a transport vehicle which can be used by the astronauts during EVA. In addition a deployable shelter is integrated in the vehicle and can be used in case of emergency or exhaustion. Thus the HTV- Shelter consists of two separate systems:

1. HTV - Human Transport Vehicle
The HTV is based on the Segway technology transportation system for astronauts on Mars. It possesses a unique wheel technology which was design for the Mars terrain. The wheels are tubeless and are stabilized by curved ribs which can absorb shock caused by the uneven topography. The folded shelter and the life support system are integrated in a box in the lower part of the vehicle.

2. Shelter
The emergency shelter is designed as a pneumatic construction. It is stabilized by L-shaped (about 45 ° inclined) inflatable seats and supporting pneumatic tubs. The astronauts enter the shelter after the supporting tubs are inflated. After pressurizing the structure the shelter is closed automatically by pressurizing the two pneumatic lip elements of the entrance.

Ottokar Benesch, Daniel Galonja, Thomas Milchram



HTV- Shelter, Renderings


es.at

„res[C]ue me“

The „res[C]ue me“ is a continuation of the jumper concept and is based on an equivalent principle. The construction consists of a highly elastic GRP-rod which is inserted into the prefabricated outer shell. Using a special folding technique, it is possible to fold the emergency shelter [150 cm high and wide] into a disc [80 cm diameter and 15 cm in thickness].

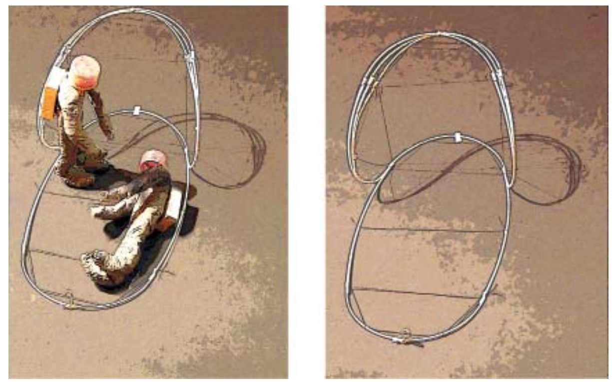
The concept is a ball-like shape, consisting of two curved surfaces. This procedure [e.g. applied to a tennis ball] was implemented in order to keep the production as easy as possible. The entrance is just along the seam. It is opened by means of a zip fastener, subsequently, the C-shaped structure rolls on the back. At the same time, the bottom surface remains unmoved. In the open state, it is now possible to transport the injured astronaut on the ground surface. The rescuer is also safe, and can close the capsule from inside again.

The elements can be summarized as follows: the shelter consists of two identical, connected areas, along whose seam a flexible rod is mounted, which holds the entire structure in tension.

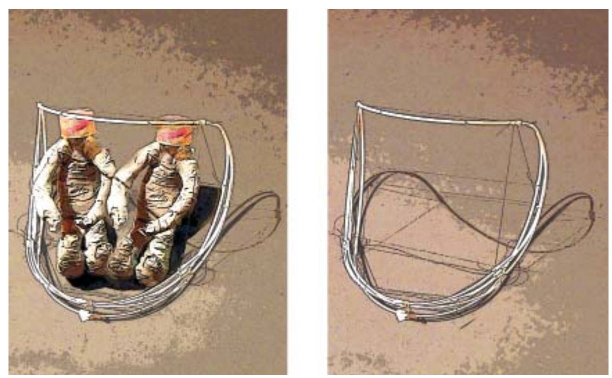
Thus the whole structure convinces on the one hand by the compactness in transport, on the other hand by having the following advantage: The „res[C]ue me“ can be set up and used without auxiliary materials [pump, air compressor, air tanks] within a few seconds.

Florian Aigner, Zuzana Kerekretyova, Thomas Kropatschek, Markus Mitrovits, Marcin Puchalski, Kristoffer Stefan, Kristina Zodl

Injured astronaut lying on the ground



Injured astronaut placed inside the capsule



Both astronauts are inside the capsule

Transport version 1

The shelter can be folded up to four times by means of a special folding technique. This results in a diameter of max. 80-90 cm and a thickness of 15 - 20 cm in the folded state.

There are also two handles on the edge of the package and by using these handles the emergency shelter is attached to the astronaut's backpack.Should an emergency occur, the astronaut must pull his red string. This opens a carbine and the package is separated from the backpack.

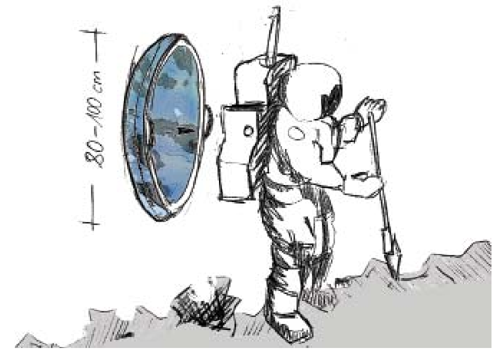
The design is convincing by two essential properties:

- Its ease in transport, which is very beneficial for each EVA, as the astronauts have both hands available.
- But above all because of its simplicity in construction due to the fully flexible fiberglass construction making the emergency shelter deployable in just 2 seconds.

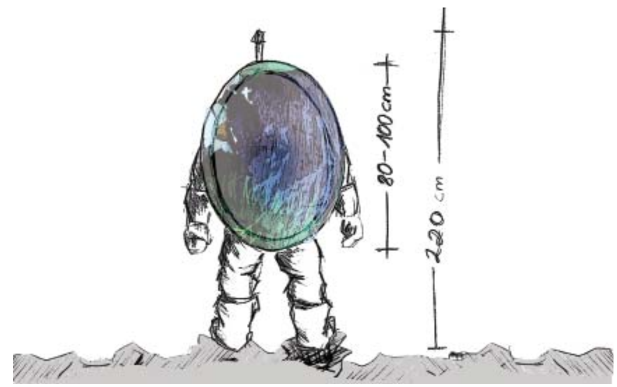
In addition, the astronauts have an emergency oxygen tank and an emergency tool available, which are located inside the shell.

The package is designed so that it can act as a barrow in case of emergency. An example:

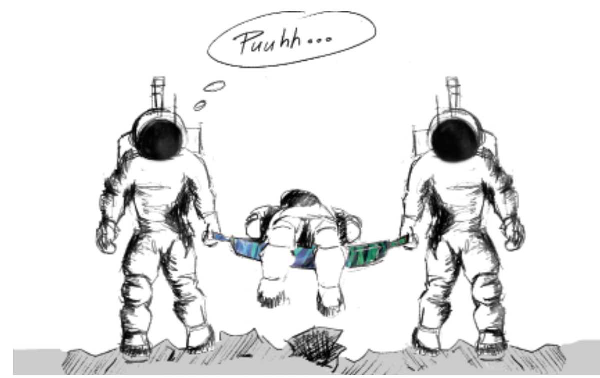
The team is few hundred meters away from the base, nausea and panic afflict an astronaut, he faints. Soon the shelter is released from the backpack, the injured person is carried on a barrow. Two astronauts lift the injured to the handrails and take him back to headquarters.



Shelter attached to the backpack



The design is convincing by its ease in transport



The package can act as a barrow

Transport version 2

This version is designed for extensive expeditions and to ensure the survival of the astronauts for several days. This three-chamber cylinder is pulled by an astronaut. On both sides there is a joint that is connected by straps to the backpack of the astronauts. Also here both hands of the astronaut are free.

The cylinder is divided into three chambers. The central area is a storage for the shelter, the two outer parts include the following utensils:

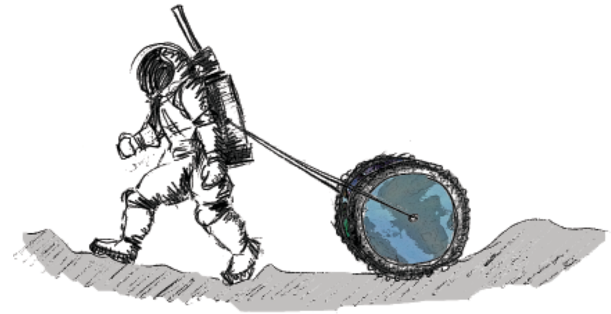
[1] primary life support system
[2] an additional four-liter O2 bottle
[3] emergency tool
[4] emergency proviant

Furthermore, the outer chambers are covered with special nap, which improve the grip during transport.

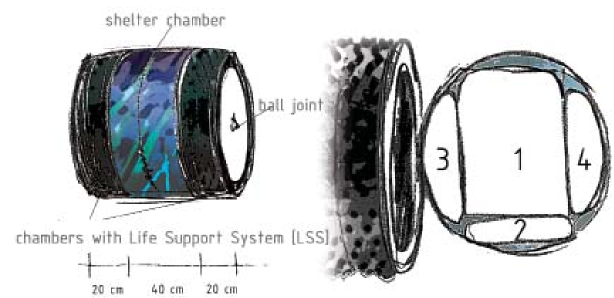
The cylinder has the following dimensions:
Diameter: 80 cm
Height: 80 cm

By opening the cylinder the emergency accommodation can be removed and unfolds within seconds. In case of exhaustion the role can act as a seat for recovery. To store the shelter, it must again be folded and placed back into the open cylinder. Then it is re-closed by means of a zipper.

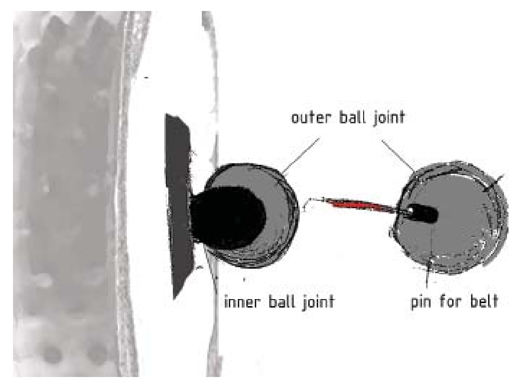
Both joints are designed as ball joints, thus the optimal range of motion can be used. On the outer joint, a pin is placed where the belt is fastened.



3-chamber cylinder is pulled behind



The cylinder is divided into three chambers



Ball joints on the sides of the cylinder

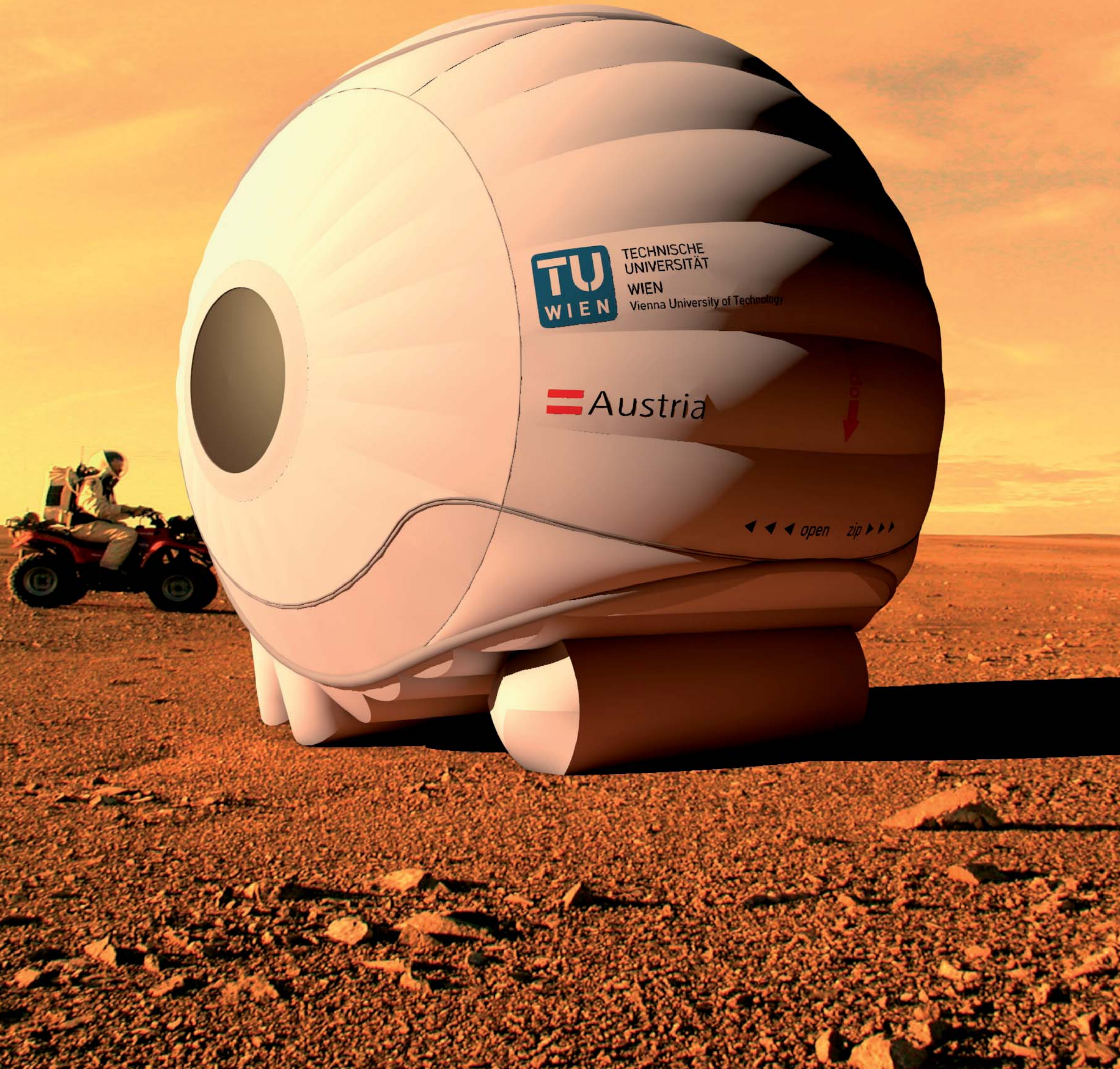
Workshop Prototype

26th - 30th November, 2012

In the last week of November the intensive workshop took place at TU Vienna facilities. During the last presentation one project has been chosen to be further developed. Here four different groups are formed in order to complete the assignment.

The groups are as follows: the *Mock-up group,* the *Scenario group*, the further development group and the *Publication group*.

The *Mock-up group* has been assigned with the task of creating a mock-up version of the chosen design project. This design would later be tested within the 2013 Mars Analog Field Simulation in the northern Sahara. The task of the *Scenario group* was to create three different scenarios that would be played out in order to test the theories and to validate the chosen shape and dimensions. Three different medical scenarios have been chosen and re-enacted. The further development group dealt with improvement of the chosen design and the further development of the interior. Also, from a variety of fabric they selected those that would best fit. The *Publication group* was in charge of creating presentations, flyers and the booklet. The main task was to gather all the information from the other groups and represent them graphically.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The Project

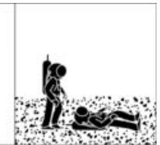
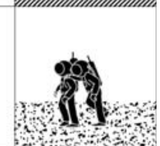
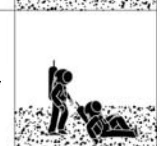
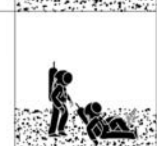
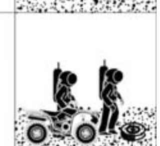
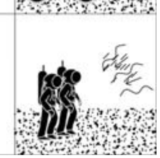
Based on three selected scenarios one mockup was designed and built. This prototype was tested in a field simulation in the Sahara while its functionality was evaluated.

Emergency Scenarios

Even though space craft design teams all over the world are working hard to minimize the hazardous impact of the harsh extra-terrestrial Martian environment on astronauts, the risk of a mechanical injury during an extra vehicular activity (EVA) is high. In addition exposure of an unprotected human body to the Martian atmosphere, caused for example by a malfunction of the space suit or the life support system, can result in serious health damage or even in sudden death. Therefore it is important to provide the astronauts with an additional crew support element that could be deployed in case of immediate emergency.

This element shall be a portable and deployable shelter operable by one astronaut in case of an emergency requiring immediate action and when return to base or rover is not possible in time. It shall temporarily provide a safe place until rescue arrives (rover, other astronaut) or immediate emergency ceases (successful first aid, change of conditions).

The shelter shall be compactly packed into an Emergency Package that shall contain the Emergency Shelter (MASH), additional air supply for the astronauts, emergency power supply for the space suit, emergency food supply and an emergency toolkit. Altogether it should not weigh more than 20kg (6.6kg on Mars). The folded shelter shall be transported with a rover and carried by one astronaut when leaving the rover. Furthermore, deployment of a portable shelter may allow prolonging EVA activities on Mars missions. Astronauts could possibly stay in the shelter overnight (if required for an experiment for example) or use it to take a short break either planned or due to an unexpected event.

1	Unconsciousness - breathing	
2	Unconsciousness - not breathing	
3	Dizziness	
4	Exhaustion	
5	Unforeseen reason for needing to remove the helmet	
6	Mechanical injury	
7	Space suit malfunction	
8	Rover / quad malfunction	
9	Solar particle event	

Tab. 01: Critical situations

Tab. 01 lists nine critical situations, which are likely to occur during EVA.

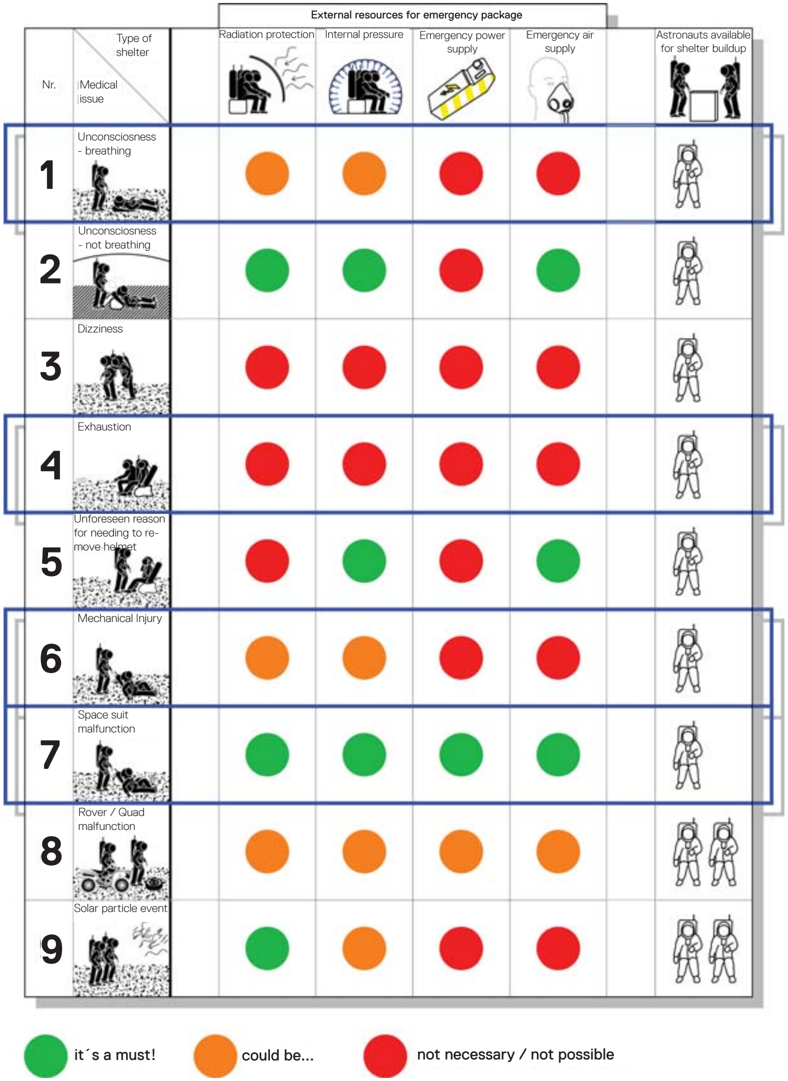
Tab. 02 rates the importance of external requirements that have to be provided to the astronauts in order to survive a critical situation. The last column shows how many astronauts are available for building up the shelter.

Tab.03 shows an overview of a spatial requirement analysis in relation to the required activities for medical actions for the MASH.

Following the external requirement analysis (Tab. 02) it can be asserted that MASH has to be designed (1) to enable pressurization (air tightness, form) and (2) to provide mechanical protection and shielding from radiation (similar to space suit requirements). Advanced radiation protection would be desirable and needs more research. Due to limited resources, these issues will not be further examined at this stage.

The analysis also shows that several critical situations would not need deployment of an emergency shelter. However it would be helpful, if astronauts could sit down and solve the problem or wait for help (e.g. simple mechanical injury) or simply take a rest. For that reason it would be good if the folded shelter also allowed 'sitting'. This does not have to be an extra element, but could be integrated for example as deployable cushions.

The space requirement analysis (Tab. 03) supports our hypothesis that MASH must be operable only by one astronaut as we cannot expect the injured one to help. Tab. 02 also shows that the selected emergency situations don't require the astronauts standing in the shelter. Therefore the height and volume of the MASH can be minimized.



Tab. 02: External requirements analysis

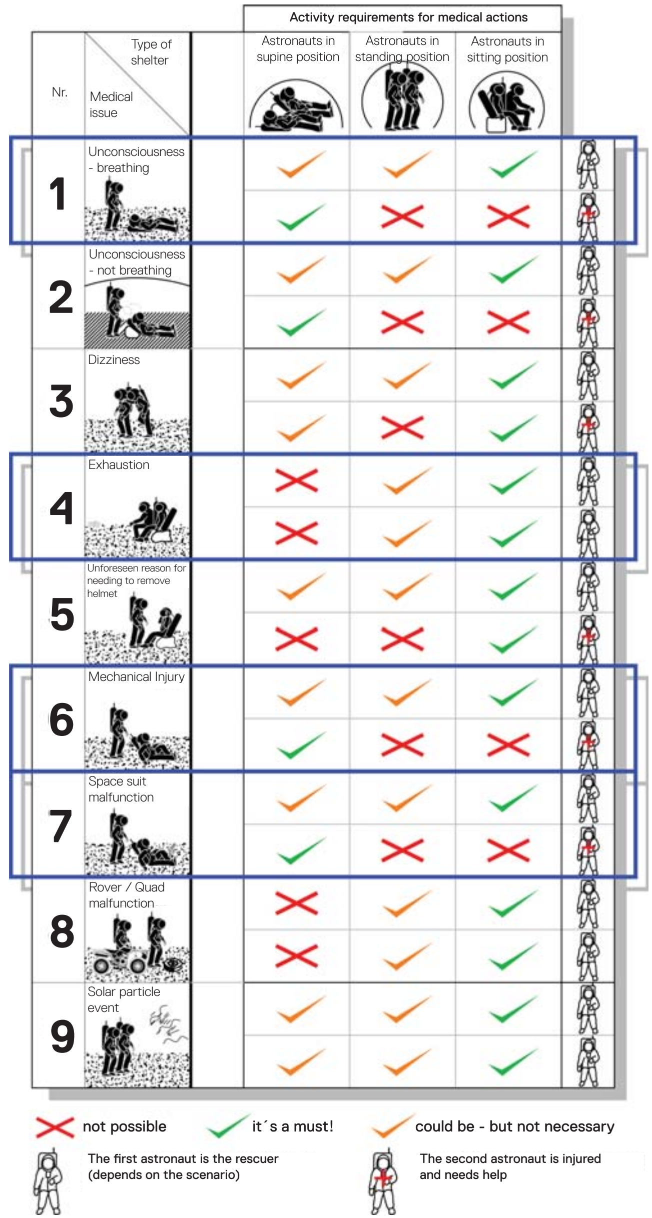
Selected emergency scenarios

The following three emergency scenarios were evaluated to be the most important / most likely to happen and therefore chosen for further inquiry:

A. One astronaut loses consciousness but is still breathing.

B. Astronauts get exhausted and have to rest for a while.

C. One astronaut falls down and suffers a mechanical injury and space suit malfunction.



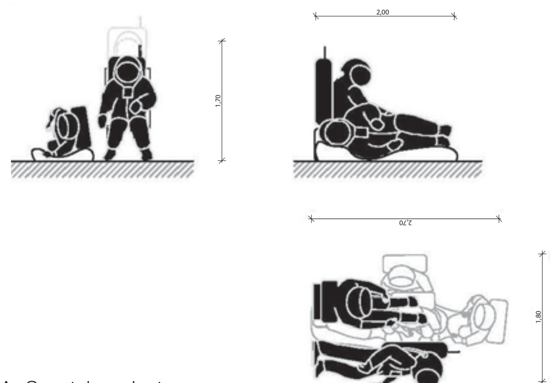
Tab. 03: Space requirement analysis

Scenario A: Unconsciousness

Selected Emergency Scenario

1. Two astronauts are on EVA.
2. Suddenly one astronaut falls to the ground and does not react. The second astronaut notices that his colleague is unconscious but breathing. Returning to the rover / habitat is not possible.
3. The emergency shelter package is opened by the non-injured astronaut. The shelter pops up. The non-injured astronaut unzips the shelter.
4. The non-injured astronaut moves (rolls) the injured colleague on a blanket and pulls him onto the floor surface of the MASH.
5. The shelter rolls over their heads. The shelter is closed with a zip by the non-injured astronaut. The injured astronaut is in lying position.
6. Compressed Martian atmosphere is pumped into the floor surface mattress. (The front cushions are inflated to enable the lying position, the back cushions are not used in this scenario)
7. (If necessary compressed air can be pumped into the MASH if there is a need to remove the helmet.)
8. The helmet of the injured astronaut can be removed if necessary.

Scenario A: Unconsciousness



Scenario A: Spatial analysis

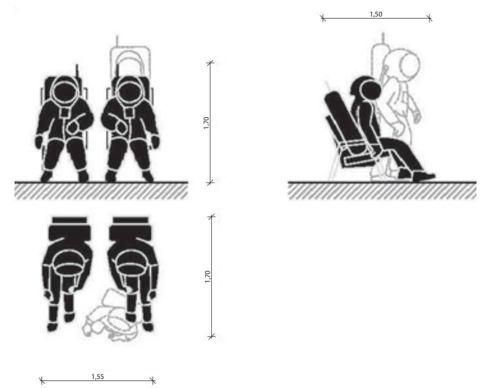
Scenario A: Simulation

Scenario B: Injury

Selected Emergency Scenario

1. Two astronauts are on EVA and have to overcome a steep slope.
2. They have to leave the rover at the top of the hill. While climbing down … (or alternative scenario)
3. … one of the two astronauts falls and injures his leg. He is no longer able to walk and return to the rover. (The injured astronaut receives a warning that his life support system was seriously damaged.)
4. The emergency shelter package is opened by the non-injured astronaut and it pops up.
5. The non-injured astronaut unzips the shelter.
6. Compressed Martian atmosphere is pumped into the cushions in the floor surface and into the stabili zing cushions (back cushion) outside the shelter.
7. The non-injured astronaut helps the injured one to enter the shelter.
8. The shelter rolls over their heads and is closed with a zip by an astronaut.
9. (If necessary compressed air can be pumped into the MASH in case the life support system was dama ged.)
10. The two astronauts are in a sitting position inside the shelter and wait for help.

Scenario B: Mechanical injury



Scenario B: Spatial analysis

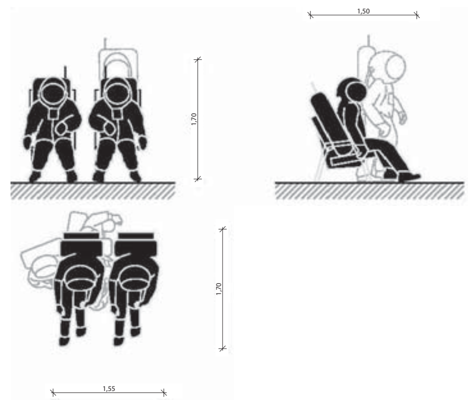
Scenario B: Simulation

Scenario C: Exhaustion

Selected Emergency Scenario

1. Two astronauts leave the rover and go on EVA.
2. After a challenging climb to the top of Mt. Apollinaris Tholus, taking three hours longer than expected, the astronauts feel really exhausted. In order to avoid dizziness or an injury the mission control suggests a break before climbing down the hill.
3. The emergency shelter package is opened, the shelter pops up.
4. An astronaut unzips the shelter.
5. Compressed Martian atmosphere is pumped into the cushions in the floor surface and to the stabili zing cushions outside the shelter. (Depending upon the slope of the terrain, either the front or back cushion are inflated)
6. The shelter rolls over their heads and is closed with a zip by the astronaut.
7. Astronauts take a rest for a few hours.
8. Afterwards, they pack the shelter and continue their mission.

Scenario C: Exhaustion



Scenario C: Spatial analysis

Scenario C: Simulation

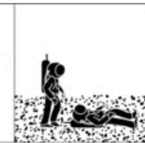
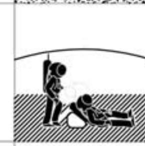
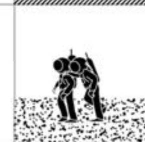
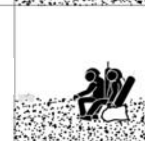
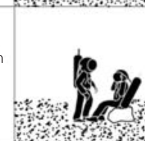
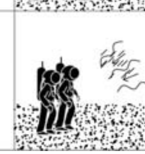
Evaluation

Emergency Scenarios

It can be concluded that the proposed emergency shelter shall provide the necessary support and protection to the astronauts in all listed critical situations except for situation 2 (one astronaut loses his consciousness and cannot breathe) and situation 9 (a solar particle event surprises the astronauts).

In case of situation 2 (one astronaut loses his consciousness and cannot breathe), it is necessary to remove the upper part of the space suit and the helmet of the injured astronaut in order to start the CPR. As the doffing of all the existing space suits takes a long time, it might not be possible to deploy MASH and remove the hard upper torso (depending upon the suit design) in time. This problem needs further scientific research but might be solved by designing suits that enable quicker doffing in case of emergency and / or to include a defibrillator in the life support system.

The shielding from radiation during solar particle events (critical situation Nr. 9) needs further scientific and material research. For the moment the proposed emergency shelter cannot provide protection in such a case but it shall be an important point in a later stage of development of the MASH.

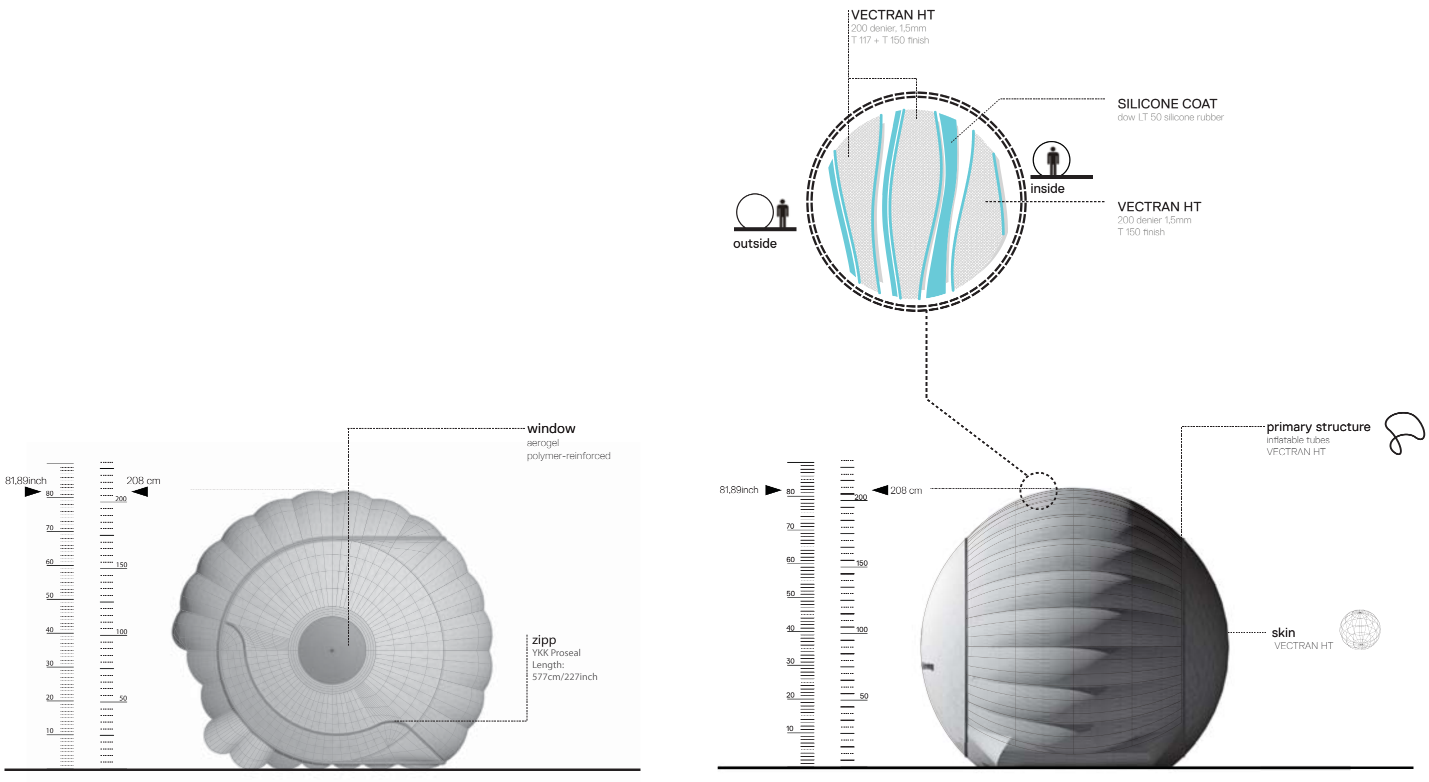
1	Unconsciousness - breathing		✓
2	Unconsciousness - not breathing		✗
3	Dizziness		✓
4	Exhaustion		✓
5	Unforeseen reason for needing to remove helmet		✓
6	Mechanical Injury		✓
7	Space suit malfunction		✓
8	Rover / Quad malfunction		✓
9	Solar particle event		✗

Tab. 04: Critical Emergency Situations: Evaluation

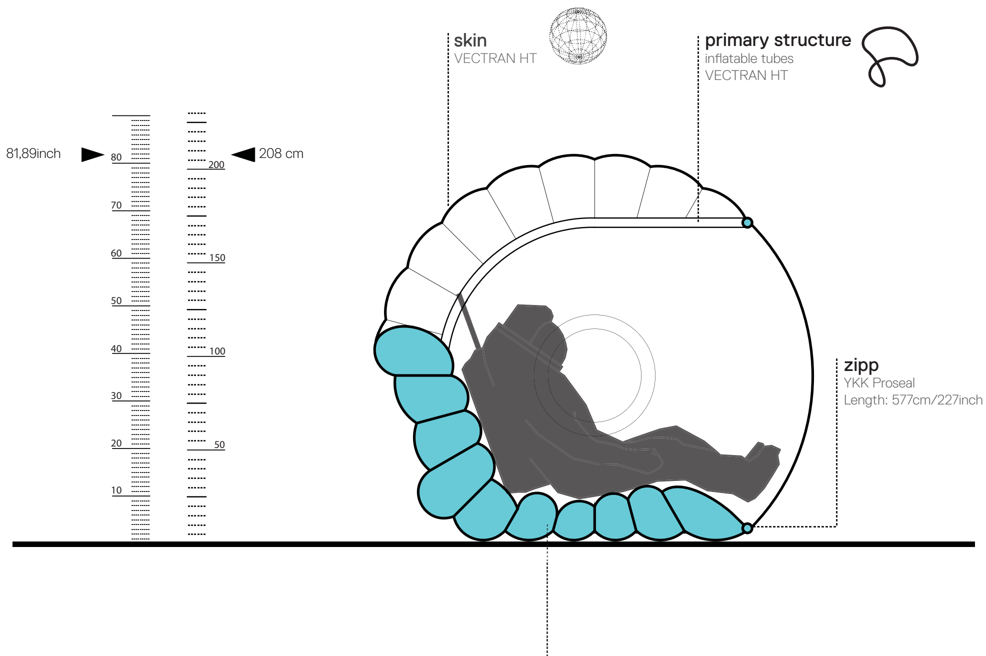
Designproject Mars

Concept

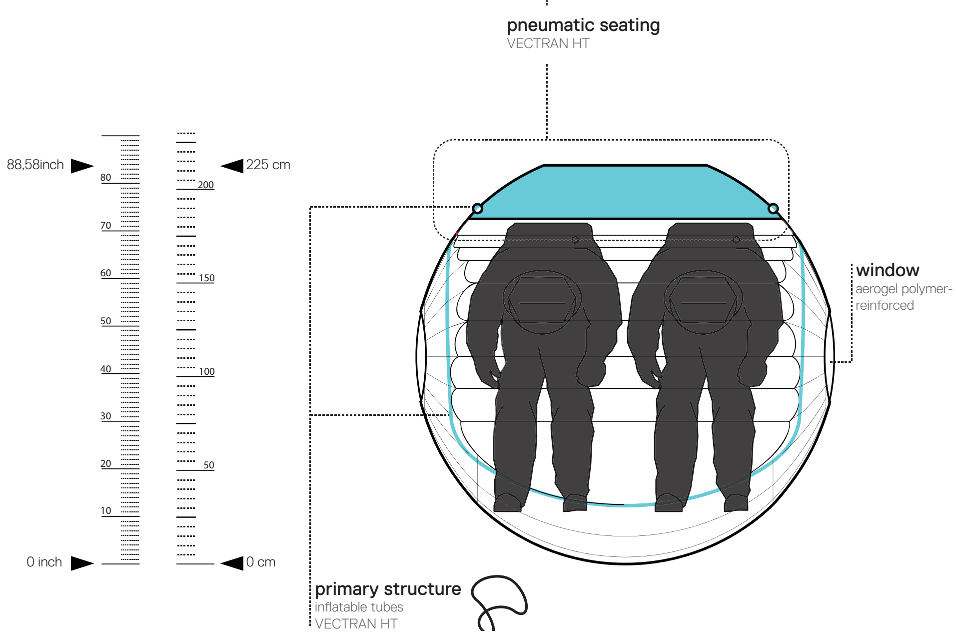
In parallel to the development of possible emergency scenarios and 1:1 mock-ups, a group of students was working on the design for Mars. Preliminary research was made into possible materials, opening mechanism and additional infrastructure for life support systems.



Preliminary design of MASH

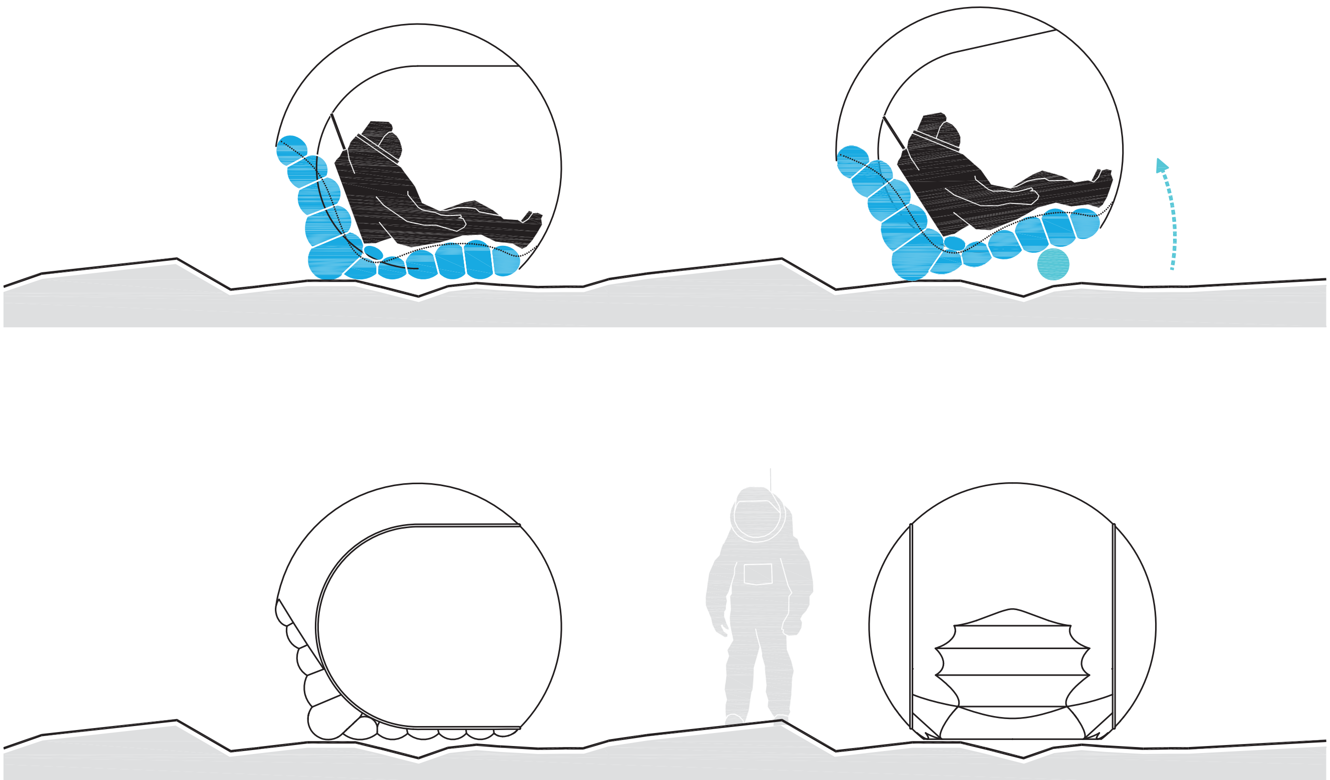


Section



Floor plan

The shelter is designed to enable adjustment to different terrain conditions. This mechanism also allows functional adaptability for different emergency scenarios.



Adaptation to different topographical conditons

Dress Rehearsal Meeting for Mars 2013

7th - 10th December, 2013

Between 7th and 10th December 100 volunteers and project partners met in Innsbruck for the “Dress Rehearsal”. People from 20 nations and 5 continents were preparing for Mars2013, the Mars analog field simulation to be conducted between the 1st and 28th of February in the Northern Sahara in Morocco. The countdown had started.

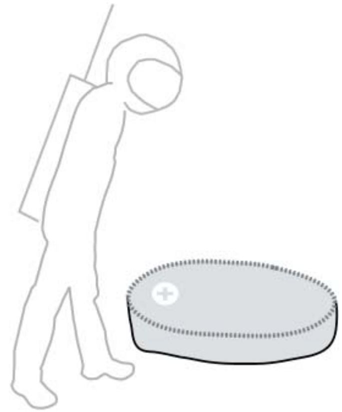
We tested the functionality of our second prototype with the AOUDA spacesuit in order to make final adjustments for the final prototype to be tested in Morocco.

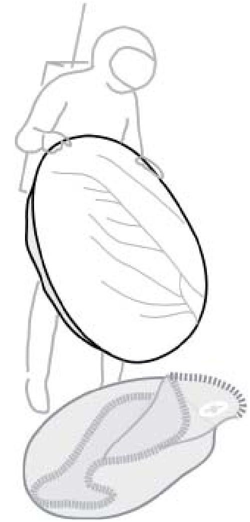
© Zanella Kux, OEWF

The Prototype

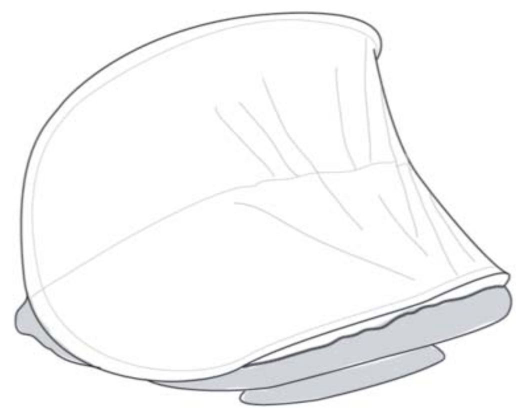
Specification

The shelter prototype has a ball-like shape and consists of two identical curved surfaces similar to a tennis ball. A highly elastic GRP-rod supports the outer shell and holds the construction in tension. Using a special folding technique, it is possible to fold the shelter [150 cm high and wide] into a disc of 80 cm diameter and about 10 cm thickness. In the compact state, the structure is under tension, which leads to an immediate unfolding when unpacked.



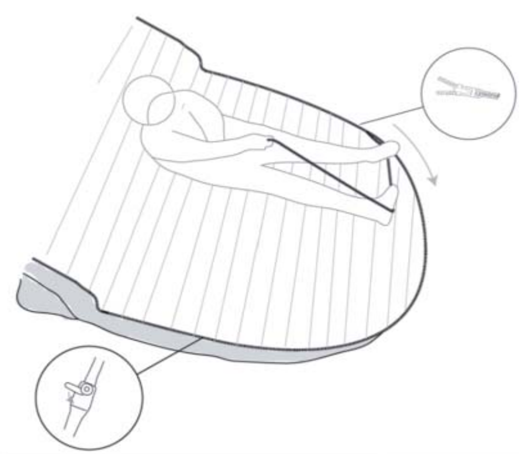


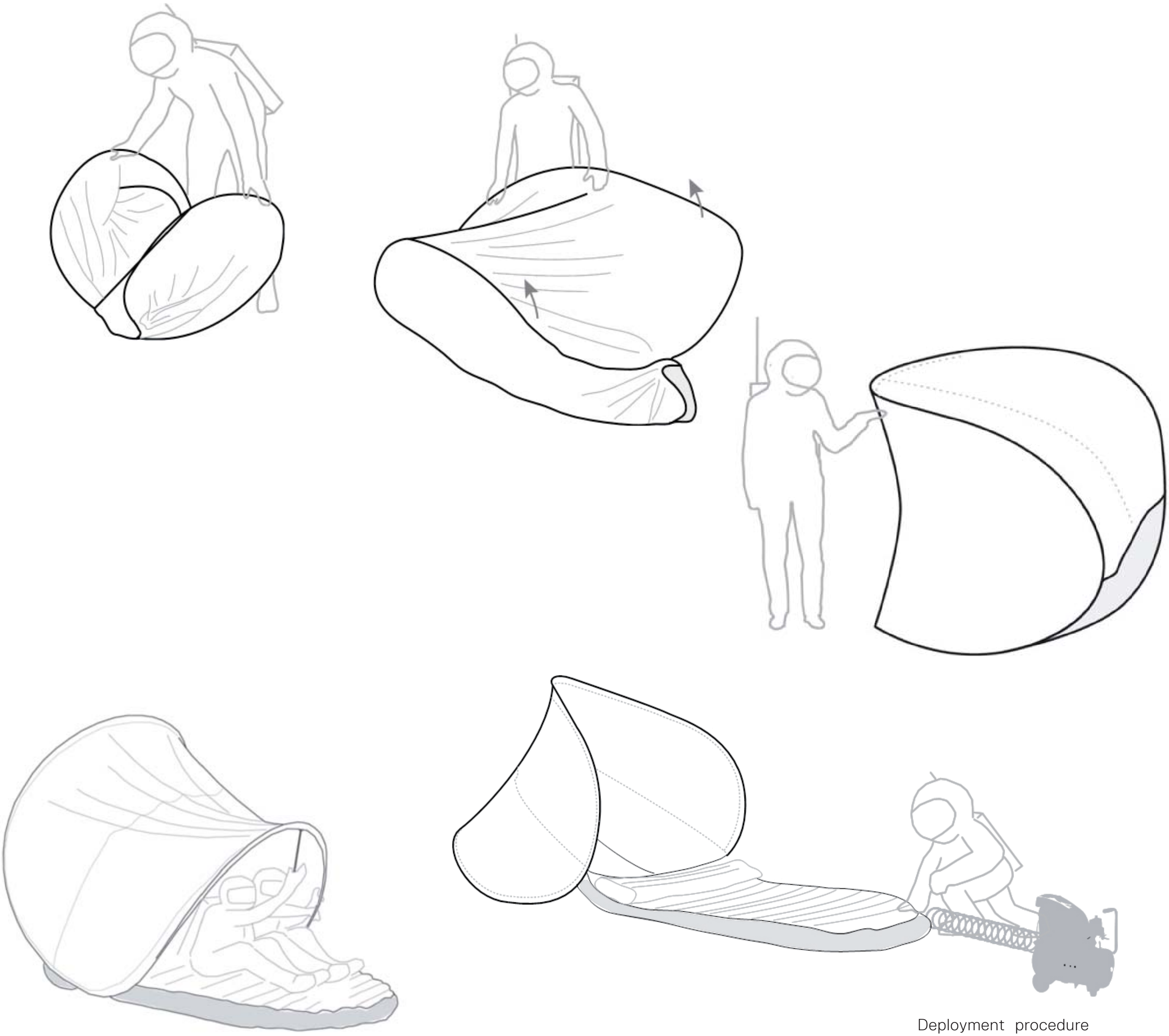
The entrance of the shelter is along the seam. Opening the structure with a zip fastener forces the upper part of the structure to roll back. The bottom surface remains unmoved. It is now possible to transport the injured astronaut on the ground surface. The rescuer enters the shelter. To separate the interior from the Martian surface the bottom part of the structure is designed as a pneumatic system which inflates automatically.



By design purpose a specific amount of air pressure in the pneumatic cushions changes the curvature of the floor mattress, causing the upper part of the shelter to tilt over the heads of the astronauts and thus it automatically closes. The shelter is then locked (zipped) by one of the astronauts using supporting ribbons.

The prototype was designed to allow functional adaptability including sitting position as well as lying position for the astronauts, necessary for procedures in emergency scenarios. The change between the two positions is achieved through air shifting between two supporting pneumatic cushions, one in front and one in the back of the shelter. The same mechanism allows adjustment to different terrain conditions and slopes.





Deployment procedure

Prototype Development

Diary by the *Mock-up group*

Day one: The first day we were mostly focused on planning the most efficient way to make the shelter. Professor Schultes was there to introduce us to the welding machine, that we would later have to use for the membrane materials for the pneumatic elements. After a couple of hours of brainstorming we started to work. The starting point was to take measurements of our model shelter. At first we wanted to make six separated parts of pneumatic cushions (like in the mock-up shelter) but we came to the conclusion that it would be better to make smaller and more narrow pieces, so that they could be replaced when needed. Because of this we had to enlarge the shelter by 2.5 percent. When we knew the exact measurements we had to first draw them on the materials we had. We started with the bottom of the shelter (a red material used for running shoes). We already knew that the elements would be 12cm wide and 170cm long. Afterwards we counted 23 pieces, although we used only 19 of them.

Day two: When we arrived at the industrial plant, we already knew that few people would be working on the pneumatic elements and that the rest would be working with the bottom of the shelter. The first group had to cut the material (l=1.70m, w=12cm). The next step was putting them together using the welding machine, but because of the air pressure inside the pneumatic elements, we had to make two stiches on each side to prevent the bursting of the cushions, which made them 1.5m. After this we had to make holes for the part where the intake valve would be. We made two holes on one side of the element only. Meanwhile the other group had already measured and drawn the lines on the material so that the knitting would be as precise as possible.

Days three and four: We proceeded with our work and already cut out the parts that were ready to be sewed. The bottom was made of two layers of material knitted together. By making two layers and putting the pneumatic elements inside it would be easier to replace them when needed.

Day five: We were halfway with the shelter. We started welding the parts together and made two stiches at each end. Meanwhile the material group already had started working on the shell. The material had to be larger than the actual shelter because we had to overlap it by 10cm to provide space for the elastic plastic rod, which served as the construction frame and was a vital part of the shelter. The most difficult part was to double stich the material because of the shape of the shell.

Days six and seven: To be able to inflate everything at the same time, we had to connect the inflatable parts with plastic tubes using a special glue for the plastic material. Then we put them in-between the two outer shell layers (the bottom of the shelter), inflated them and it worked. We took out the inflatables and then we all started working on the shell of the shelter. We encountered our first problem when putting together the zippers. To set them precisely we had to start from both ends and meet in the middle. This proved to be quite difficult, but we managed in the end. We used Aquaseal zippers to make sure that air and water would not come inside.

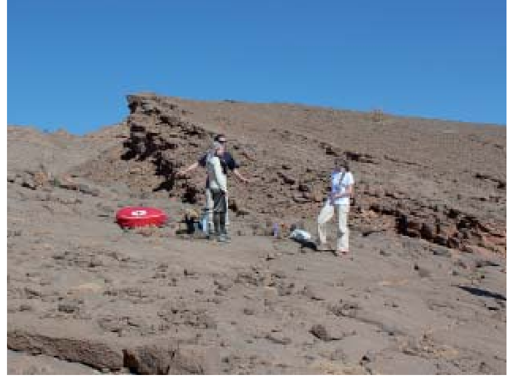
Days eight and nine: After placing the zippers and sewing the bottom to the upper shell of the shelter, we placed the elastic plastic rods inside the shell. However the shelter was not standing straight, so we had to place one more rod inside. Then we discovered another problem: Even though the zipper worked perfectly and was sewed from both sides equally, the connection between the bottom and the shell had not been sewn in a perfectly straight line, but had a noticeable tilt. We had to fix this by separating the seam and sewing everything together again.

Day ten: When the shelter was "finished" we had to install the zipper pullers, shell puller and make the transportation bag. We had problems sewing the parts of the bag together because it was a circle and the material would often get stuck in the knitting machine.

Days eleven and twelve: During these two days we worked on re-working the new roof that would be the same material as the one at the bottom. The interior was already finished but we also wanted to have a window in the shelter, on one hand so that the astronauts would be able to see out side and on the other hand, so it would be easier to take photos of the inside from outside once the shelter is closed.

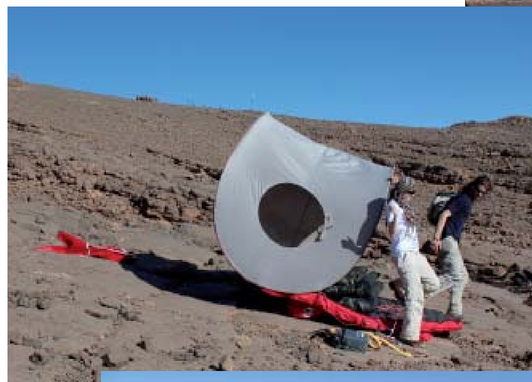
Field Study in Morocco

04th - 08th February, 2013



Day one: Arrival

First, admissions and briefing on the camp-rules. Dinner and setup of the personal tents, then overnight sleep in temperatures around 0 degrees Celsius.



Day two: Exploring the surrounding area, first tests

Breakfast at sunrise.
Set up of the control unit for the pneumatic structure At the same time exploration trip with cross-country vehicle into the surrounding area. Three test sites with different topologies were selected (09:45-13:30).

Lunch (13:30-14:00)

First tests conducted by the students on a slope terrain. Unpacking and setting up the primary structure. Inflating the pneu-structure, starting with the mattress and the seats, followed by the first and the second backup pneu. Adaption to the terrain by active and passive change of air. Discussing the error sources and weaknesses so that they can be improved in the future. Time measurements of all relevant sesquences. Dismantling of the shelter with sensitivity to the proper folding direction to facilitate the build-up of subsequent tests (ground on ground). Transfer back to the base camp. (14:30-18:15)

Log of the daily activities (19:30-20:19)

Dinner, report on the flight plan for the next day.





Day three:
Shelter set up near the base camp (well-regulated assembly was guaranteed) (08:30-10:00)

Interviews with the media. (10:00-11:00)

The Deployable Shelter is tested with the improved measures and the change in position from sitting to lying. Yet the Vienna UT-students are the test subjects. Active de-aeration with a hand pump to minimize pack size. (11:00 – 13:00)

Lunch 13:00 – 13:15

Ride to test site with flat terrain, stony ground and adequate setting for high quality movie recording of media teams from Servus TV and BR-alpha with the ÖWF crew. All subsequent development work and testing are documented on film.
Arrival of the first analog-astronaut (Daniel-Aouda X) and his security support (Safety-Dr. Pavan). First ergonomic tests with radio communication between students and Astronaut:
- Enter the shelter - OK
- Taking the sitting position - OK (automated closure of the shelter, little room for antenna)
- Actuation of the locking mechanism - OK (better than expected - better than in our own tests)
- Comfort-Test - very well
- Testing the change in position – Possible, but only little effect: Uneven weight distribution, since two occupants, but only one space suit. (+45 kilo)
+ targeted active control of the rear supporting pneu even with a load on it by sitting tester works smoothly
- opening of the shelter - OK
- The first tester decides to stay in the shelter to relax.

Arrival of the second analog astronaut (Gernot Grömer-Aouda S), preparation of the film crew. Both astronauts enter the already established and inflated Shelter simultaneously. All steps work just as well as in previous tests carried out with only one analog astronaut.

Short interference from pressure loss due to dissolved hose connection (surprising demonstration of the lying position).

Mutual removing the helmet works, but a slight lack of space. Interviews with analog astronauts by Servus TV through the communication window. Interview with Polina Petrova by BR-alpha. (13:30 – 17:00)

Return to base camp. Group photos of all camp participants. (17:00 – 17:30)

Dinner
(19:30 – 21:00)

Talk with Daniel (Aouda X-tester) on the test procedure. He is very satisfied with the processes, the seat feeling he describes with the words „Most convenient, ever occupied seating position with spacesuit“ (22:00 – 22:15)

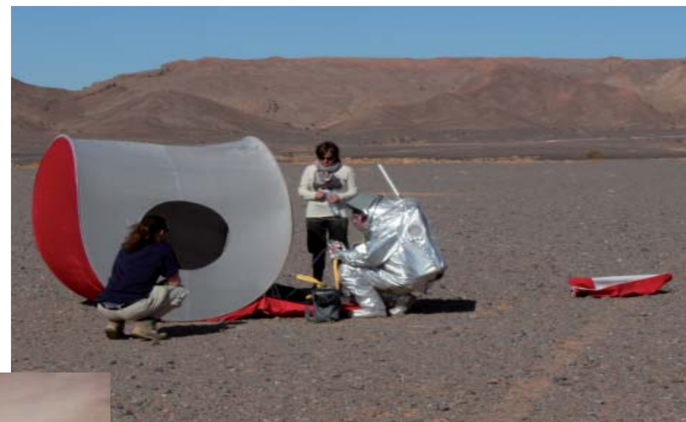
Day four:
To ensure an independent workflow of the analog astronauts, the transport as well as the complete dismantling is being without space suits. The activation of the pneus is discussed to solve any errors in the field simulation.   (12:00-13:00)

Preparation for the test with the film crew „platon TV“ and the 2 analog astronauts. The shelter is being transported for 100 meters by an analog astronaut using the handles, later being rolled (same tester, but swapped suits compared to yesterday). One astronaut takes out the shelter and unfolds it, he connects the control unit as well as the pump and starts the pressure build-up. The second astronaut arrives. After the desired state of pressure is reached, they sit down, the shelter closes automatically. The zippers are closed on both sides and the astronauts stay for 20 minutes in the shelter. One astronaut completes the first of two folding steps to pack up the shelter again, test ends here. (14:00-16:00)

Final works (marking the connections of the pressure hoses and renewing the Velcro to the seat-pneus) are made. The shelter is being packed and tests concerning mobility are carried out with Rover. (17:00-19:00)

Final briefing with a wine-tasting and toasting to a successful mission.

Interview with Daniel concerning the Shelter. (21:00-21:30)



Post-Mission-Evaluation

The Emergency scenarios were tested by the student team (Zuzana Kerekretyova, Nikolaus Gutscher and Kristoffer Stefan) the OEWF analog astronauts (Christoph Gautsch , Gernot Grömer and Daniel Schildhammer) during the analog simulation mission.

The preliminary measurable objectives were as follows:

1. FUNCTIONAL USABILITY OF THE PROTOTYPE
The prototype was made to fit a number of human activities based on the most likely emergency scenarios during an EVA on Mars. The following emergency scenarios have been tested during the simulation:

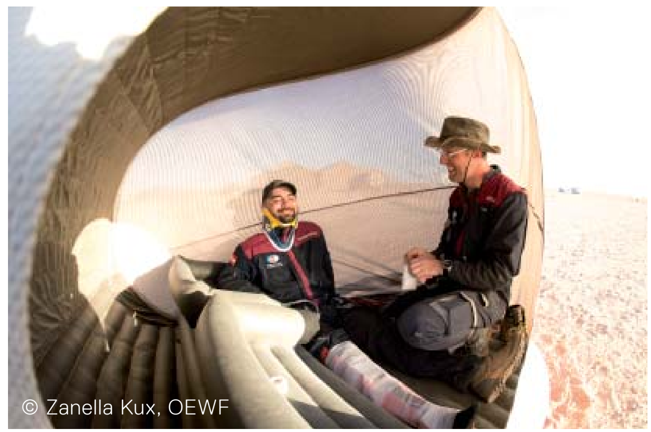
- Scenario A: One astronaut loses consciousness but is still breathing
- Scenario B: Injury of an astronaut during an EVA
- Scenario C: Astronauts get exhausted and need to rest for a while

2. ERGONOMIC USABILITY AND ITS ADABTABILITY
All scenarios have been tested and evaluated according to the following issues:

- Interaction between the proposed structure and its users (handling and activities in the shelter)
- Off-nominal situations to test the flexibility of the prototype
- Ergonomic and spatial suitability to actions and
- Individual perception of comfort in relation to these activities

3. DEPLOYMENT PROCEDURE
On-site the TU-student team and the OEWF analog astronauts tested the deployment procedure. In parti cular the following activities were tested:

- Handling of the mock-up in packed state and transportation
- Deployment of the structure, including opening the package and inflating the floor membrane
- Deployment of the structure under different topological conditions
- Retraction of the Shelter and
- Function of the selected pneumatic system



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The evaluation of the tests indicate a good functional usability of the mock up. In the following the main results are listed.

Handling of the mock-up in packed state and Transportation

Although the handling of the packed shelter was not a design criteria at this stage and only needed to transport the prototype, it has been tested by the analog astronauts.
Rolling of the 'suitcase' is a good option (Carrying it like a rucksack is not possible with the Aouda space suit, because of the position of the life support system on the astronaut´s back).

GG: Transporting the shelter in a packed state is fairly difficult due to the size and the weight. I used a combination of rolling it and dragging it when transporting the shelter over a distance of ca. 200 m (which was already a little exhausting in the Aouda.X). A mounting on an All-terrain-Vehicle might do the trick.

Deployment of the structure

The deployment (pop up) works as expected and takes less than a 1 min. Opening (unzipping) the shelter was tested a number of times. Some difficulties were detected due to the small size of the zips pull tabs. Additional ribbons were then connected to the pull tabs allowing an easier use with the space suit gloves.

The floor surface (pneumatic cushions) cannot be automatically inflated in the current mock up thus the deployment procedure of the pneumatic floor cushions was not tested due to time matters. In all of the tests carried out by the analog astronauts the pneumatic mattress was inflated before they enter the shelter.

GG: This is super-easy and very comfortable. It would be great to include a pressure indicator which tells when the shelter is fully inflated.

Adaptability to the terrain

The deployment on a slope and rocky surface worked well. The mechanism that allows adjustment to terrain conditions is working well.

Entering the shelter

A stick was used to hold the shelter up in order not to interfere with the antenna. By design intention a specific amount of air pressure in the pneumatic cushions changes the curvature of the floor mattress, causing the upper part of the shelter to tilt over the heads of the astronauts and thus automatically closes. The procedure of entering the shelter worked well.

GG: Upon entering, the helmets banged against each other when trying to enter at the same time. The solution was that the astronauts agree who steps in first, balances the inflated floor, whilst the other sits down.

CG: To enter the shelter is ok. But if you are just one person, you have to make sure to stay in the middle because otherwise it is a bit tricky to keep the balance.

Closing the shelter from inside

The mechanism of closing the zip with the integrated ribbon is working well. It was noticed, that the simulation crew (without spacesuit) had sometimes difficulties to close the zipper, whereas the sim-crew (with astronaut shoes) did not. In addition all parts have to be constructed with high precision in order to work well. The stick used as aid to enter the shelter was sometimes a barrier in closing the shelter.

GG: Closing the zipper with the stick and the rope is quite easy with some exercise.

CG: The ropes are a huge help but it is still hard work to close it. Actually the first part is the hard one. As soon as you have the zip half way closed it works fine.

Different Body positions

The prototype was designed to allow functional adaptability including sitting position as well as lying position for the astronauts necessary for different emergency scenarios. The change between the two positions is achieved through air shifting between two supporting pneumatic cushions, one in front and one in the back of the shelter. This adaptability was tested with two astronauts inside the shelter. The mechanism worked well and fast.

Astronauts claim that sitting in the shelter is very comfortable and really allows them to relax. The measurements of the astronauts CO2 levels (carried out by the ÖWF) also support this claim. The sitting height is sufficient. The position of the arm-supports is alright (but could be increased by 5-10 cm).

The ergonomic usability in the lying position was not sufficient. The problem was that the life support system on the back and the antenna did not allow the astronauts to lean back and they did not feel comfortable.

GG: We originally anticipated that one could even sleep in the shelter. The seats are really comfortable and one can roll a little bit to the side. However, due to the antenna system on the suits, the other astronaut has to watch whenever one moves. At one point, we broke the antenna mounting INSIDE the PLSS due to the pressure of the shelter on the antenna (we fixed it afterwards – but it is virtually impossible to get a "feel" if you are touching the shelter skin inside unless someone was watching out).

DS: It was easy to enter in the shelter, but to sit down was challenging if you are alone. The seats start rocking if you sit down alone on one side. Changing the body position was possible but difficult due to lack of air pressure (rocking).

CG: I think they were fine.

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Size of the Shelter

It was possible for the non-injured astronaut to take off the helmet of the injured one. More free space to move and for facilities to deposit the helmets could be implemented in a next prototype

GG: We tested an unsuited scenario: it was no problem at all to apply a splint to a suspected tibia fracture, apply a triangular bandage to a broken arm wrist and apply a cervical collar after a neck injury. The space is large enough to accommodate these *operations. I do not think, a splintering of a leg can be done in a donned mode due to the size restrictions.*

CG: For the purpose of use I guess the size is big enough. Of course more space inside is always fine, but on the other side you have to transport the shelter and for this a smaller size is better.

GG: Great, if it wasn't for the size of the antennas, one could even move within the shelter and find a sleeping position.

Leaving the shelter

While getting out of the shelter the astronauts sometimes had to kneel, but they do not see it as a problem.

GG: In the Aouda.S it was significantly easier as in Aouda.X. Plus, I also realized, when doing the test after a long EVA (when I was already a little exhausted), it was significantly more difficult. In that case, Aouda.S had to get out first and then assist in getting up.

CG: To leave the shelter was not a big deal. It is much easier to open the zip of the shelter than to close it.
DS: With the right technique it was easy to leave the shelter. (Kneel down first, than stand up). In principle the size of the shelter is sufficient. The only criteria are the length of the antenna during reaching different body positions.

Retraction of the Shelter

Although retraction of the shelter was not the main design focus, it was tested by the analog astronauts. The folding procedure was not possible for just one astronaut. For two astronauts it was possible but took too long.

Pneumatic system

For initial testing the concept for the pneumatic system forming the sitting position and separating the interior from the Martian surface worked well. For further development some adjustments will have to be made.

For maximizing user comfort and to prevent undesirable weight redistribution destabilizing, a more differentiated chamber configuration is needed (Additionally, the inner pressure can be increased). External parts like the control panel and the inflation system have to be integrated in the shelter structure to avoid the need for post-deployment operations from the exterior.

Finally, manually operated actions should be minimized or avoided. If possible all system-related procedures should be automated and controlled using an interface.

GG: Just an idea: As the shelter has a system of pressure valves already anyway: How about including a more segmented version of the pressurized

furniture, so that – depending on the usage- one either has the couch-seats, or just a flat floor, or even maybe a small table between the astronauts?

GG: Determining when the final pressure is reached in the inflatable is a little bit subjective – we learned it after some trials, but it would be great to have a pressure indicator to check when it is inflated, and also to monitor the loss rate in case of a not-fully closed valve.

Additional Gadgets

In a next prototype a number of additional gadgets could be implemented for further testing. If tested in the dark small lamps and/or phosphorescent elements (zipper sliders and ropes, stick, maybe the contour of the shelter) should be integrated.

GG: Just an idea: Mounting a small LCD beamer with a power supply could result in an in-house video projection towards the front side. They come really cheap and they could either be used to project vital data/communication or – in a more terrestrial application- serve as an in-shelter entertainment system . On a more serious side: if one includes a set of electronics, LED-illumination would enable us to work also in the dark.

GG: Indicating the pressure seal by e.g. including a little electronics which activates e.g. a LED light when the zippers from left and right are touching (assuming that this indicates a full sealing), would be great. In reality, this would be a necessity, as opening the helmet needs a redundant confirmation of pressurization.

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Medical Evaluation

Chan Sivanesan
Intern, Crew Medical Support Office (HSO-UM)
European Astronaut Centre

The aim of the medical review is to examine the challenges posed by the use of an emergency deployable shelter on Mars. This review focuses on the shelter prototype designed by a team at the Vienna institute of technology. The team envisioned nine emergency scenarios during an EVA on Mars which would require the use of this shelter.

This review has identified fifteen medical issues and human factors that require consideration to ensure a safe environment for astronauts in these scenarios. Following the classification of the risk involved, four high risk medical issues were explored in detail. Specific recommendations will be made to the team to effectively manage these issues. Recommendations will also be made to improve the general efficacy of the shelter.

Final Evaluation Results

The final results of the architectural and medical evaluation will be presented at the 19th *IAA Humans in Space Conference*, Cologne, Germany in July 2013 and the *64th International Astronautical Congress*, Bejing, China in September 2013.

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A 1:1 prototype for a deployable and portable emergency shelter for future Mars missions has been developed and built by a group of master students of architecture at the Vienna UT. This prototype was one of the 14 scientific experiments that were tested during the Morocco Mars Analog Field Simulation in February 2013. This booklet presents the preliminary design concepts and the final prototype, as well as potential emergency scenarios and their evaluation.

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