



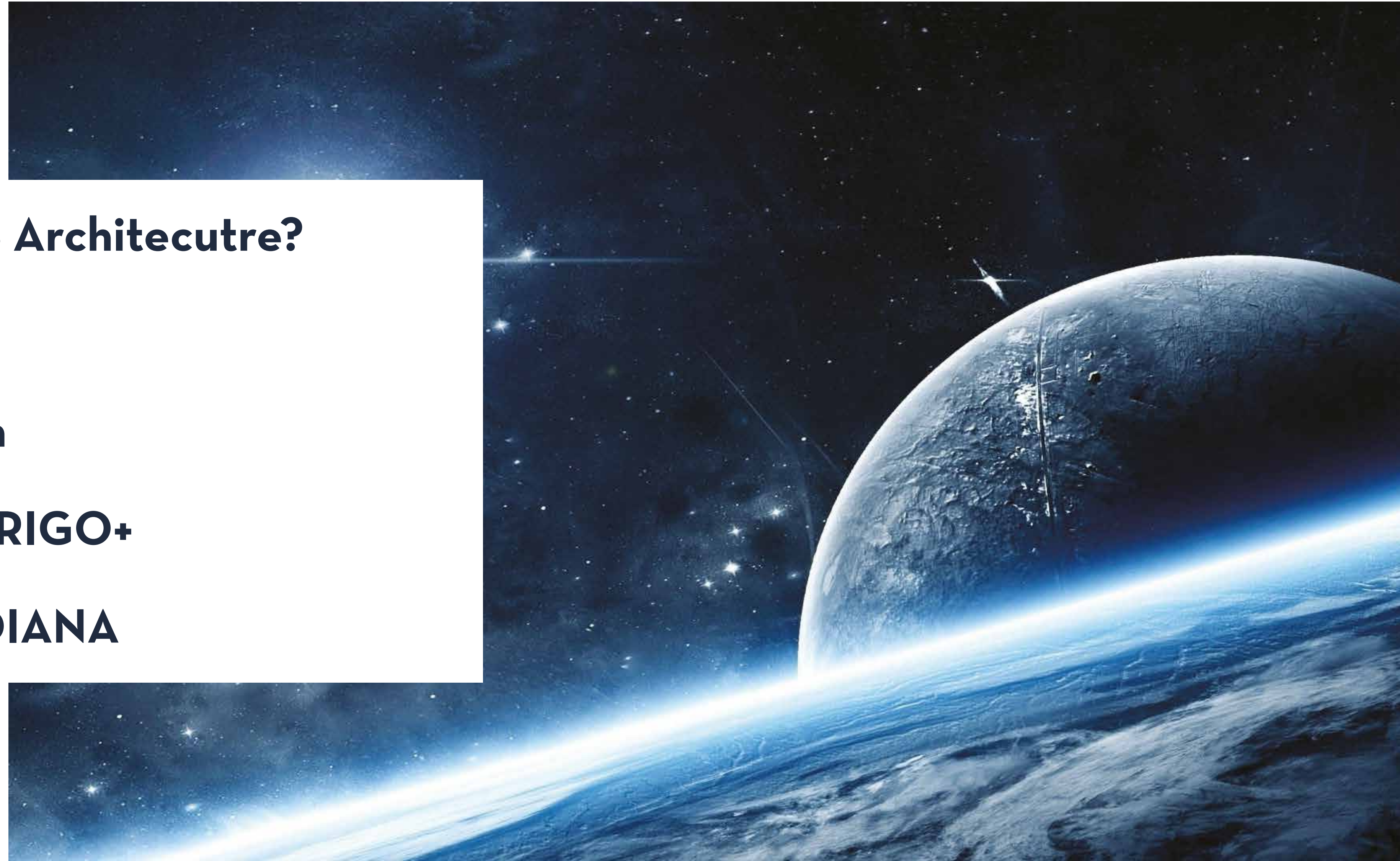
introduction to

SPACE ARCHITECTURE

Alma Kugić | The Brijuni Conference 2022



- **What is Space Architecture?**
- **Habitability**
- **Mars vs. Moon**
- **Mars base - ORIGO+**
- **Lunar base - DIANA**



WHAT IS SPACE ARCHITECTURE?



LUNAR HABITATION / Foster + Partners. Image Cortesía de Foster & Partners.
A space residence developed through study and experimentation that could house up to four people.

- Space Architecture is the theory and practice of designing and building inhabited environments in outer space.
- It encompasses architectural design of living and working environments in space related facilities, habitats, and vehicles.
- Designing these forms of architecture presents a particular challenge to ensure and support **safety, sustainability, habitability, reliability, and crew efficiency, productivity and comfort** in the context of extreme environments.

WHAT IS SPACE ARCHITECTURE?



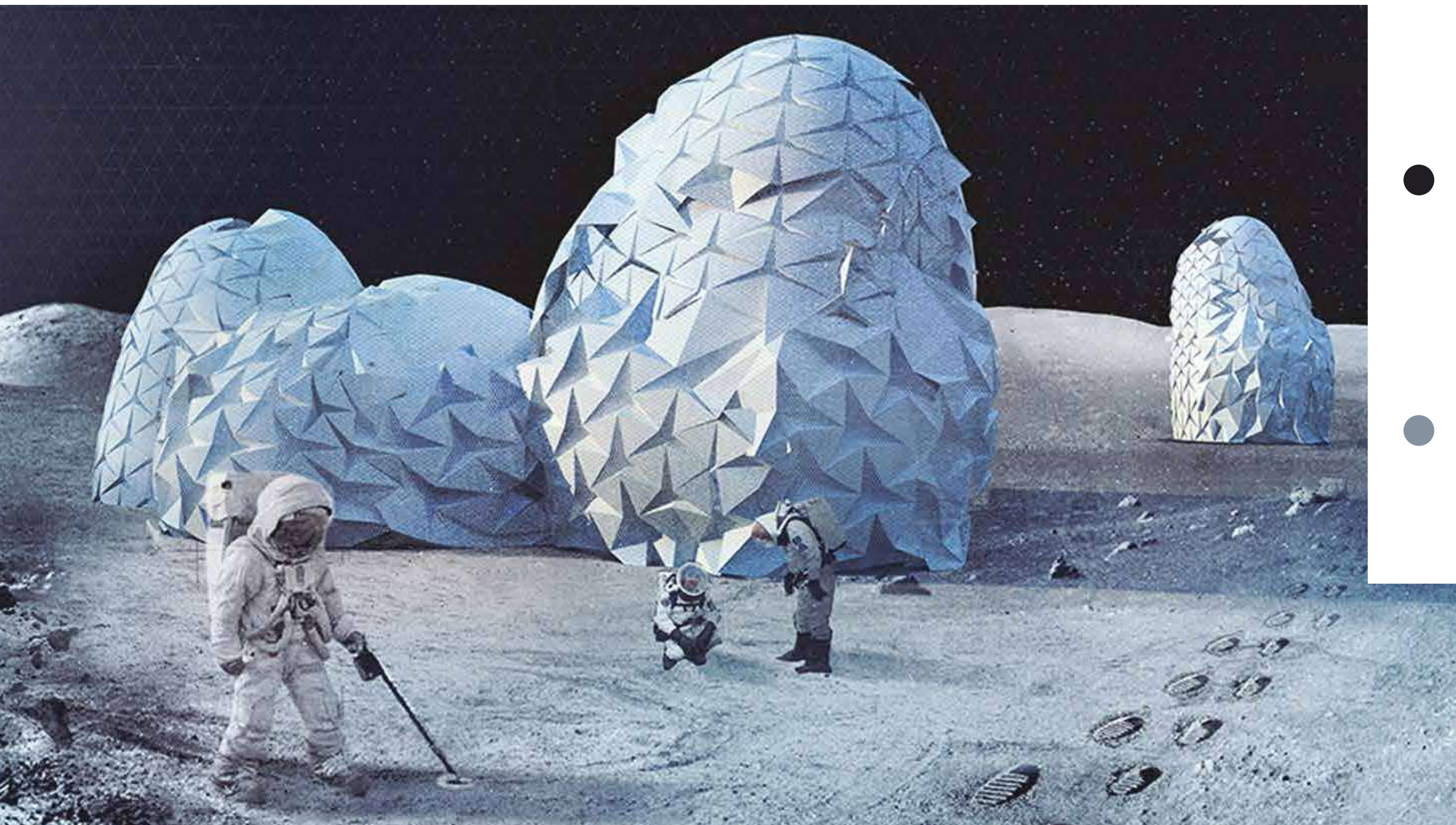
LUNAR HABITATION / Foster + Partners. Image Cortesía de Foster & Partners.
A space residence developed through study and experimentation that could house up to four people.

- The active participation of architects in the aerospace industry began in the 1960s.
- Space Architecture was born in the early 1980s with a handful of architects and designers working on the International Space Station.
- Today, a growing international community of architects and industrial designers is at work across the space field.

WHO ARE SPACE ARCHITECTS AND WHAT DO THEY DO?

Space architects are involved in all areas of human space projects and human mission development including:

- habitable base (or space station) and rover inner and outer design
- optimal space distribution, power and water supply, waste recycling, transportation support, radiation protection, building process...
- understanding of extreme environments and impact on human health and environmental design
- extreme Earth environment habitat design and construction.

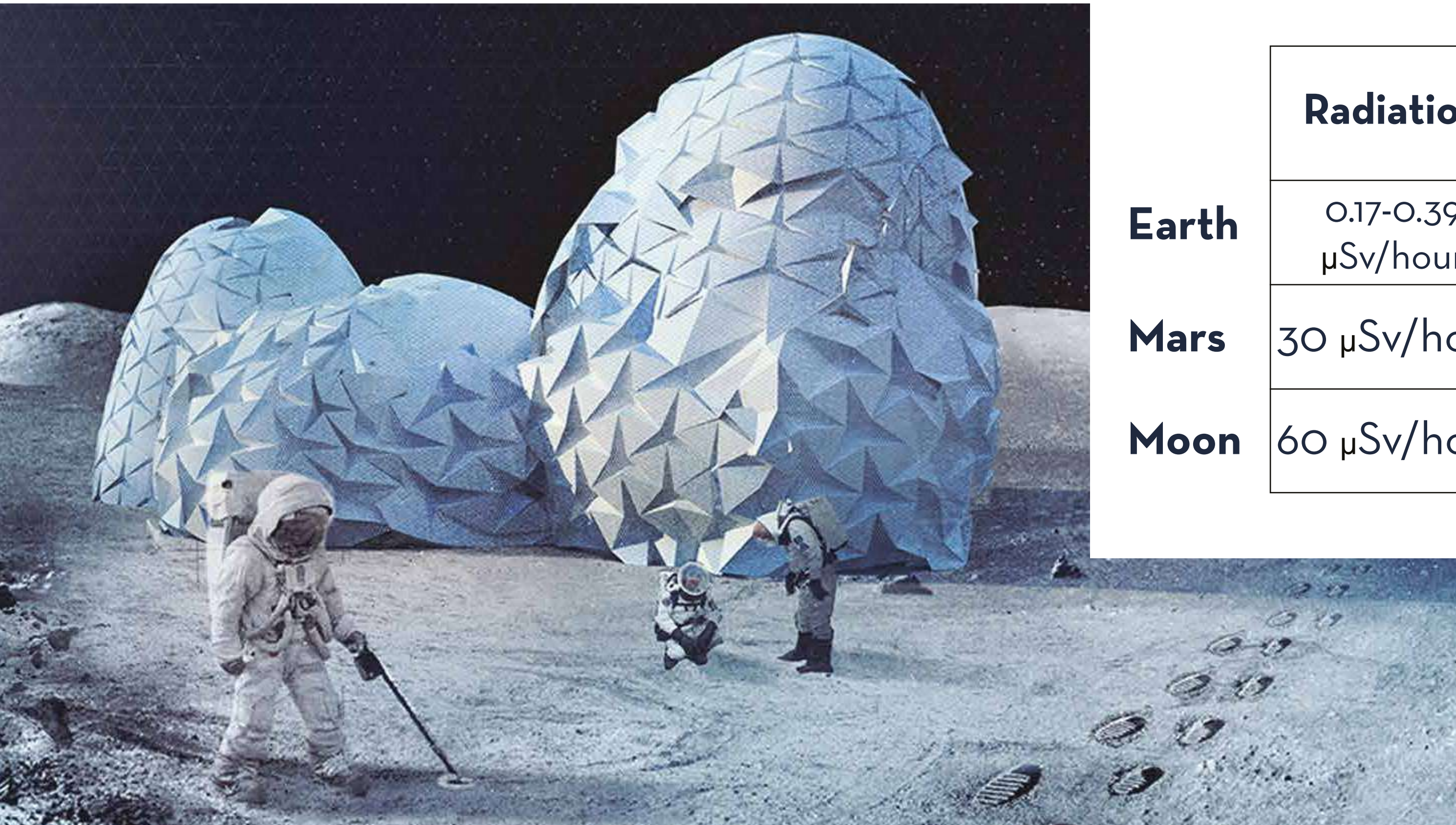


TEST LAB / Monika Lipinska, Laura Nadine Olivier and Inci Lize Ogun. Image Cortesía de Eleven Magazine.

A self-sustaining lunar settlement, designed as a place for living, working, and research.

Fundamentally, space architecture is an extension of Earth architecture.

Space architecture beyond Earth distinguishes from terrestrial architecture by extreme environmental conditions:



	Radiation	Atmospheric pressure	Gravity	Average temperature
Earth	0.17-0.39 $\mu\text{Sv}/\text{hour}$	101.3 kPa	9.807 m/s^2	13 $^{\circ}\text{C}$
Mars	30 $\mu\text{Sv}/\text{hour}$	0.7 kPa	3.721 m/s^2	-57 $^{\circ}\text{C}$
Moon	60 $\mu\text{Sv}/\text{hour}$	0.0 kPa	1.62 m/s^2	-30 $^{\circ}\text{C}$

TEST LAB / Monika Lipinska, Laura Nadine Olivier and Inci Lize Ogun. Image Cortesía de Eleven Magazine.

A self-sustaining lunar settlement, designed as a place for living, working, and research.

The goal is still the same: to provide a shelter that protects and supports good quality of life for the inhabitants.

- 1** The environment of a deep-space mission represents a physiological and psychological contradiction to the terrestrial environment in which humans evolved.
- 2** The impact of architecture on human psychology has led to architects giving a lot of importance to the needs and desires of the occupants of the spaces that they are asked to design.
- 3** Optimal performance and welfare of crew members will depend on successful adaptation to the habitat and challenges of the extreme environment

MARSHA/ AI Space Factory. Image © AI SpaceFactory and Plomp.
Marsha challenges the image of architecture in the Space era, focusing on highly livable spaces as they relate to us Earth-dwellers.



WHAT IS HABITABILITY?

- The term Habitability describes the suitability and value of a built habitat for its inhabitants in a specific environment over time.
- One of the critical characteristics of living and working in extreme environments is the dependency on the habitat and its technological capability as well as the sociospatial framing.
- Inhabitants who are exposed to remote and hostile environments, not only must overcome the challenges posed by the dangers and limitations imposed by the particular environment itself, but also experience significant distress from being confined indoors and isolated from civilization and social contact.



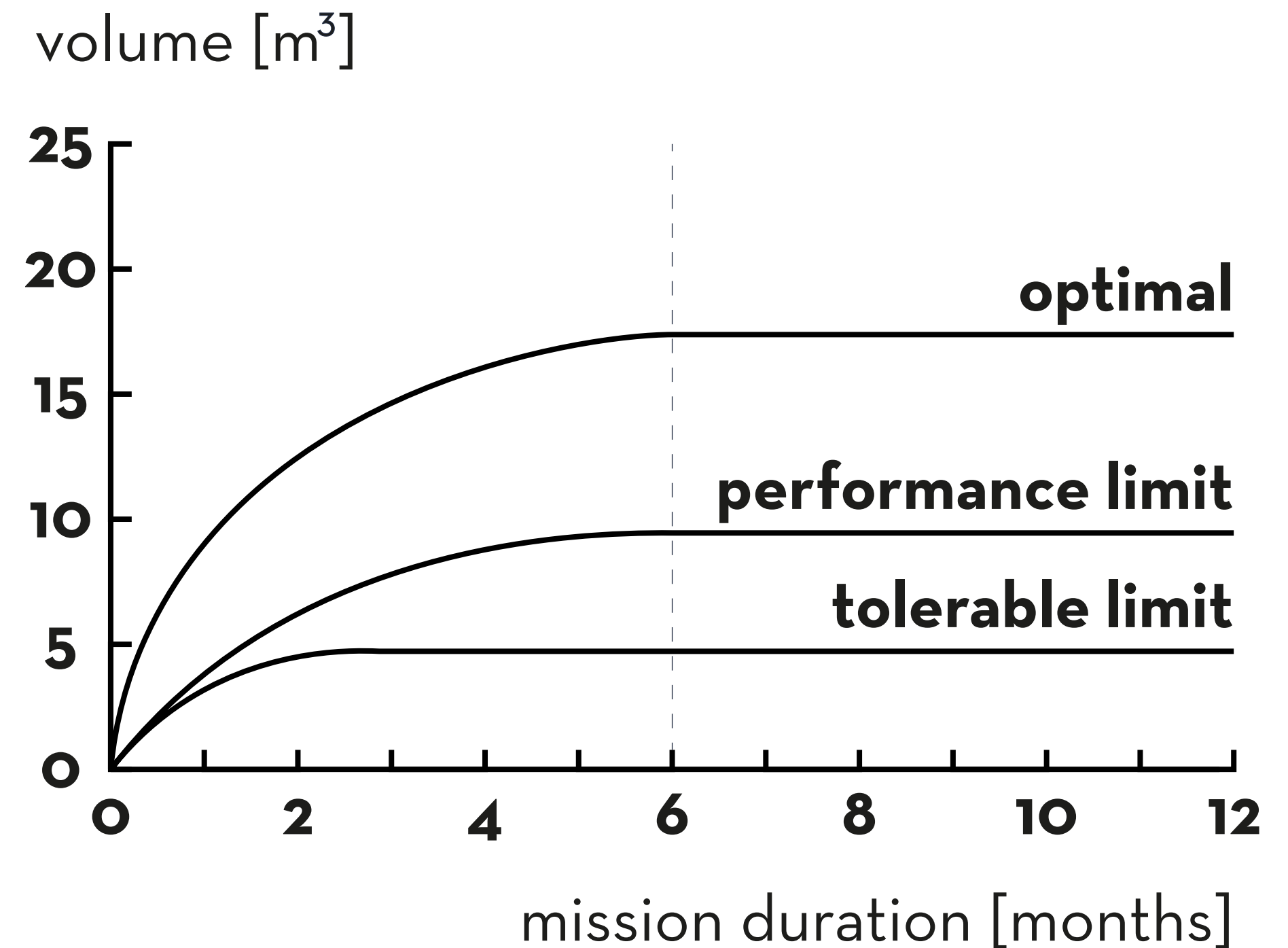
HABITABILITY FACTORS: Optimal Space Distribution

- There are two different human spaceflight types: short-duration and long-duration missions.
- Short-duration missions are fast and intense, often compared to a camping lifestyle, where minimum comfort is acceptable.
- Long-duration missions are missions where people would be residing (habitating) in hostile environment over extended period of time and characterized by lots and lost of monotony, boredom and repetition.

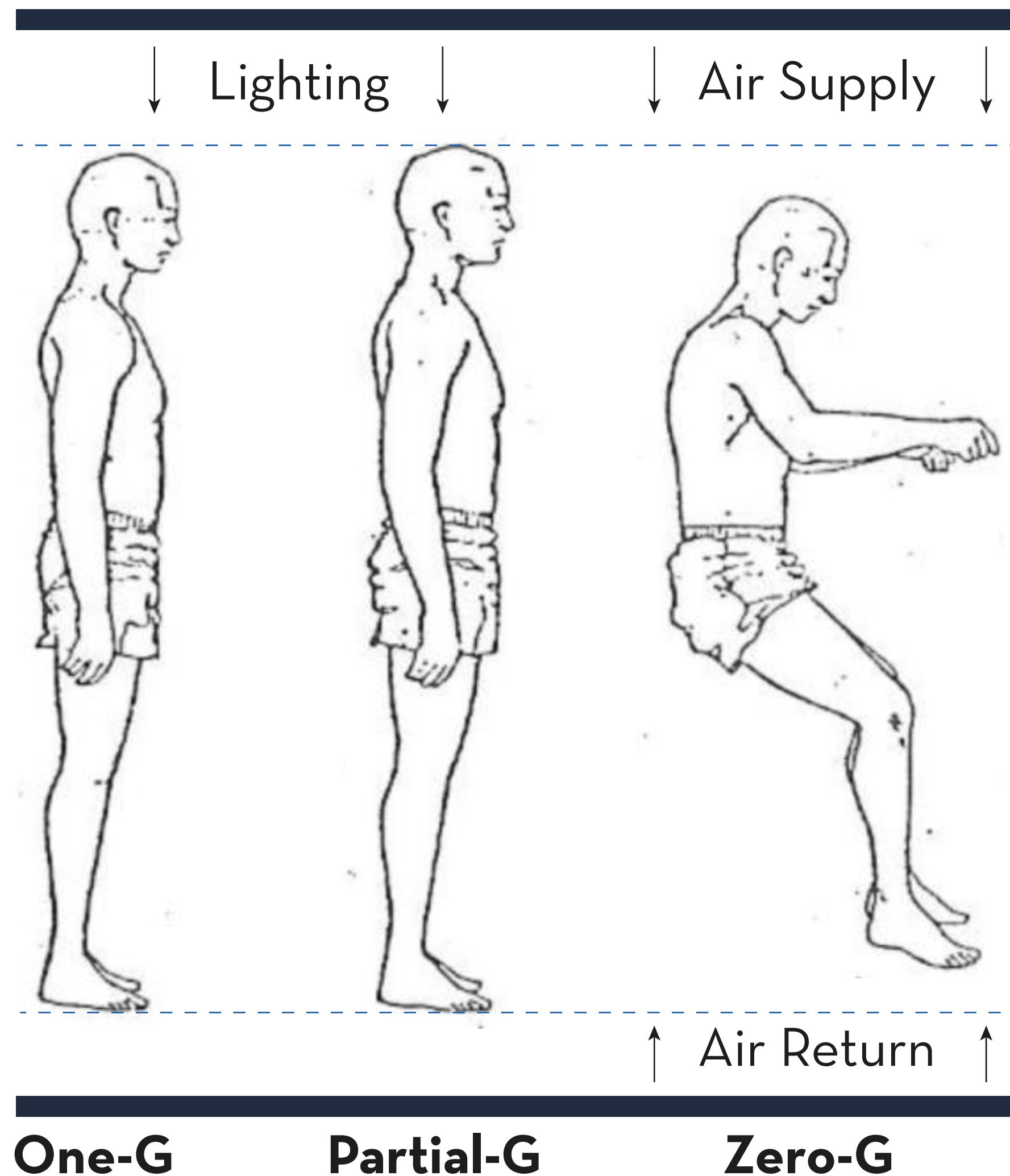


HABITABILITY FACTORS: Habitable Volume

- In order to calculate the category of the mission, there are three important parameters for confinement: number of people, duration of the mission and volume of the habitat.
- As the number of people increase, and the number of days spent in the outer space, so should the volume of the habitat.
- Graph shows Habitable volume per crew-member as a function of mission duration and performance level:



NASA-STD-3000, 1995,
from Celentano, Amorelli, & Freeman, 1963



Lunar Mission Anthropometry
Design Challenges and Consequences, Brand Griffin, 2021

HABITABILITY FACTORS: Anthropometry

- Anthropometry is the study of the measurements and proportions of the human body.
- Deals with measurement of reaching abilities, maneuvering and other aspects of space and equipment use.
- It helps determine the optimal comfort levels for crew members in a designed space.

MARS vs. MOON



MARS

MOON

distance from Earth:
travel duration:

55.7 - 401 mil. km
approx. 6 months
(every 2 years)

384 400 km
2.5 - 4 days

atm. composition:

96% carbon dioxide
1.9% nitrogen
1.9% argon
0.1% oxygen

vacuum

gravity:
temperature:

1/3 g
-153 °C to 20 °C

1/6 g
day 134 °C
night 153 °C

1 year:
1 day:
wind speed:

687 days
24 h 39 m
144 km/h

365 days
28 days

water:
radiation:

in form of vapor and ice
30 μSv/hour

-
inside craters
60 μSv/hour

ORIGO+

IN-SITU_3D_PRINTED_AND_ROBOTICALLY_ASSEMBLED_MARS_HABITAT

AB - ORIGO

Mars Science City, SS 2020

Studio

Department of Building Construction and Design, TU Vienna

Institute

Dr. Sandra Häuplik-Meusburger

Mentor

Julian Graf & Alma Kugić

Students

“International station and international bases on the
Moon and Mars:prospects of creation and space architecture”
March 2021.

2nd place

“Student Poster Competition”
International Conference on Environmental Systems: ICES 2021
July 2021.

3rd place

“Martian Hub” by UNI
March 2022.

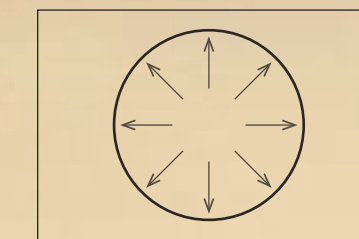
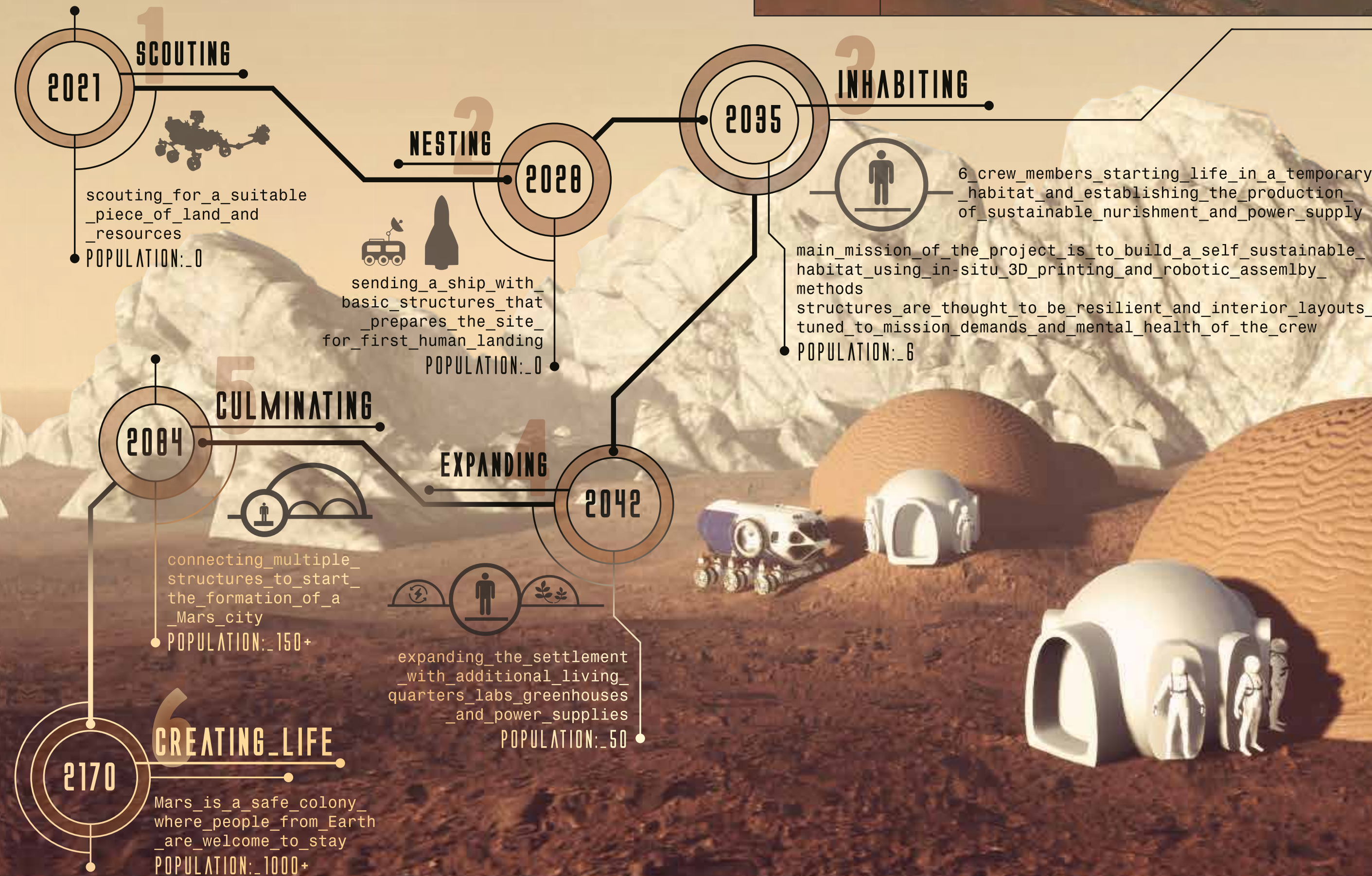
Editor’s choice

ORIGO+

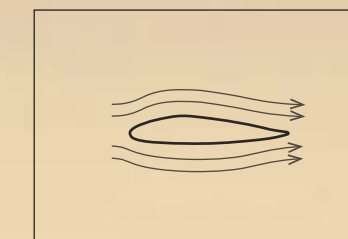
IN-SITU_3D_PRINTED_AND_ROBOTICALLY_ASSEMBLED_MARS_HABITAT



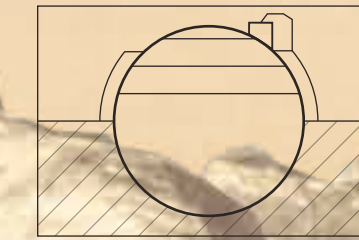
LOCATION: MELAS_CHASMA
 YEAR: 2035
 CREW_MEMBERS: 6_PEOPLE
 HABITAT: ORIGO+
 MISSION: PREPARING_HABITAT_FOR_EXPANSION



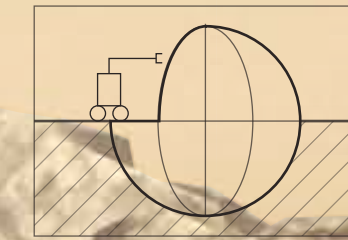
INHERENT_STABILITY



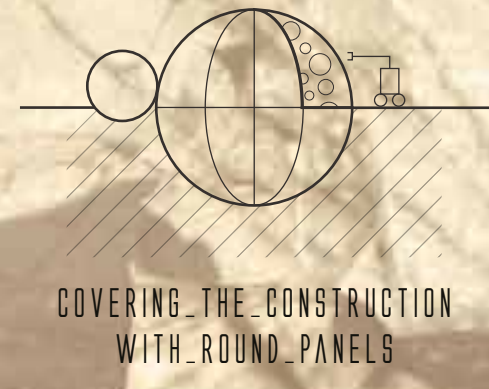
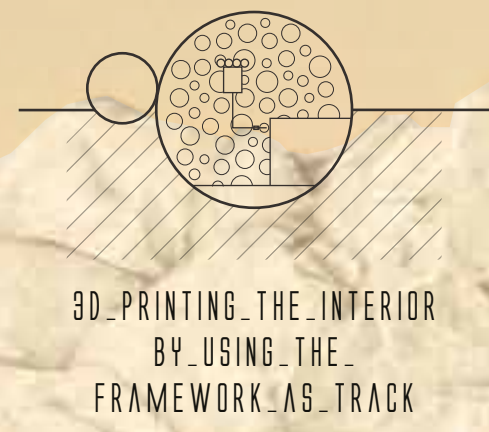
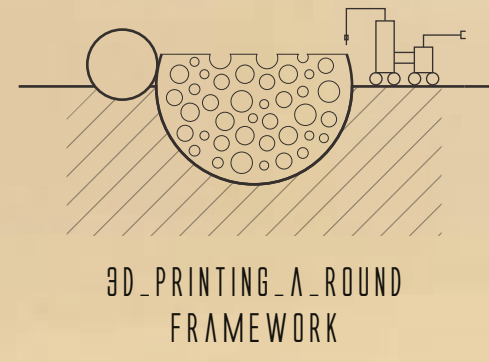
AERODYNAMIC



FORM_SUITED_FOR_3D_PRINTING



ROBOTICALLY_ASSEMBLED



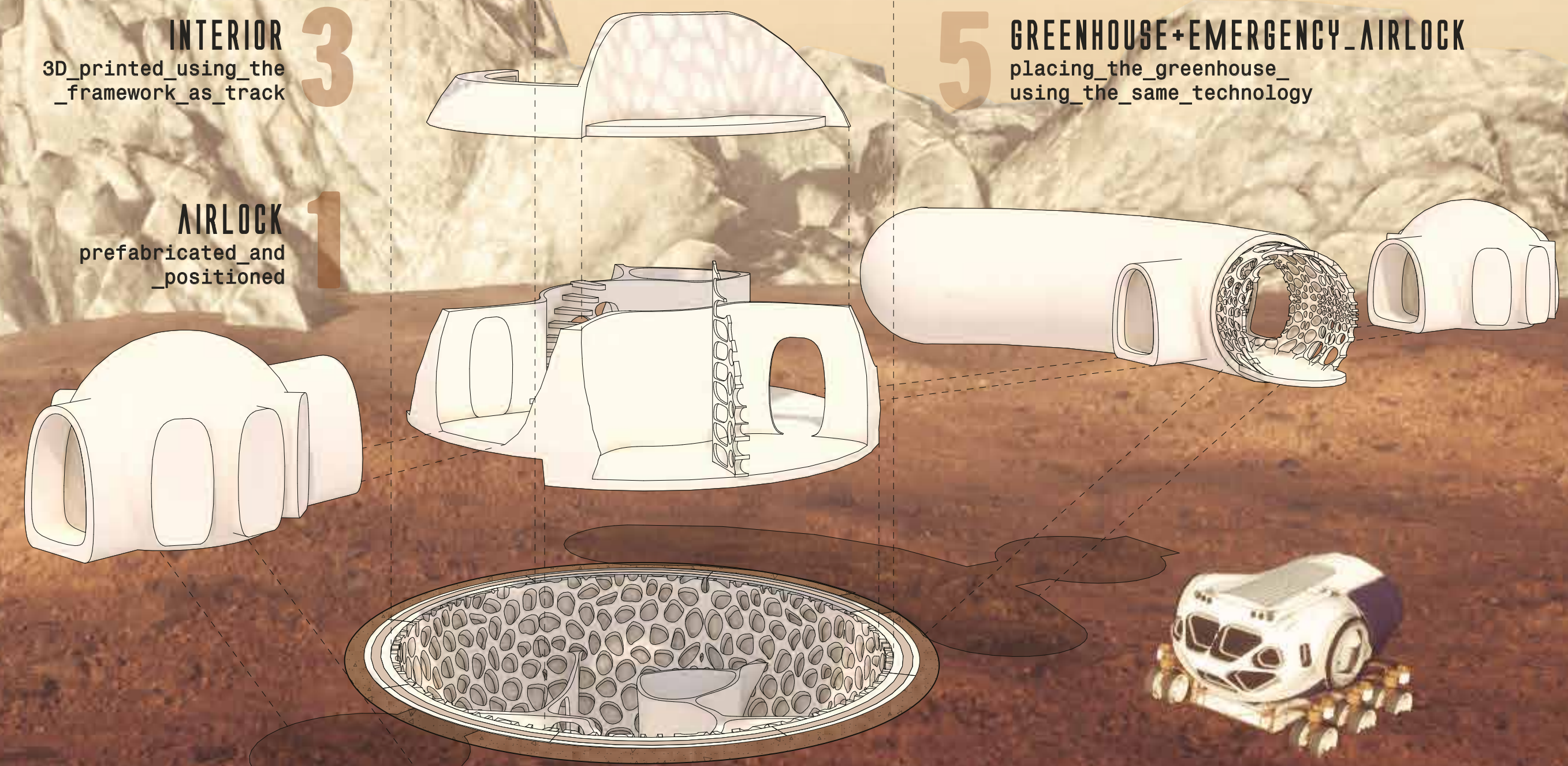
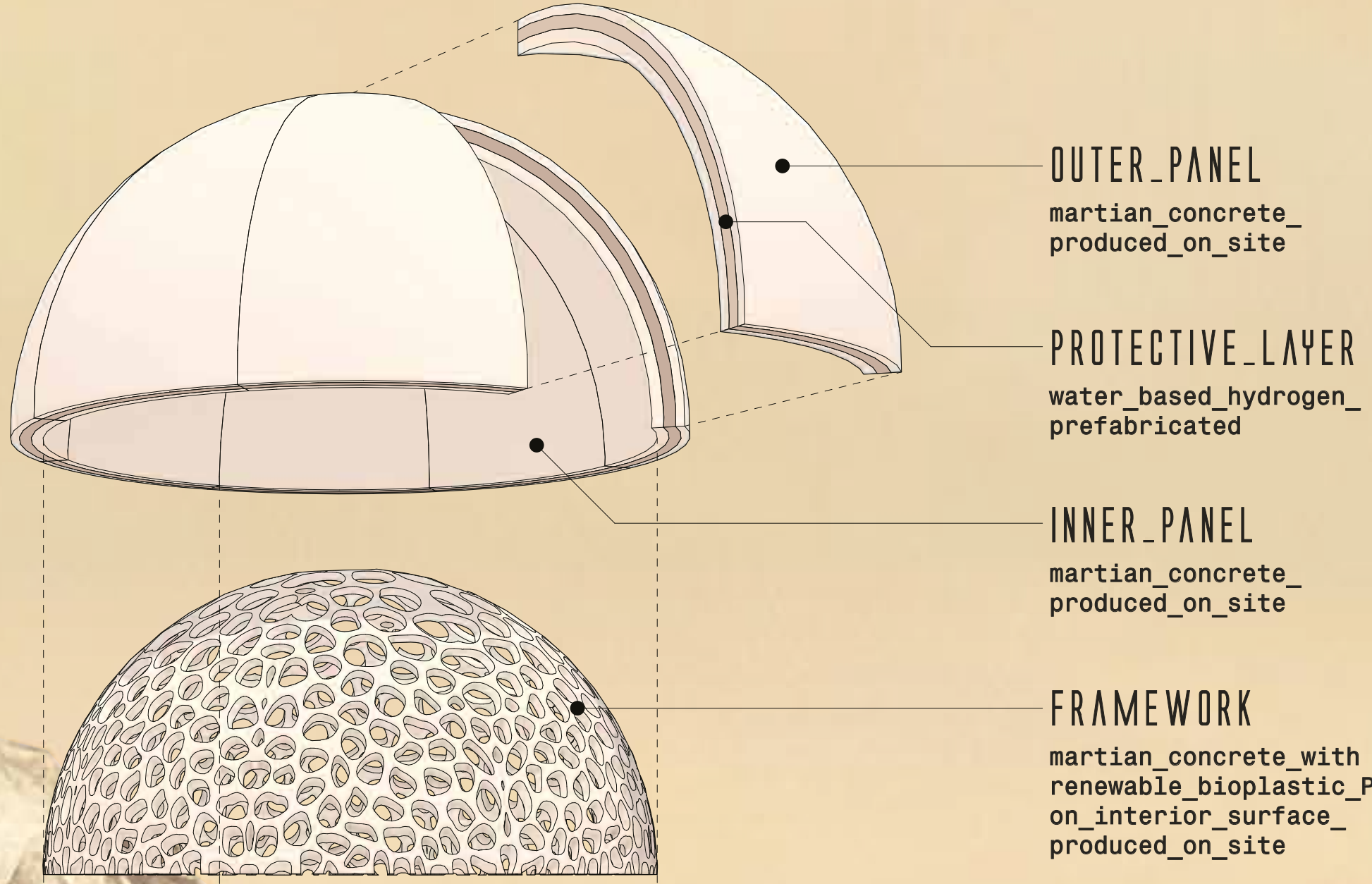
4
PANELS
 triangle_panels_for_shielding_against_radiation_robotically_assembled

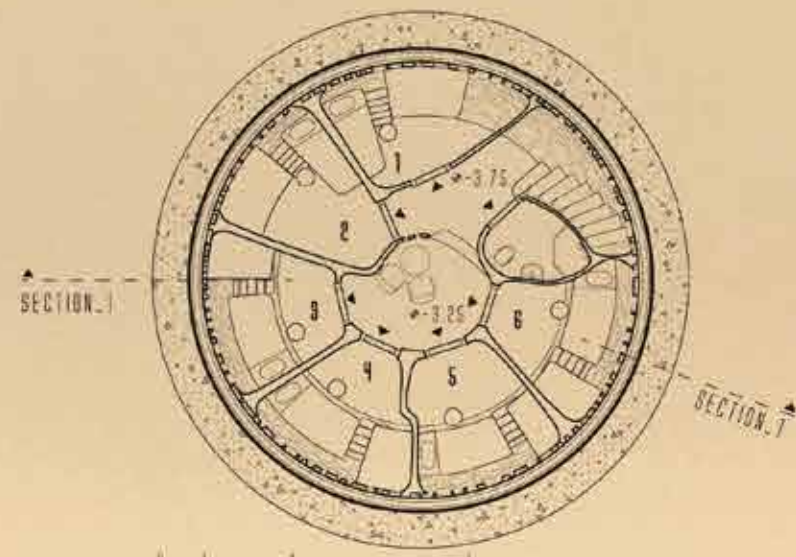
2
FRAMEWORK
 a_round_grid_as_a_structure_carrier_3D_printed_on_site

3
INTERIOR
 3D_printed_using_the_framework_as_track

1
AIRLOCK
 prefabricated_and_positioned

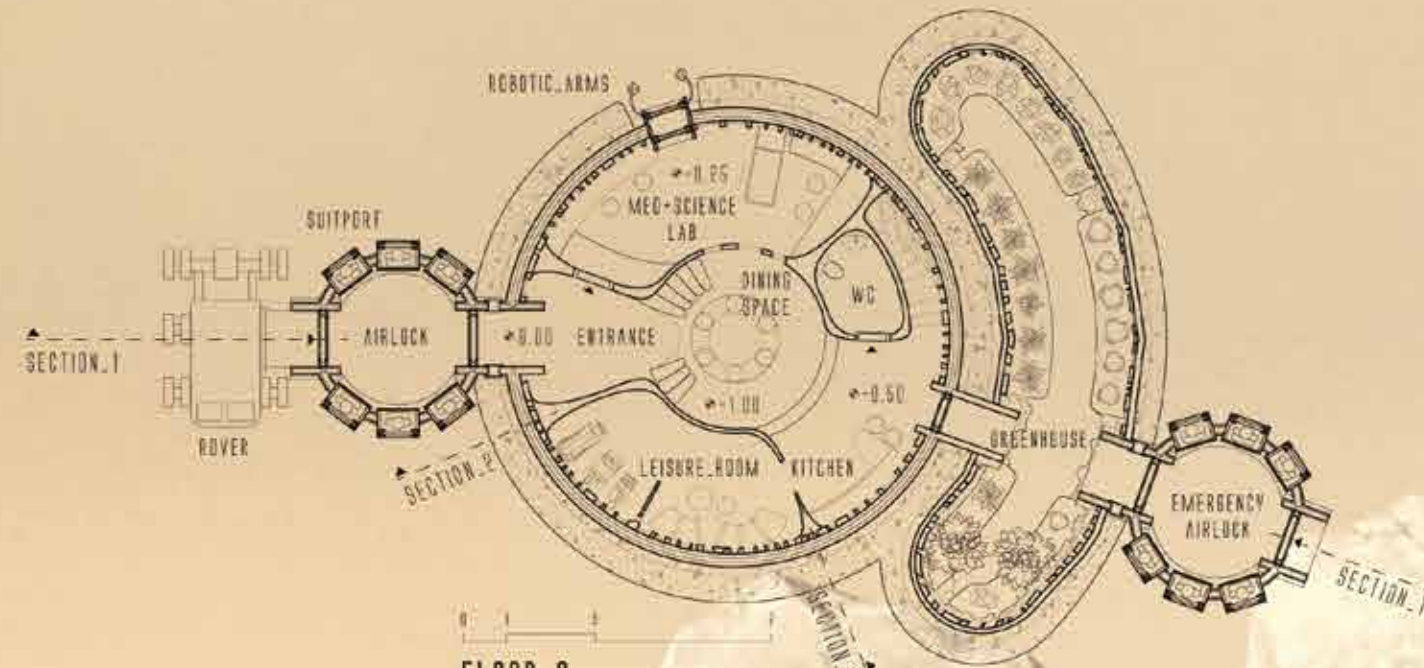
5
GREENHOUSE+EMERGENCY_AIRLOCK
 placing_the_greenhouse_using_the_same_technology





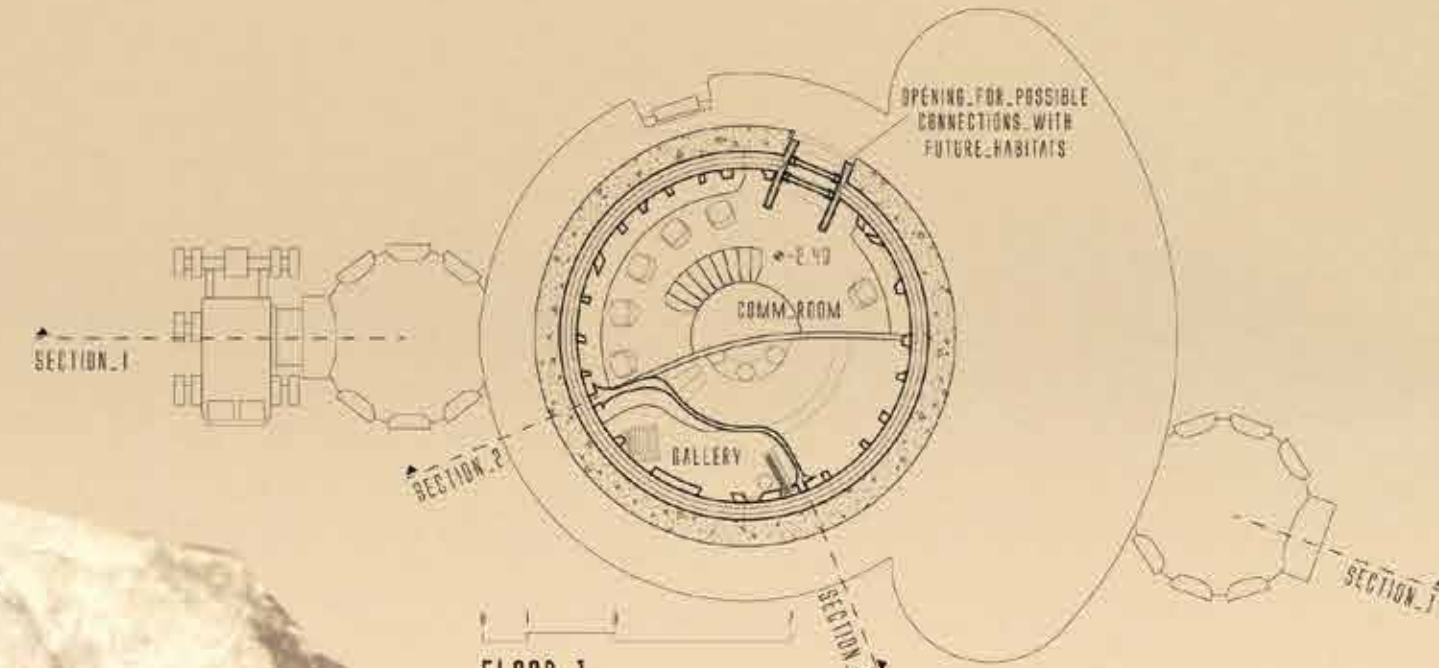
FLOOR_-1

QUARTER_1	3.07_m²
QUARTER_2	4.68_m²
QUARTER_3	2.18_m²
QUARTER_4	2.70_m²
QUARTER_5	2.91_m²
QUARTER_6	2.23_m²
BATHROOM	3.17_m²
HALLWAY	11.10_m²
FLOOR_-1	31.99_m²



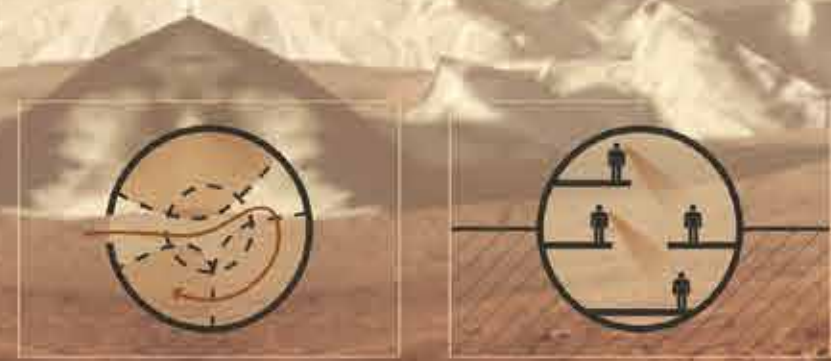
FLOOR_0

ENTRANCE	8.04_m²
MED+SCIENCE LAB	19.08_m²
DINING SPACE	14.04_m²
KITCHEN	10.65_m²
LEISURE ROOM	15.09_m²
WC	3.56_m²
AIRLOCK	7.00_m²
FLOOR_0	77.46_m²



FLOOR_1

COMM_ROOM	41.60_m²
GALLERY	10.40_m²
FLOOR_1	52.00_m²



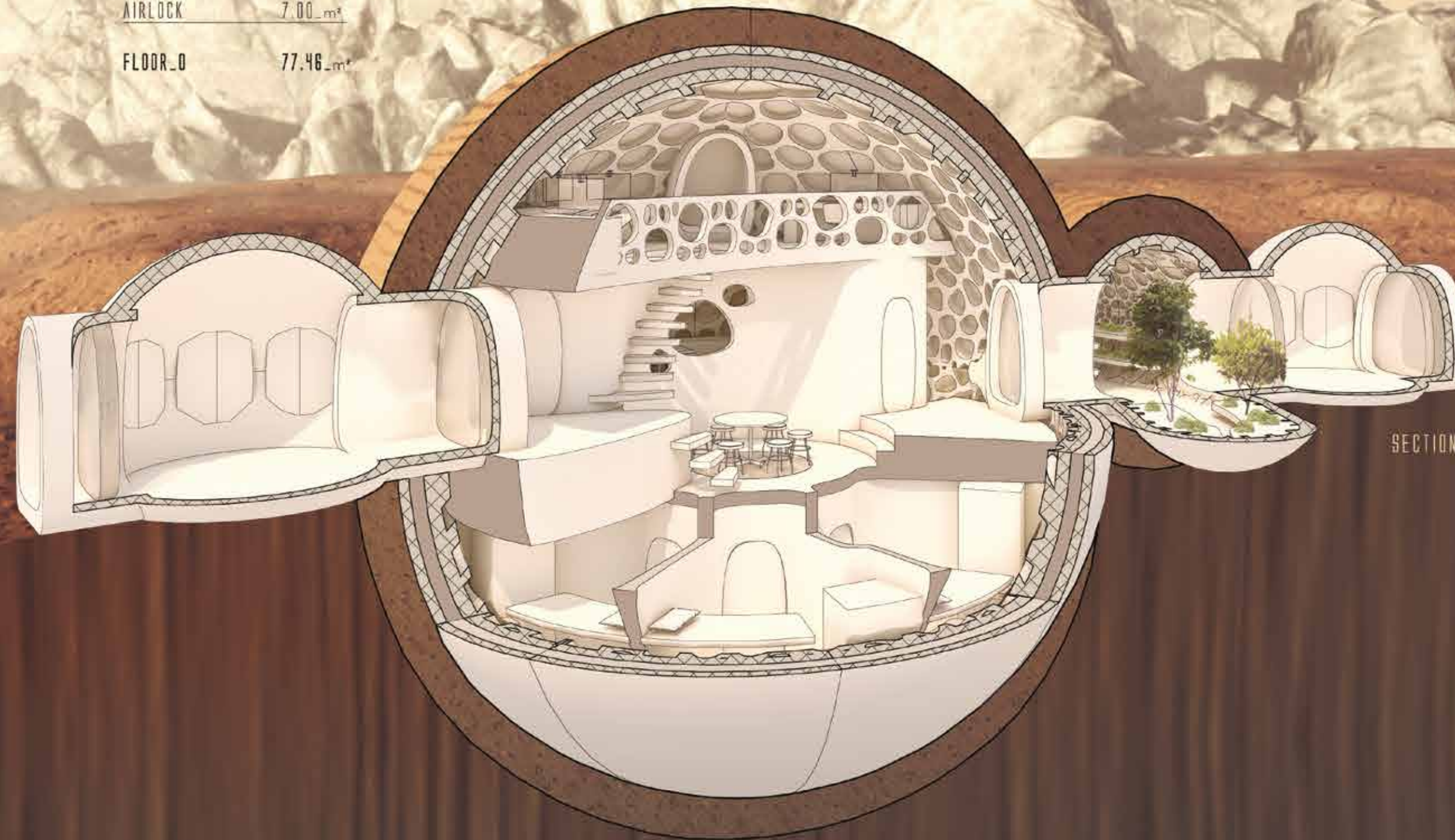
FLUID ROOM PROGRAM

VISUAL LINKS BETWEEN DIFFERENT LEVELS



LOGICAL SPACE HIERARCHY

FUNCTIONAL CONFIGURATION ACCORDING TO RADIATION



SECTION_1

CREW_MEMBERS:

ADDI
CAPTAIN+SYSTEM_ENGINEER
AUSTRALIA

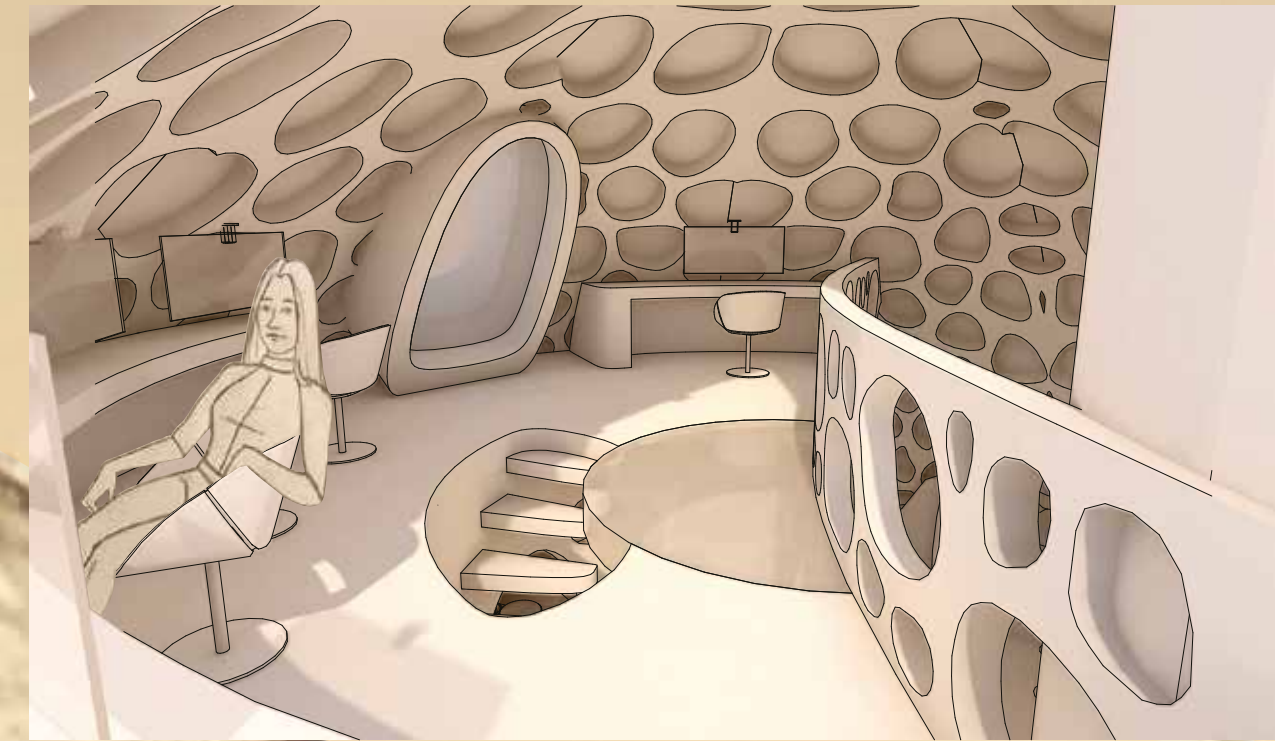
LI-WEI
BIOCHEMIST+PHYSICIAN
CHINA

JACKSON
PILOT+MARINE_INTELLIGENCE
USA

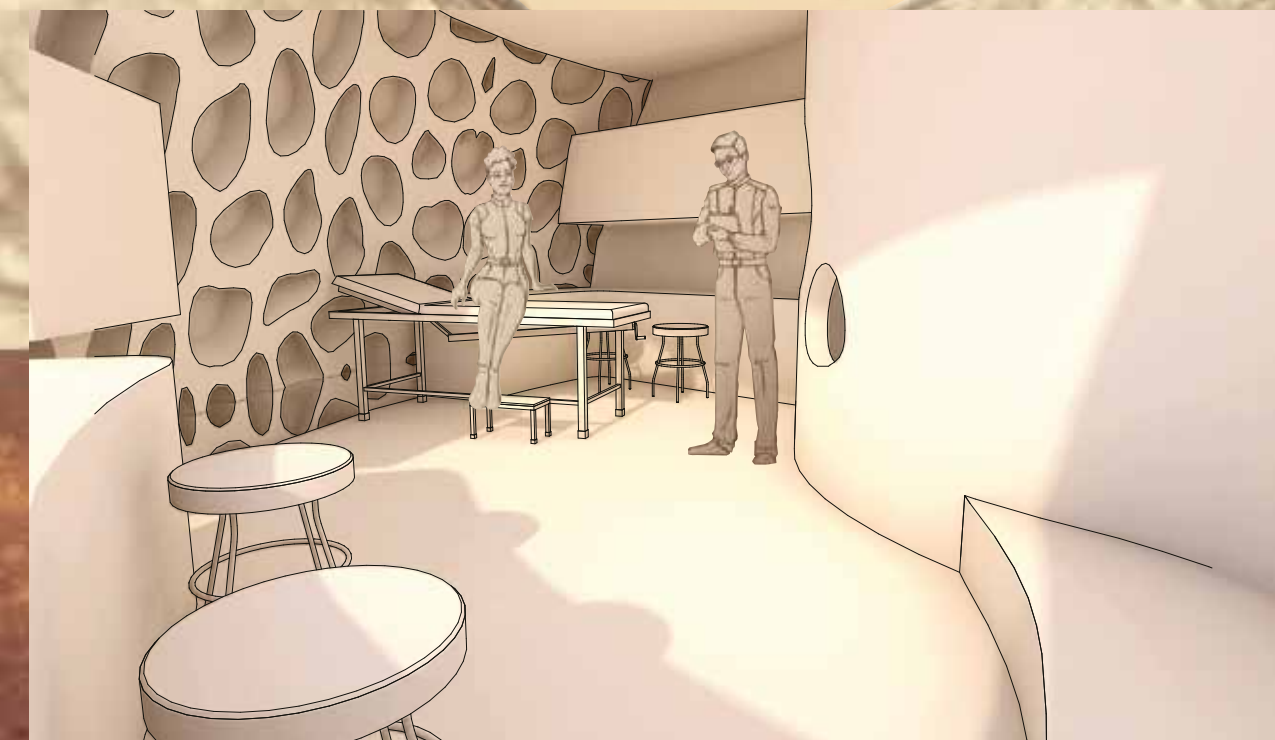
AMINA
BOTANIST+EXOBIOLOGIST
UNITED ARAB EMIRATES

MALIKA
MECHANICAL_ENGINEER+ROBOTICIST
SOUTH AFRICA

SERYOZHA
GEOLOGIST+GEOCHEMIST
RUSSIA



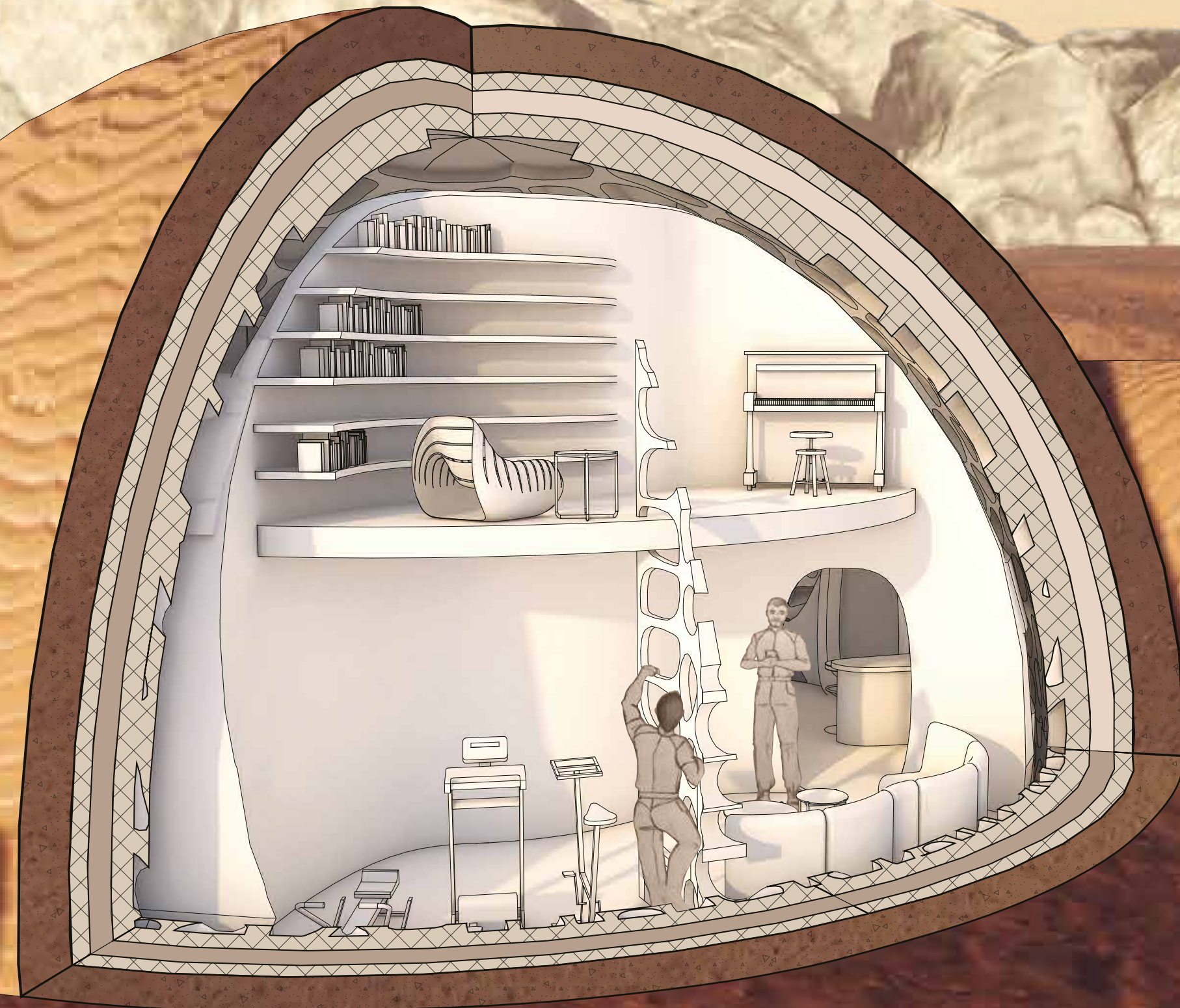
COMM_ROOM



MED+SCIENCE_LAB



DINING_ROOM

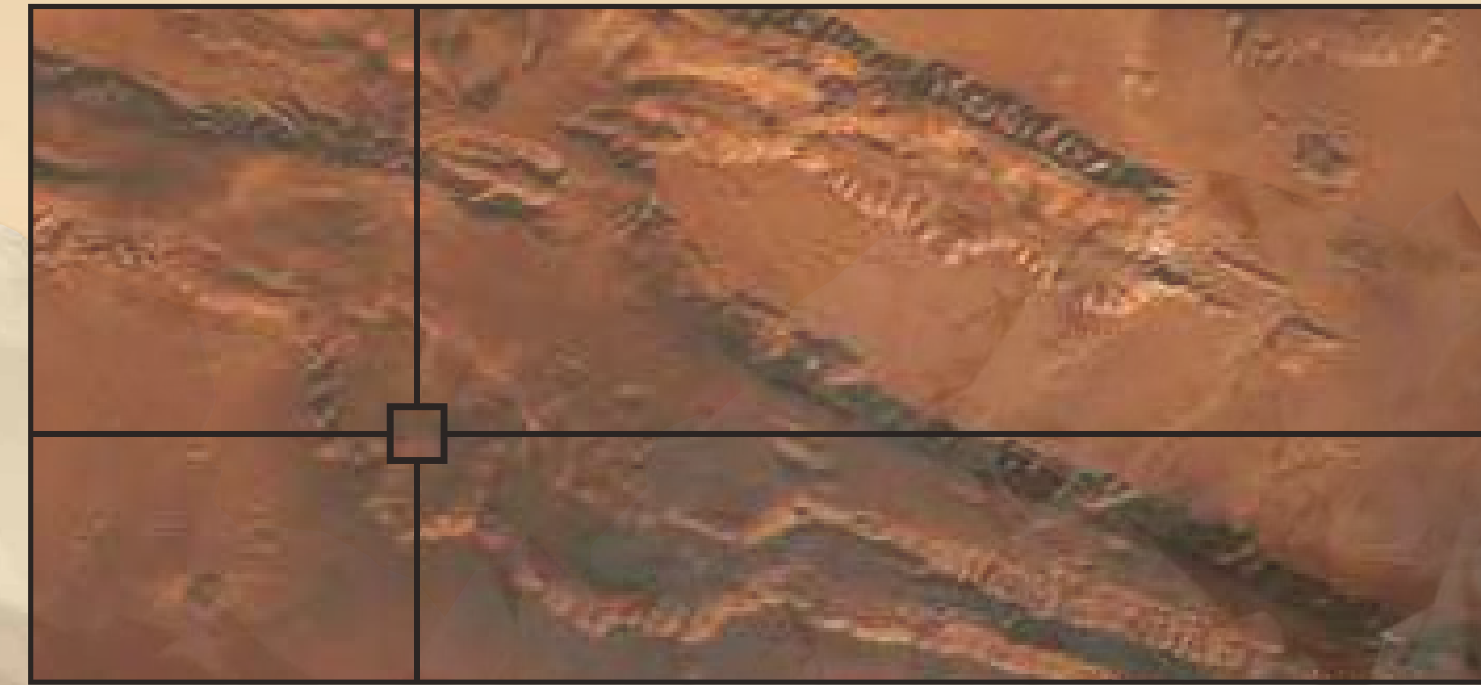


LEISURE_ROOM
+GALLERY
SECTION_2

ORIGO+

IN-SITU_3D_PRINTED_AND_ROBOTICALLY_ASSEMBLED_MARS_HABITAT

EXPANSION



LOCATION: MELAS_CHASMA
YEAR: 2042
CREW_MEMBERS: 50_PEOPLE
SETTLEMENT: ORIGO+EXPANSION
SIZE: 4000 m²
MISSION: EXPANDING_THE
SETTLEMENT





COMMUNICATION
SATELLITES

SOLAR_PANELS

PRESSURIZED
VEHICLE

NODE_WITH
SUITPORTS

AIRLOCK_WITH
SUITPORTS

CARGO

1 PRIMARY_HABITAT MODULE

it consists out of
initial habitat which
was later expanded with
two additional habitats

it is used primarily for sci-
entific research on
Mars and as a medical labora-
tory and a
hospital

6 sleeping quarters
per habitat: total of 18
inhabitants

every habitat has his
own greenhouse and
kitchen

2 SECONDARY_HABITAT MODULE

three more habitats have
been built in order to
increase the number
of visitors and research
areas

it is used for plant
research and production.
due to it's "green"
interior it is also
used as a place for
socializing and relaxing

6 sleeping quarters
per habitat: total of 18
inhabitants

all habitats are
connected above or
underground

3 TERTIARY_HABITAT MODULE

a total of two more
habitats were planned
before the Expansion
faze is completed

it is used for robot
and vehicle maintenance
and production and as
a main module for
communication with
Earth

7 sleeping quarters
per habitat: total of 14
inhabitants

every habtat has a safe
haven for it's inhabitants
in case of a solar
particle event



Lunar base design concept of DIANA

Dedicated Infrastructure and Architecture for Near-Earth Astronautics

Alma Kugic • Madison Diamond • Elizabeth Gutierrez • Denis Acker • Adrian Pippert
Nadine Barth • Prishit Modi • Javier Palacios Calatayud • Hubert Gross • Vincent Krein

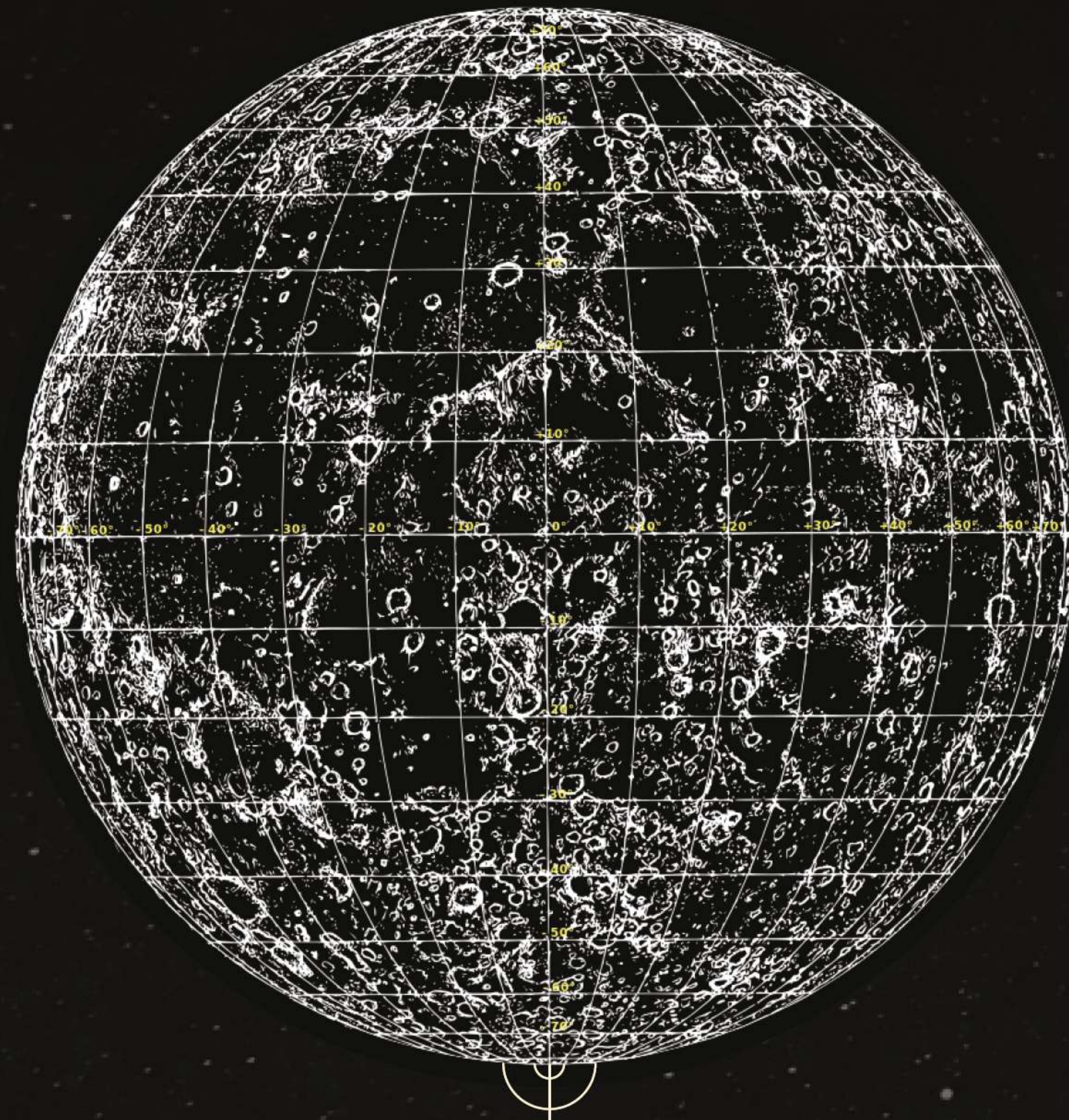


51st International Conference on
Environmental Systems, July 2022

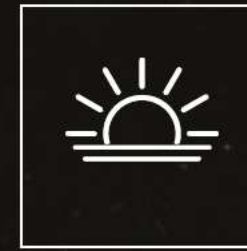
ICES - 2022 - 298

LOCATION

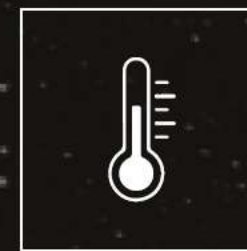
LUNAR SOUTH POLE - DE GERLACHE CRATER 88.71°S, 68.7°W



POTENTIAL
PRESENCE
OF WATER



AVAILABLE
SUNLIGHT



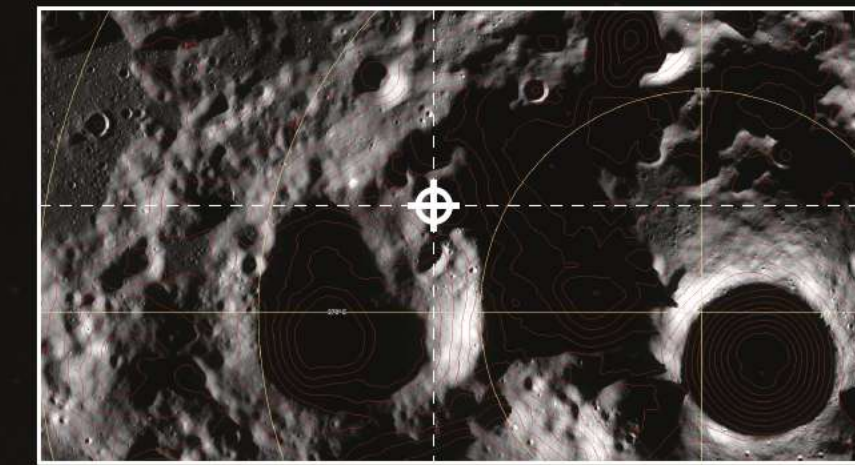
MILD
TEMPERATURE
DIFFERENCES



RELATIVELY
FLAT TERRAIN



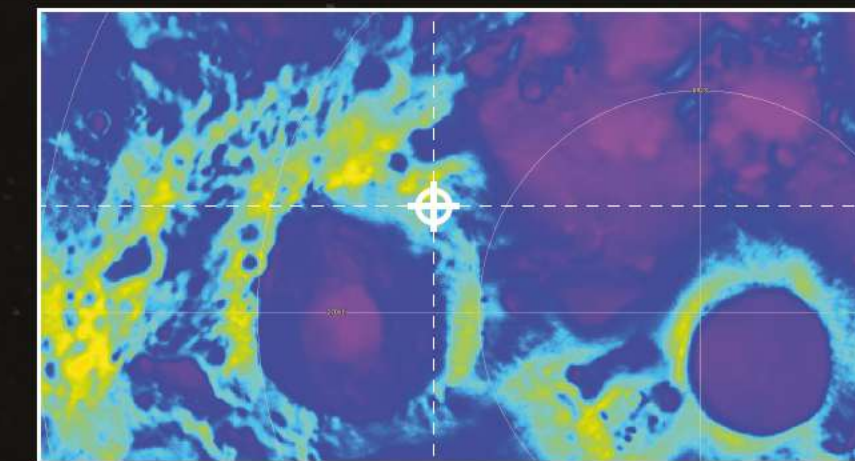
EARTH
VISIBILITY



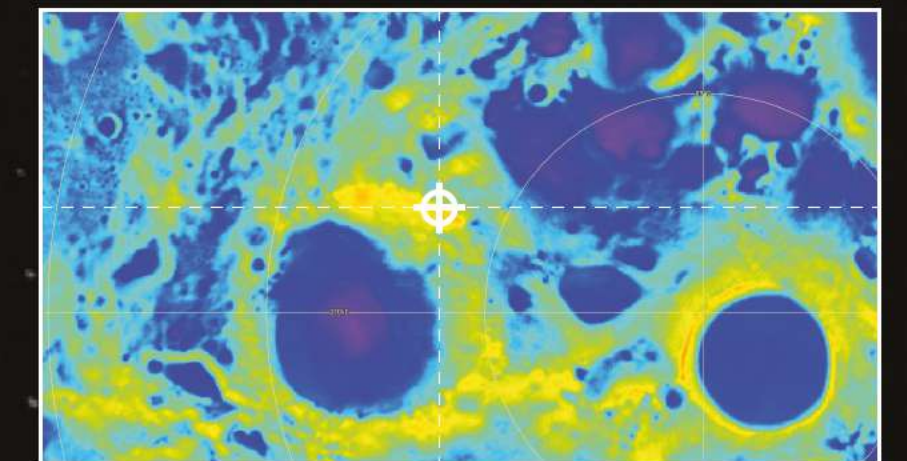
Lunar base location terrain contour



Lunar base location terrain slope = 1.23°



Avg. Winter temp. = 103.0 K



Avg. summer temperature = 180.7 K



Earth visibility = 0.60 (min = 0, max = 1)



Sun visibility = 0.65 (min = 0, max = 1)



MODULES





SOCIAL MODULE

-  Kitchen
-  Living room
-  Lounge
-  Sleeping quarters x 4
-  Hygiene facility
-  Storage
-  Safe Haven

MULTIPURPOSE LAB MODULE

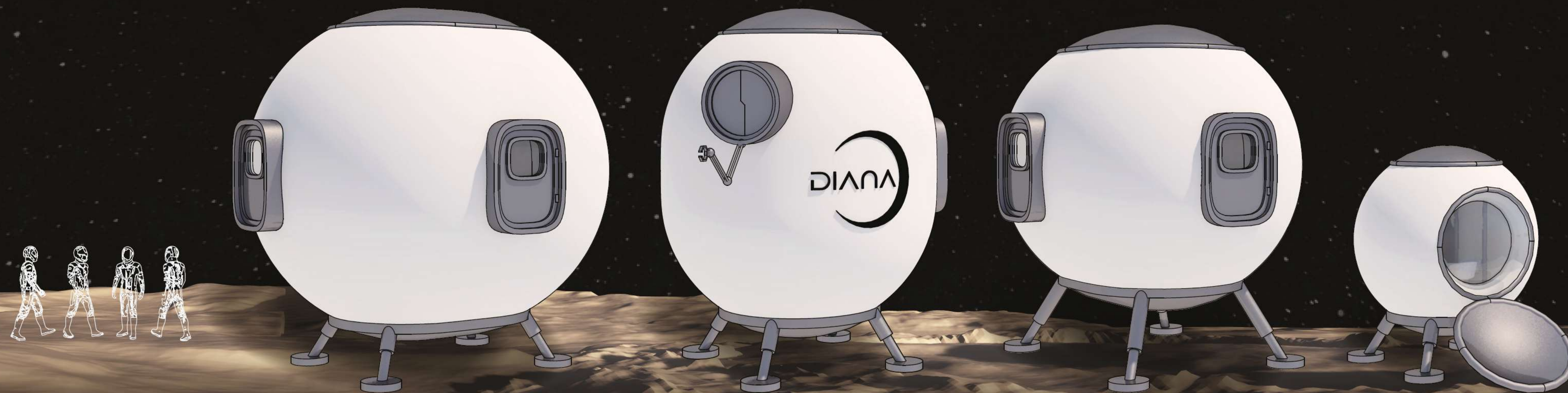
-  Science Laboratory
-  Communications
-  Med bay
-  Storage

GREENHOUSE

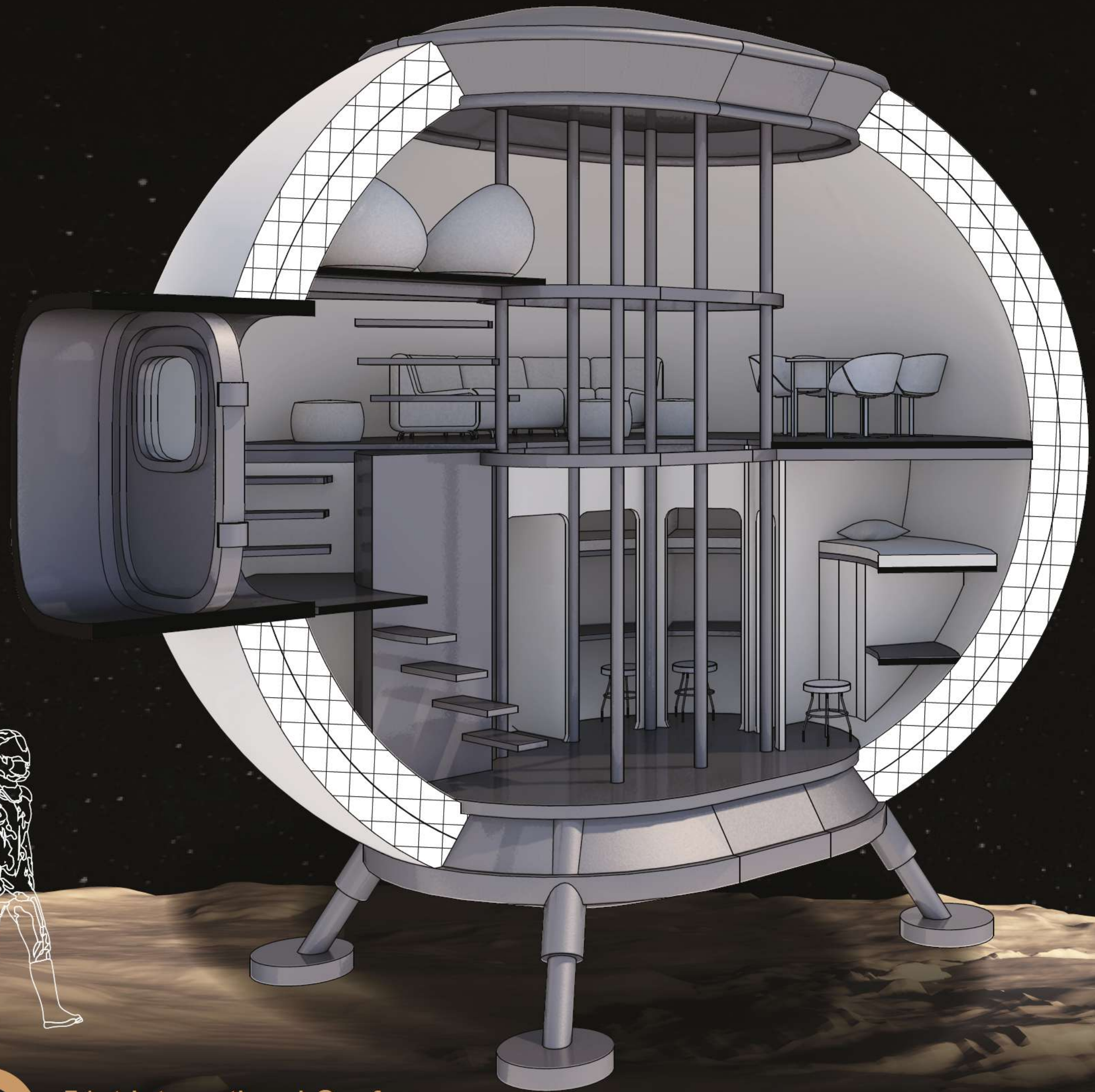
-  Food production
-  Gym
-  Hygiene Facility
-  Storage


WINDOW MODULE

-  Dining room
-  Earth view



HABITATION AND SOCIAL MODULE



	SIZE	PRIVACY	CREATES CONTAMINANTS	STERILITY REQUIRED	NOISE REQUIREMENT	NOISE PRODUCTION
 LOUNGE	9.40 m ²	SEMI PRIVATE	X	X	QUIET/NONE	INTER-MEDIATE
 LIVING ROOM	15.39 m ²	SHARED	✓	X	X	INTER-MEDIATE
 KITCHEN	6.13 m ²	SHARED	✓	✓	X	NOISY
<hr/>						
 SLEEPING Q.	0.82 m ² x 4	PRIVATE	X	X	QUIET	QUIET
 HYGIENE F.	0.52 m ² x 2	PRIVATE	✓	X	X	NOISY
 SAFE HAVEN	8.32 m ²	SHARED	✓	X	X	INTER-MEDIATE
 STORAGE	4.16 m ²	SHARED	X	X	X	X



MULTIPURPOSE LAB MODULE

SIZE	PRIVACY	CREATES CONTAMINANTS	STERILITY REQUIRED	NOISE REQUIREMENT	NOISE PRODUCTION
7.60 m ²	SHARED /SEMI PRIVATE	✓	✓	X	INTER-MEDIATE
3.67 m ²	SHARED /SEMI PRIVATE	X	X	X	INTER-MEDIATE
3.67 m ²	SEMI PRIVATE	✓	✓	QUIET	QUIET/NOISY
0.92 m ²	SHARED	X	X	X	X

SCIENCE LAB.



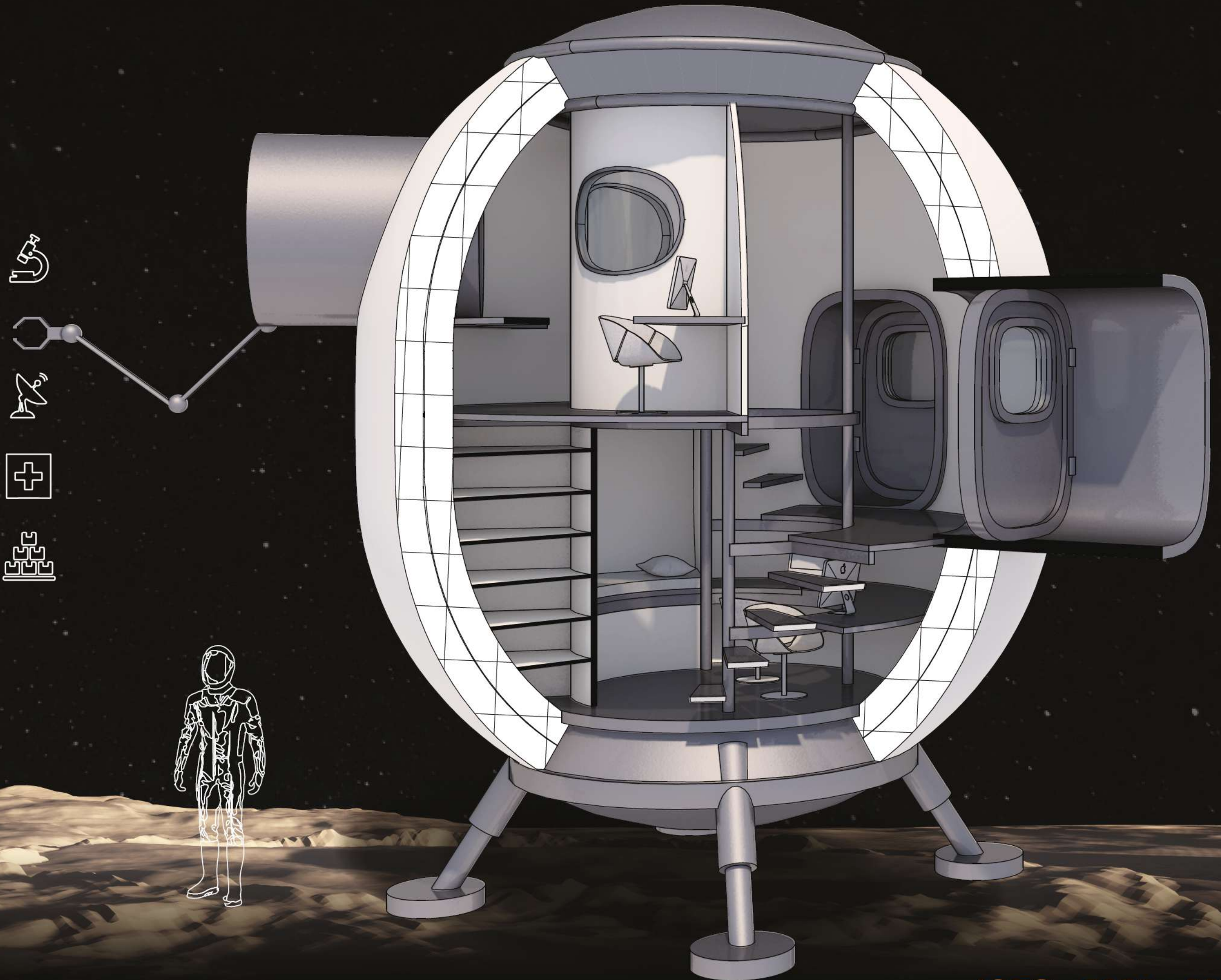
COMM ROOM



MED BAY







STORAGE



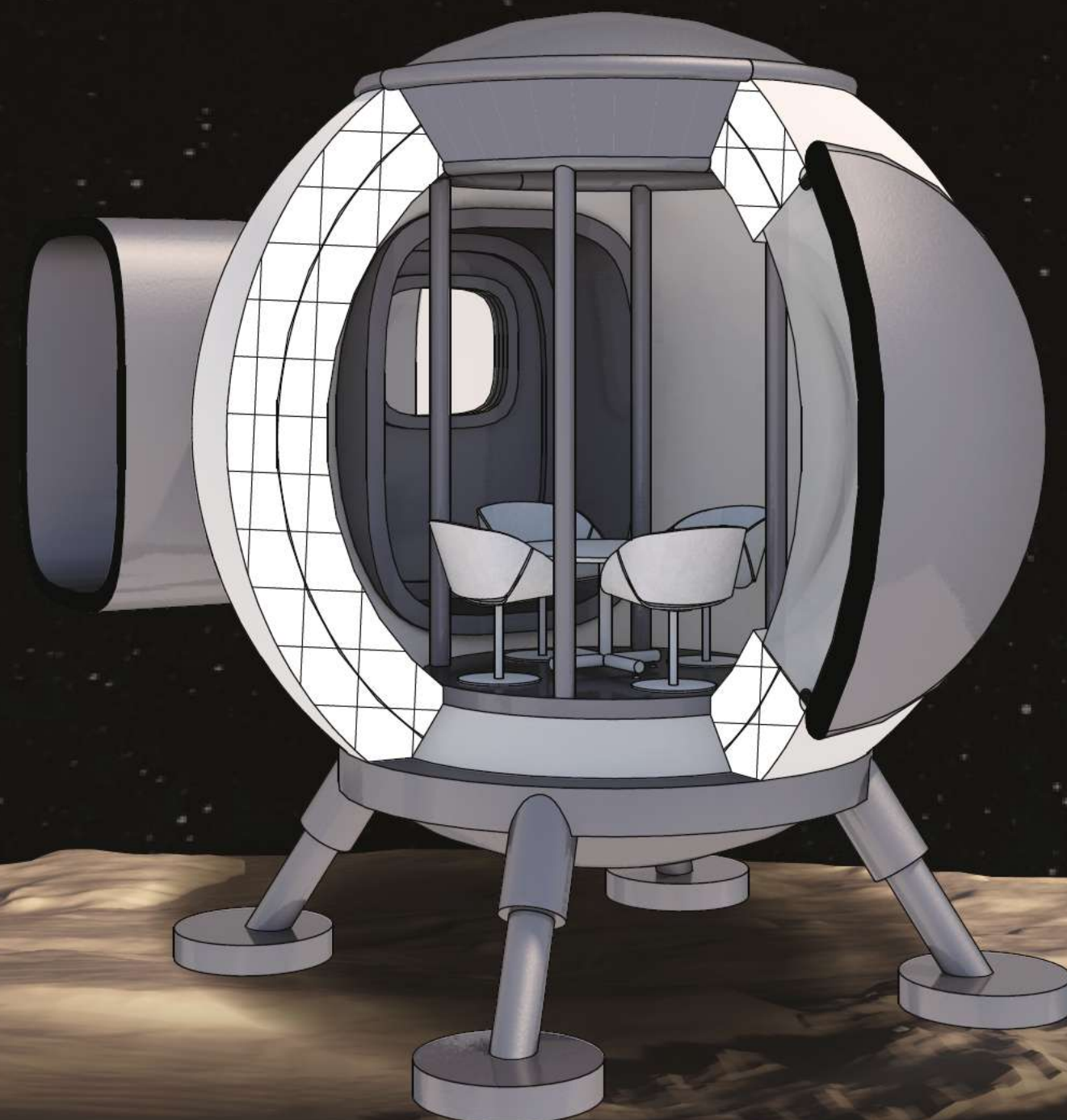
GREENHOUSE MODULE



	SIZE	PRIVACY	CREATES CONTAMINANTS	STERILITY REQUIRED	NOISE REQUIREMENT	NOISE PRODUCTION
 GREENHOUSE	23.82 m ²	SEMI PRIVATE	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	NOISY
 GYM	9.16 m ²	SEMI PRIVATE	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	NOISY
 HYGIENE F.	1.25 m ²	PRIVATE	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	NOISY
 STORAGE	9.01 m ²	SHARED	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

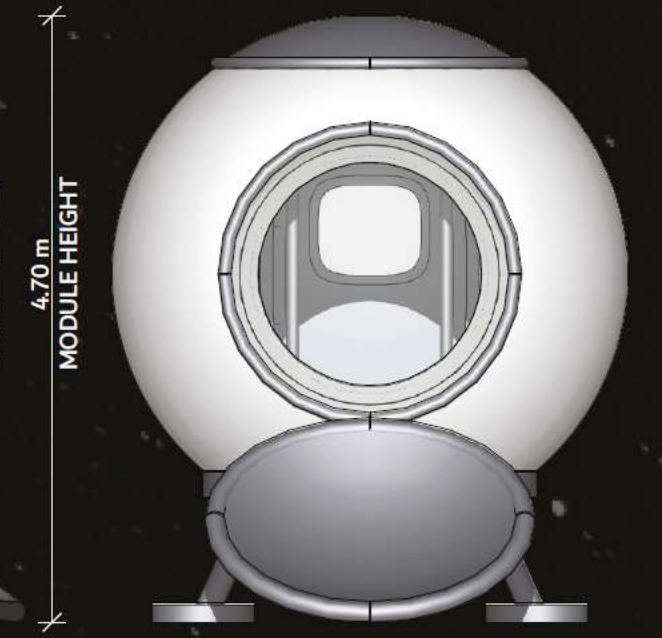
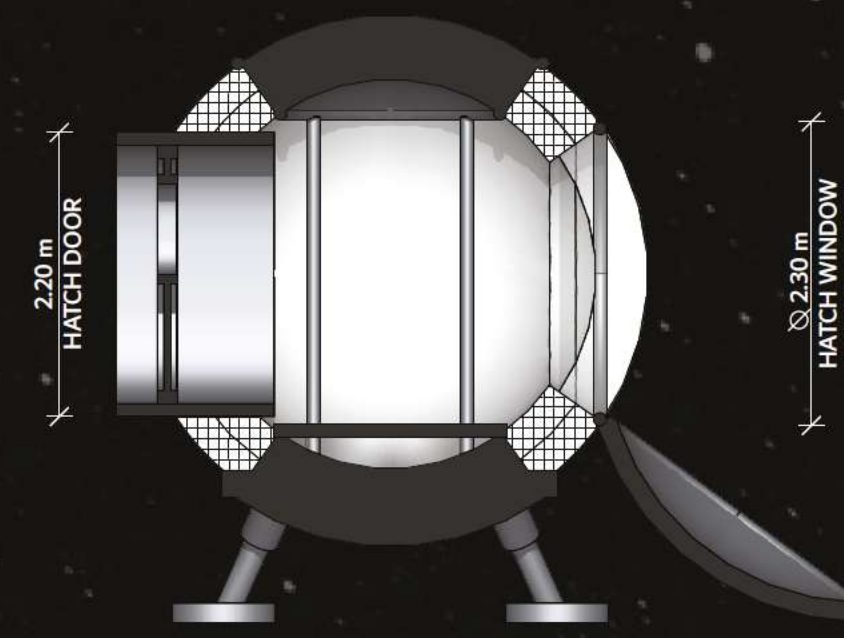
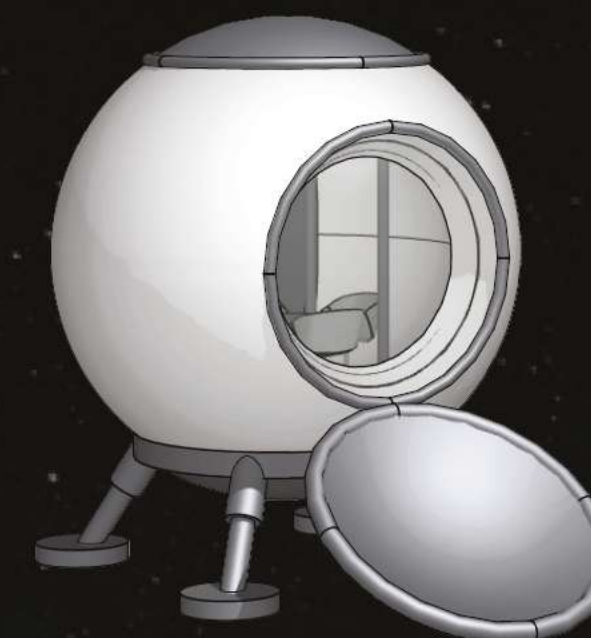


WINDOW MODULE



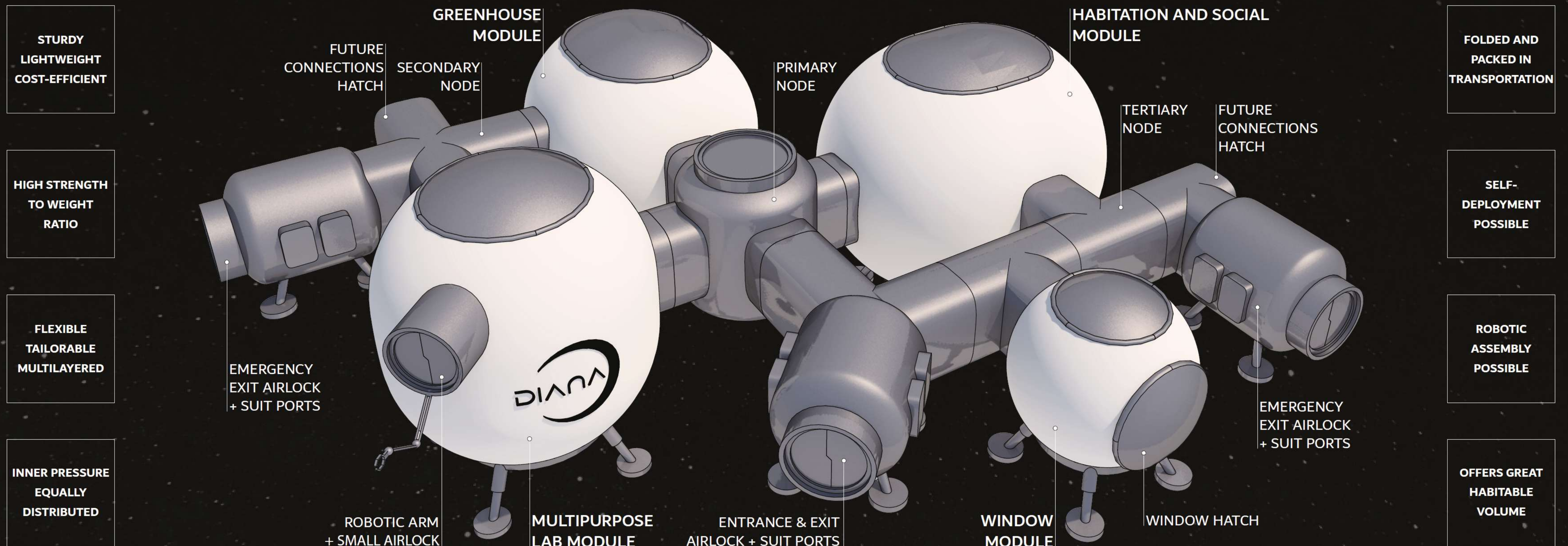
DINING ROOM

SIZE	PRIVACY	CREATES CONTAMINANTS	STERILITY REQUIRED	NOISE REQUIREMENT	NOISE PRODUCTION
2.53 m ²	SEMI PRIVATE	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	QUIET	QUIET



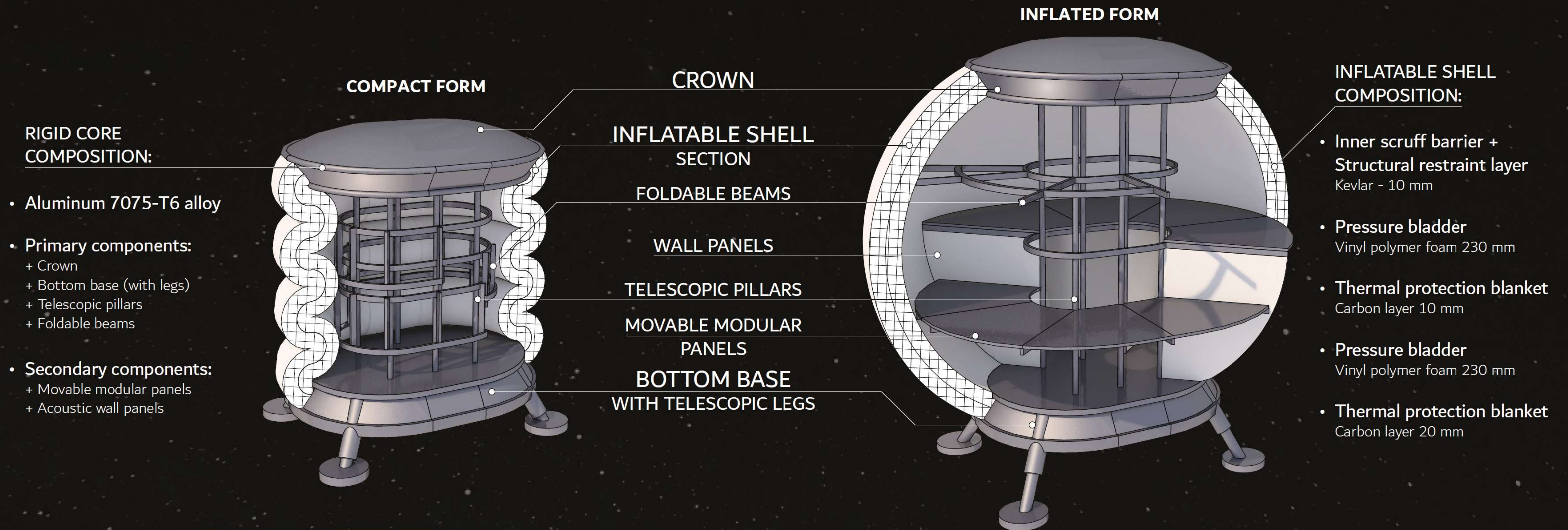
CONSTRUCTION AND MATERIALS

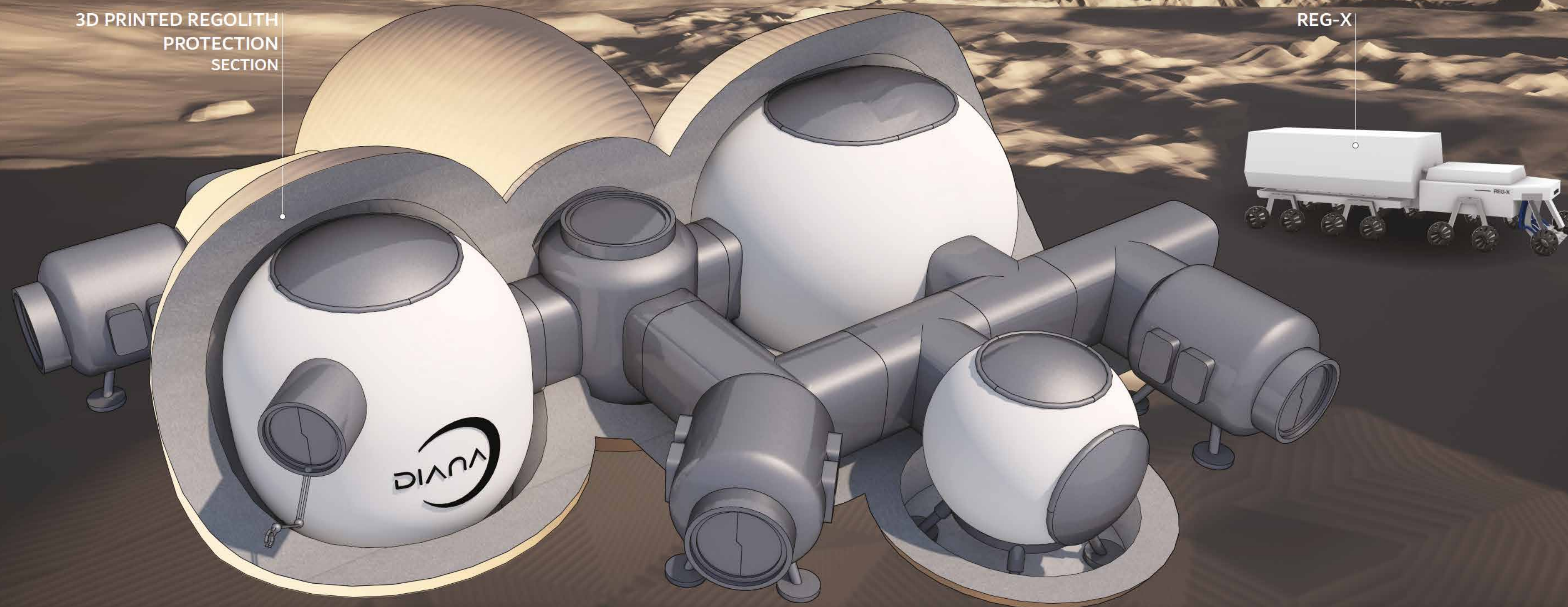
HYBRID STRUCTURE INFLATABLE SHELL + RIGID CORE



CONSTRUCTION AND MATERIALS

COMPACT VS. INFLATED FORM





MINIMIZING
COST AND
LAUNCHES

PROVIDING
VARIETY OF
CONSTRUCTION
MATERIAL

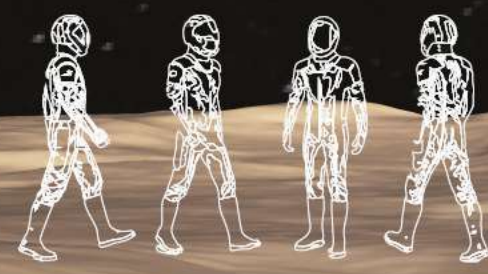
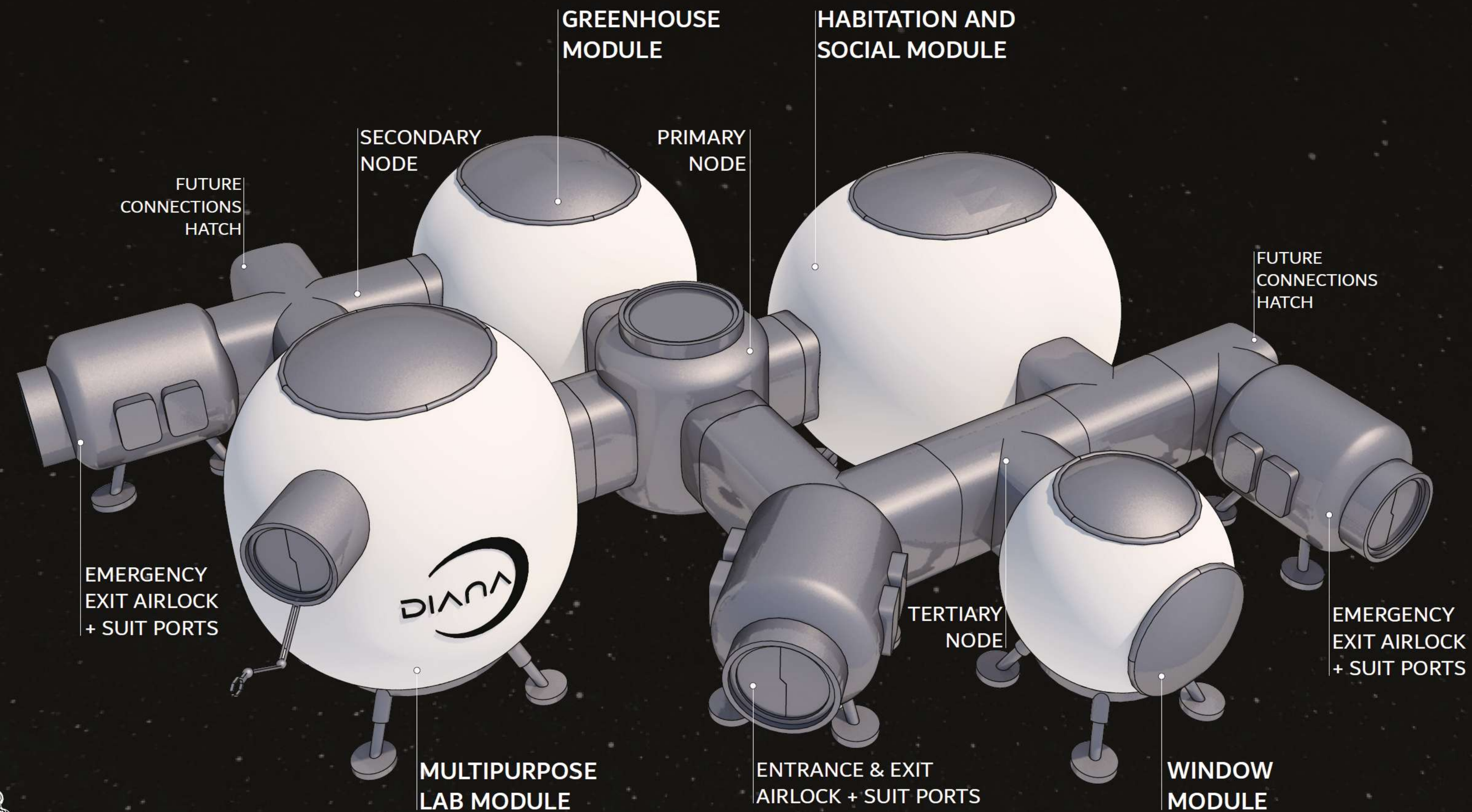
3D PRINTED
REGOLITH SHELL
FOR RADIATION
PROTECTION

PNEUMATIC
EXCAVATION
ROVER
REG-X



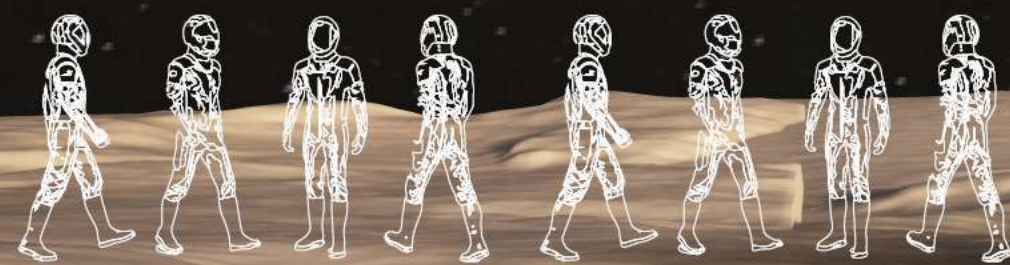
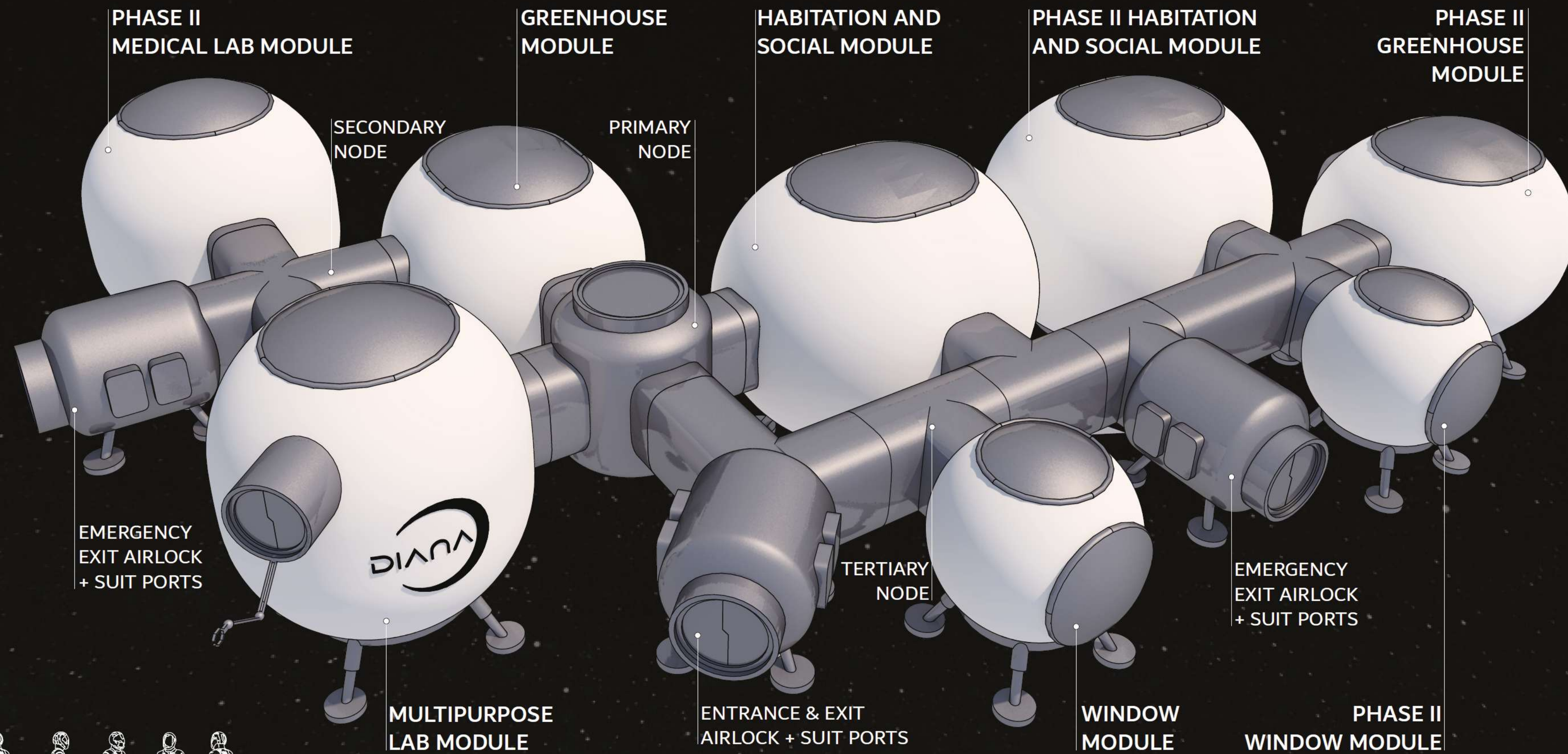
INITIAL BASE - YEAR 2031

CRUCIFORM SCHEME

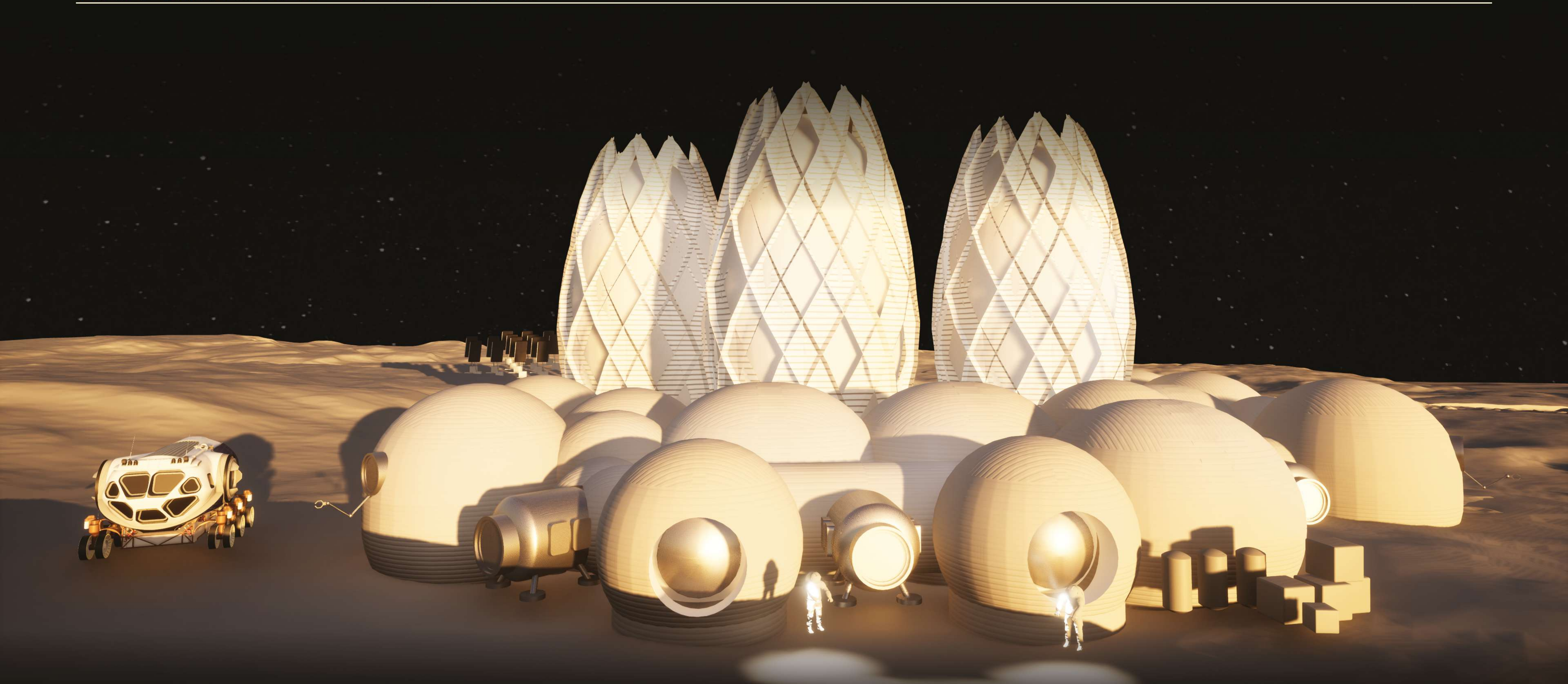


EXPANSION I - YEAR 2037

CRUCIFORM SCHEME



EXPANSION II - YEAR 2046



A background image of space featuring a view of Earth from orbit, showing the blue atmosphere and white clouds. The planet is partially obscured by a dark, rocky celestial body in the foreground. The sky is filled with numerous stars and a bright light source on the left, creating a lens flare effect.

THANK YOU!

Alma Kugic

alma.kugic@gmail.com

www.linkedin.com/in/alma-kugic