

Resilient Extraterrestrial Habitats

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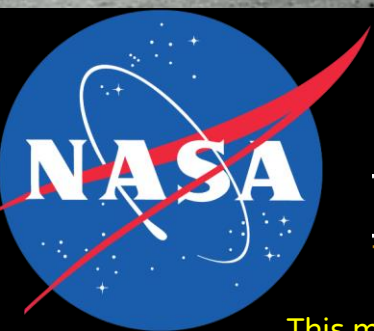
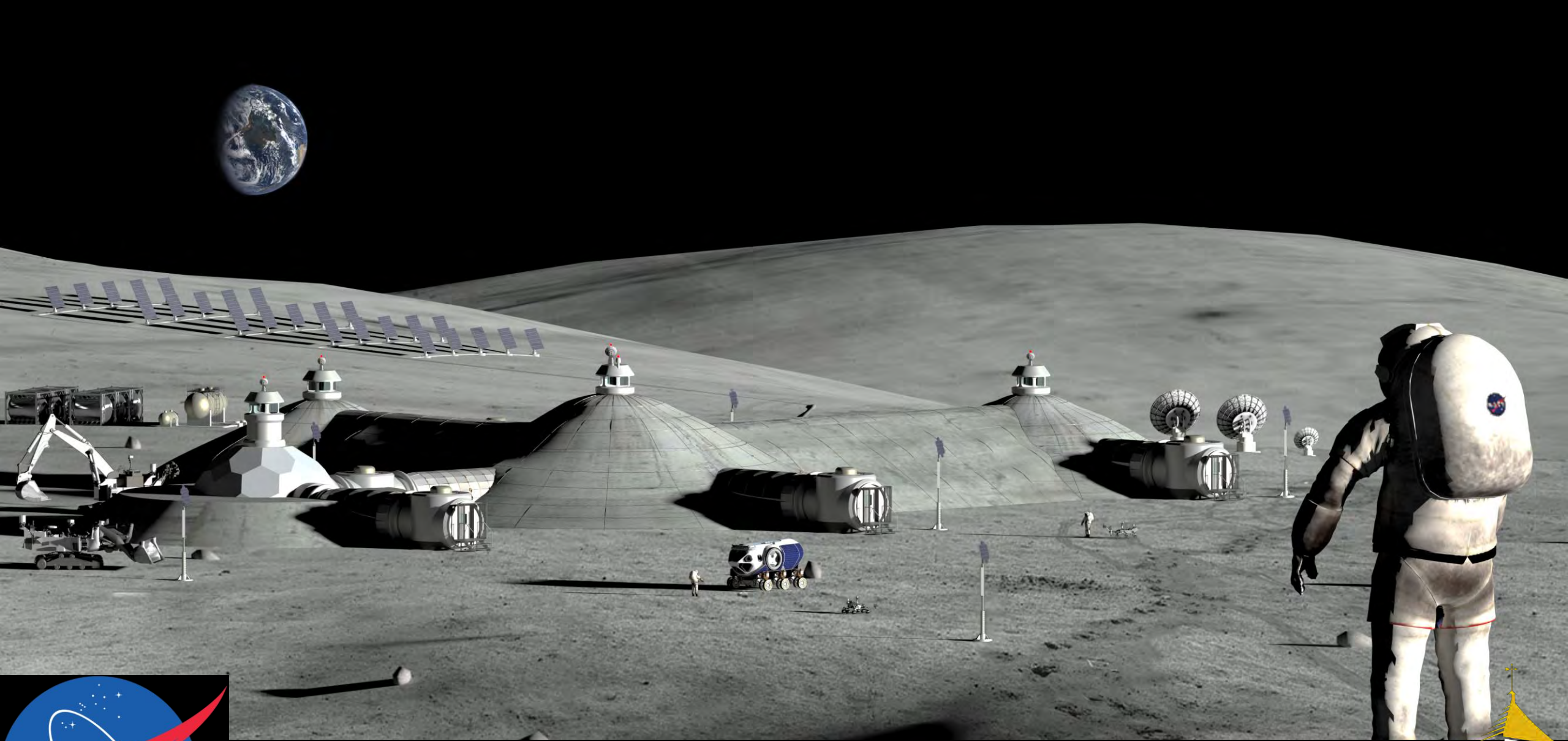


Overview

- Background
- The Lunar Environment
- Challenges and Opportunities
- Why do we need *smart* and *resilient* space habitats?
- Concluding remarks

Experience with extreme conditions ...*on earth*





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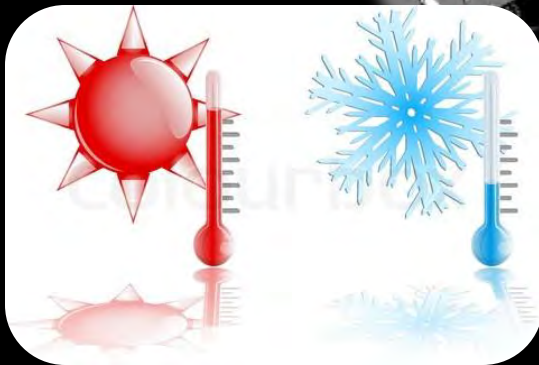
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This material is based upon work supported by NASA under grant or cooperative agreement award number



Deep space habitats are vulnerable

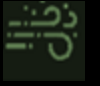
The Lunar Environment



The Lunar Environment



Radiation



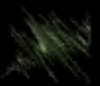
Dust



Extreme
Temperatures



Meteorite
Impacts



Seismic



Equipment
Failure



Biofilms/
Hazards

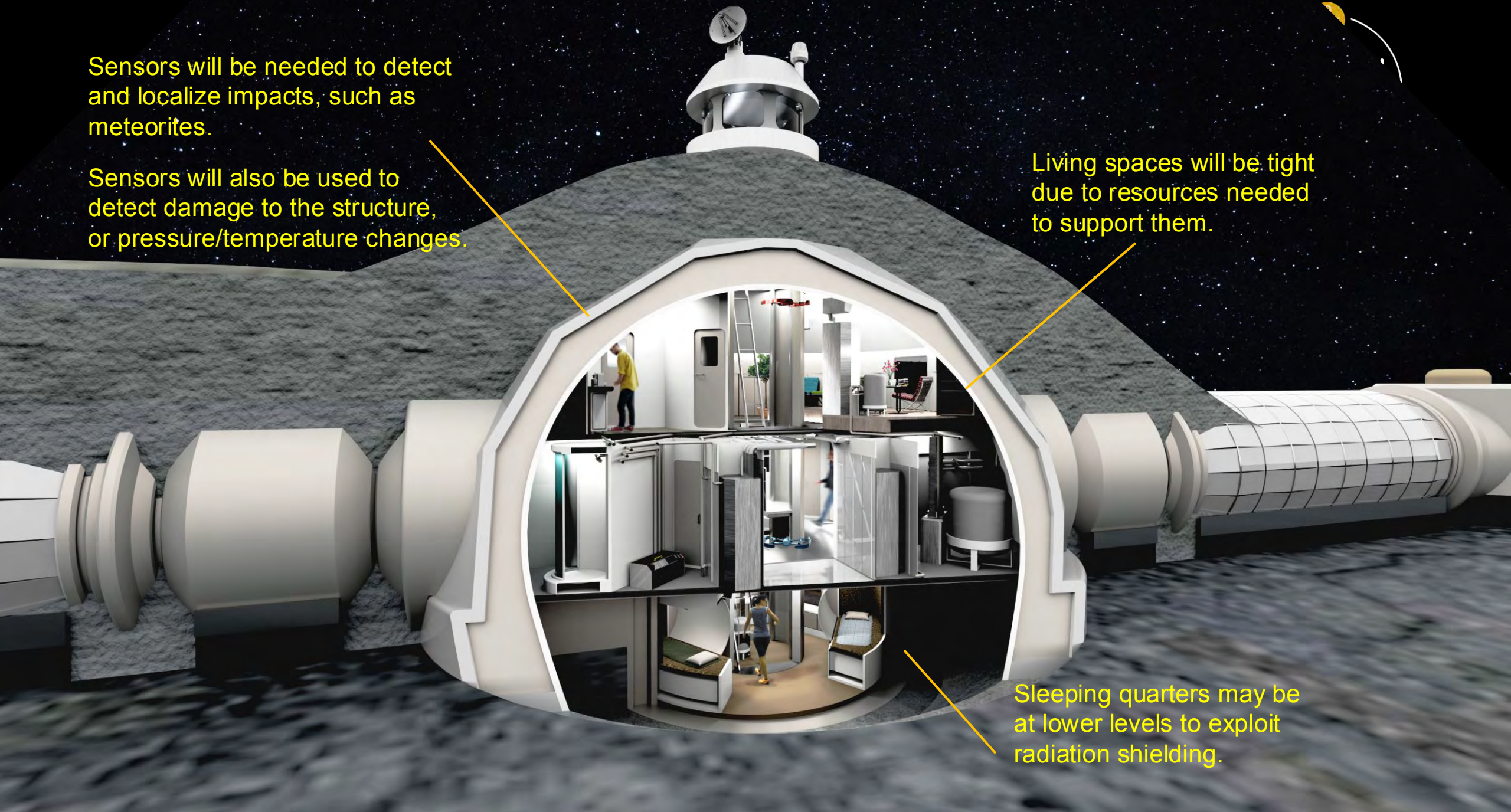


Sensors will be needed to detect and localize impacts, such as meteorites.

Sensors will also be used to detect damage to the structure, or pressure/temperature changes.

Living spaces will be tight due to resources needed to support them.

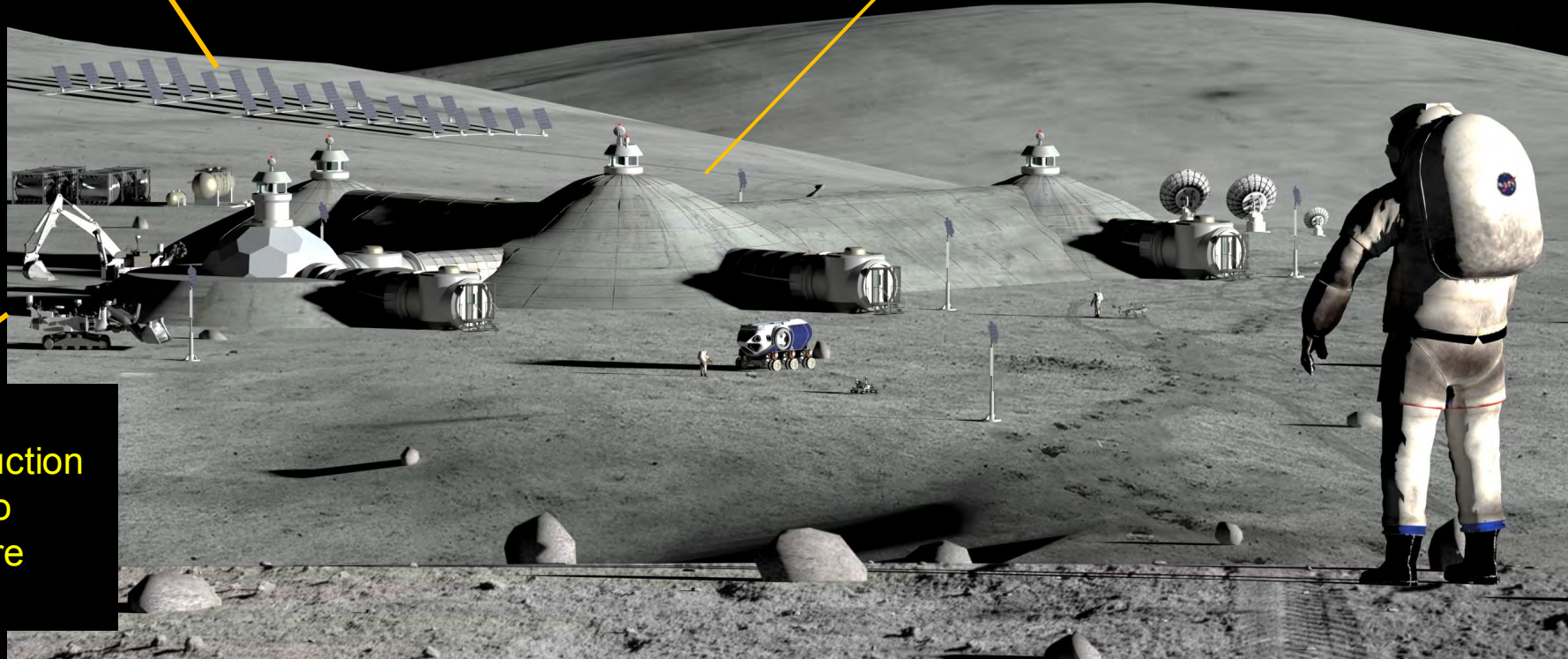
Sleeping quarters may be at lower levels to exploit radiation shielding.



Lunar habitat system

Solar panels offer one source of power, but dust storms will disrupt their use and will degrade their performance.

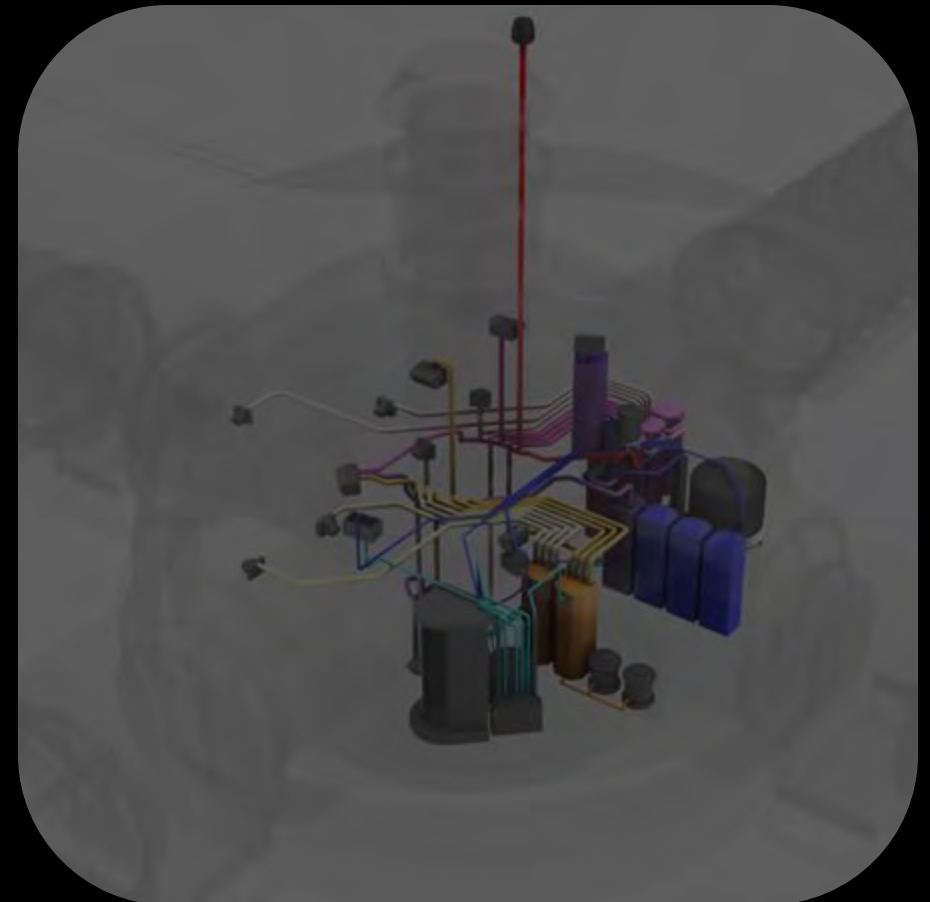
The habitat must offer protection from radiation. Regolith may be used to shield the habitat.



Humans cannot easily do construction in space suits, so robotic means are needed.

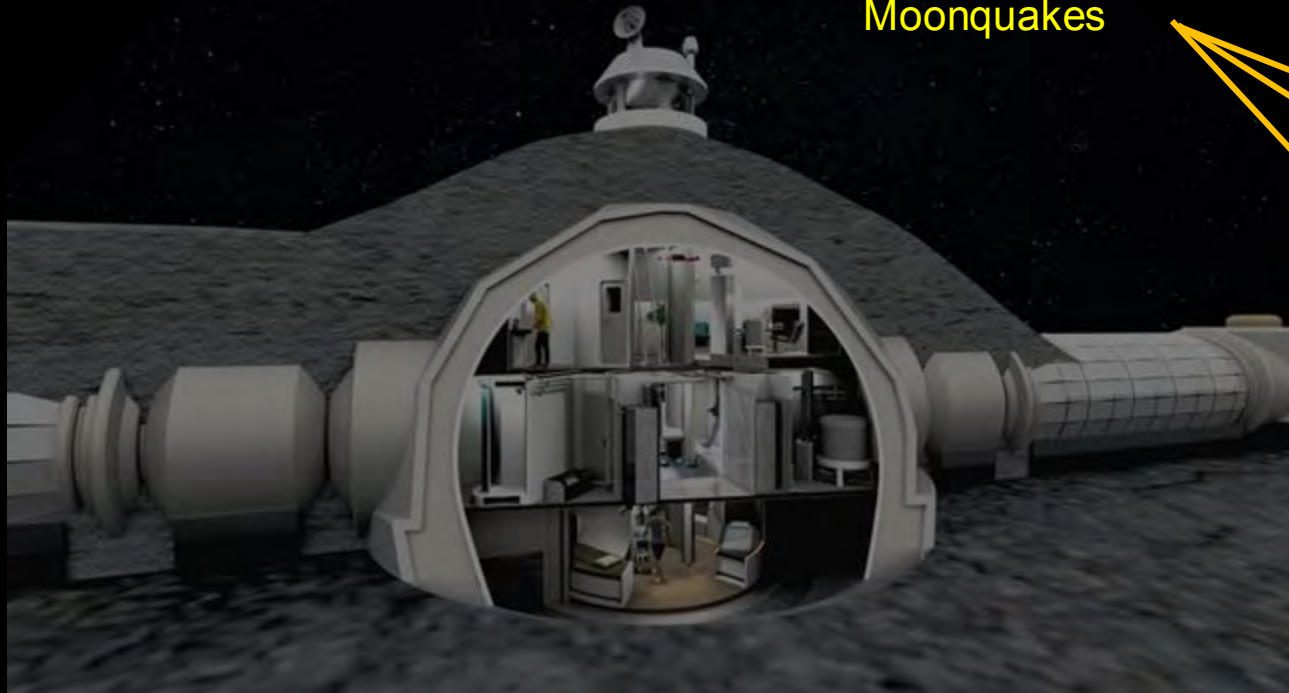
Credit:
Takaharu Igarashi

Lunar habitat system



Lunar habitat system

Environmental Control & Life Support , highly interconnected with the structure, vulnerable to Moonquakes



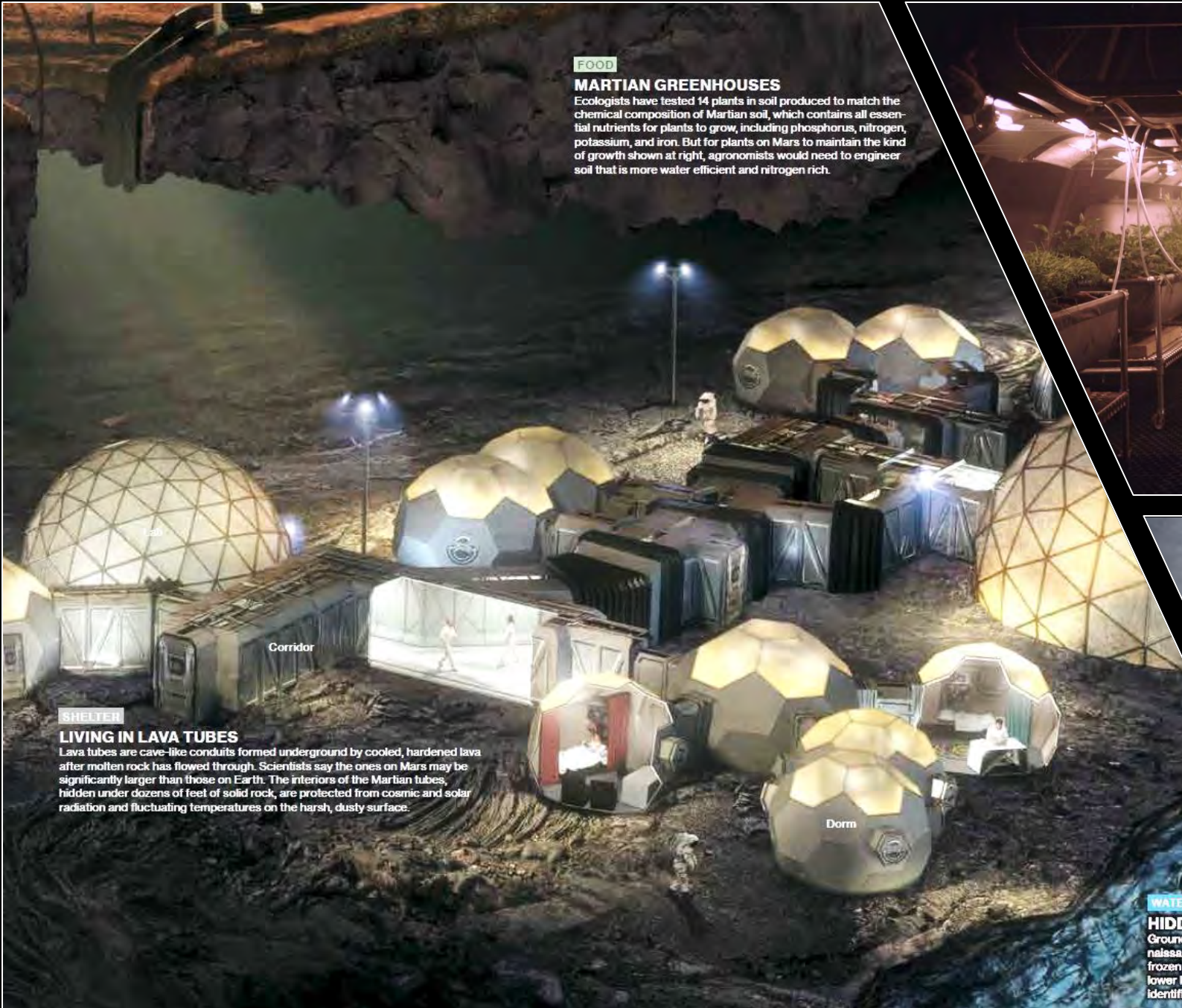


Where will we live?

FOOD

MARTIAN GREENHOUSES

Ecologists have tested 14 plants in soil produced to match the chemical composition of Martian soil, which contains all essential nutrients for plants to grow, including phosphorus, nitrogen, potassium, and iron. But for plants on Mars to maintain the kind of growth shown at right, agronomists would need to engineer soil that is more water efficient and nitrogen rich.



SHELTER

LIVING IN LAVA TUBES

Lava tubes are cave-like conduits formed underground by cooled, hardened lava after molten rock has flowed through. Scientists say the ones on Mars may be significantly larger than those on Earth. The interiors of the Martian tubes, hidden under dozens of feet of solid rock, are protected from cosmic and solar radiation and fluctuating temperatures on the harsh, dusty surface.

Corridor

Dorm

WATER

HIDDEN GLACIERS

Ground-penetrating radar from Mars Reconnaissance Orbiter has revealed frozen water preserved beneath the surface at lower latitudes than where ice had previously been identified. These glaciers extend for



Lunar habitat system: Requirements

- Sufficient area/volume for the crew
- Protection from radiation, vacuum, temperatures, micrometeoroids
- Thermal/pressure management system
- Life support system
- Sensors – to provide a situational awareness
- Structure that is robust to:
 - Gravity loads
 - Moonquakes
 - Thermomechanical loads
 - Dust abrasiveness
 - Vacuum

Steps in (any) construction project



- Site selection, data collection
- Design based on known information about the site, loads, hazards
- Excavation, site preparation
- Foundation
- Construction, but not like on Earth
- Verification along the way
- Regolith layer (water/ice alternatively)
- Questions:
 - When do you pressurize?
 - What safety factors are needed?
 - What lunar features can you leverage?

Alternatives



- Materials
 - Metal
 - Inflatables
 - Composite materials
 - In situ materials (regolith)

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 - Composite materials
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Construction with Regolith Materials

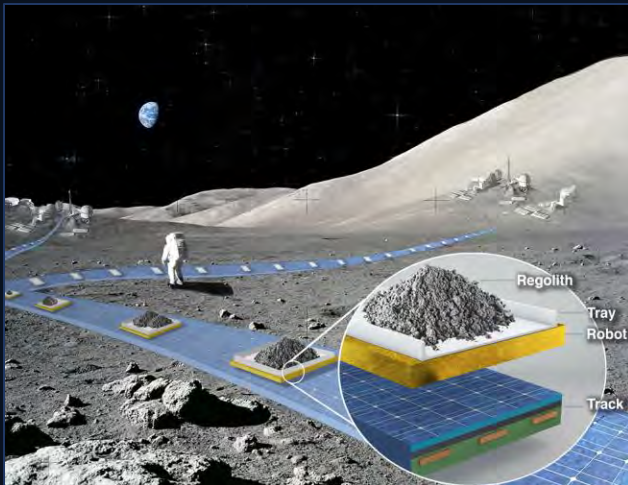


Using robotic technology (teleoperated / automated):

1. Regolith excavated, collected and transported to site
2. Regolith-based indigenous materials are manufactured
3. Protective layer 3D printed using material

Verification of strength will be necessary

<https://sservi.nasa.gov/articles/building-a-lunar-base-with-3d-printing/>



Other Renditions of 3D Printing Habitats

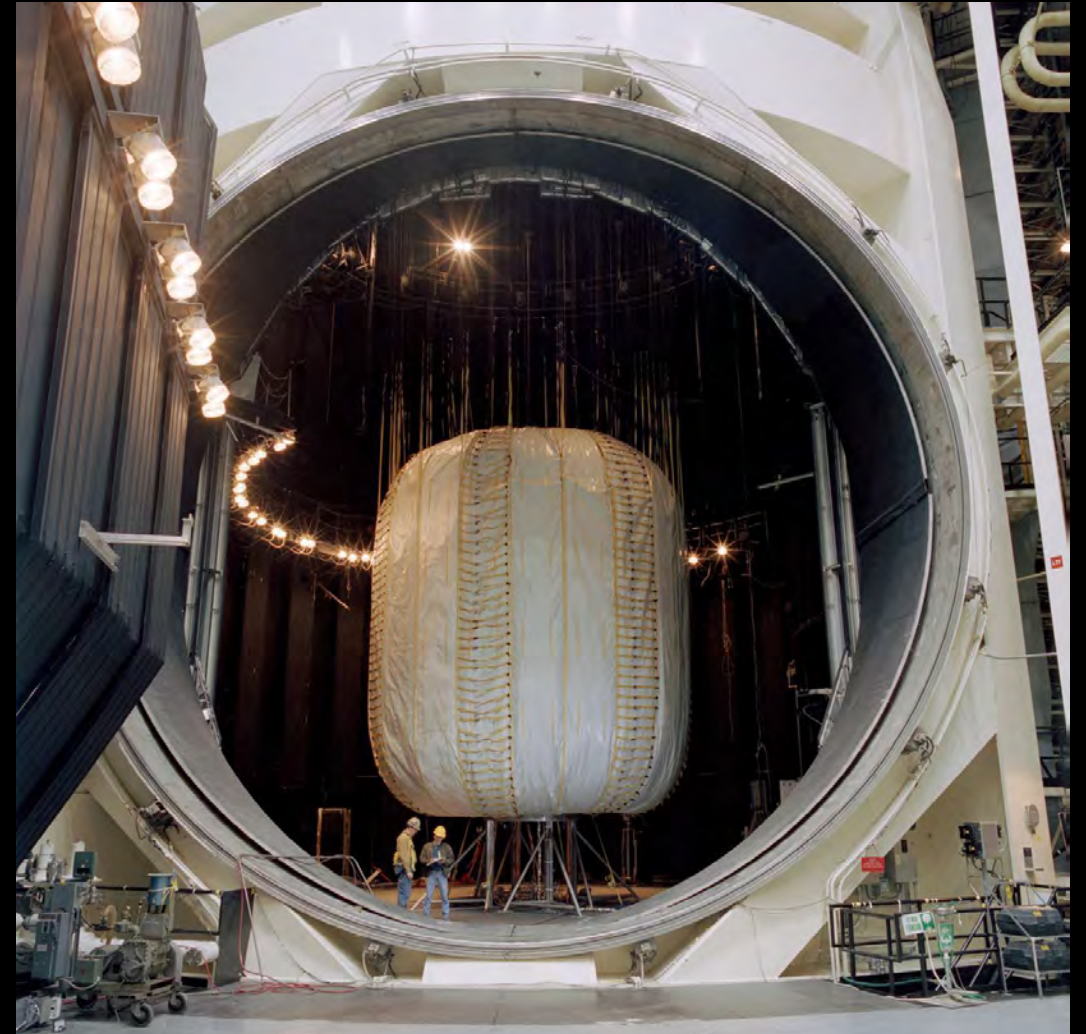


<https://www.nasa.gov/oem/surfaceconstruction>

Advantages of Inflatable Habitat

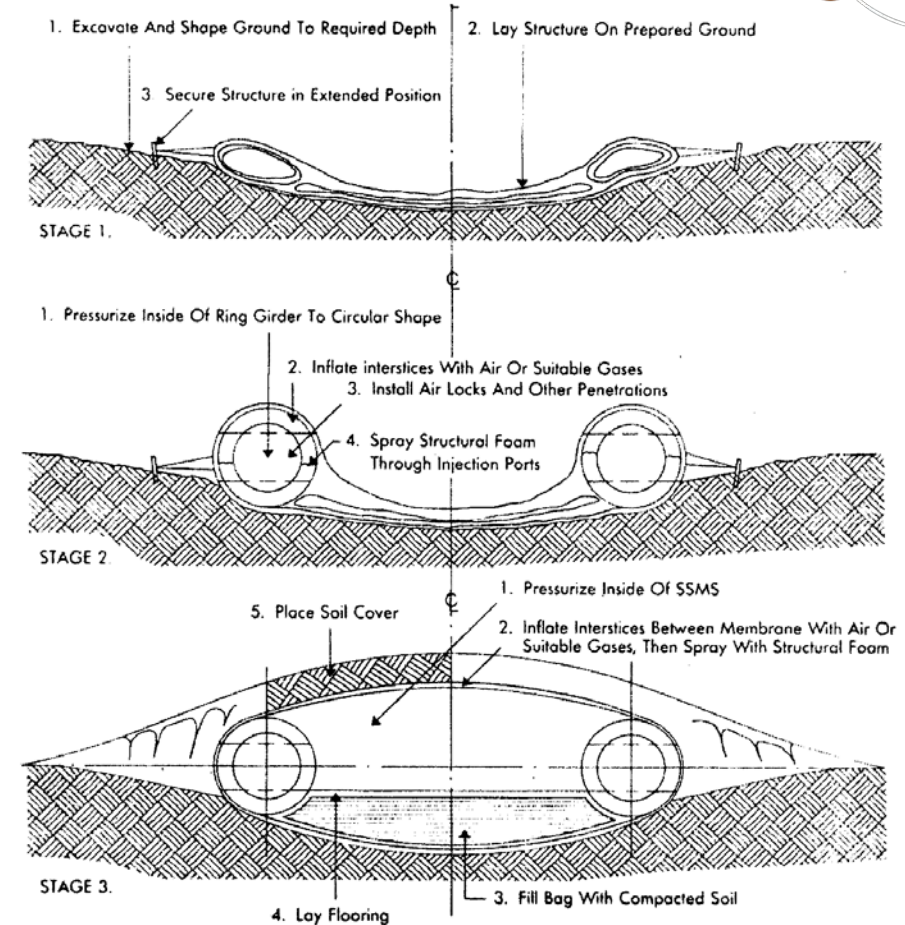


- Light-weight
- Prefabricated
- Able to handle the pressure/vacuum
- Resistant to micrometeoroids
- Modular construction options
- Cost-efficient
- Proven technology
- Available now!



Construction of Inflatable Habitat

1. Earthwork preparation of building site
2. Deploy and secure inflatable
3. Pressurize interior compartment
4. Construct regolith protective layer over membrane



Inflatable membrane structure—construction sequence [reprinted with permission by ASCE from Chow and Lin (1988, p. 372)]

Other Renditions of Inflatable Habitats

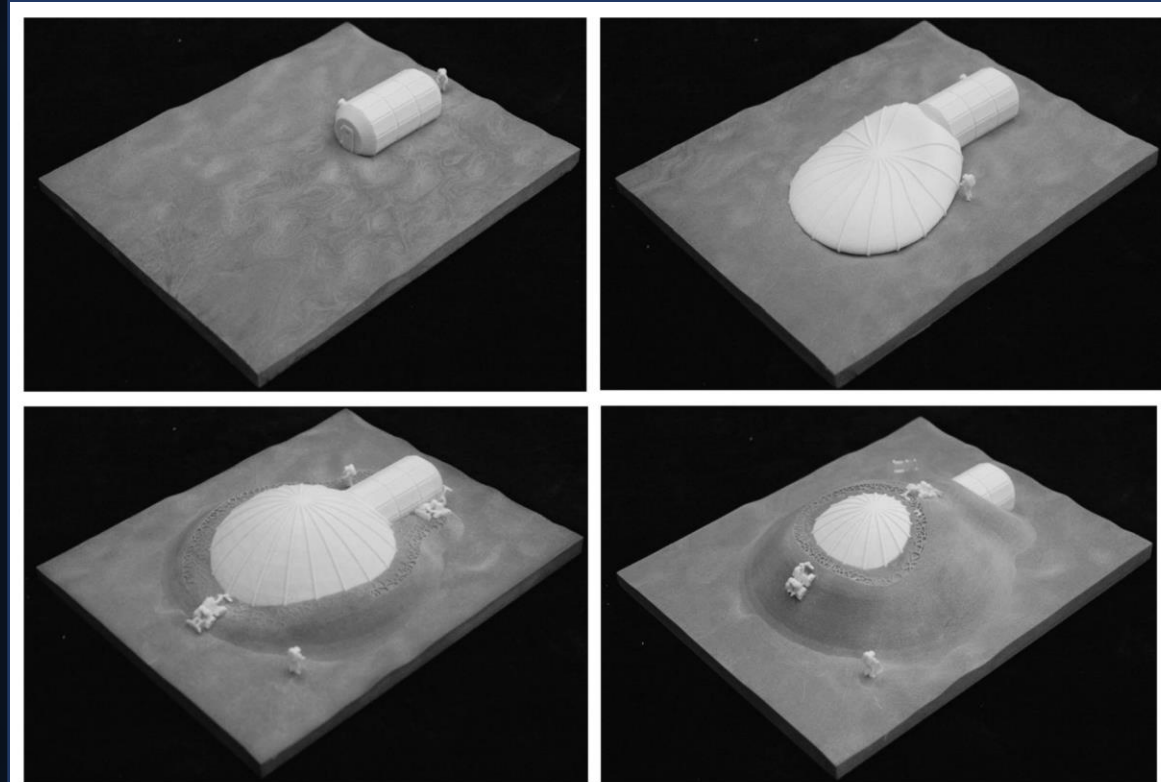


Fig. 1. Exemplar sequence of construction of the lunar outpost by means of two cooperating autonomous vehicles.

Cesaretti, et al., 2014

Feasibility with Current Technology

- RegoLight collaboration project has made bricks from concentrated beams of light in order to test artificial material processing with regolith



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Feasibility with Current Technology



- RegoLight collaboration project has made bricks from concentrated beams of light in order to test artificial **material** processing with regolith
- It takes approximately 5 hours to produce a brick in their lab
- *If a machine on the lunar surface could make up to 50 standard size bricks simultaneously + 100 of these machines ~ 100 days to cover a 12-meter diameter dome with 2-meter layer of regolith (recommended thickness for radiation protection)*

Feasibility with Current Technology



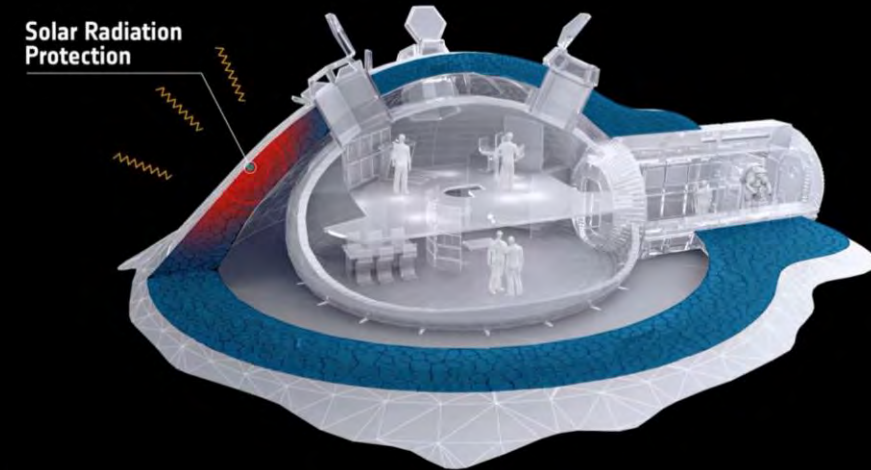
- Samples have been made of regolith
- Bricks have been made of regolith
- Little structural testing has been done
- Scaling is a question that needs to be addressed
- These require a great deal of water, oxygen, power or equipment

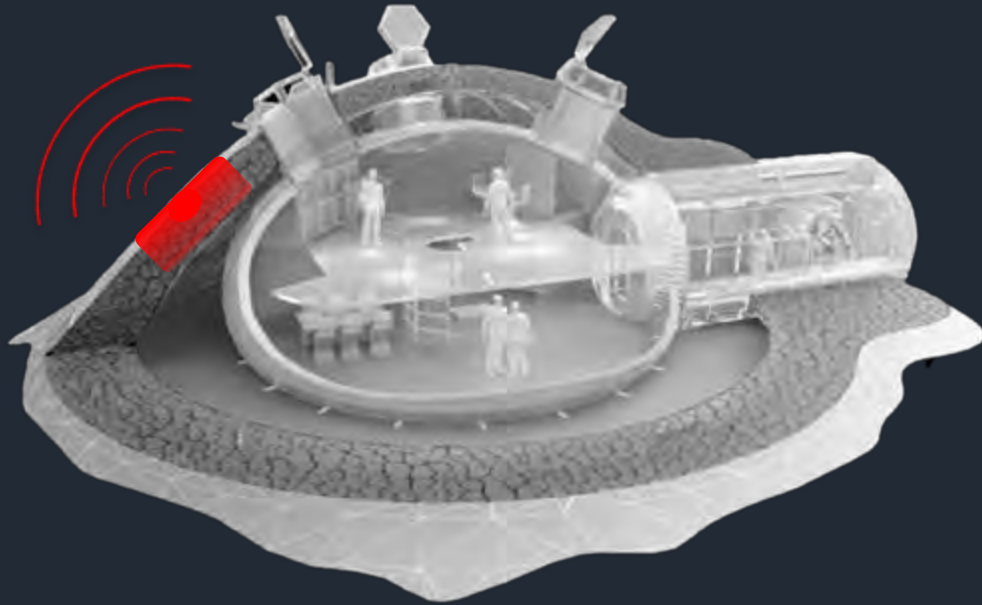
- Autonomous construction is not yet possible, except simple tasks
- Humans would find it difficult to do construction on the Moon in a spacesuit

Key objective: resilience



Credit: European Space Agency



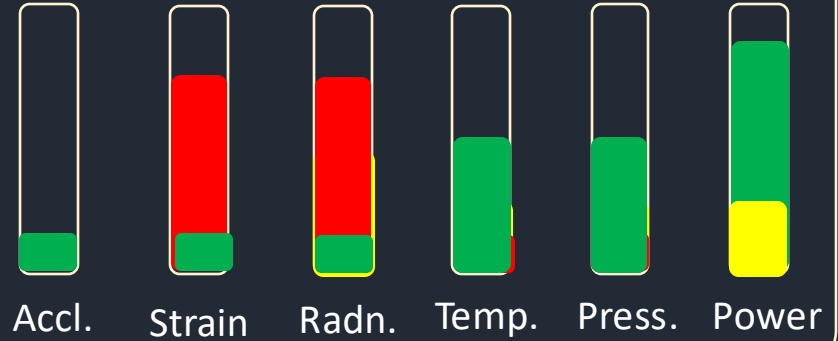


Notification bar

Micrometeoroid impact is detected

SAFE

Monitoring data



Control panel

Structural protection

Thermal protection

Radiation protection

Damage detection

Thermal output ↑↓

Power supply ↑↓

System repair

Questions for you



- What *smart features* would you want in your Lunar habitat?
- What *disruptions* would you be most concerned with?
- What would you want the robots to do?



Thank you!

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VISIT OUR WEBSITE:

<https://www.purdue.edu/rethi/>



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