Abstract #1654

English

Building with reinforced ice in space

Water will be a highly sought after resource in space. Water's usefulness in propellant production, radiation shielding, life support, and food production is well known. Water is also the best building material found in space. This presentation will discuss the use of reinforced ice as a building material. The presentation will start with a review of structures built with reinforced ice, and previous research into the material properties of reinforced ice. There is a long history of building with ice on Earth. The first large scale engineering research into building with reinforced ice occurred during Project Habakkuk, a plan to make an aircraft carrier with reinforced ice during World War 2. Recently domes with spans greater than 25 meters have been made from reinforced ice. The presentation will then illustrate the advantages of reinforced ice as a building material in space. Water ice reinforced with regolith has many advantages over other ISRU building materials. Water ice can be found throughout the solar system, including on the Moon, in some asteroids, and on Mars. Because of the low temperatures at which ice will sublimate, evaporate, and melt, there are a variety of low energy techniques for extracting water from the ground. Once it is removed the low working temperature allows for simple material handling and construction techniques that are not possible with other materials. Finally, habitable structures constructed from reinforced ice will have excellent radiation shielding properties because of the large hydrogen content of water. The presentation will then discuss the challenges of building with reinforced ice, and solutions to those challenges. There are several challenges to building with reinforced ice. Structures built with reinforced ice must be kept sufficiently cold and stresses must be kept sufficiently low to prevent creep deformation of the structure. In addition, a system must be put into place to prevent sublimation of the ice. Finally, the presentation will discuss ongoing research in reinforced ice material properties and techniques for building with reinforced ice on planetary surfaces and in free space. Designs of several types of structures (pressurized habitats, trusses) will be presented to illustrate the usefulness of reinforced ice as a building material.

French

No abstract title in French

No French resume

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Biographies

Biography submitted with the abstract

Arthur Ruff is the CEO and founder of ISRU Tech Inc. which builds technology to reduce the cost of space exploration and development through the use of materials found in space. He began his career in Mission Control on the Space Station program in 1996. In 2015 Mr. Ruff won NASA's "Space Pioneering - Achieving Earth Independence" competition with the design of a Martian habitat made from reinforced ice.

Biography in the user profile

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Building With Reinforced Ice

Outline

Background

Advantages of using reinforced ice over other ISRU building materials

Challenges of building with reinforced ice, and solutions to those challenges

Sample designs using reinforced ice

History of building with ice

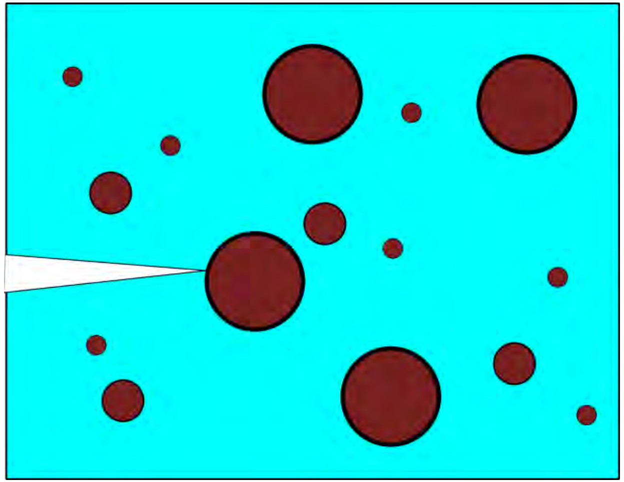
Igloo / Iglu

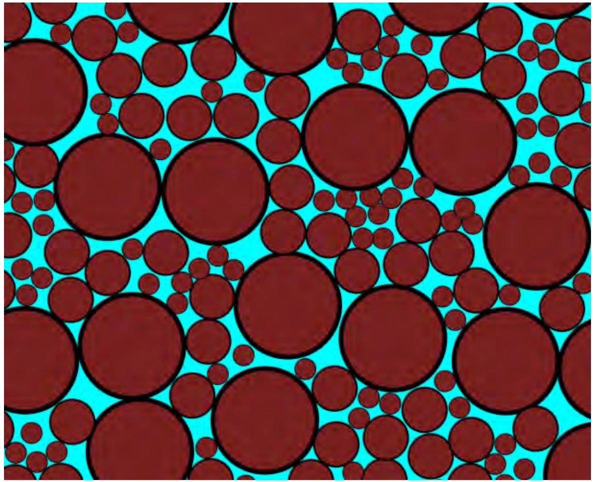
Project Habakkuk and Pykrete

Ice domes, Eindhoven University of Technology, Netherlands

Material Properties of Reinforced Ice

Crack Propagation





Material Properties of Reinforced Ice

Tensile Strength

- 1 to 3 MPa for ice
- 3 to 7 MPa for reinforced ice

Creep Deformation

- Creep is the limiting material behavior.
- Stresses must be kept below 500 kPa

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Ease of extraction

Many different techniques to extract water

Temperature requirements range from 0 C to 300 C

Much easier than almost all other ISRU resources

Low working temperature

Building structures with reinforced ice is as simple as pouring concrete into a form.

Water/regolith mixture is poured and frozen layer by layer.

Superior radiation shielding

High hydrogen concentration.

Easier to pump water/regolith than to bury a habitat with loose regolith.

No duplication of equipment

Wherever we go, we will be extracting water if it is available.

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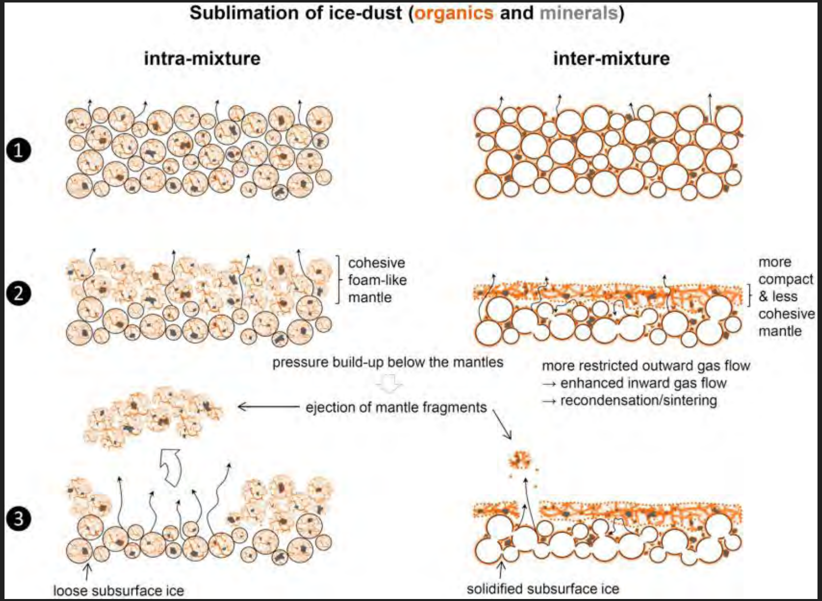
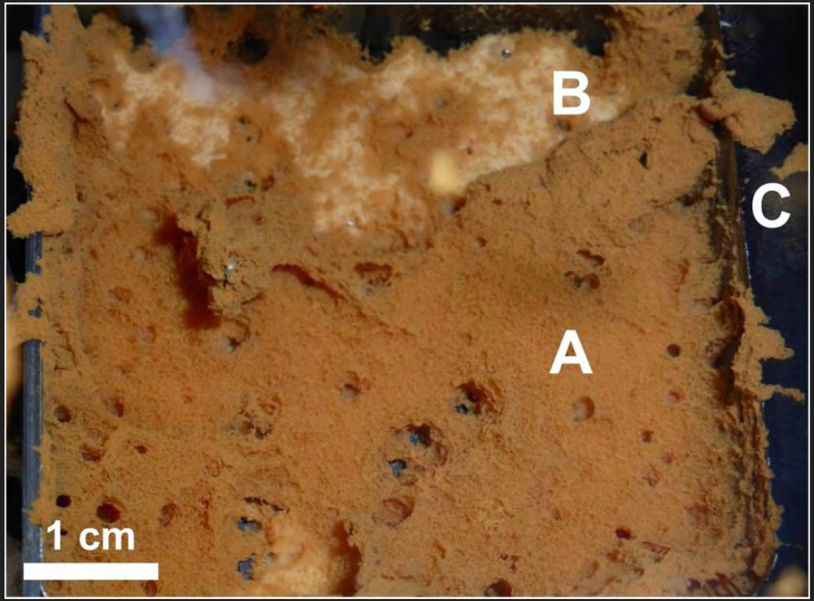
Sublimation

Sublimation barrier

What happens if you get a hole in your sublimation barrier?



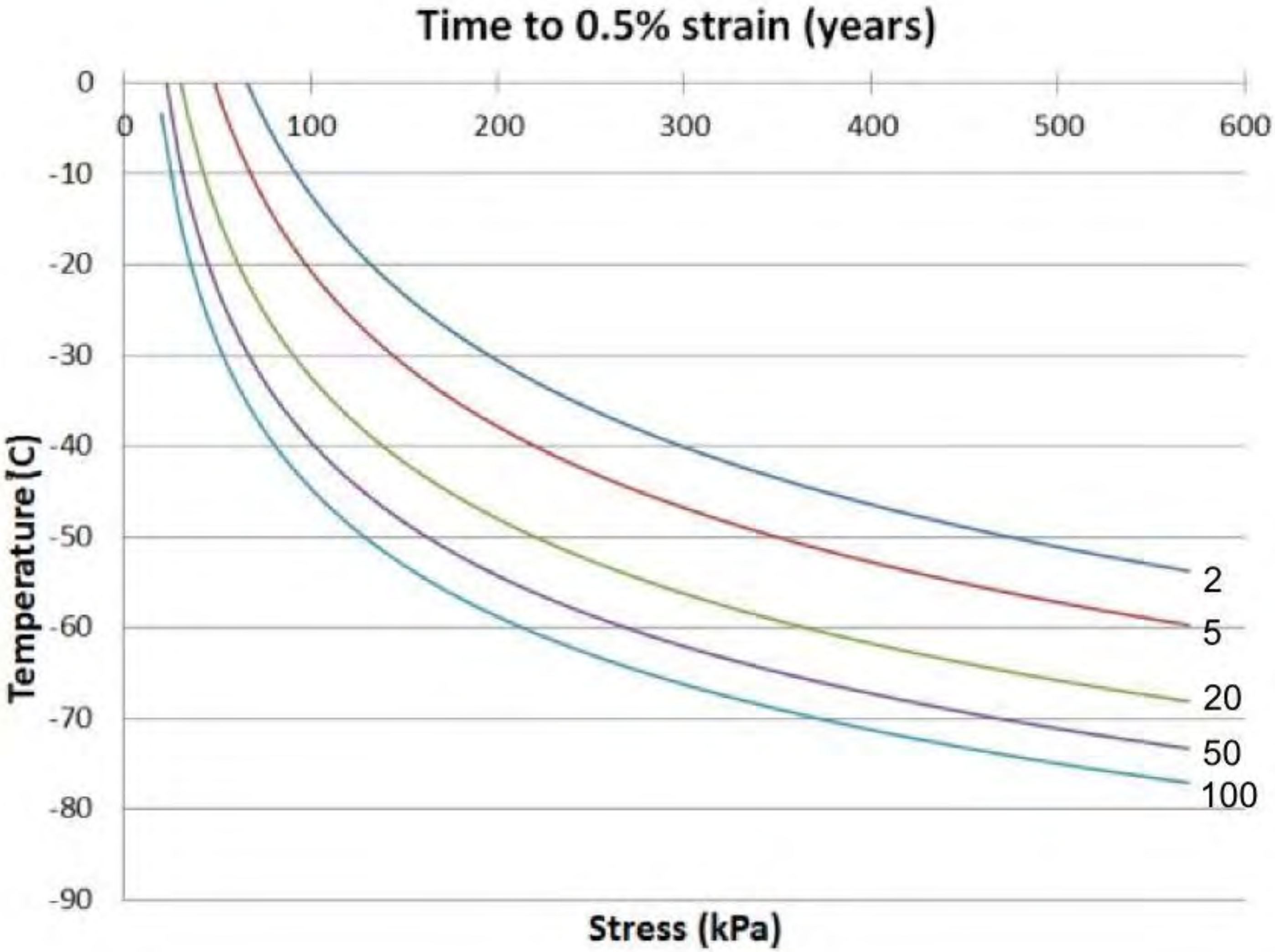


Poch et al., Icarus 266 + 267, 2016

Creep

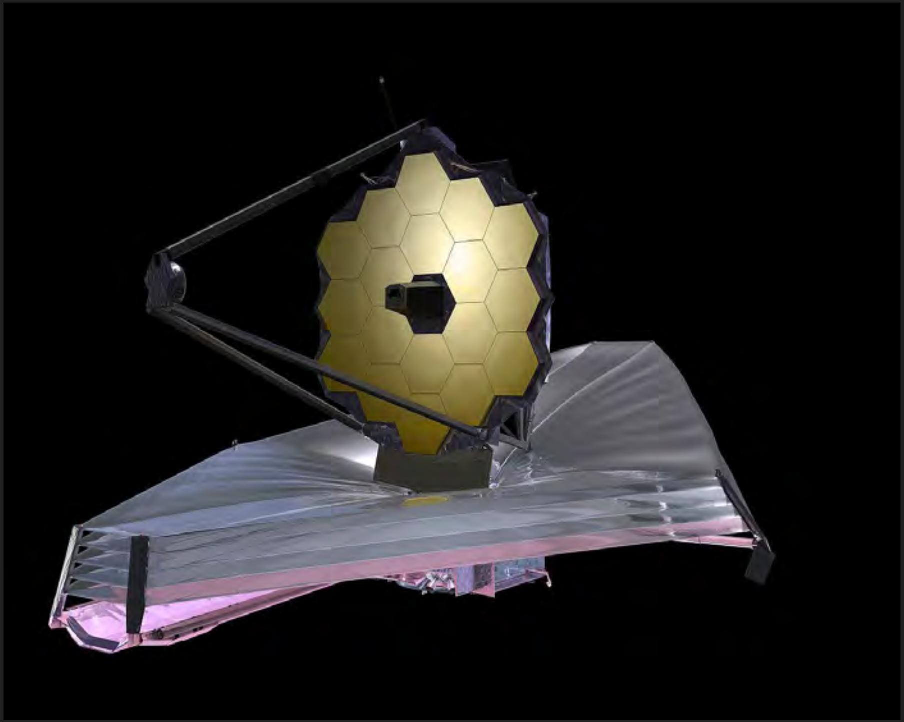
Elastic deformation: If you increase the load, the material deforms. If you keep the load constant, the material doesn't deform.

Creep deformation: Material continues to deform under constant load. Creep rate is temperature and stress dependant.



How long will an ice structure last?

Keep it cold - sun shade



James Webb Space Telescope with sunshade.

For an ice structure, a single layer shade with the ice structure doing a “barbeque roll” is sufficient to Mercury’s orbit.

Strength to weight ratio

Reinforced ice shouldn’t be used for structures that need to be accelerated a lot.

Water has many other uses

There will be many demands on the water supply. If those demands can’t be met, either increase the supply or decrease the demand.

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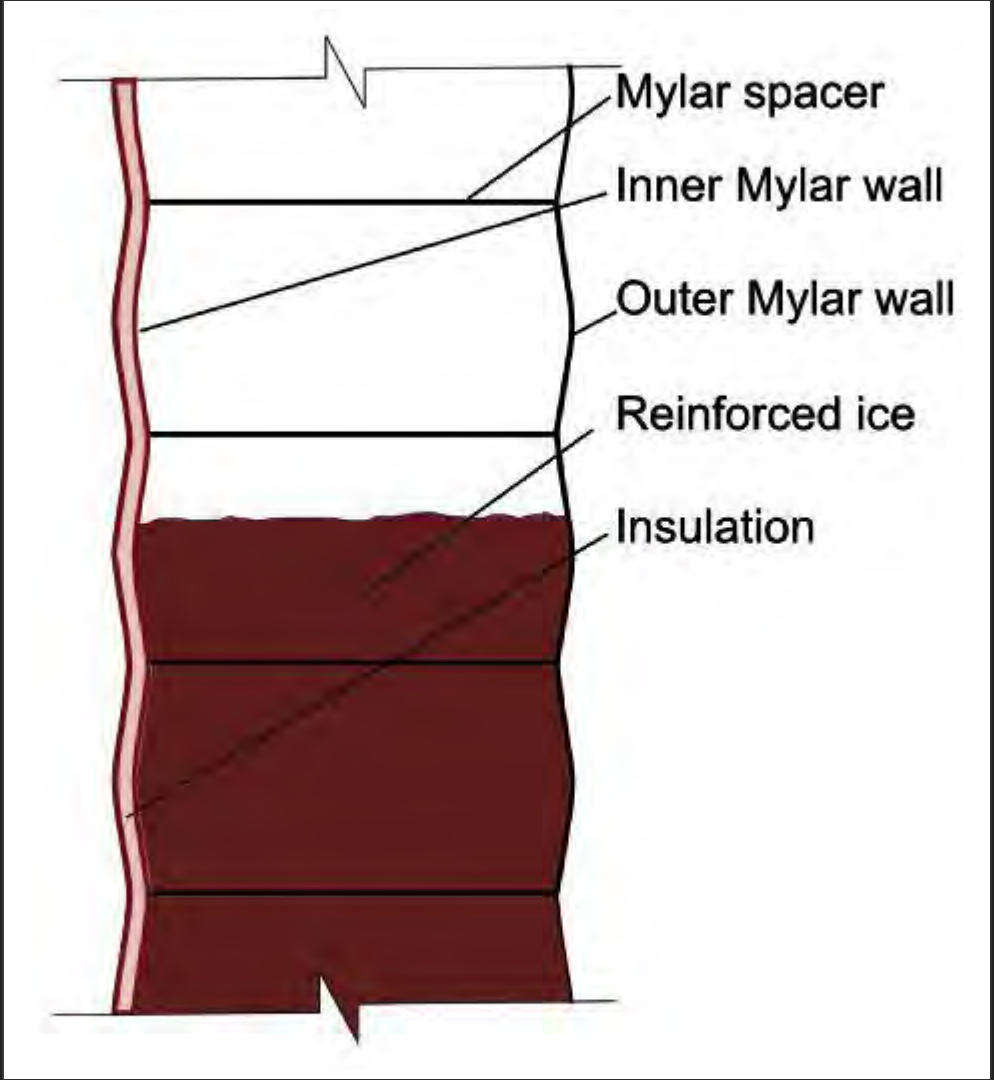
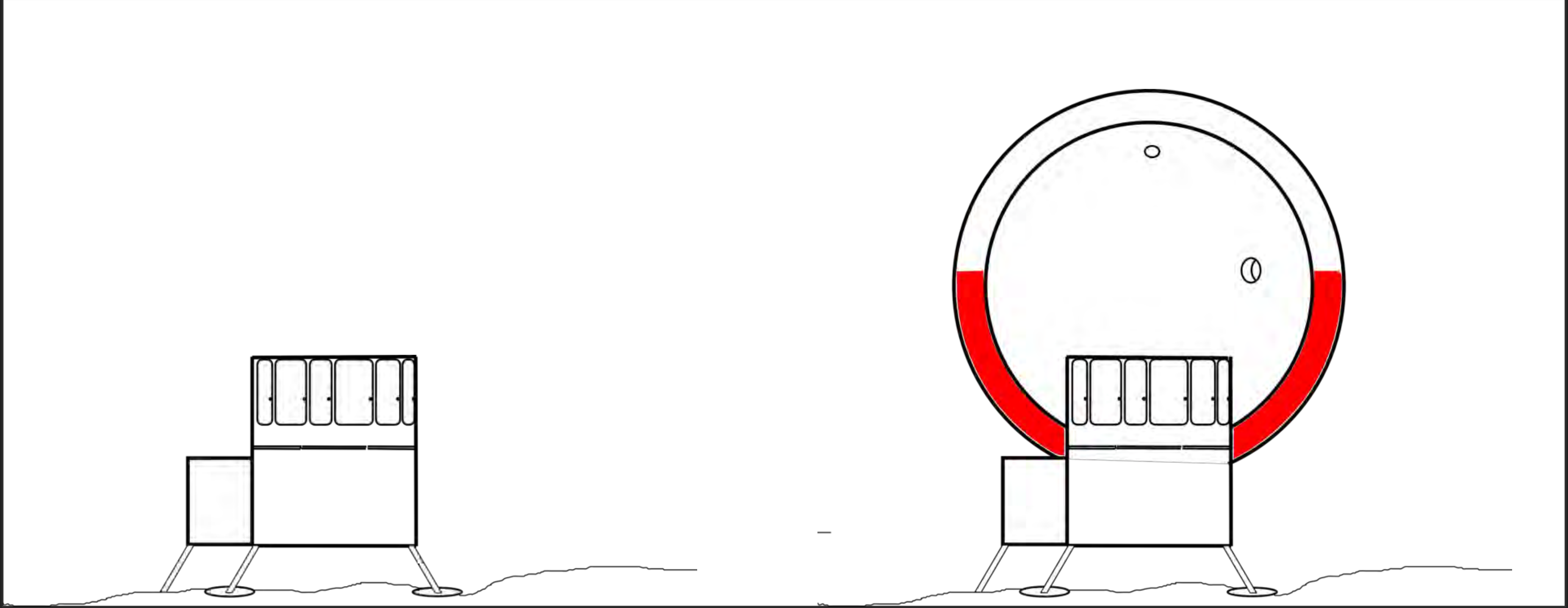
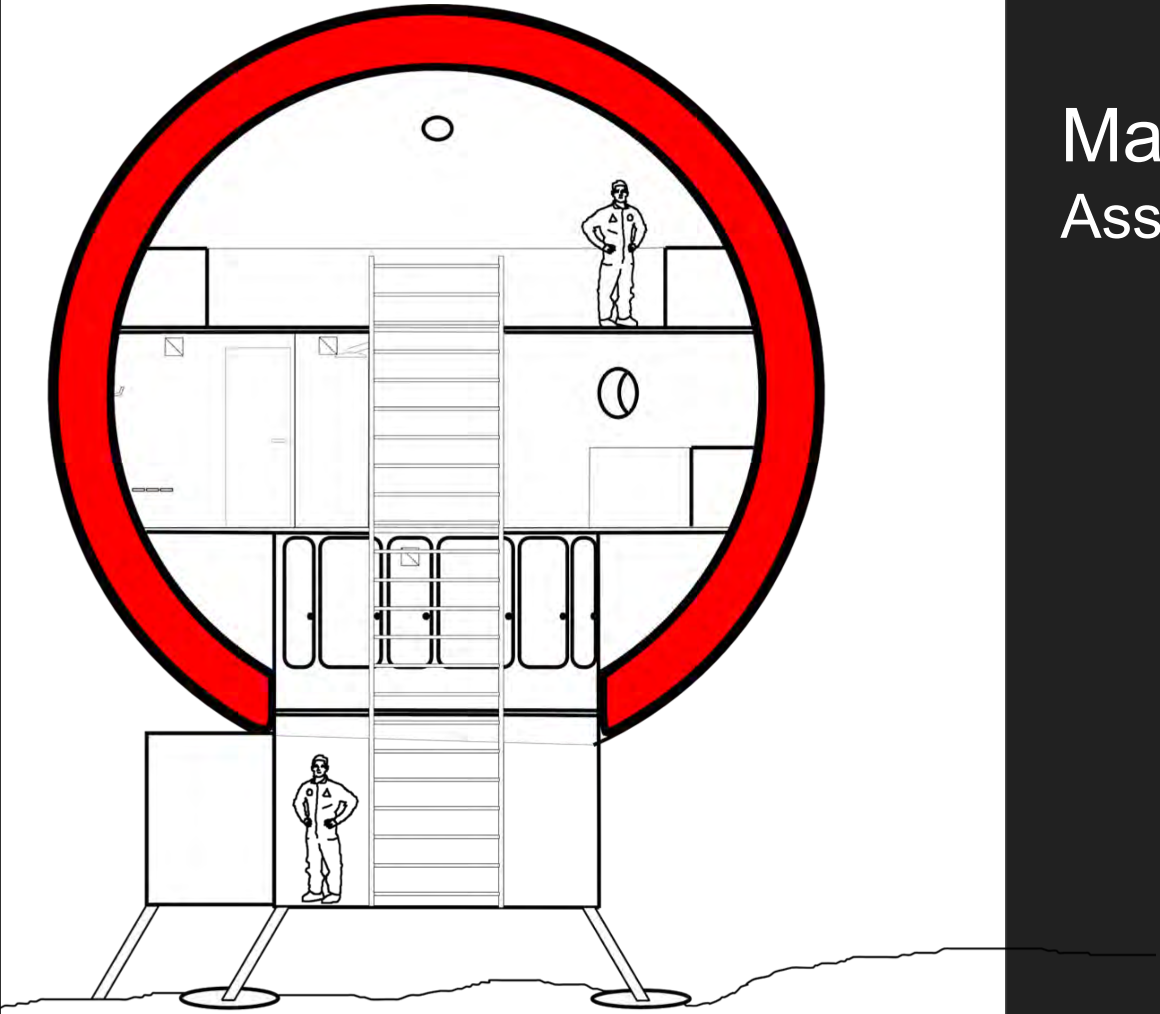


Mars habitat construction

Wall cross section during filling

Mars habitat construction
Assembly sequence





Mars habitat
Assembly complete

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