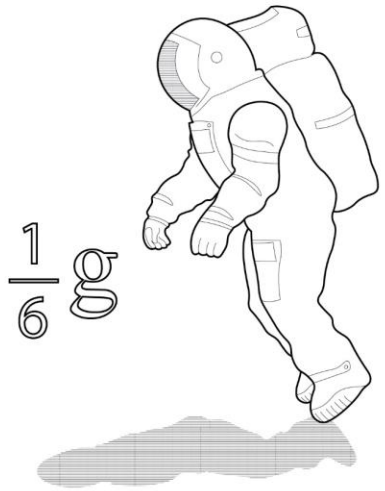
Capsule City on the Moon

Mobile/Stationary hybrid mode of lunar habitat

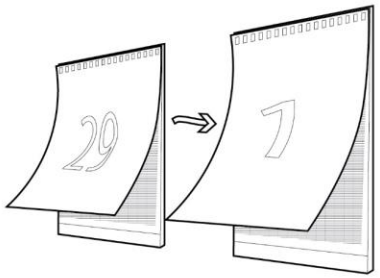
Walter Chung | Design Tutor: Henriette Bier

Lunar Architecture and Infrastructure Graduation Studio AR3CP120

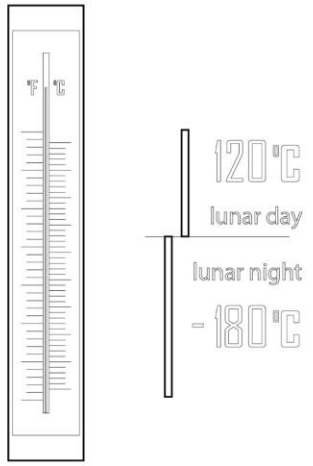
*Harsh **Conditions** on Moon*



One-sixth of gravity on Earth

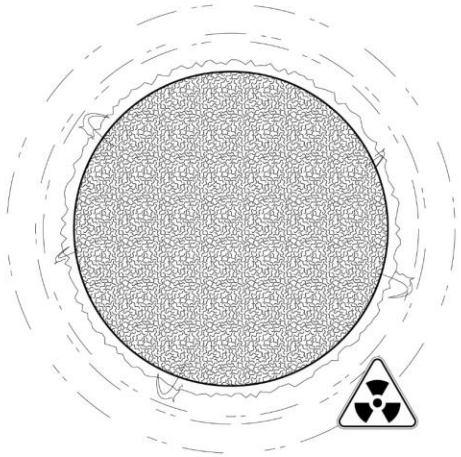


29-day lunar day cycle

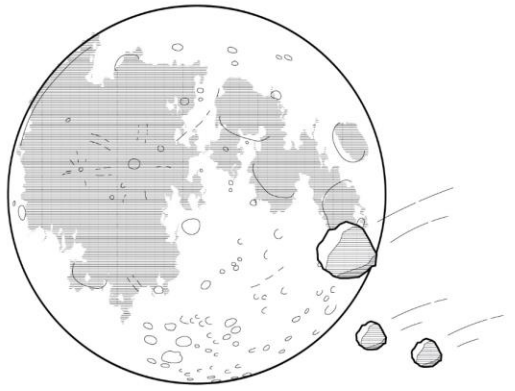


Extreme temperatures

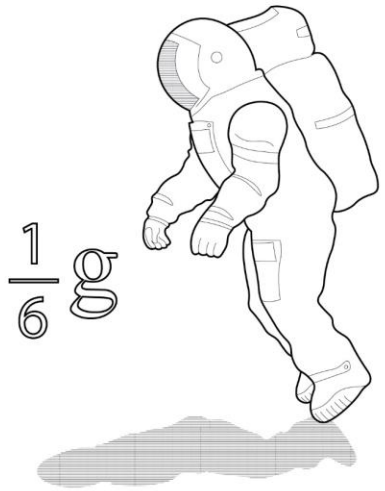
Lack of atmosphere



High level of radiation



Micrometeorites



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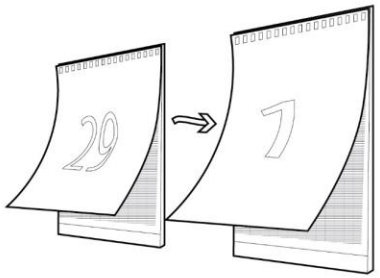

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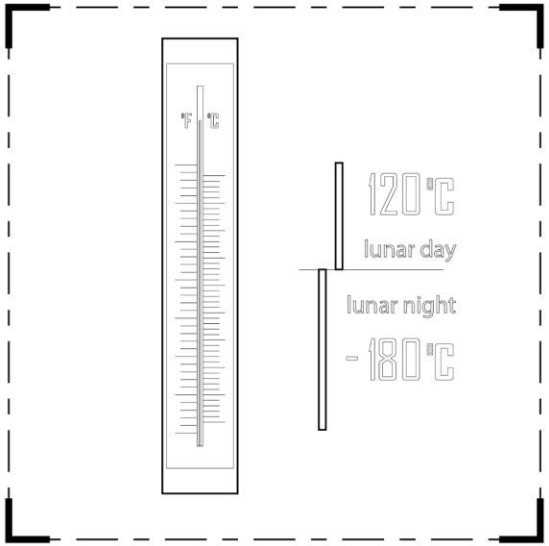

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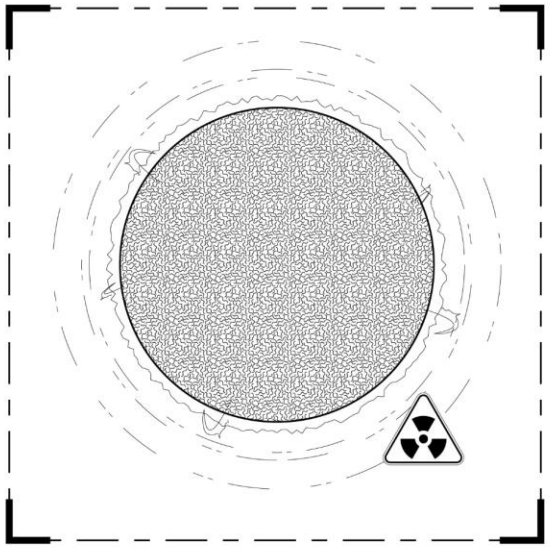

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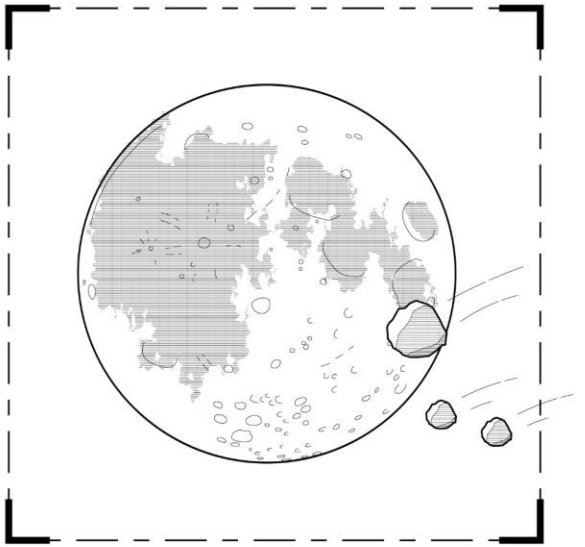
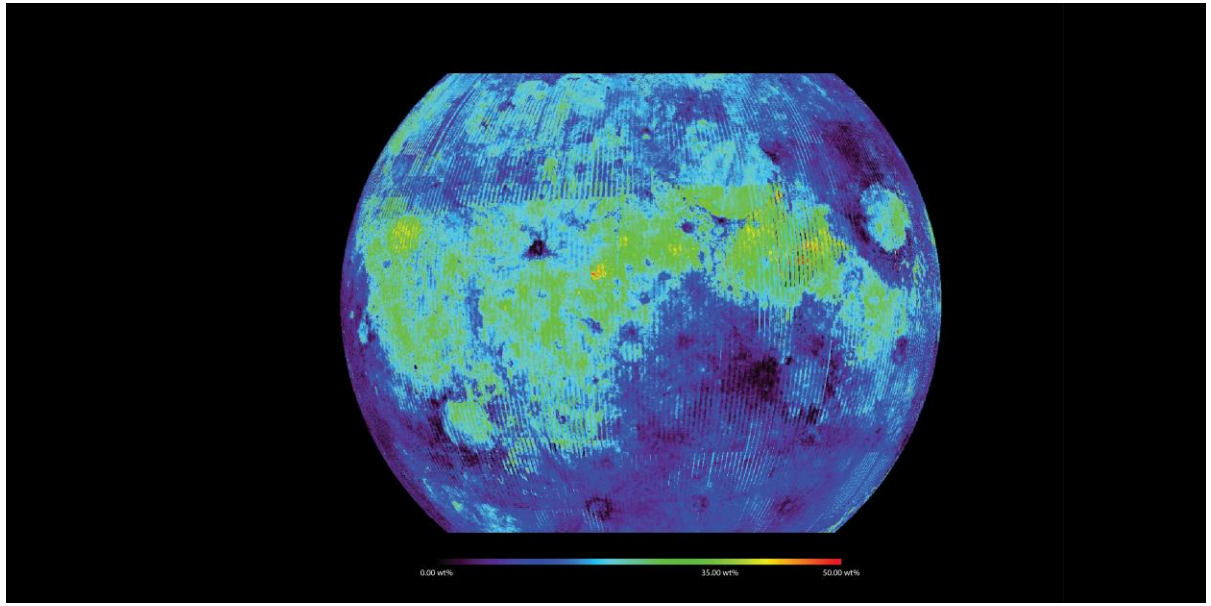


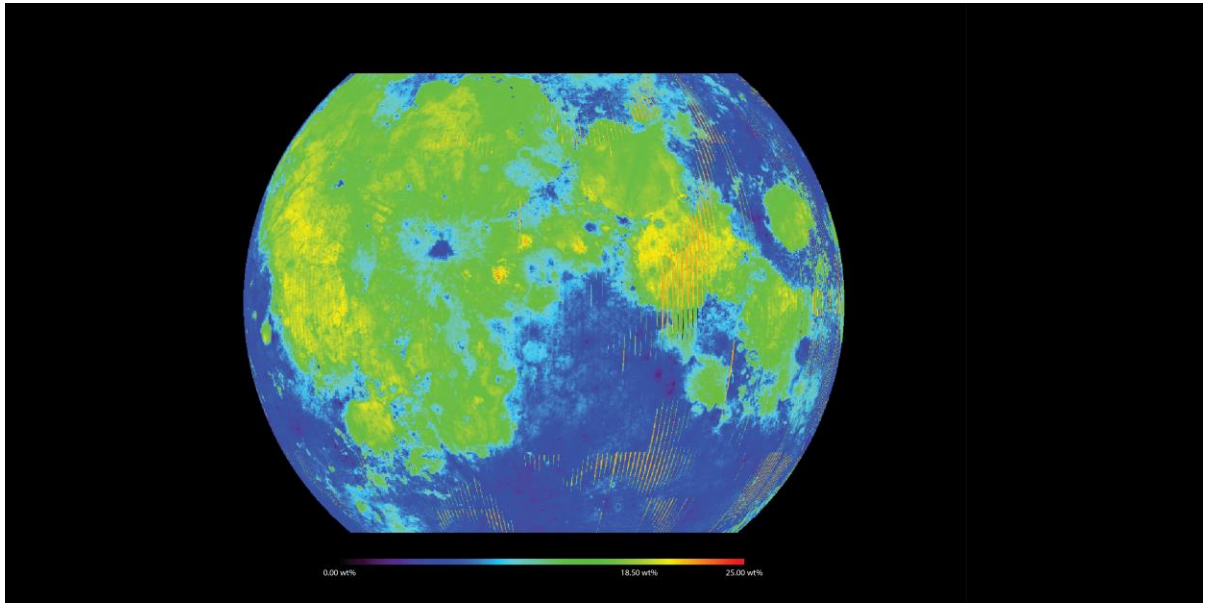
Micrometeorites

Lunar Base and 3D Printed Habitat on Mars | Hassell Studio

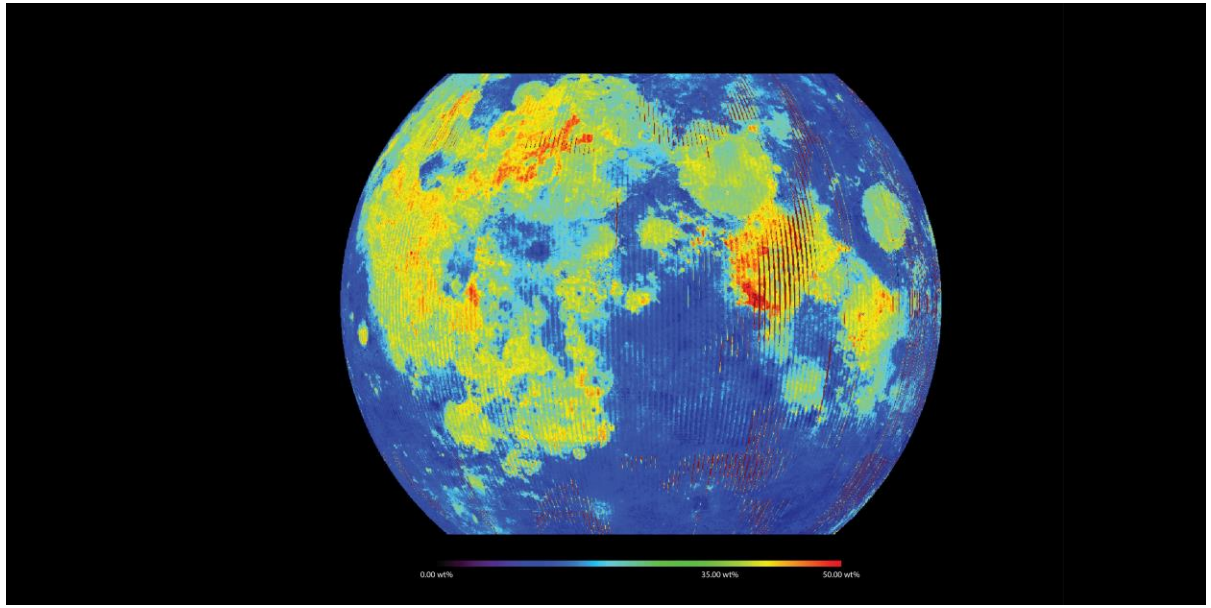
Scattered ***Resources***



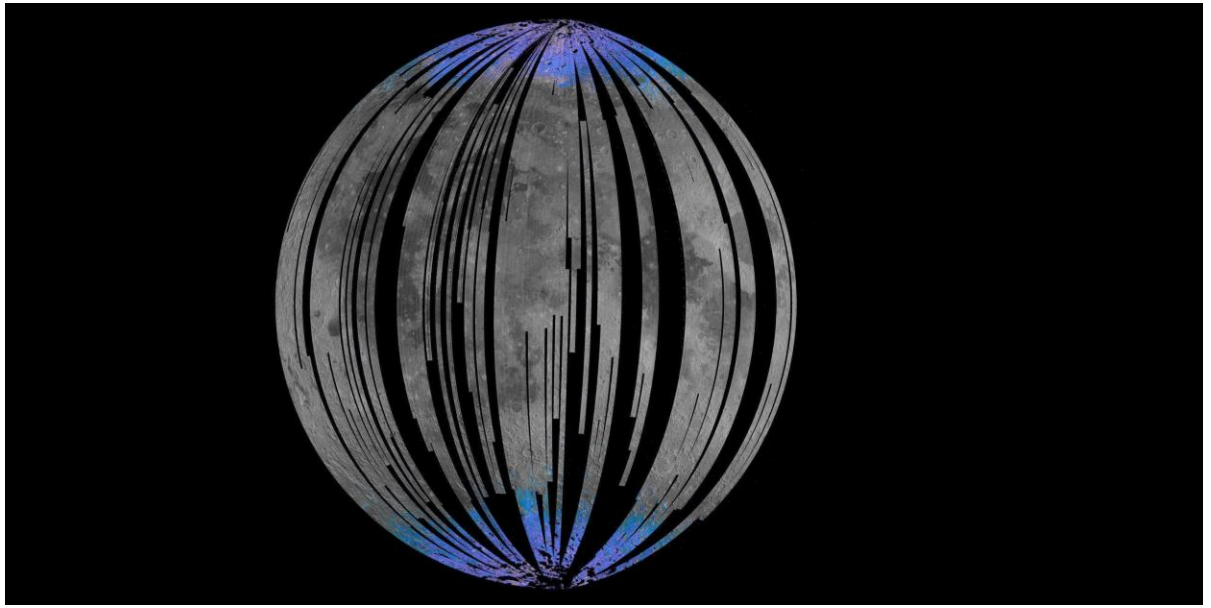
Orthopyroxene



Iron oxides

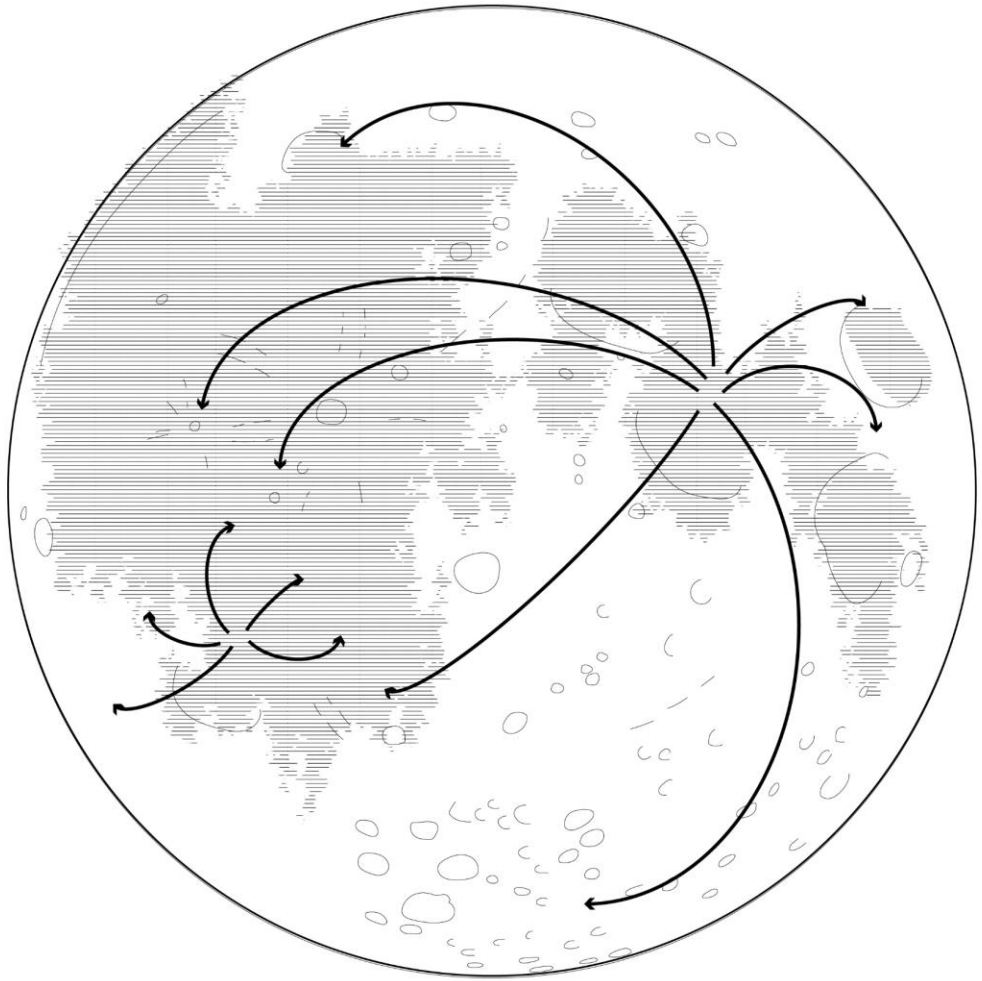


Clinopyroxene



Water

Scattered Resources on Moon



Mobility demand for resource extraction or mission

Mobile lunar base?

	Stationary Lunar Base	Mobile Lunar Base
Advantages	Accumulation of assets in one location / economy of agglomeration.	Greater mobility of assets affords superior exploration opportunities and operations.
	Economies of scale in one location.	Makes best advantage of commonality and economy of scale through mass production.
	Potential for larger, permanently situated habitats (e.g. inflatables).	Ability to easily modularize the Habot modules to match launch vehicle capacity.
	Potential to use regolith as ISRU radiation & micrometeoroid shielding.	Greater systemic redundancy.
	Ability to situate power supply permanently (i.e. nuclear reactor) in a crater near the base, and to fill in the crater with regolith for final burial and disposal.	Ability to bring the science lab to multiple sites of interest – excursions are not "just picking up rocks."
		Single type of EVA access module for both excursion rovers and base.
		Can establish a Landing Zone at each new location and moving Habot units from the Landing Zone is not a burden.
Disadvantages	Program RISK of putting the fixed base in the "wrong" location and needing to support distant science field operations.	Risk of a roving base not returning to the ascent vehicle.
	Necessity for dissimilar heavy equipment movers and pressurized rovers.	Risk of reconnecting modules at new base location.
	Cost and burden of moving all modules and equipment from the Landing Zone.	Increased complexity.
	Risk of stranding a rover excursion crew far from the base.	Must carry its own radiation shielding.
	Ability to satisfy only a small subset of the scientific constituencies.	

Comparison between stationary lunar base and mobile lunar base

Advantages of mobile lunar base

- From body enclosure to habitat enclosure
- Mobility and flexibility of assets
- Multiple sites of interest
- Avoid the risk of a fixed base in the wrong location

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Comparison between stationary lunar base and mobile lunar base

Concerns of mobile lunar base

- Use of regolith as radiation shielding
  - Carbon radiation shielding as a substitute

Carbon Radiation Shielding for the Habot Mobile Lunar Base

Marc M. Cohen
Advanced Projects Branch, Space Projects Division, NASA-Ames Research Center

ABSTRACT

Radiation is the leading showstopper for long duration human exploration of the lunar surface. The need for an effective and safe radiation shielding material has become the "Holy Grail" of radiation protection research. This paper reports the results for one material in particular – carbon – in the "Bioshield" particle accelerator test of candidate radiation shielding at Brookhaven National Laboratory, sponsored jointly by NASA and the Italian Space Agency. Shielding samples were bombarded by both Iron and Titanium nuclei beams at1 GeV/n relativistic energy. This paper reports the results for Fe. The target behind the shielding was a lymphocyte culture; created using advanced cytogenetic techniques (premature chromosome condensation and fluorescence in situ hybridization). The shielding samples included aluminum, PMMA acrylic/Lucite, polyethylene, and lead.

Solar Particle Event (SPE), and secondary neutron risks and environment on the lunar surface.

An essential aspect of this research is that it grows from a specific project in architectural design research to solve the particular problem of providing radiation shielding for the Habot module during its mission on the lunar surface. It is not an effort to find the ideal radiation shielding material for all missions, modules, or applications. If other habitats, modules, or vehicles benefit from this research, that is a bonus, but it is not the criteria for success.

The ubiquitous requirement for the Habot is that it is mobile. This mobility requirement means that the shielding must be sufficiently compact and lightweight to not impede the design or versatility of the Habot module.

HABOT MOBILE LUNAR BASE

Carbon Radiation Shielding

Cohen, M., "Carbon Radiation Shielding for the Habot Mobile Lunar Base," SAE Technical Paper 2004-01-2323, 2004, https://doi.org/10.4271/2004-01-2323.

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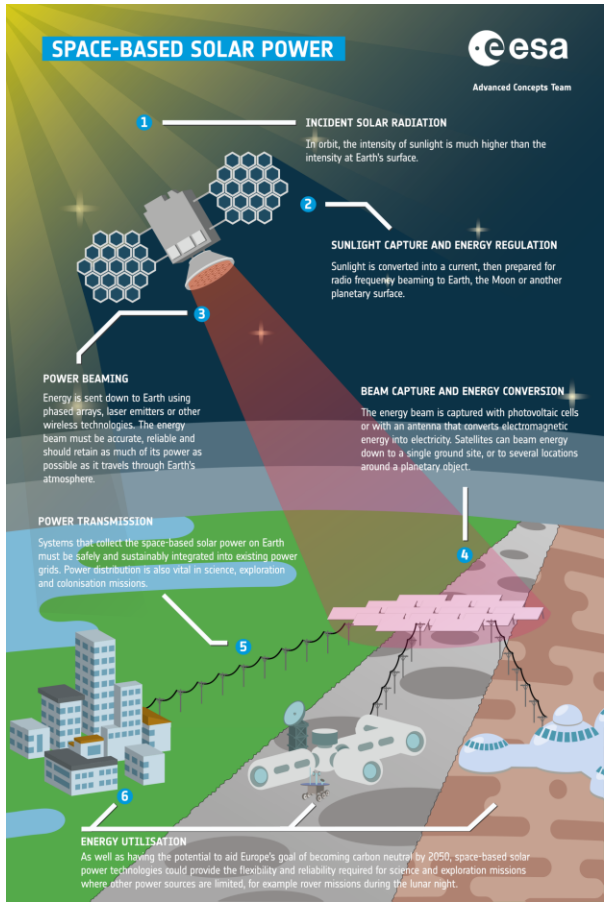
Concerns of mobile lunar base

- Permanent location for nuclear reactor power supply
  - Power beaming satellite as a mobile solution



Space-based solar power | European Space Agency
https://www.esa.int/ESA_Multimedia/Images/2020/08/Space-based_solar_power

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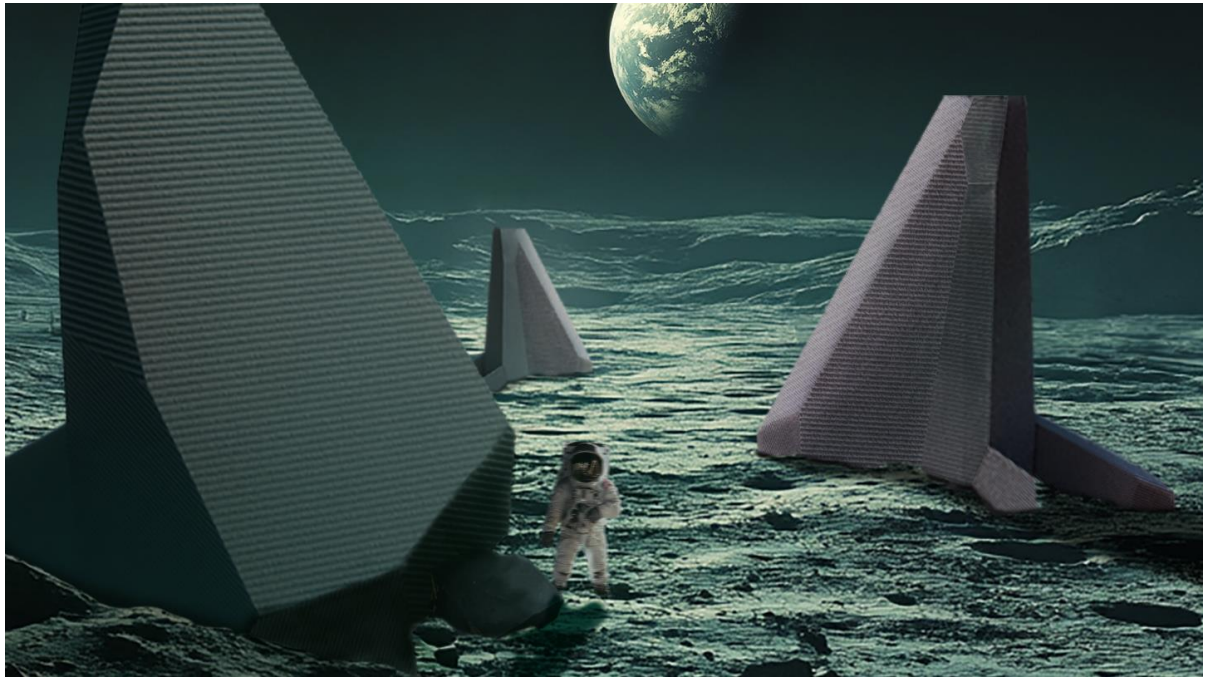
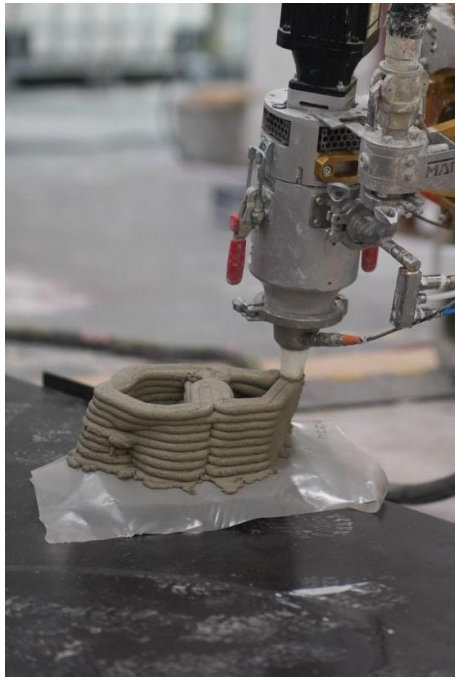
Mobile *lunar base +* ***Stationary*** *lunar base*

How could a hybrid system of mobile and stationary architecture be implemented in the lunar habitat?

Stationary lunar base

Workshop Reflection





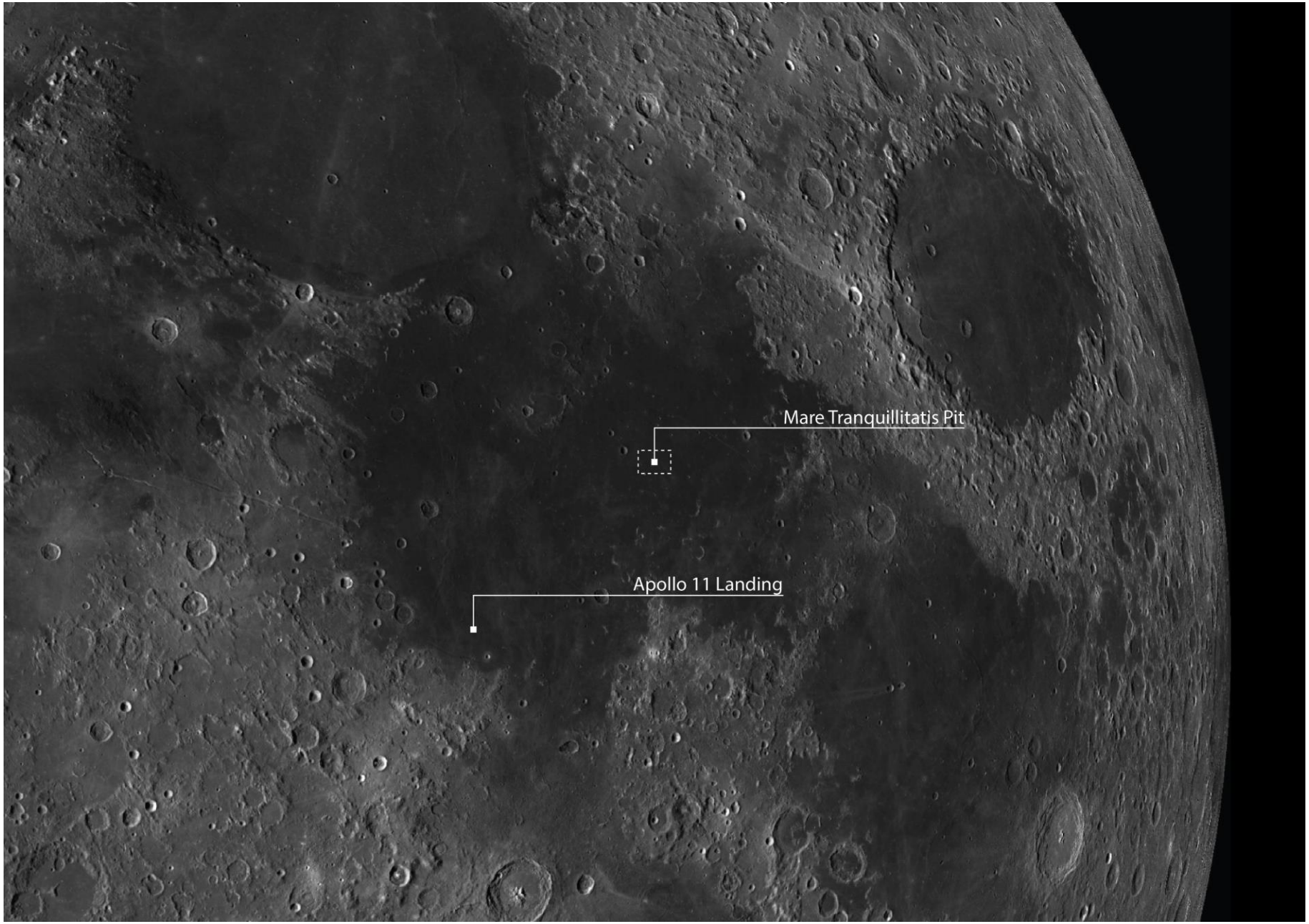
Excavation as a part of construction

Vertical massing to support stacking

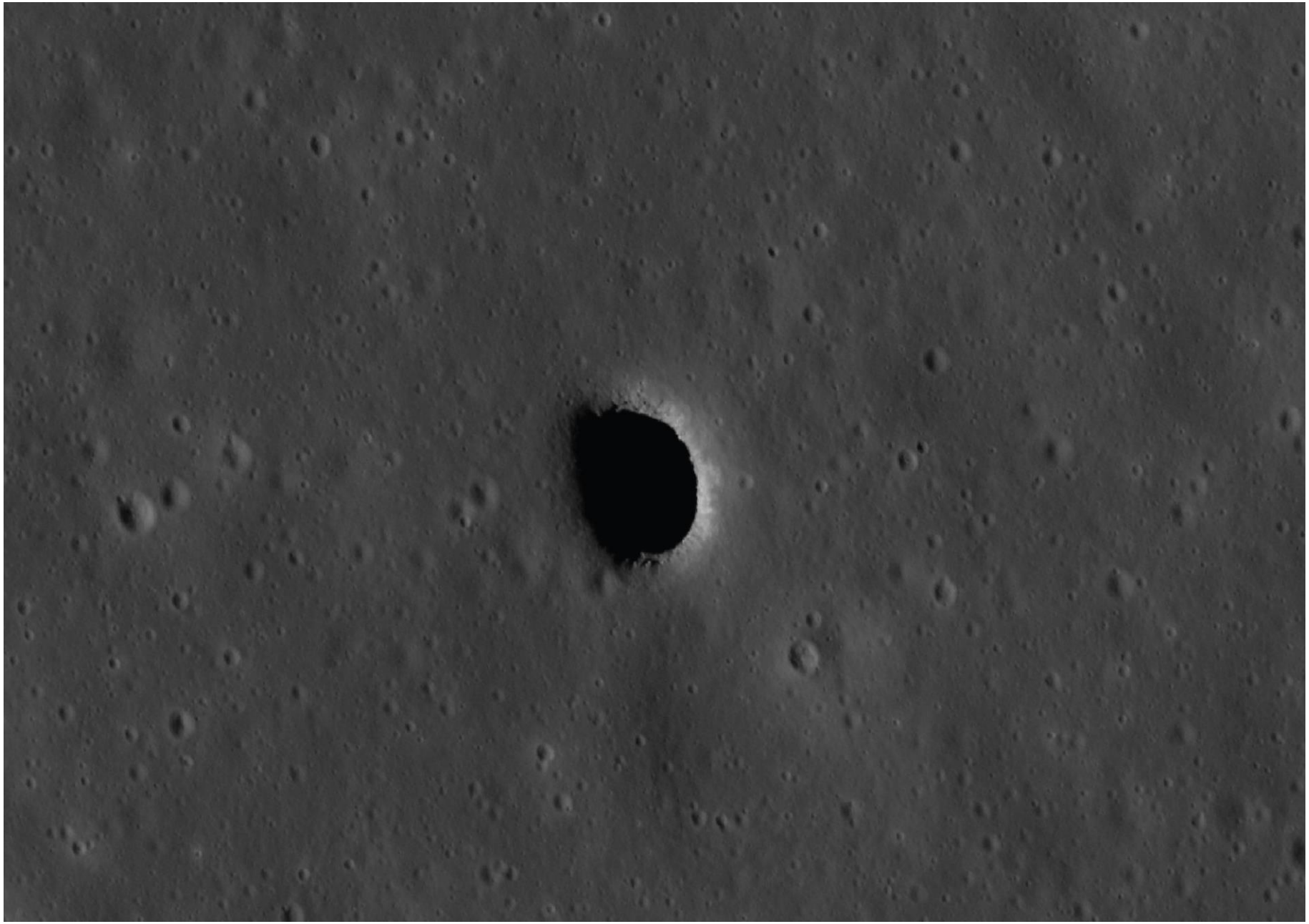
Stationary lunar base

Existing Topography *to Avoid Excavation*

Exploration on lunar lava tubes



Mare Tranquillitatis Pit (MTP)



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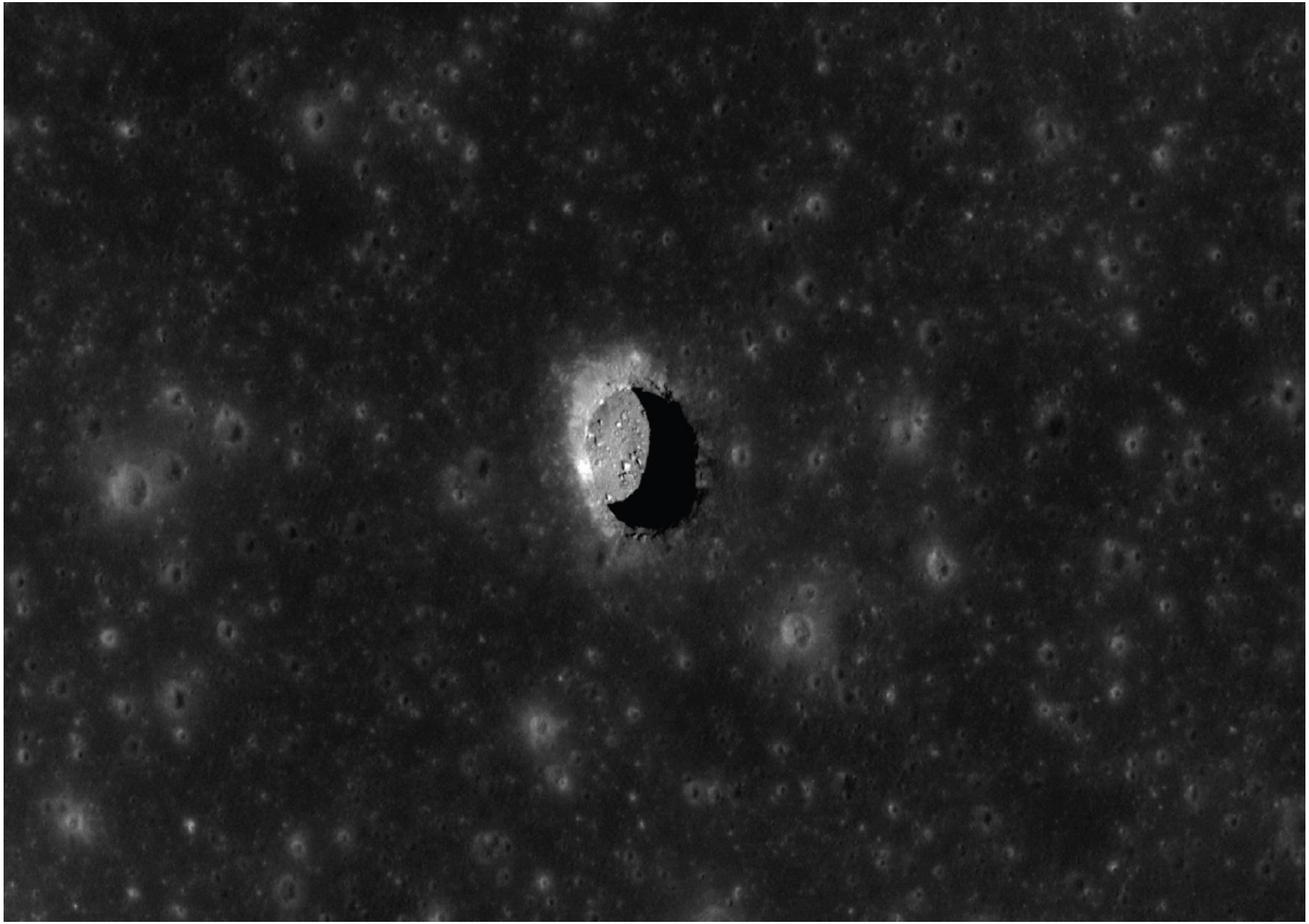

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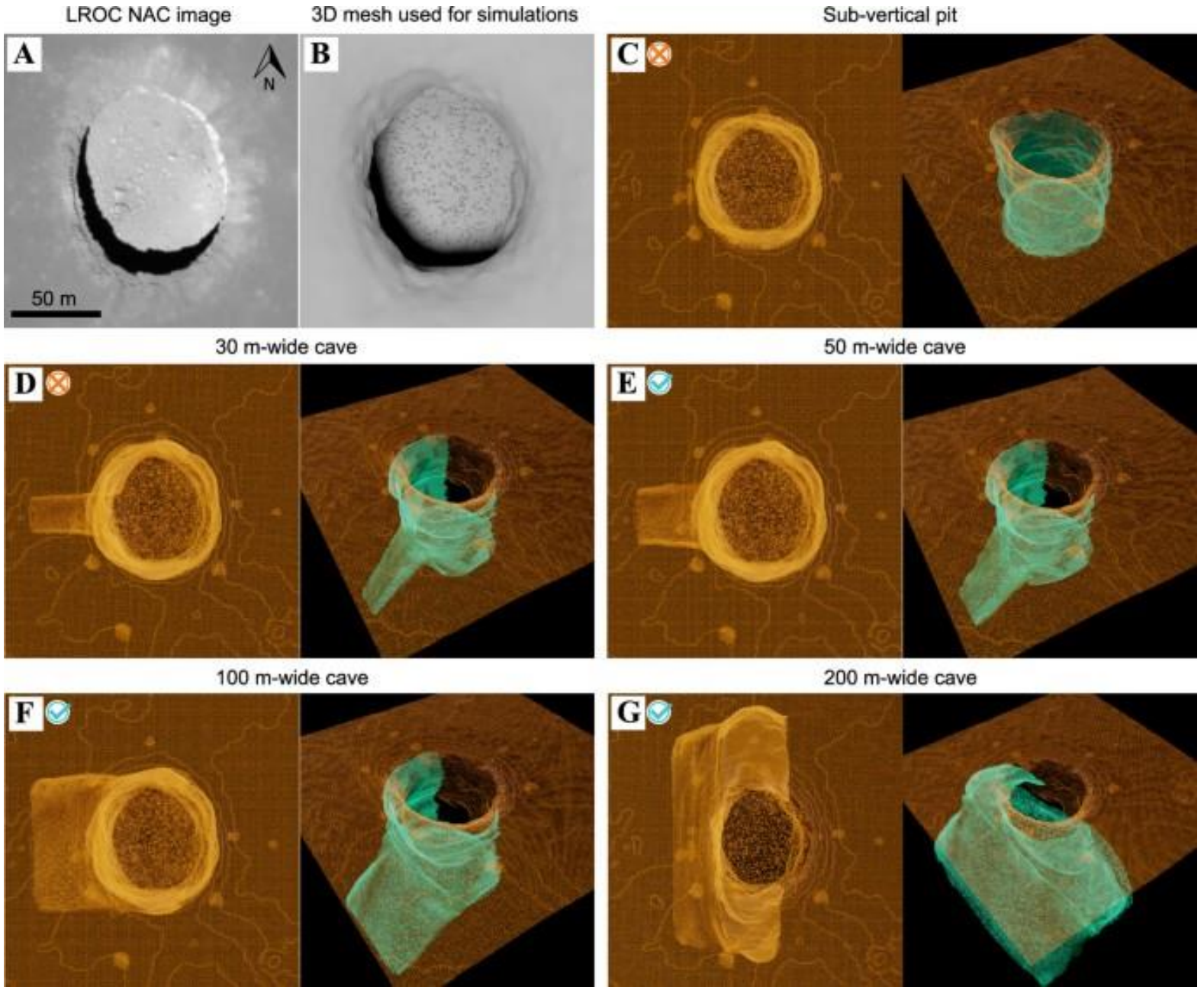

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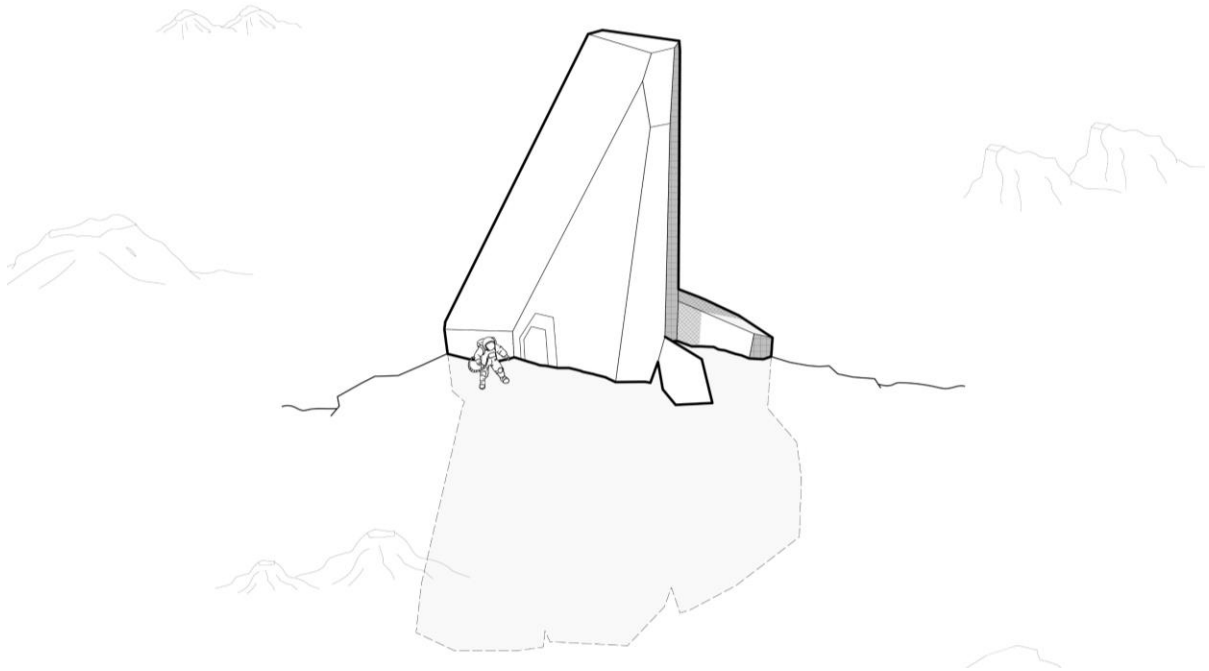
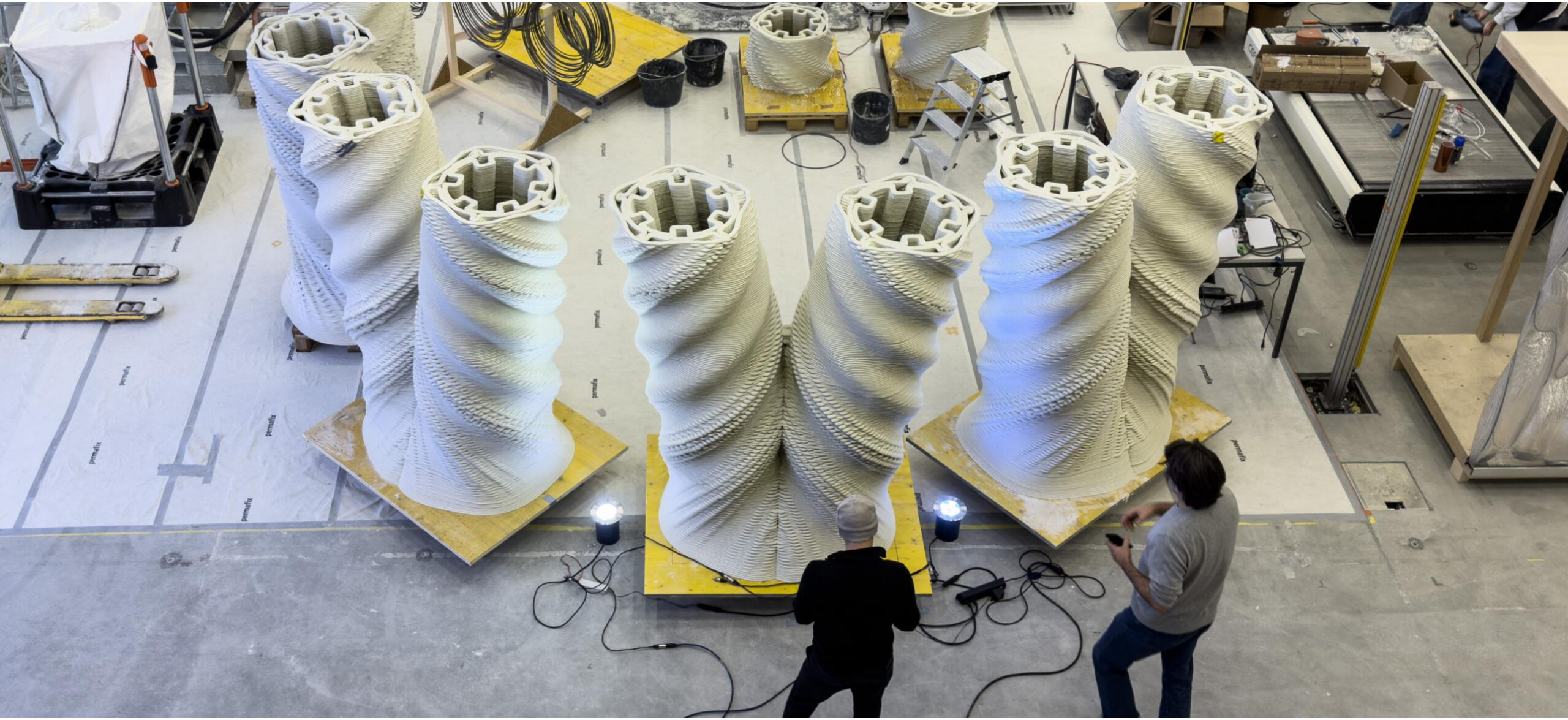


Vertical massing to support stacking

Stationary lunar base

*Vertical Development of **Regolith Printing** Construction*

- Structure
  - 5 levels consisting of 32 3D-printed columns
  - Columns are reinforced and fully structural
- Dimension
  - Height: 30m
  - Diameter: 7m to 9m
  - Printing layer height:10mm



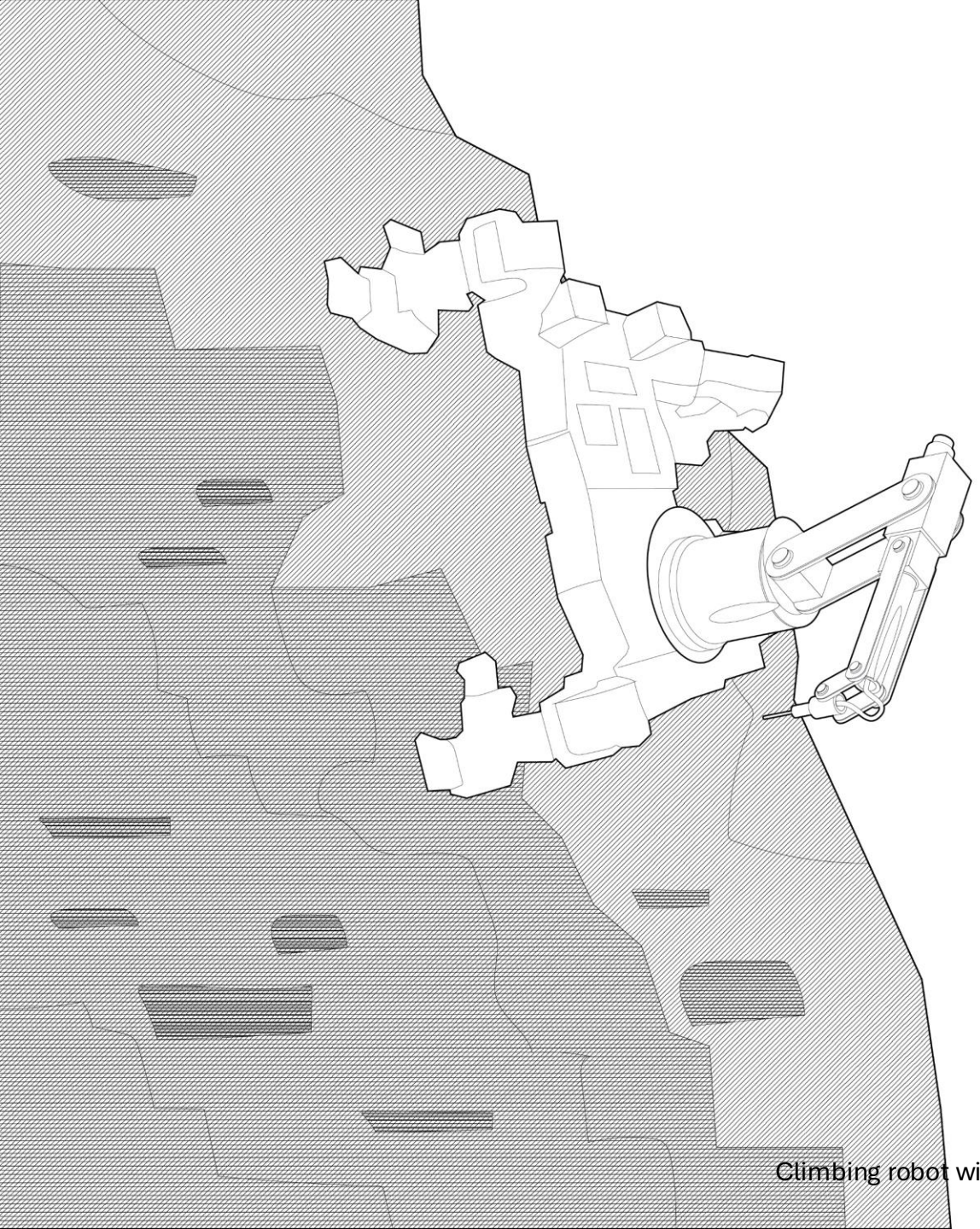
Tor Alva | ETH Zurich

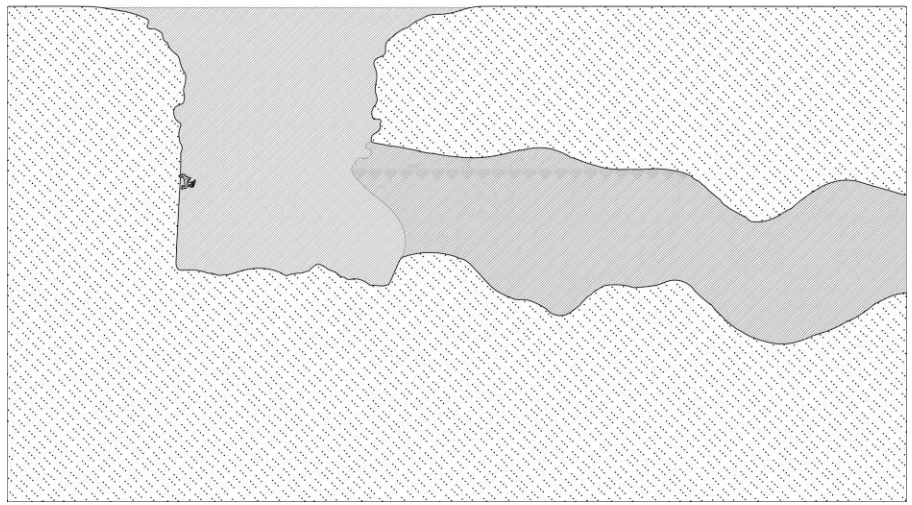
LORIS climbing robot

+

Mobile 3D printer | TU Delft Master Thesis Lorenzo Worang

Climbing robot with 3D printing inside lunar lava tubes

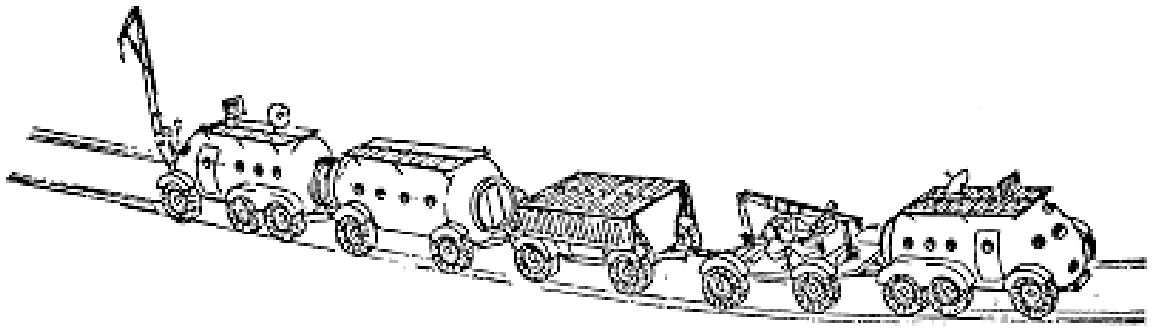




Climbing robot with 3D printing inside lunar lava tubes

Mobile lunar base

Modular Reconfiguration



“Tractor Train” and “Wagon Train” concepts

Cohen, M., Mobile Lunar and Planetary Bases. https://spacearchitect.org/pubs/AIAA-2003-6280.pdf

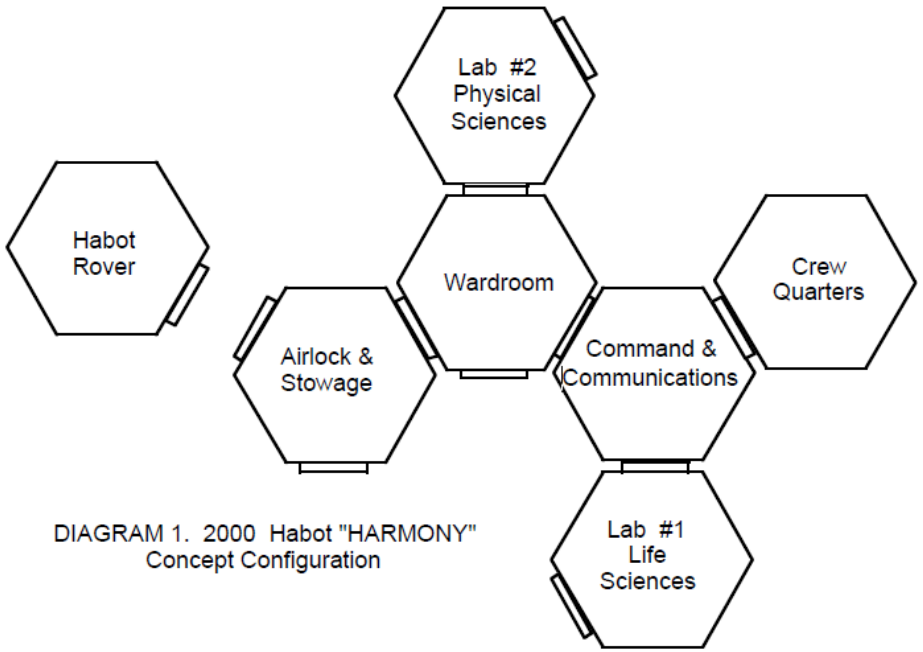


DIAGRAM 1. 2000 Habot "HARMONY"
Concept Configuration

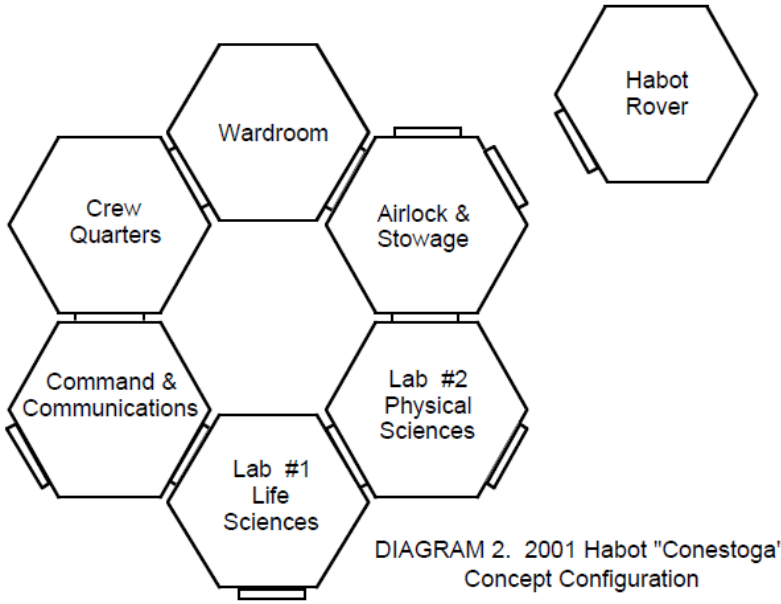
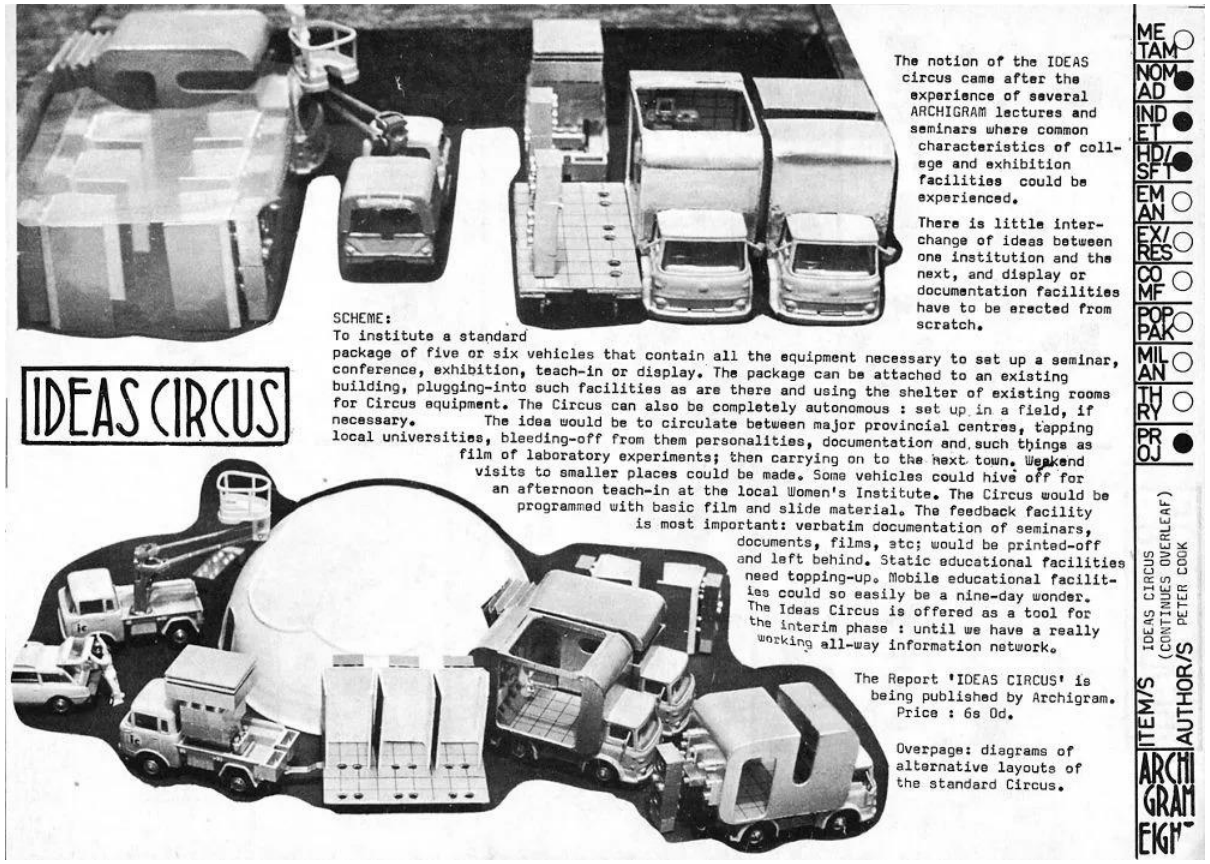


DIAGRAM 2. 2001 Habot "Conestoga"
Concept Configuration

Habot Conceptual Configuration Plan

Cohen, M., Mobile Lunar and Planetary Bases. https://spacearchitect.org/pubs/AIAA-2003-6280.pdf



IDEAS CIRCUS

The notion of the IDEAS circus came after the experience of several ARCHIGRAM lectures and seminars where common characteristics of college and exhibition facilities could be experienced.

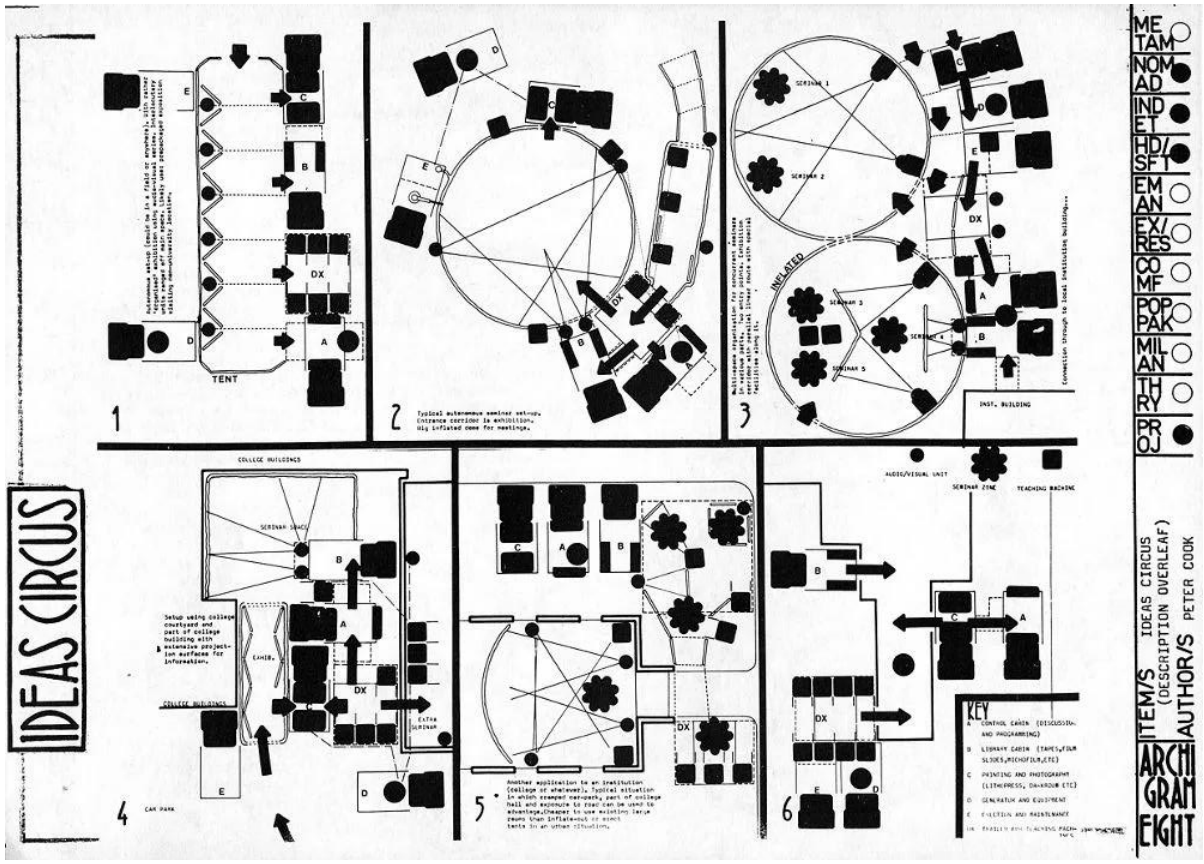
There is little interchange of ideas between one institution and the next, and display or documentation facilities have to be erected from scratch.

SCHEME:
To institute a standard package of five or six vehicles that contain all the equipment necessary to set up a seminar, conference, exhibition, teach-in or display. The package can be attached to an existing building, plugging-into such facilities as are there and using the shelter of existing rooms for Circus equipment. The Circus can also be completely autonomous : set up in a field, if necessary. The idea would be to circulate between major provincial centres, tapping local universities, bleeding-off from them personalities, documentation and such things as film of laboratory experiments; then carrying on to the next town. Weekend visits to smaller places could be made. Some vehicles could hive off for an afternoon teach-in at the local Women's Institute. The Circus would be programmed with basic film and slide material. The feedback facility is most important: verbatim documentation of seminars, documents, films, etc; would be printed-off and left behind. Static educational facilities need topping-up. Mobile educational facilities could so easily be a nine-day wonder. The Ideas Circus is offered as a tool for the interim phase : until we have a really working all-way information network.

The Report 'IDEAS CIRCUS' is being published by Archigram. Price : 6s 0d.

Overpage: diagrams of alternative layouts of the standard Circus.

ITEM/S IDEAS CIRCUS (CONTINUES OVERLEAF)
AUTHOR/S PETER COOK
ARCHIGRAM EIGHT



Ideas Circus | Archigram

Archigram Issue no. 8 (1968)

Scenarios and Volume Study

Astronomical Observation

Resource Extraction

Distant Geological Mapping

Laboratory Experimentation

Daily Living

1-2 person light task	**4 person heavy duty**	**Stationary living**
Rover Terrain Mapping	Resource Extraction Distant Geological Sampling	Laboratory Experimentation Daily Living
Simple tasks/ *Can be completed in short period*	*Need to carry heavy loads/* *Require more human inspection*	*Equipment that cannot be moved*

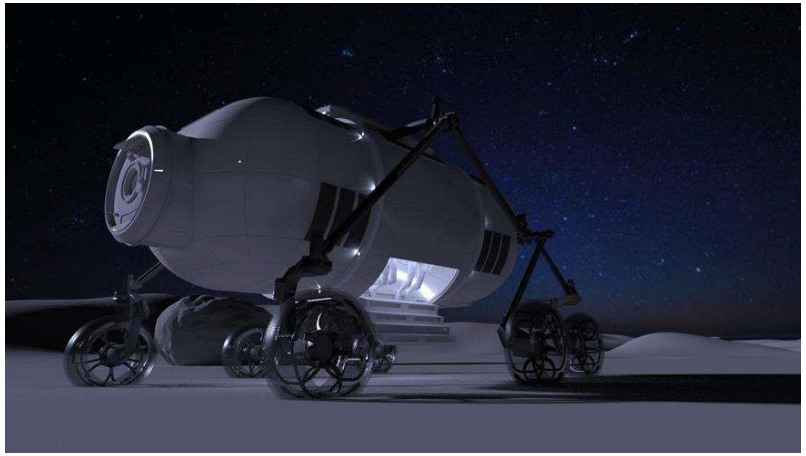
Stages of Construction

MOBILE

STATIONARY

LUNARK | SAGA Architects

2-person



LADE | AIAA

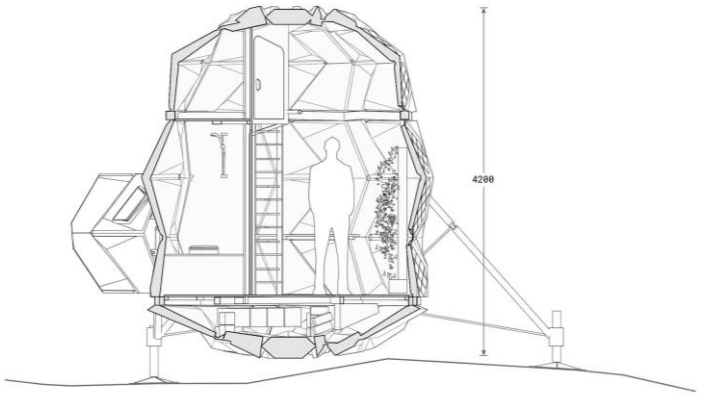
4-person

SURFACE HABITAT | AIAA

4-6 person

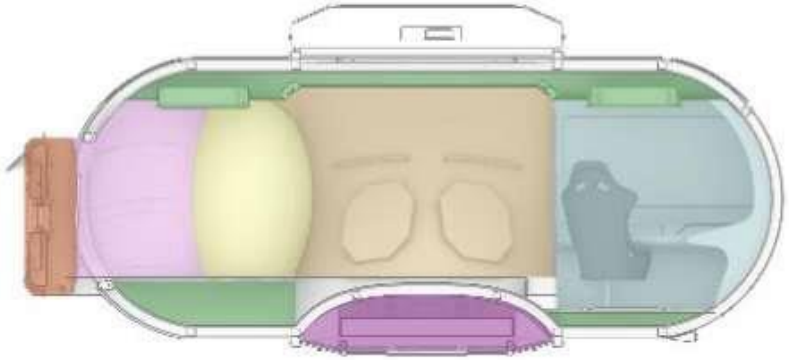
MOBILE

STATIONARY



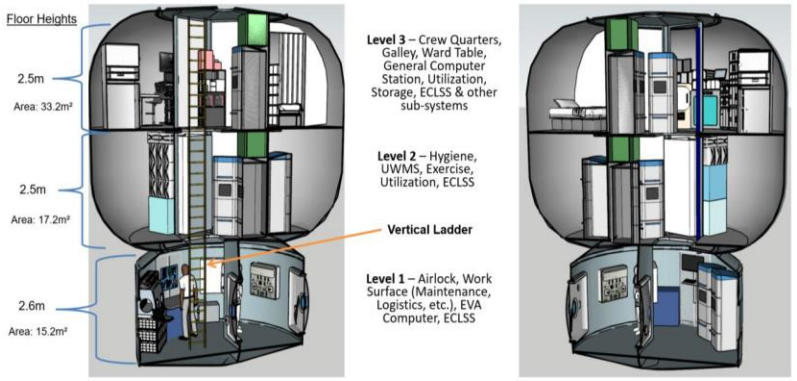
LUNARK | SAGA Architects

2-person



LADE | AIAA

4-person



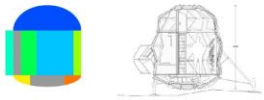
SURFACE HABITAT | AIAA

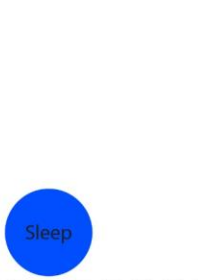
4-6 person

LUNARK 2-person

Sleep
Airlock Storage Bathroom Work ECLSS
Waste Storage Batteries

17m3

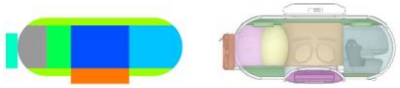


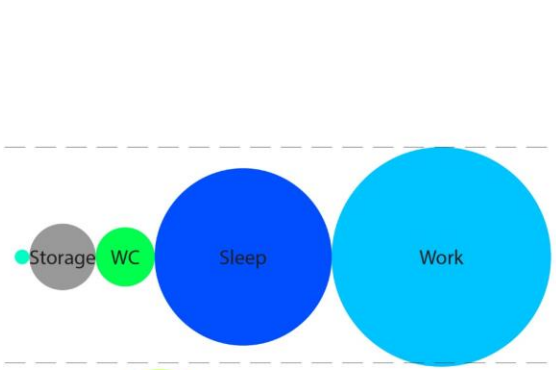


LADE 4-person

ECLSS
Airlock Storage Bathroom Sleep Work
Batteries ECLSS

54m3

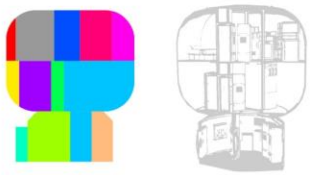


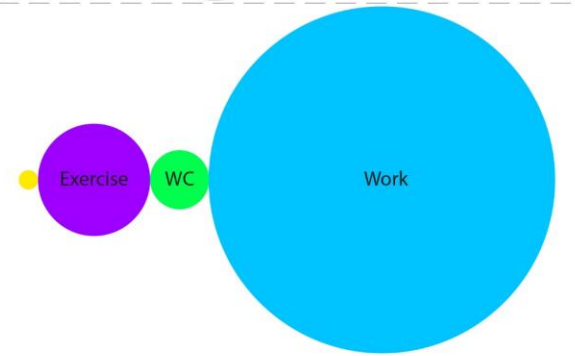


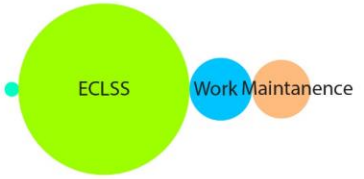
SURFACE HABITAT 4-6 person | 30-day mission

Meal Prep Storage Sleep Laboratory Medical
Waste Exercise Bathroom Work
Airlock Work Maintanence

162m3







Section comparison

LUNARK 2-person

Sleep
Airlock Storage Bathroom Work ECLSS
Waste Storage Batteries

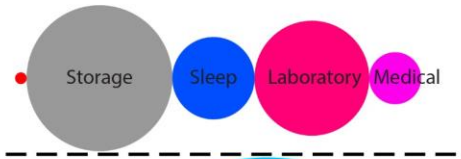
LADE 4-person

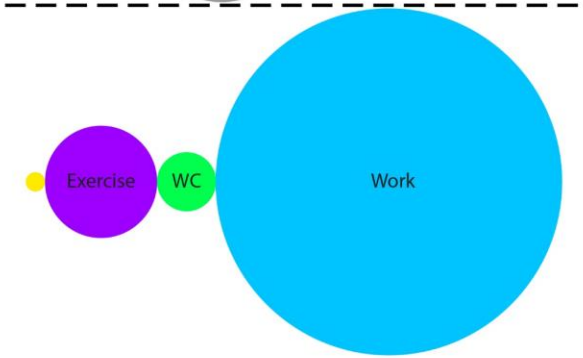
ECLSS
Airlock Storage Bathroom Sleep Work
Batteries ECLSS

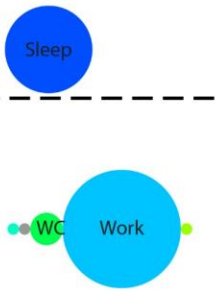
SURFACE HABITAT 4-6 person | 30-day mission

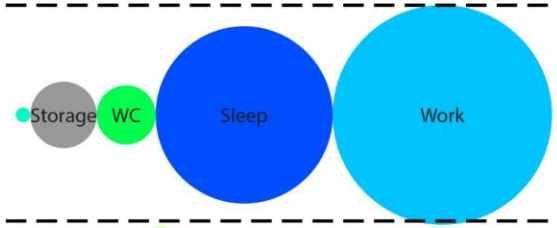
Meal Prep Storage Sleep Laboratory Medical
Waste Exercise Bathroom Work
Airlock Work Maintanence

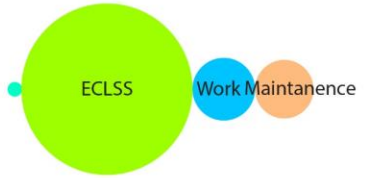
Multi-level Approach











LUNARK 2-person

Sleep
Airlock Storage Bathroom Work ECLSS
Waste Storage Batteries

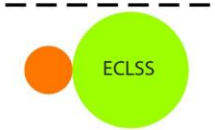
LADE 4-person

ECLSS
Airlock Storage Bathroom Sleep Work
Batteries ECLSS

SURFACE HABITAT 4-6 person | 30-day mission

Meal Prep Storage Sleep Laboratory Medical
Waste Exercise Bathroom Work
Airlock Work Maintanence

Underfloor



LUNARK 2-person

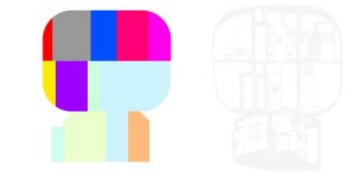
Sleep
Airlock Storage Bathroom Work ECLSS
Waste Storage Batteries

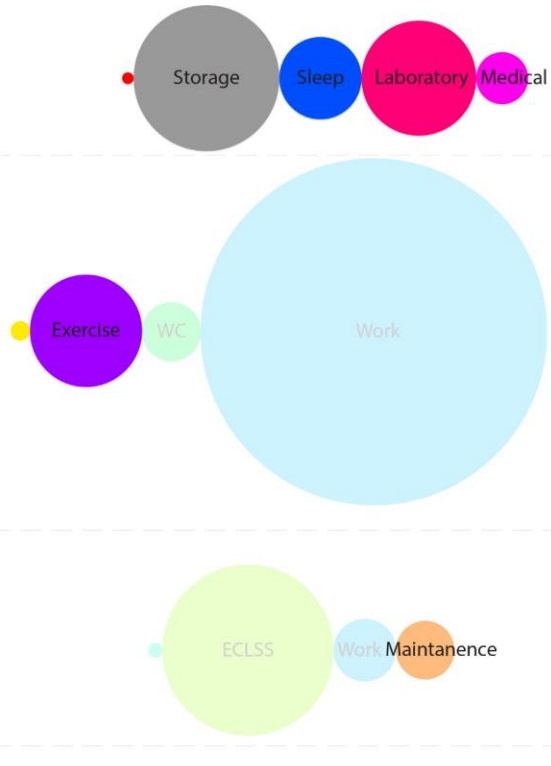
LADE 4-person

ECLSS
Airlock Storage Bathroom Sleep Work
Batteries ECLSS

SURFACE HABITAT 4-6 person | 30-day mission

Meal Prep Storage Sleep Laboratory Medical
Waste Exercise Bathroom Work
Airlock Work Maintanence

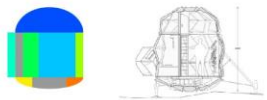




LUNARK 2-person

Sleep
Airlock Storage Bathroom Work ECLSS
Waste Storage Batteries

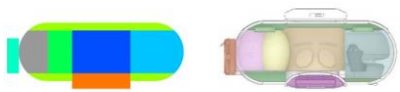
17/2 = 8.5m3



LADE 4-person

ECLSS
Airlock Storage Bathroom Sleep Work
Batteries ECLSS

54/4 = 13.5m3



<<<< *80m3*

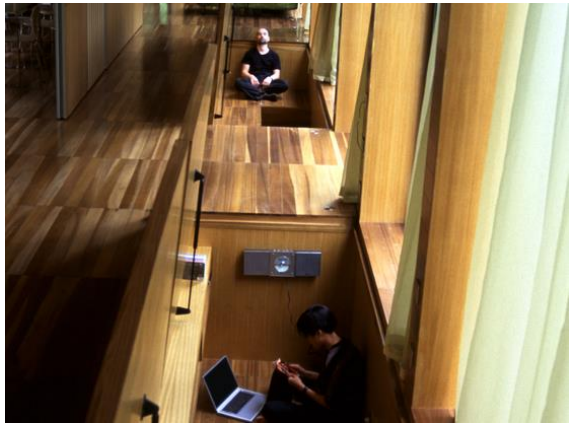
As recommended

Section comparison

User Experience

Relatively confined space especially for mobile units.
How to make it more interesting?

Figure 1: chaise longue made of thermoplastic elastome
the shape change from 'sitting' to 'lying' is obtaine



ers (TPE) fabricated via robotic additive manufacturing;
d by tuning the stiffness through material deposition

Rolling Architecture

- Roll It experimental housing
  - Flexible space within a minimum housing unit
- What if the housing module can roll

Roll It experimental housing, University of Karlsruhe

Roll It experimental housing, University of Karlsruhe

On Casters/Wheels

- Shelves modules
- Bedroom modules

Shelves modules by PKMN Architectures


Bedroom modules by Ruetemple

Compressing

- Changing volume by compressing?

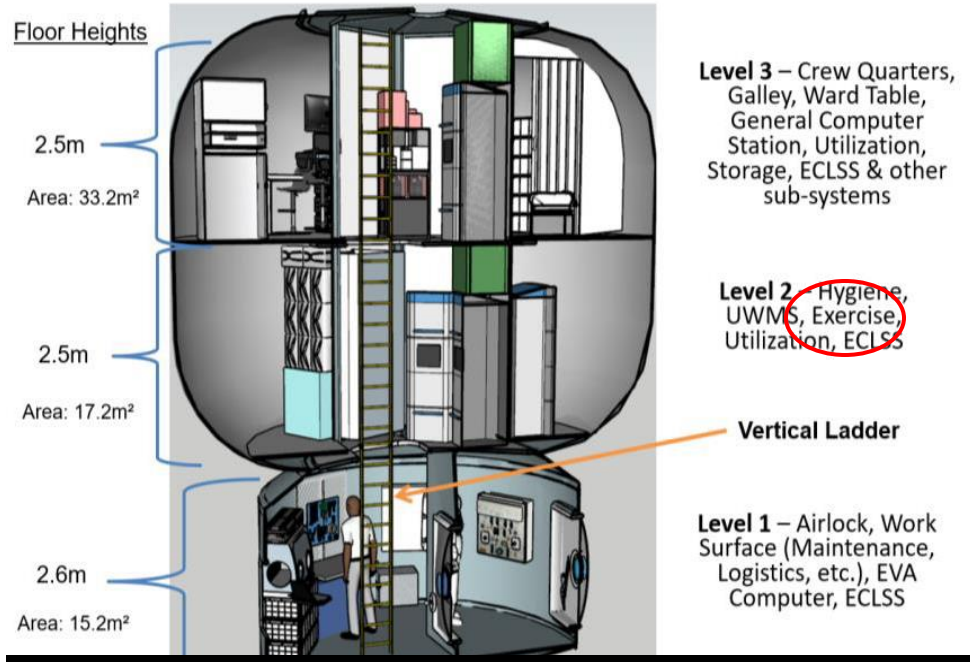
Variable Stiffness Chair, TU Delft

Variable Stiffness Chair, TU Delft

Inflating

- Changing volume by inflating?
- Open spaces that does not require fix equipments
    - i.e. Stretching and exercise spaces

Surface Habitat, AIAA



Surface Habitat, AIAA

Folding

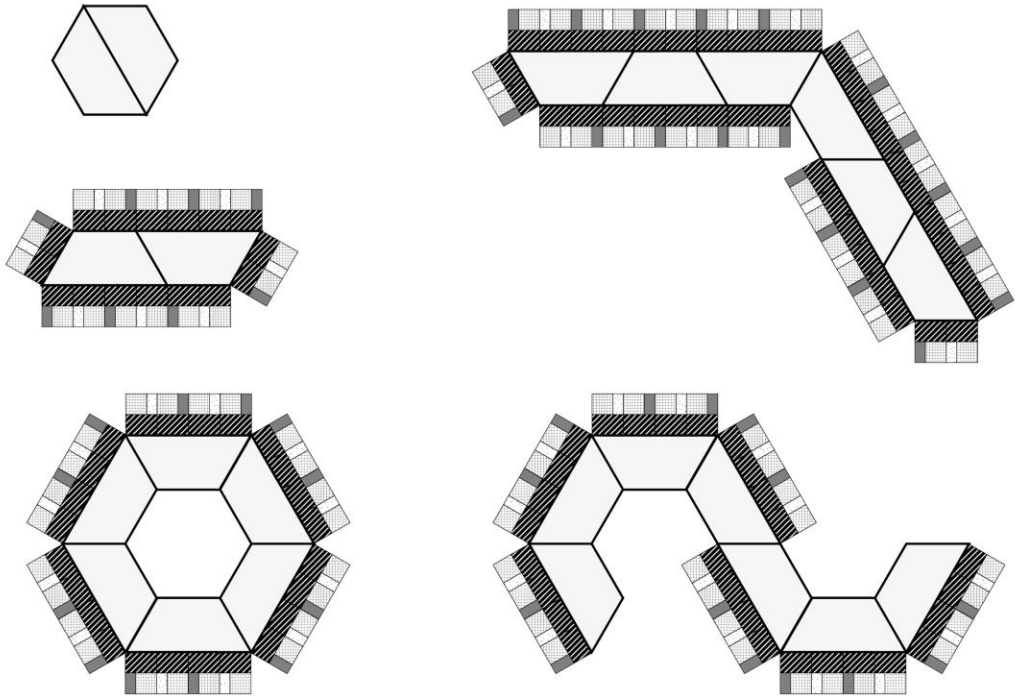
- Foldable floors
- Foldable houses

Suitcase House by Gary Chang

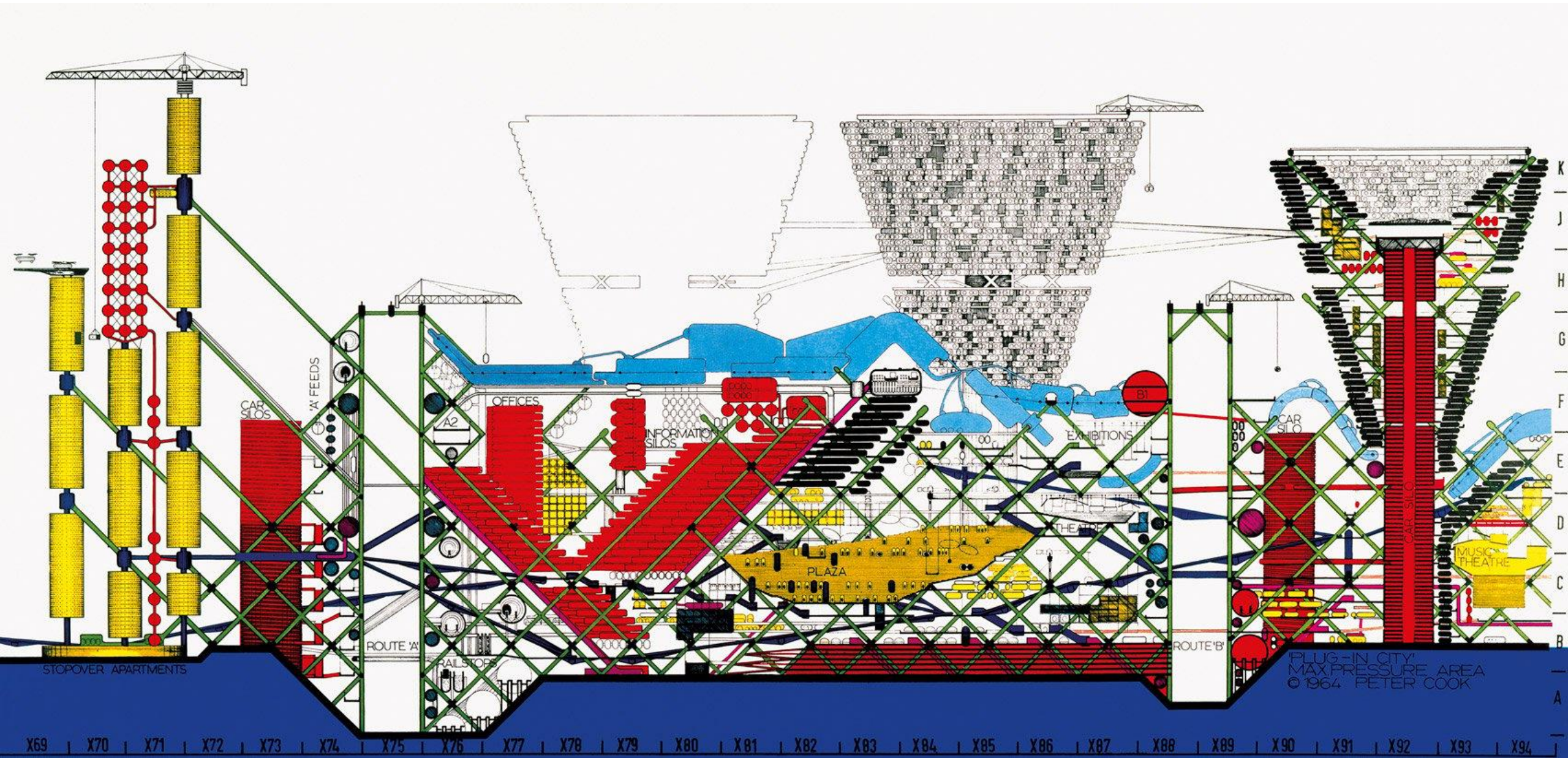
Foldable House by Brette Haus

Reconfiguration

- More variations to create freshness to the space
- Stimulate thinking

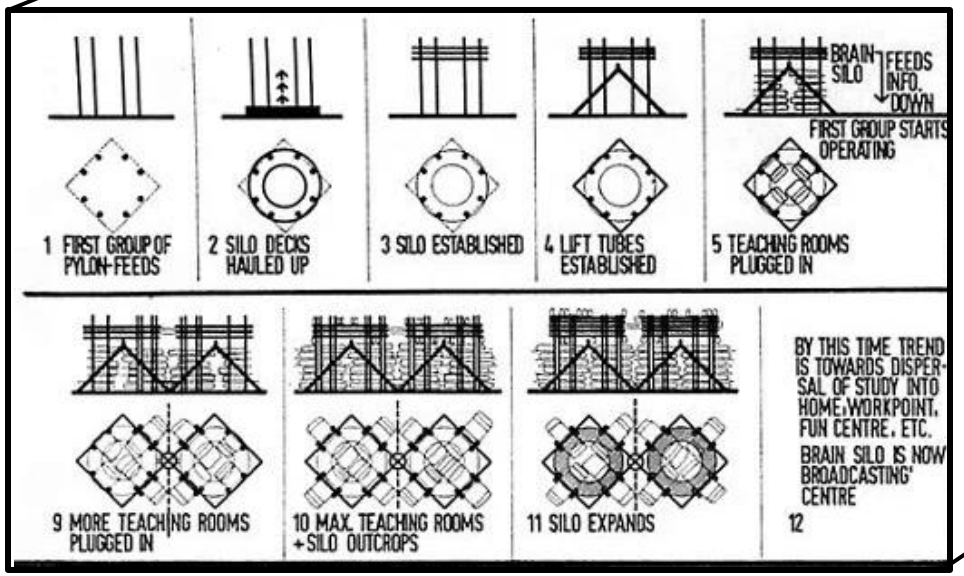


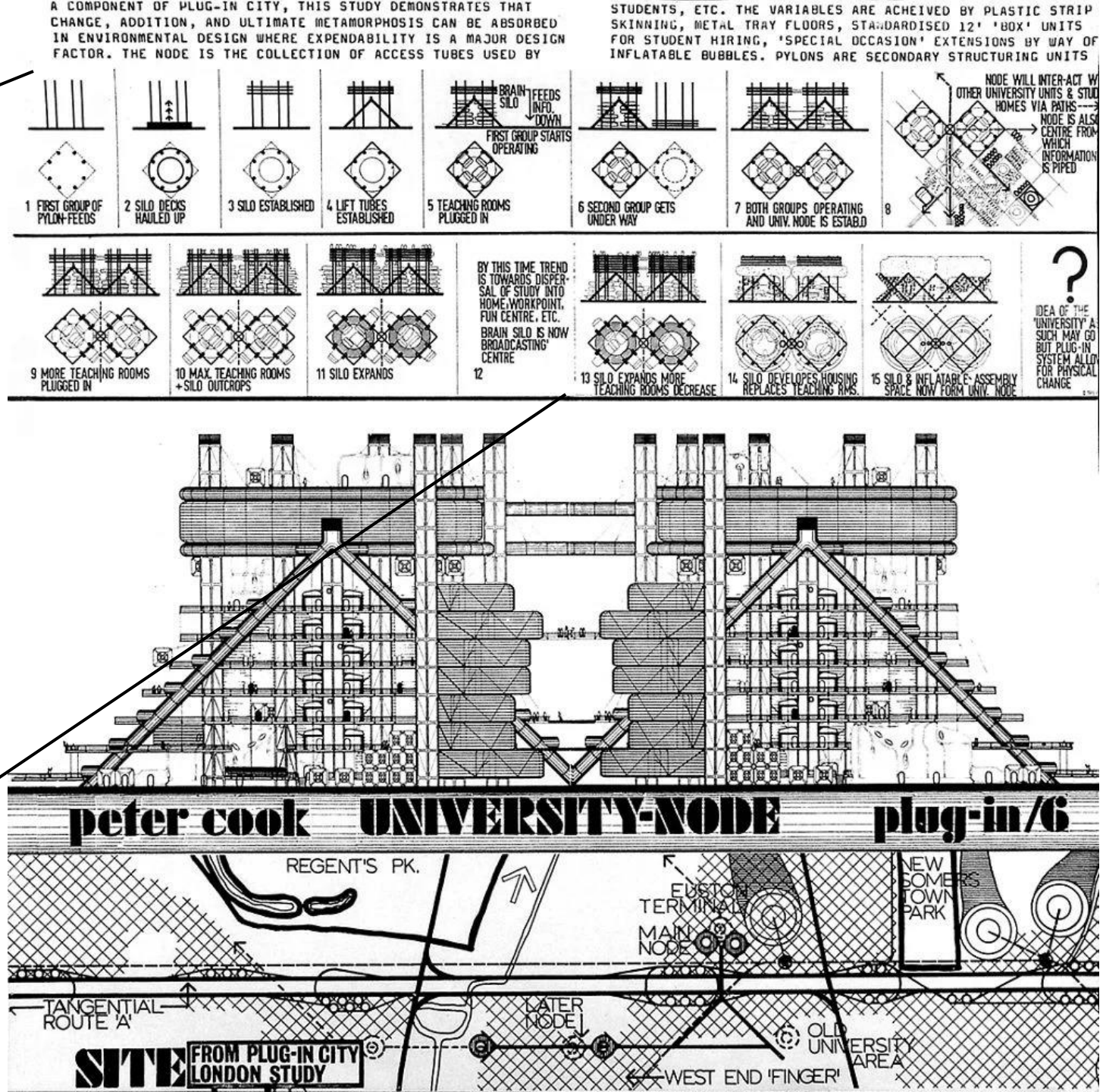
Assembly between Mobile and Stationary Architecture



Plug-in City Section | Archigram

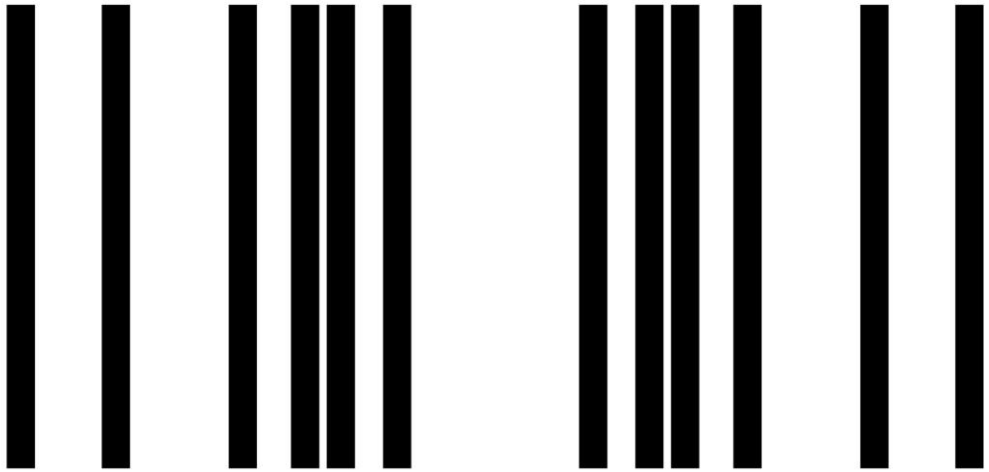
Archigram Issue no. 5 (1964)





Plug-in City University Node | Archigram

Archigram Issue no. 6 (1965)



Plug-in City University Node | Archigram

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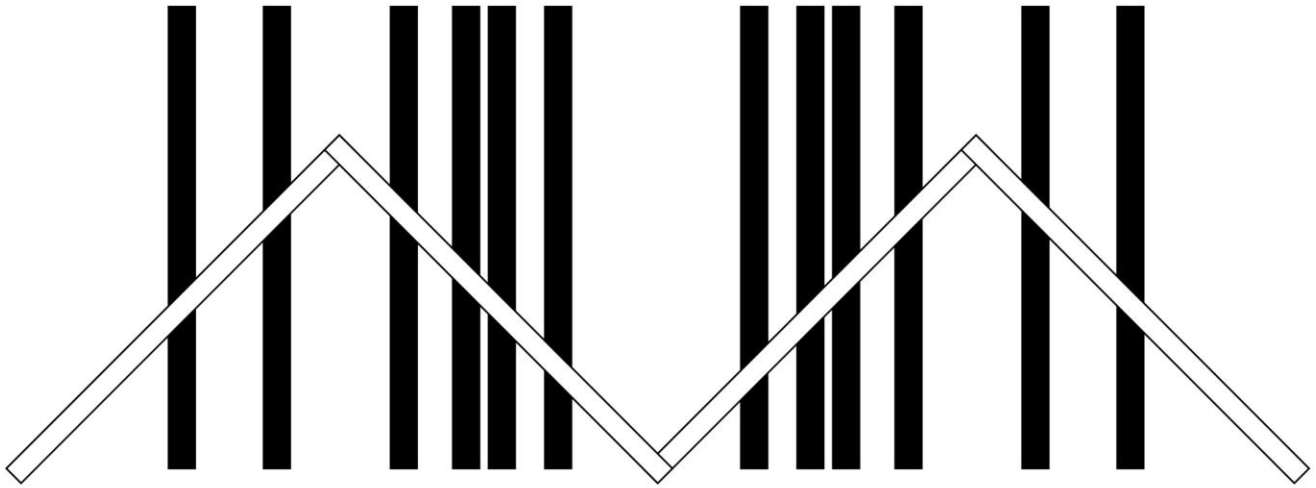

Plug-in City University Node | Archigram

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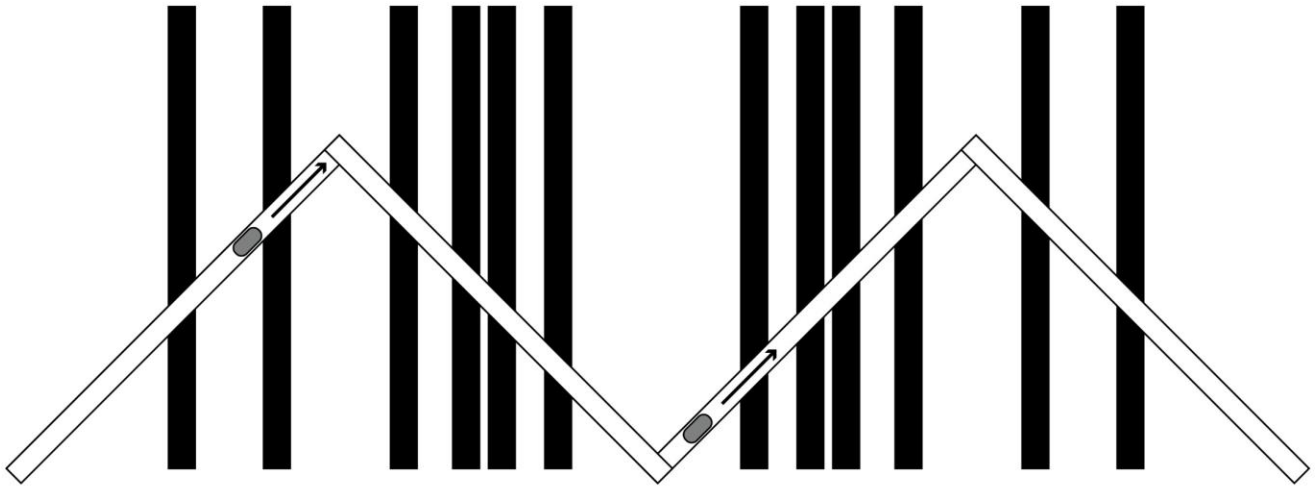

Plug-in City University Node | Archigram

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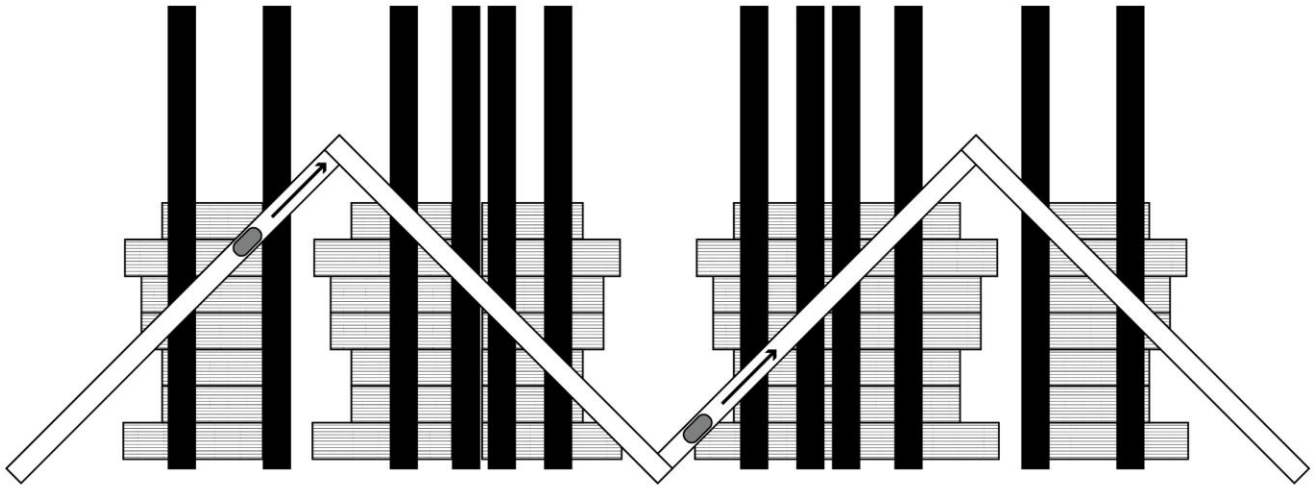

Plug-in City University Node | Archigram

Archigram Issue no. 6 (1965)

Megastructure

Transit Connection

Modular Units

~2030

~2070

Stages of Construction

Megastructure

Vertical **Tower**

Regolith 3D-printing

Transit Connection

Modular Units

Horizontal **Spanning Structure**

Aluminum

~2030

~2070

Stages of Construction