

VOMB

Rebecca M.L. Johansson

VOMB

Rebecca M.L. Johansson, Chalmers University of Technology, School of Architecture & Civil Engineering, Gothenburg, Sweden 2023



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Master of Architecture. Chalmers University of Technology.
School of Architecture & Civil Engineering, Gothenburg, Sweden, 2023.

ABOUT

© Rebecca M.L. Johansson (aka Liedberg)

Master of Architecture, MPDSD

Chalmers University of Technology

School of Architecture & Civil Engineering, 2015-2019, 2023

Direction: Material turn

Tutor: Jonas Lundberg

Examiner: Kengo Skorick

Selection of courses

Course in extraterrestrial living conditions at GU, ASF904, 2021-2022

Course in astronomy at GU, ASF914, 2022

Course in astrobiology & philosophy at CTH, SEE045, 2021-2022

Course in linear algebra at LIU, 2015-2016

Extra courses in biology and essay on aquatic life

Selection of projects at Chalmers

VOMB (Master Thesis), ACEX35, 2023

A BODY OF WORK, Architecture and cultural heritage, ARK626, 2019

FISKOTEKET, Local Context, ARK174, 2019

KOPP LA AV, with Aleksej Beilin & Martin Lindholm,

Nya Ögon på Betong, 2016

Work experience: Atrio Arkitekter i Västervik AB, 2019-2023

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For an inspiring presentation of Life on Mars, 2019

Space Architect Taylor Phillips-Hungerford

For inspiration of a Venusian habitat

Aerospace Engineer and Space Architect Jasleen Kaur

For inspiration of inflatable structures and folds

Pins Design Sweden AB

For printing this book



VOMB Intro Movie

TOC

ABSTRACT	4
SAMMANDRAG	4
INTRODUCTION	5
I. WHAT, WHEN WHY EVEN?	7
PROJECT PROGRAMME	8
BACKGROUND	8
GOALS	9
DELIMITATIONS	9
METHOD & APPROACH	10
THESIS TIMELINE	11
MAIN ARGUMENTS	12
COUNTERARGUMENTS	13
II. VOMB	15
VOMB SECTION	18
DESIGN PRINCIPLES	19
DOCKING	20
DESIGN FEATURES	21
VIEW OF HABITAT COMPLEX	22
FOLDS	30
MOODBOARD	31
SECTION OF VENUS	32

LOCAL CONDITIONS	32
DESIGN FOR HEALTH	33
VENUSIAN RESOURCES	34
ON VENUSIAN RESOURCES	35
VOMB DEPLOYMENT	36
JOURNEY IN SPACE	36
PROJECT CONTEXT	37
III. STEM FROM NATURE	39
EVOLUTION	40
THE "SUPRAORGANISM"	40
FACTORS	41
OUR ENVIRONMENT	41
OUR SENSES	42
SENSORY DEPRIVATION	43
IV. APPLY SPACE RESEARCH	45
EARTH RESOURCES	46
ON EARTH RESOURCES	46
SPACE ARCHITECTURE PROPOSALS	47
TO BUILD BEYOND EARTH	47
EXISTING SPACE PROJECTS	48
SENSE ANALYSIS	49
LIFE SUPPORT SYSTEM	50
MELISSA	50
MODULE THINKING	51
V. OUR NEIGHBOURS	53
THE SOLAR SYSTEM	54

DISTANCE	54
TEMPERATURE	55
RADIATION SHIELDING	55
PHOTOVOLTAIC POTENTIAL	55
ELECTRIC FIELD & MINING	56
ATMOSPHERE & PRESSURE	56
GRAVITY	56
ON ADAPTATION	57
VI. SPACE & HEALTH	59
SPACE HEALTH CONCERNS	60
FACTORS	60
COUNTERMEASURES	62
NASA PROPOSALS	62
OWN PROPOSALS	62
ON ADAPTATION	63
VII. DESIGN INVESTIGATIONS	65
AQUATIC STUDIES & SKETCHES	66
STUDYING SOFT SHAPE	68
EXPLORING FOLDS	70
SOFT ORIGAMI	72
SIMULATING SHAPE	74
FORM COMBINATIONS	75
VIII - SUMMARY & SOURCES	77
CRITISISM	78
SUMMARY	79
SOURCES	80

ABSTRACT

Ever since our first observation of the universe, outer space has been something that many of us have thought about. When referring to space, it has usually been called something underlining its depth or unknown character, e.g. “nothingness” or “way beyond”. Today, our fascination for space has spread to multiple sectors, one of them being architecture.

Space exploration has brought valuable knowledge and inventions, however, not without consequences. As of today, all resources for space projects have been extracted from Earth, both financially and in terms of material. Space travel has also brought many health concerns to the human body and mind. Given this situation, the aim of this thesis was to design a visionary, functional and conceptual architectural proposal, focusing on the following questions:

What can space architecture do for longterm resilience in space, both for human well-being and the human being as a species?

If we want to expand in space, where would we settle first and why, from a health perspective?

In order to continue with space research, we need to construct better material cycles for future space projects to come. In order to carry out longer manned space missions, more knowledge on human health needs to be applied.

SAMMANDRAG

Sedan vår första observation av universum så har yttre rymden varit något som många av oss funderat kring. När vi har hänvisat till rymden så vi ofta framhävt dess djup eller okända karaktär t.ex. “det stora intet” eller “långt bortom”. Idag har vår fascination för rymden spridit sig till flera sektorer, varav en är arkitekturen.

Utforskandet av rymden har gett värdefull kunskap och upphov till nya innovationer, men inte utan konsekvenser. I dagsläget har alla rymdprojekt tillverkats av resurser från Jorden, både ekonomiskt och materiellt. Rymduppdrag har också gett upphov till en rad hälsoproblem, både fysiskt och psykiskt. Med denna situation i åtanke så var målet med detta masterarbete att designa ett visionärt, funktionellt och konceptuellt arkitektoniskt förslag, detta utifrån följande frågeställningar:

Vad kan rymdarkitektur göra för långsiktig resiliens i rymden, både för människans välmående och människan som en art?

Om vi vill kolonisera i rymden, var skulle vi resa först och varför utifrån ett hälsoperspektiv?

För att kunna fortsätta med rymdforskning så behöver vi bygga upp bättre materialcykler för framtida rymdprojekt. För att kunna genomföra längre bemannade rymduppdrag så behöver vi applicera mer kunskap kring människors hälsa.

INTRODUCTION

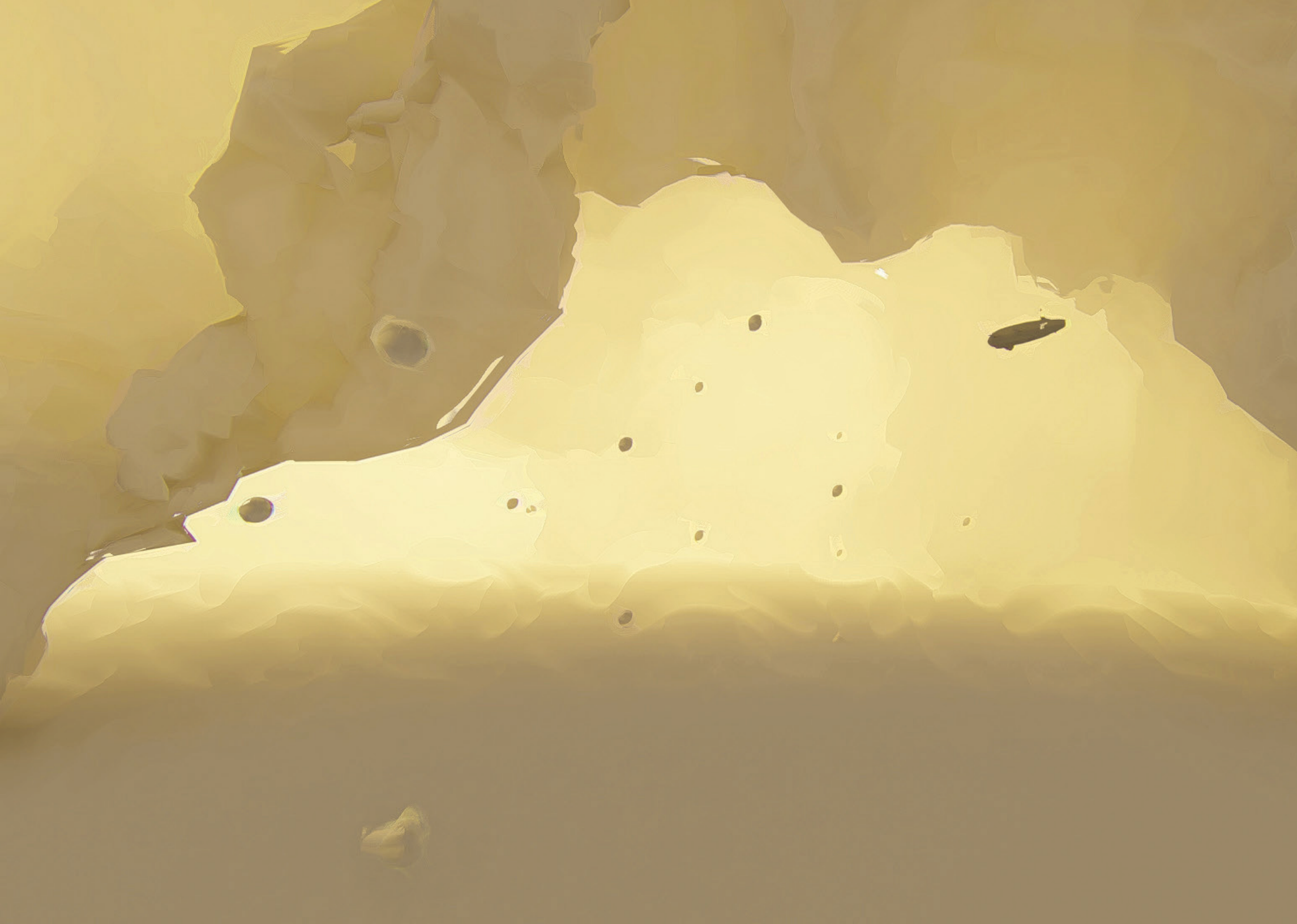
Since our first steps on Earth, the human species has evolved by adapting and shaping the environment to its needs. Yet, despite technological advancements and inventions, some environments have represented a huge challenge for our health. One of these environments has been outer space.

Therefore, this thesis was conceived to explore possible architectural solutions for human health in space, by stemming from biology, applying space research, as well as sketching and modeling with physical & digital models.

Because there were no established material production in space at the time of composing this thesis, the author included speculative ideas about the topic, partly because of the unexplored industry. While this may be seen as an Achilles' heel, it was necessary to bring substance/context to a conceptual project, touching upon sci-fi.

As a result, VOMB presented architectural products of different space innovations and multiple identified health concerns, focusing on those presented by NASA in presentation from 2015 and a webpost by NASA (2022c), which included potential countermeasures.





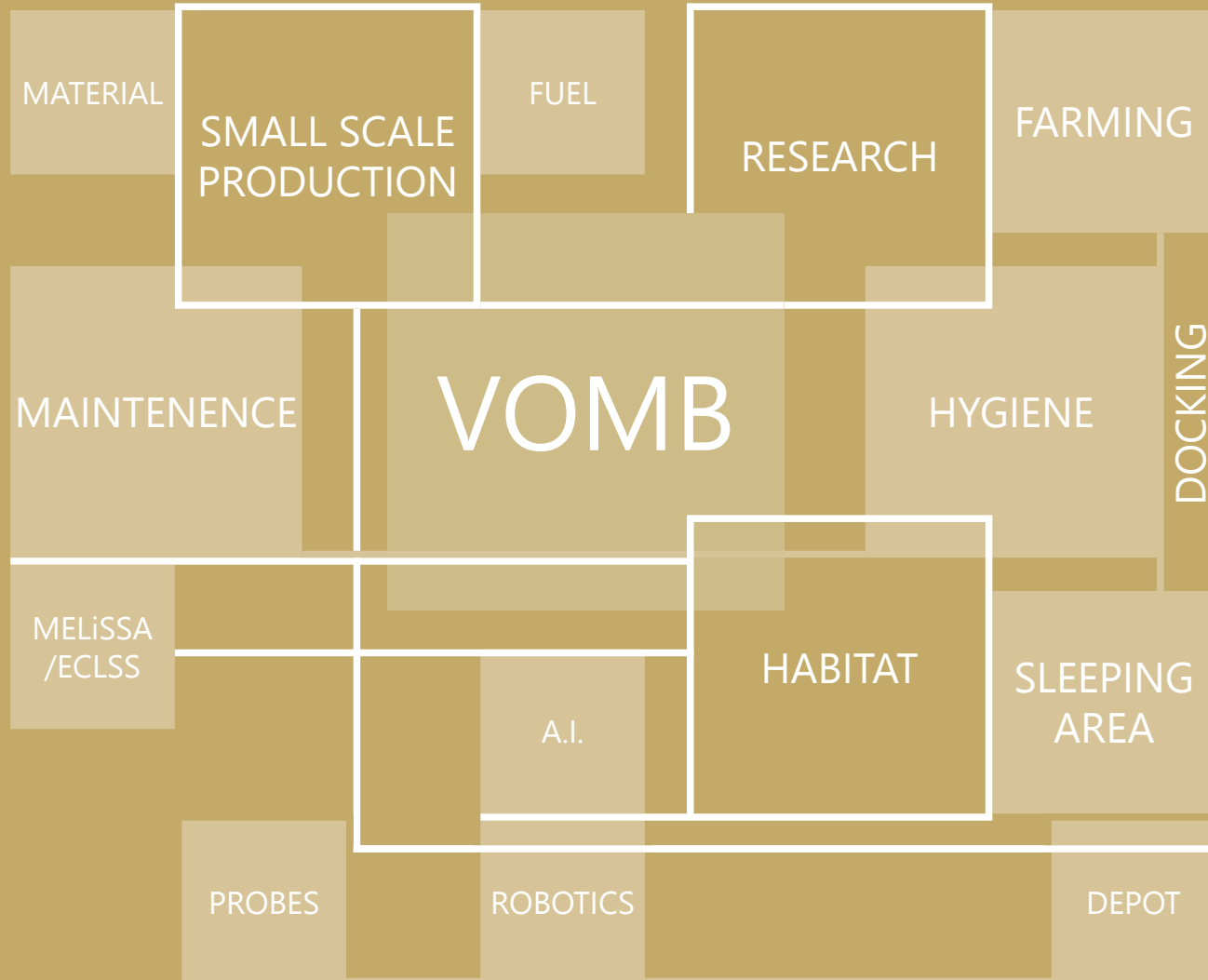
It's three months since our mission started.

Soon, our blimp will arrive at the habitat, I think while looking out from the window.

They said that Venus would have little to look at because of the altitude, however, they never considered the ever-changing landscape of sulfuric clouds...

I. WHAT, WHEN, WHY EVEN?

PROJECT PROGRAMME



BACKGROUND

The background revolves around two questions:

1. What can space architecture do for longterm resilience in space, both for human well-being and the human being as a species?

This is important to investigate in order to explore possible architectural solutions, which may support human well-being, adding knowledge about ourselves & how we may thrive better in our current environment.

2. If we want to expand in space, where would we settle first and why, from a health perspective?

From an evolutionary perspective, this is a valid question to investigate. Mars and the Moon are often mentioned as potential sites for future expansion, not necessarily because of their conditions, rather because of a romanticized image. By approaching this question from e.g. biology & health concerns, instead of sci-fi media, the answer may be different and provide an alternative proposal to existing iterations. In regard to outcome, this thesis aims to work as a source for future architectural space projects. That being said, the main audience of this thesis are architects or students within architecture, preferably with an interest in space architecture/ astronomy. In order to achieve the desired outcome, VOMB uses three goals to limit its content & structure aims (see next page).

GOALS

1

Visionary

The first goal of VOMB is to be visionary and provide a contrast to already existing habitat proposals in space, focusing on published architectural works at Chalmers University of Technology. This goal is met by using a set of methods & tools listed on next page.

2

Functional

The second goal of VOMB is to propose a structure with a realistic functionality and context in relation to identified risks & needs within space architecture today, focusing on human health. These needs are linked to an presentation about health concerns published by NASA (2015).

3

Conceptually realistic

The third goal of VOMB is to design a realistic concept that, hypothetically, better maintains human health in comparison with the ISS. This is in regard to the current challenges and health concerns as well planetary conditions. This goal is something that, potentially, can be tested in high-fidelity environments or mock-up interiors of the proposal. Depending on the aspects we want to measure, these interiors may also be built on Earth.

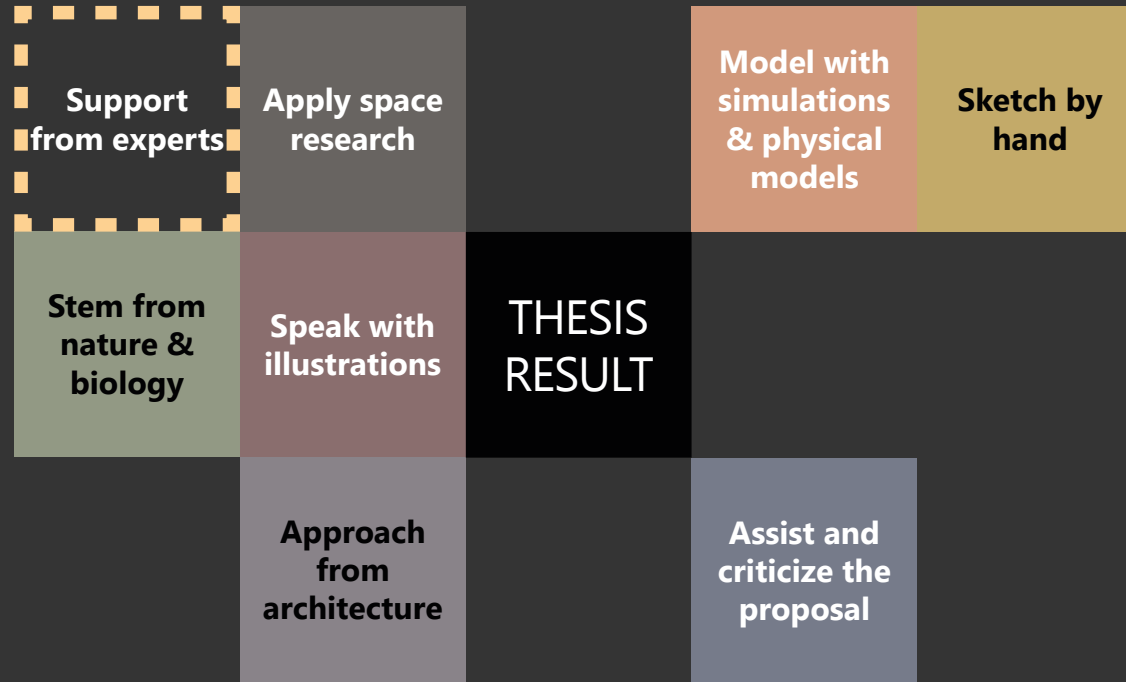
DELIMITATIONS

This thesis explores the future scenario of space habitats in the 22nd century. In context, this is more than 70 years after the retirement of the ISS (NASA, 2022a) and 65-70 years after NASA:s planned launch to Mars (NASA, 2017c).

Because of the limitation of 80 pages, more elaborate sections on human psychology, senses and biology are limited to provide a short, yet comprehensive overview of the approach, leaving more pages for architectural drawings, design investigations and criticism. The criticism part is meant to add comments on some of thesis chapters as well as acknowledge areas where the thesis may lack in content, once the full project is presented.

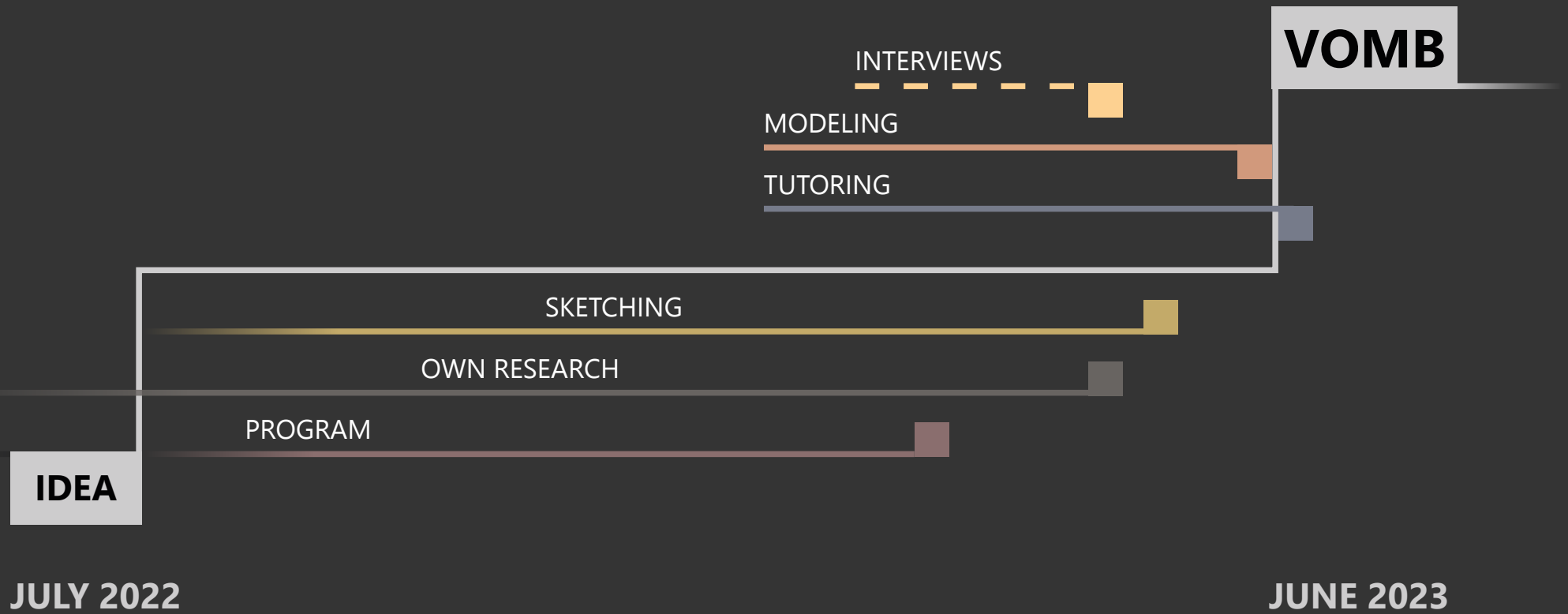
Unlike many other architectural proposals, the goal of VOMB isn't necessarily to illustrate a permanent colony for generations of human settlers, but to design an environment that, hypothetically, is more comfortable than the ISS. As a whole, VOMB is designed for four to eight astronauts, missioned to explore the possibilities of extraterrestrial industries and habitats. The project is divided multiple phases, focusing on the VOMB-habitat. Detailed drawings of life supporting systems, unique for this thesis, are not the main priority. VOMB applies the already existing closed-loop proposal "MELiSSA" (ESA, N/Da) instead of the open ISS ECLS-system as its core (NASA, 2017a).

METHOD & APPROACH



- For fresh sources
- Because of topic
- For shape/geometry
- For idea spawning
- Because of background
- For pedagogics
- Because of profession
- For judging realism

THESIS TIMELINE



ARGUMENTS FOR SPACE EXPLORATION

I: PRESERVE EARTH'S RESOURCES

While rocket launches, space shuttles and the deployment of new satellites may be tools to gain knowledge about Earth & outer space, their consumption of Earth's resources is a fact (Peter, 2022).

Today, there are mines everywhere, miles underground and even at the bottom of the Earth's ocean (AEMA, N/D).

By supporting the development of a more independent space economy and mine e.g. asteroids, we may counter future depletion of resources on Earth (Yarlagadda, 2022).

II: SUPPORT RESEARCH IN SPACE

Physical research in space is capable of bringing additional knowledge to simulations conducted here on Earth. Looking at previous research from the Apollo projects, we can confirm that many technologies and inventions of today's society stem from these space projects. Examples include solar panels, food storage, memory foam in beds and protection against radiation (NASA, 2004).

In addition to that, just like previous space projects, future explorations may provide knowledge within the field of space missions & health, requiring the unique attributes of humans in space (NASA, 2015).

III: ELIMINATE POTENTIAL THREATS

The physical resources applied to space-based projects rarely return to Earth unless we intend it to.

By developing a concept of extraterrestrial mining and material production in space, we may, potentially, present an alternative to current resource extraction (Yarlagadda, 2022). However, we may also eliminate potential threats in our solar system, mainly Near-Earth Asteroids, also called "NEA:s". NEA:s include e.g. Apollo-asteroids and Aten-asteroids, which cross the orbit of Earth (NASA, N/Dc; NASA N/Dd; Yarlagadda, 2022).

COUNTERARGUMENTS

ANSWERS

RISK

- *It's too great of a risk with space missions, we don't need it.*

THAT DEPENDS ON OUTCOME

- According to NASA (2015, p.30) the human mind has proven to be sensitive for long missions in space. Depending on outcome, we need to evaluate risks versus possible gains. The proposal of VOMB aims to minimize the risks in regard to travel duration & human health in space.

DISTANCE

- *The project is too far away. It's better to choose Antarctica as a site.*

THAT DEPENDS ON LOCATION

- Projects are already being conducted in Antarctica (NASA, 2021c), though few architectural proposals touch upon fuel production or space-mining in a complete extraterrestrial environment.

COST

- *Too much financial resources are pumped into it.*

TRUE

- Simply minding the sheer amount of financial resources being invested, this is a valid argument. According to a Webinar with Nicolas Peter at the International Space University (2022) the global market size of space industry was roughly 350 billion USD in 2020. However, space exploration projects has proven to bring valuable knowledge and technical advancements, which can be applied on Earth (NASA, 2004).

“We came all this way to explore the moon, and the most important thing is that we discovered the Earth.”

- Bill Anders

*Lunar Module Pilot/Astronaut at Apollo 8
(NASA, N/Da)*





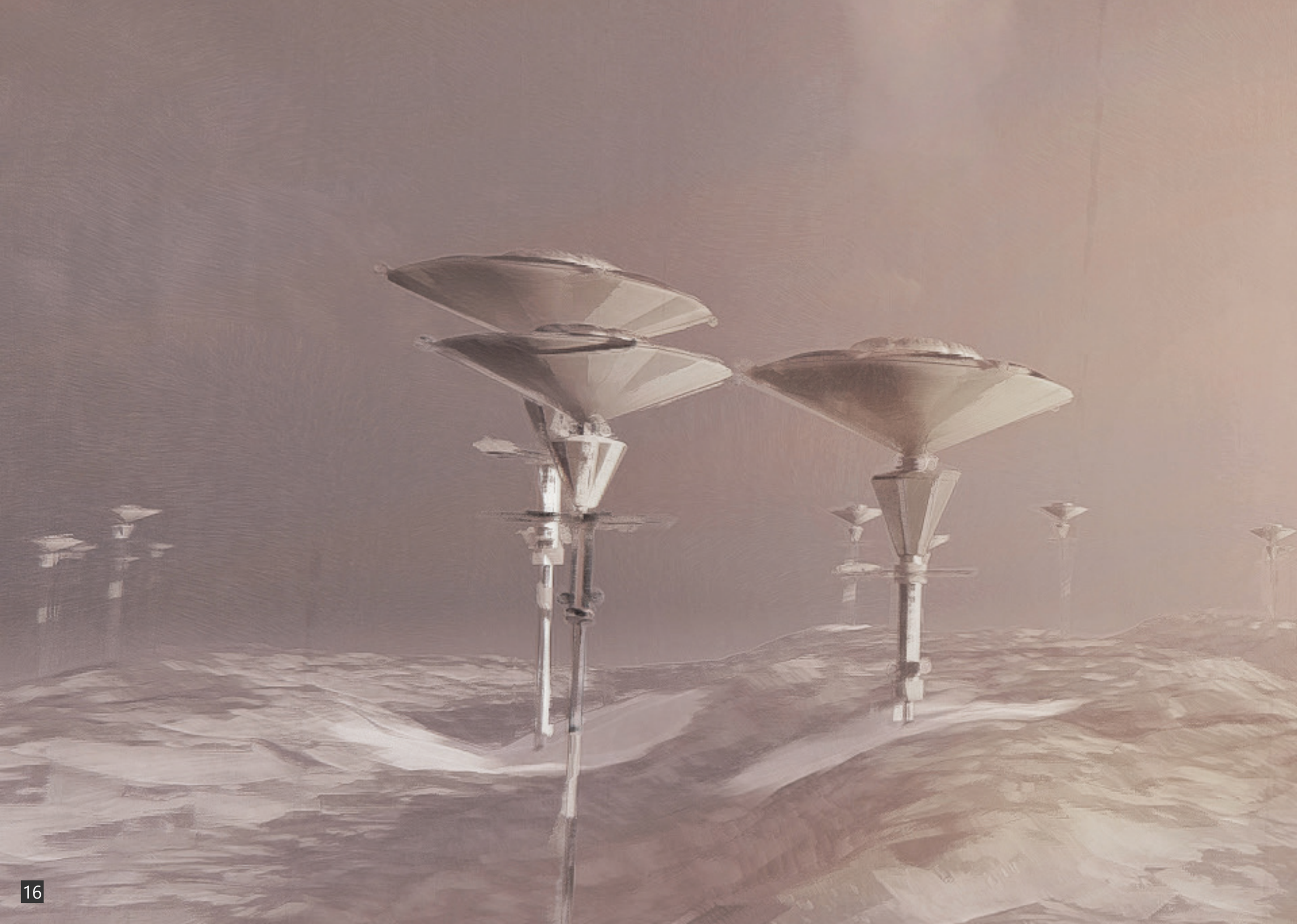
... In the far distance a gas mining station can be seen hovering above the clouds. The sky is slightly brighter now.

We are approaching the Venusian Observatory & Mining Base.

Imagine, the Martian team won't arrive until another two months. I fix my eyes on a nearby gas mining station for a moment.

I'm glad that we will arrive at the habitat soon...

II . VOMB





VOMB SECTION

HYDROGEN BALLOONS
STRAPPED TO CORE, SIMILARLY TO A HIAD, FOR
POSSIBLE ADDITIONS

GREEN CONE

CONE-SHAPE FOR CENTERED
WATER CIRCULATION, PLANT FARM,
PNEUMATICALLY REINFORCED FEP-WALLS

GALLERY

POST-CONSTRUCTED PNEUMATIC
FLOORING (LITTEKEN ET AL., 2019) WITH
INFLATABLE BASE OR FOLDABLE TRUSSES

ELEVATOR/STAIRCASE

CORE WITH INFRASTRUCTURE AND
AIRTIGHT ROLL-UP DOORS

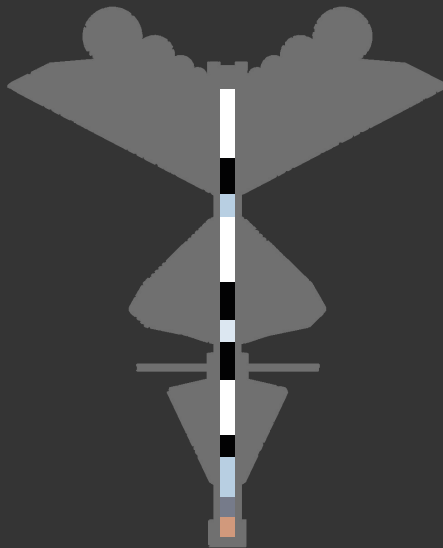
MODULAR TECH CORE

MELISSA-CENTER & INSECT FARMS (GAS
CHAMBERS FOR MINING BASES) TO ISOLATE
NOISY ACTIVITIES



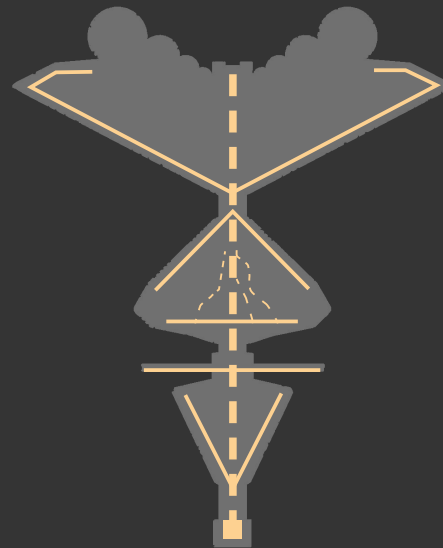
SCALE 1:1000

DESIGN PRINCIPLES



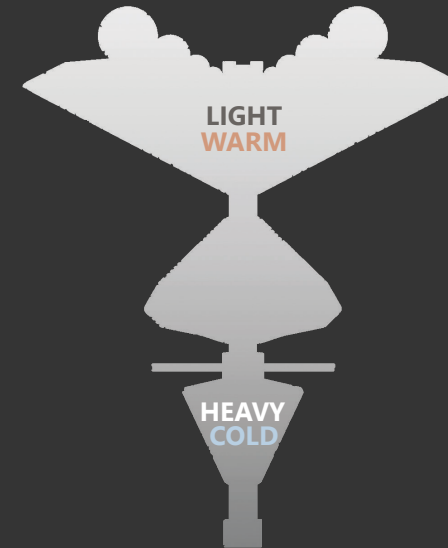
WATER/STORAGE

- - WATER TANK
- - FIXTURE CONNECTION
- - AIR INFLATION SYSTEM
- - SPINE STORAGE
- - MELISSA



ELECTRICITY

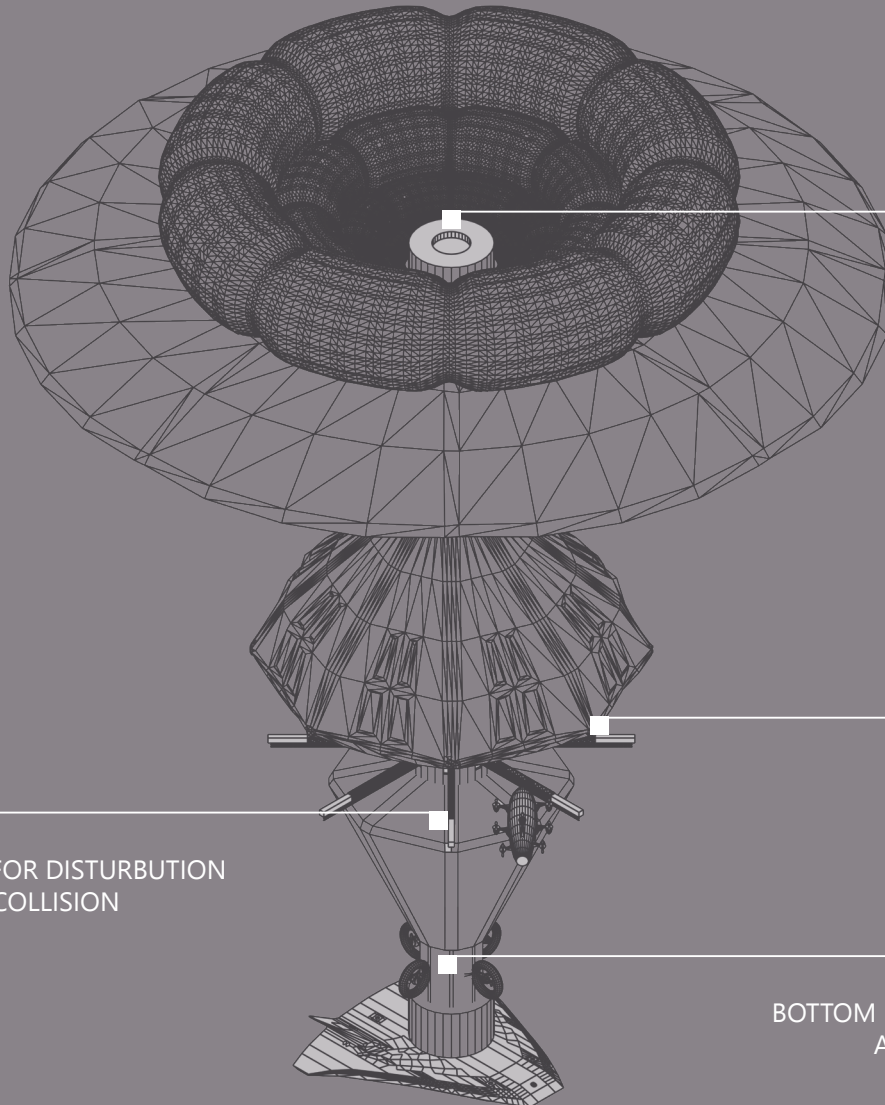
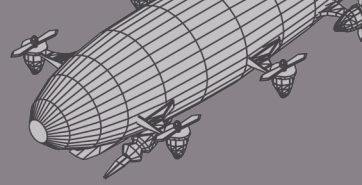
- SENSORS
- ELEVATOR
- ELECTRICITY & BATTERY
- CABLES/BRANCHES ALONG PNEUMATIC ARMS



WEIGHT & TEMP

- BOBBER-DISTRIBUTION
- AIR AS NATURAL LIFTING GAS
- EXTERNAL HYDROGEN BALLOONS (FOR MORE LIFTING CAPACITY)

DOCKING



BLIMP
TOP ENTRY FOR LESS SIZE
RESTRICTIONS

TRACKS
FOR CHARGING AND
PARKING ROBOTS

ROBOT
MIDDLE ENTRY FOR DISTURBUTION
AND TO AVOID COLLISION

JET
BOTTOM ENTRY FOR AERODYNAMICS
AND TO AVOID ENGINE HEAT

DESIGN FEATURES

Compliant mechanisms & origami

In order to lower part count & avoid joint friction, VOMB uses 3D-printable compliant mechanisms for tools and equipment. Inflatable rooms (hubbles) are used to divide the habitat into neat spaces, These rooms can be easily moved or adjusted in case the needs would change or to introduce novelty.

Soft robotics

To avoid extra weight during the journey, VOMB uses soft robotics & blimps for maintenance of the interior and exterior.

Storage

To avoid a reaction between hydrogen and oxygen, VOMB has exterior hydrogen depots and balloon rings. The interior spine is used to store tools, inflatables, gas for facade bladders, furniture and food.

Washing clothes

Today, it's not possible to wash clothes on the ISS. As an alternative, NASA (2003) offers four choices:

1. Wear it again
2. Turn it into a shooting star
3. Grow plants with it
4. Feed it to bacteria

Thanks to potential water production (Phillips-Hungerford, 2017; NASA, 2019), VOMB may be capable of washing clothes.

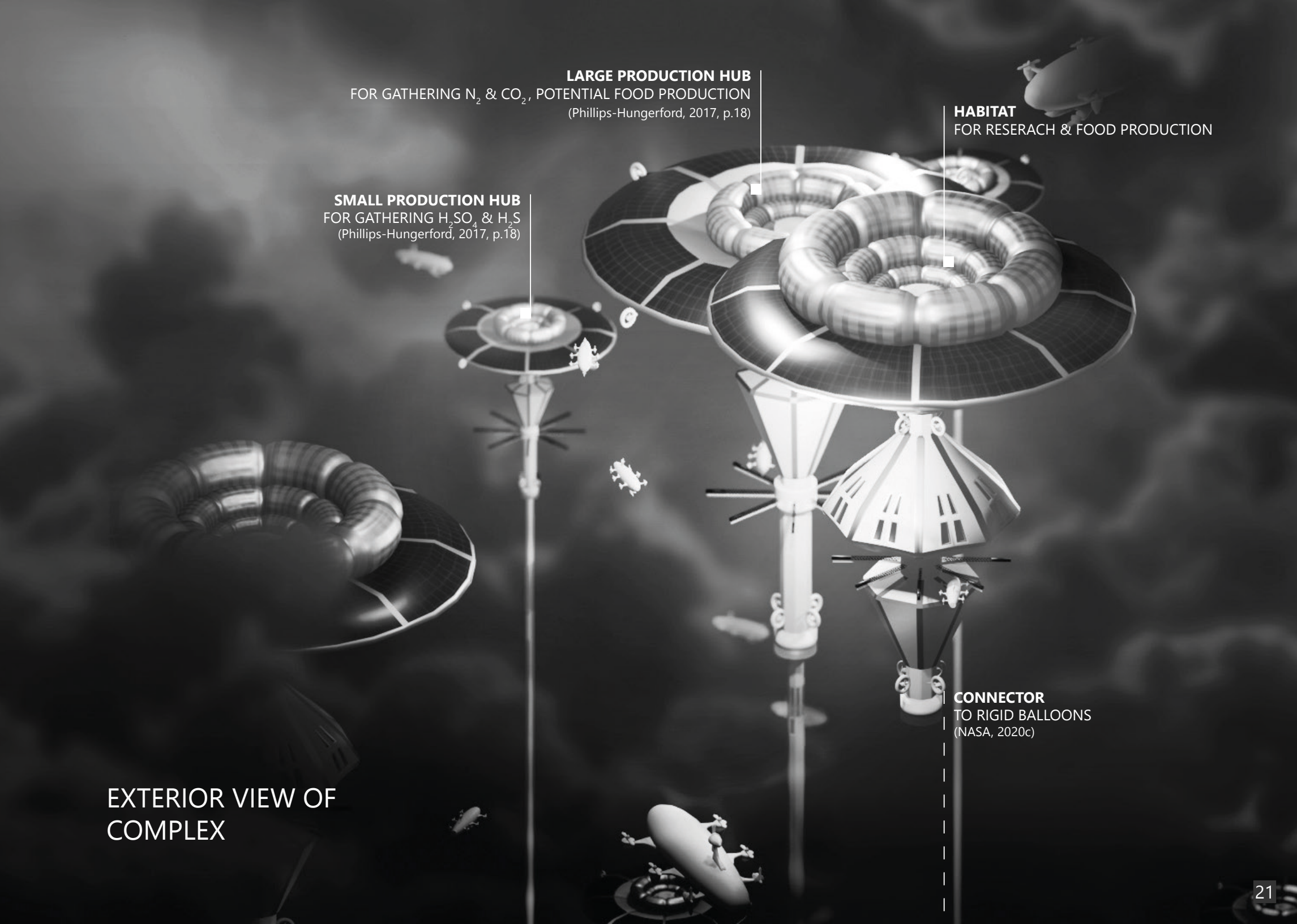
LARGE PRODUCTION HUB
FOR GATHERING N_2 & CO_2 , POTENTIAL FOOD PRODUCTION
(Phillips-Hungerford, 2017, p.18)

HABITAT
FOR RESEARCH & FOOD PRODUCTION

SMALL PRODUCTION HUB
FOR GATHERING H_2SO_4 & H_2S
(Phillips-Hungerford, 2017, p.18)

CONNECTOR
TO RIGID BALLOONS
(NASA, 2020c)

EXTERIOR VIEW OF
COMPLEX

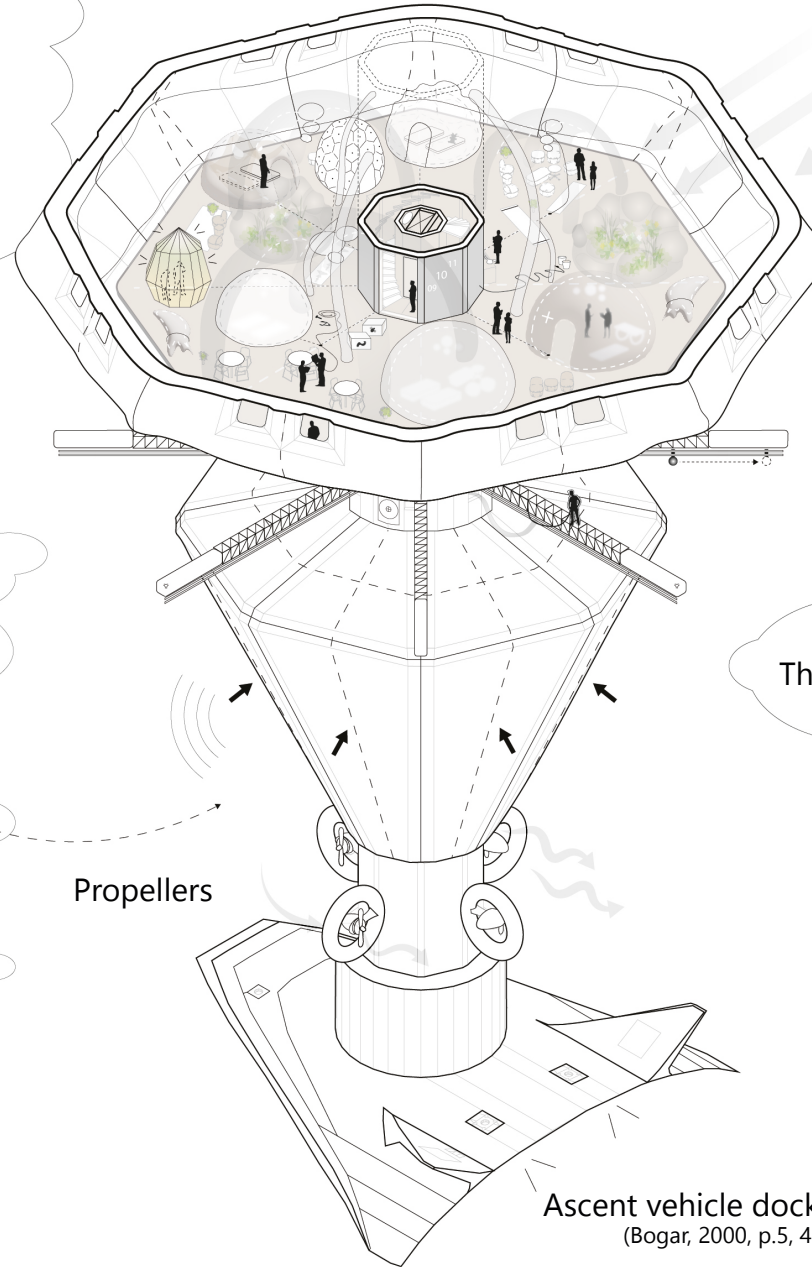
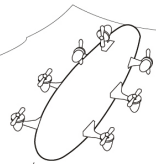


HABITAT

CASE: MEDICAL EXAMINATION & MEETING

Clouds of sulfuric acid

Solar rays



Atmospheric filter robot

Ground heat

Propellers

Thunder

Acidic precipitation

Ascent vehicle docking
(Bogar, 2000, p.5, 40-41)

0

50 METERS
SCALE 1:500

Light therapy room to
balance daylight and mood
(Bertoldi et al., 2021)

Dialer & VR-room
(Pneuhaus, N/Da)

Personal "hubbles"
in different materials

Compliant
mechanism tools

Inflatable fixtures/pergolas for a forest-like volume
(Pneuhaus, N/Db)

Yeah!
They'll visit
you too

Green house
for hobby/health

Temporary arrangement
for medical examination

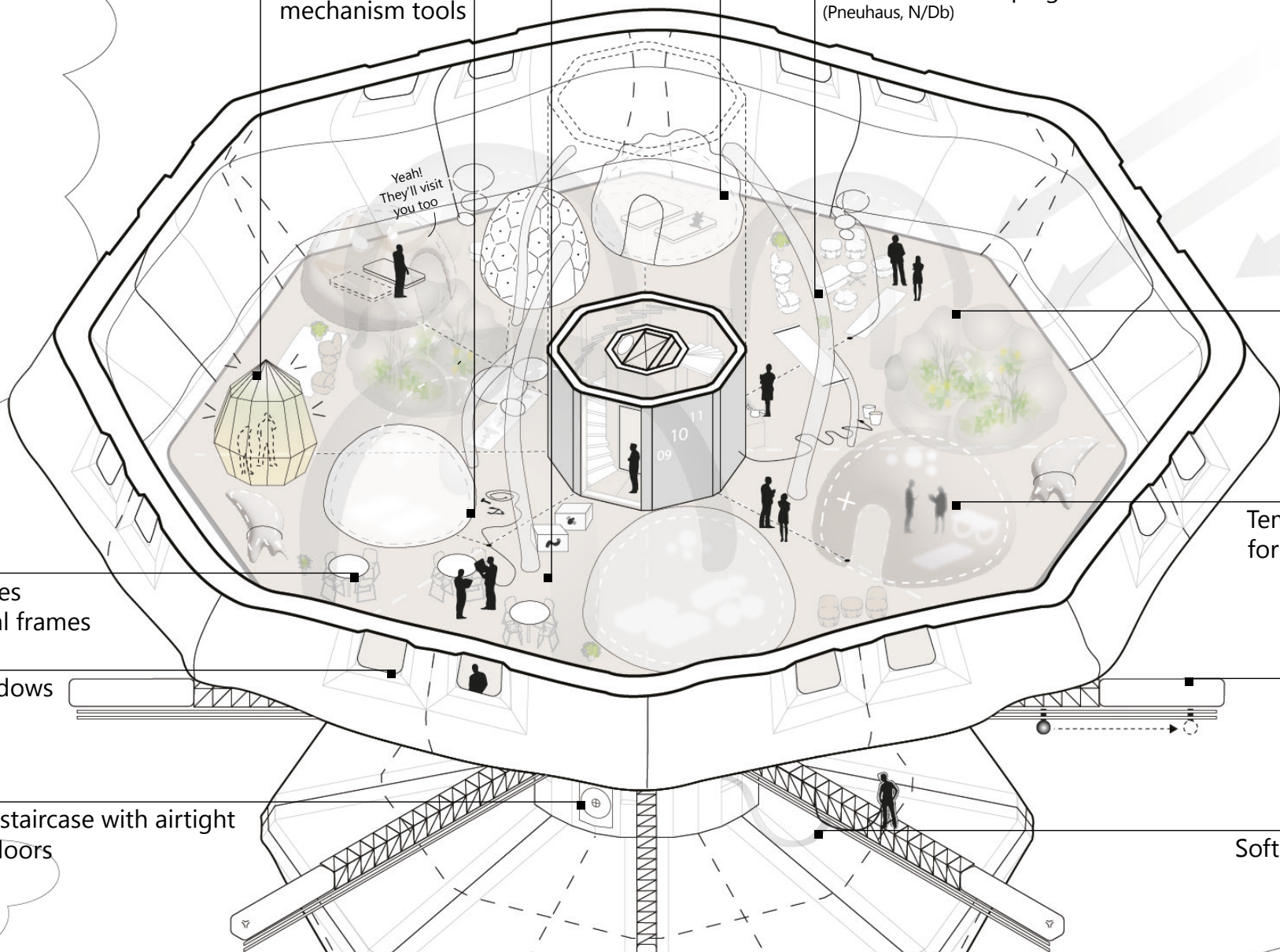
Inflatables
as spatial frames

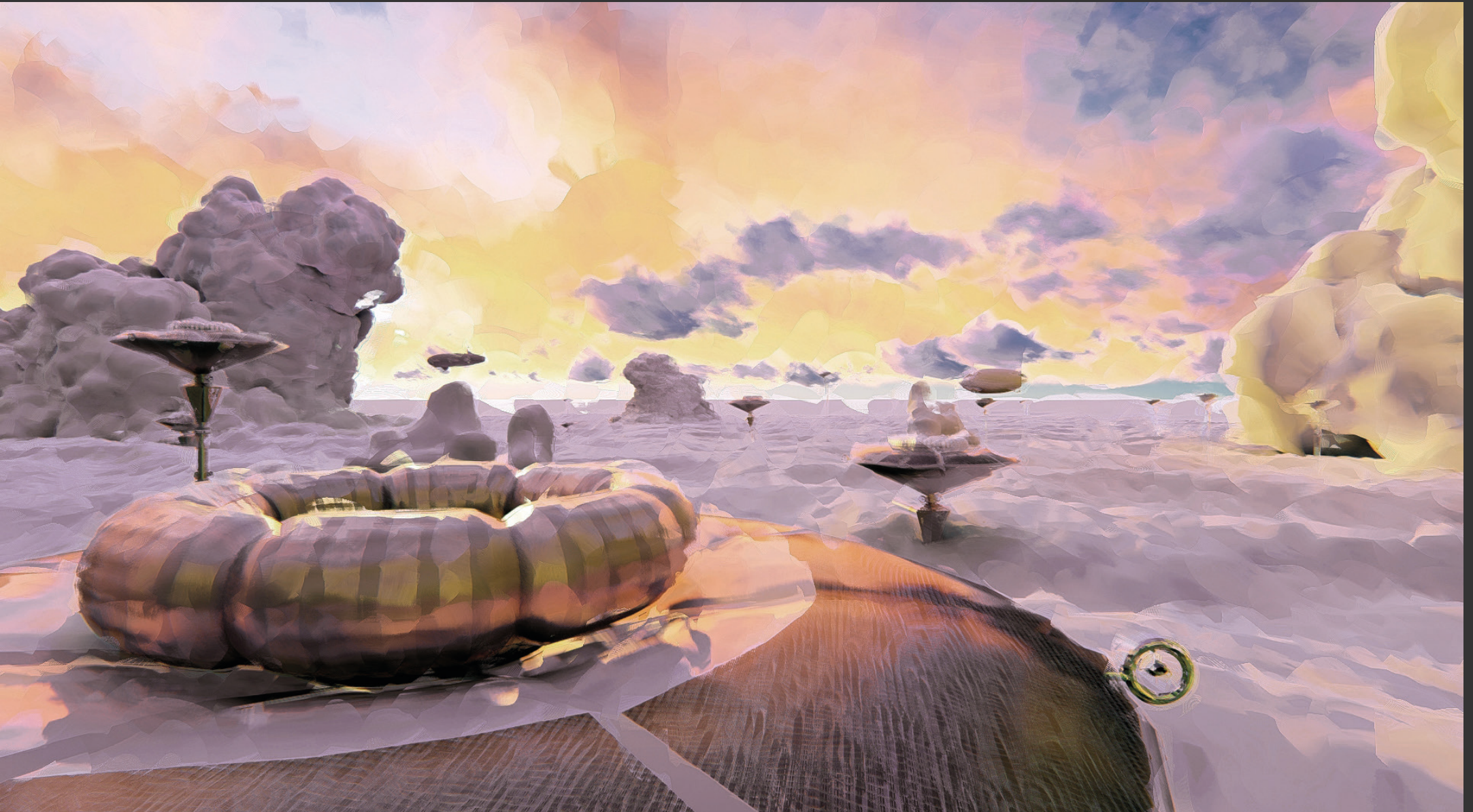
FEP-windows

Collision protected
FEP-covered tracks
for robot charging

Vault to staircase with airtight
roll-up doors

Soft robotic maintenance





Exterior view during morning, displaying hydrogen balloons and photovoltaic surfaces



Exterior view during sunset. Nearby colonies act as visual points of reference in the ever-changing landscape of clouds



Inflatable hubbles with soft fabric interiors for warmer impression, filtering sunlight, as well as dividing and animating the area with organic grammar



A. Large (Habitat) scale

Long visual distance to neighbouring colonies through semitranslucent FEP-windows, normal temperature, plastic/metal materials, surfaces reflecting skybox and planetary activities

B. Medium (Cone) scale

medium visual distance, humid, green, bright/dark depending on setting, plastics and carbon fiber contrasting with living material

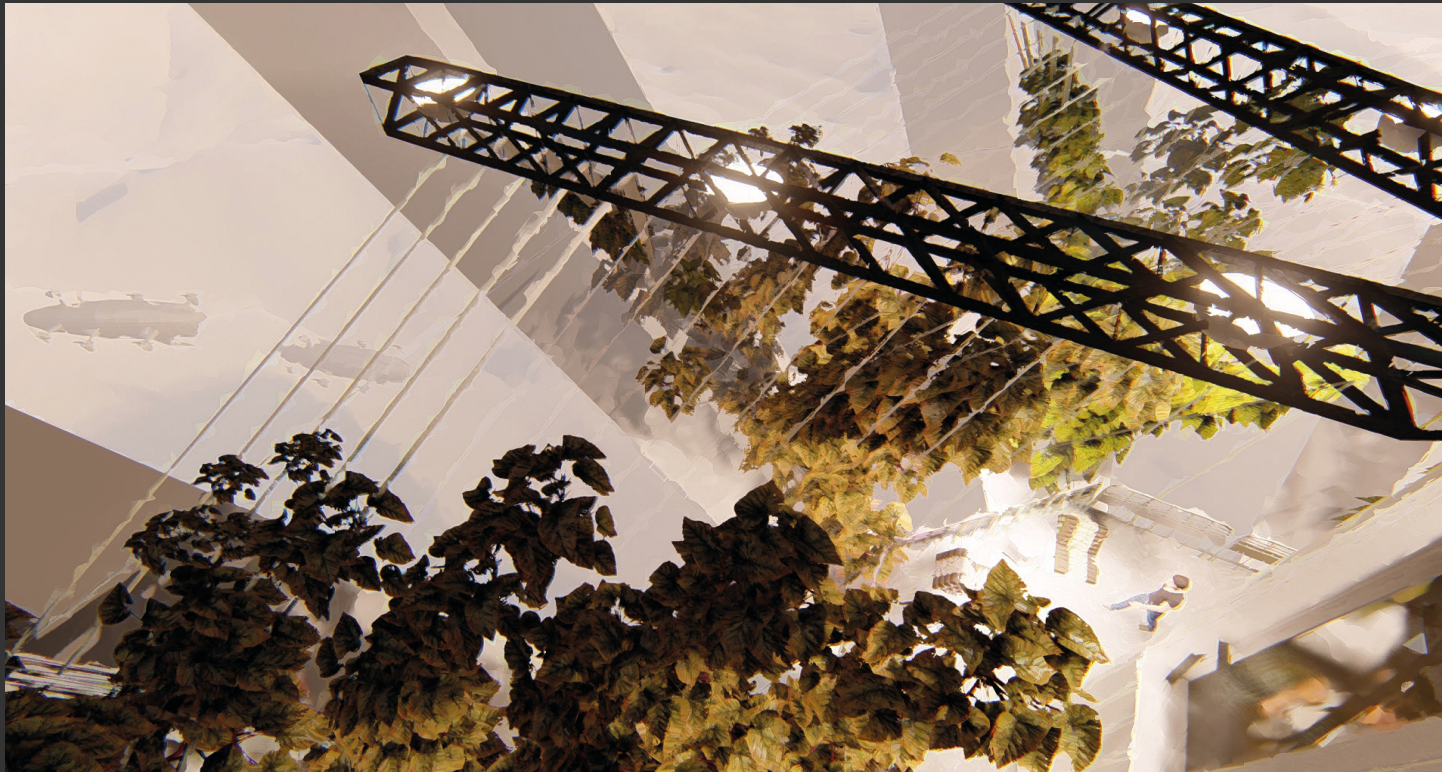
C. Small (Hubble) scale

Short visual distance, partly humid, green, plastic/natural/fabric materials, familiar "Earth-objects" and personal belongings



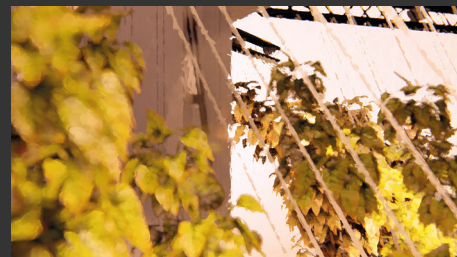
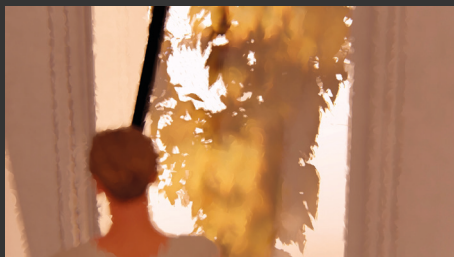


Greenhouse version with post-constructed catwalk, ponics, artificial light (no FEP-walls for natural light)



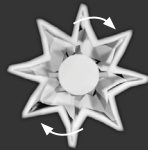
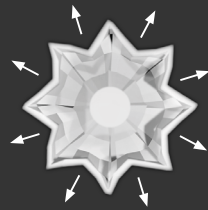
Greenhouse view showcasing visual connection through FEP-facades, including activities outside the habitat, e.g. other habitats, robots, cloudscapes and various weather formations

Visitors can rest their eyes in this huge aquarium-like view, without having to go underground for radiation protection



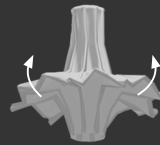
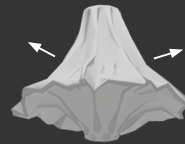
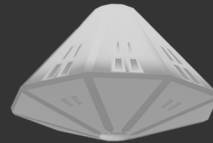
Sequences from staircase when entering from blimp docking station

GREEN CONE FOLD



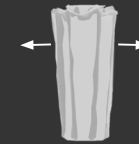
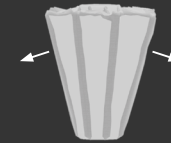
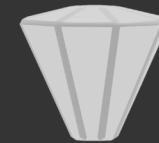
Void for storage of hydrogen balloons. Reinforced folds. Stiffer top for docking.

HABITAT FOLD



Adjusted fold to fit post-developed pneumatic flooring, regulating structure movements.

TECH CONE FOLD



Vertical structure with umbrella fold to avoid damaging sensors (Kaur, N/D, p.17).

MOODBOARD



1. Semitranslucent walls, Inflatable Lunar habitat by (NASA, 2013)

2. “The Compound Camera”, interior photo of inflatable structure (Pneuhaus, N/Da)

3. Inflatable Re-entry Vehicle Experiment (IRVE) (NASA (2009)

4. Domes showcasing structural variation, materials; bioplastics/plastics (ripstop nylon & PVC), & printed meshes/fabrics common in inflatables

5. “The Compound Camera”, exterior photo of inflatable structure by (Pneuhaus, N/Db)

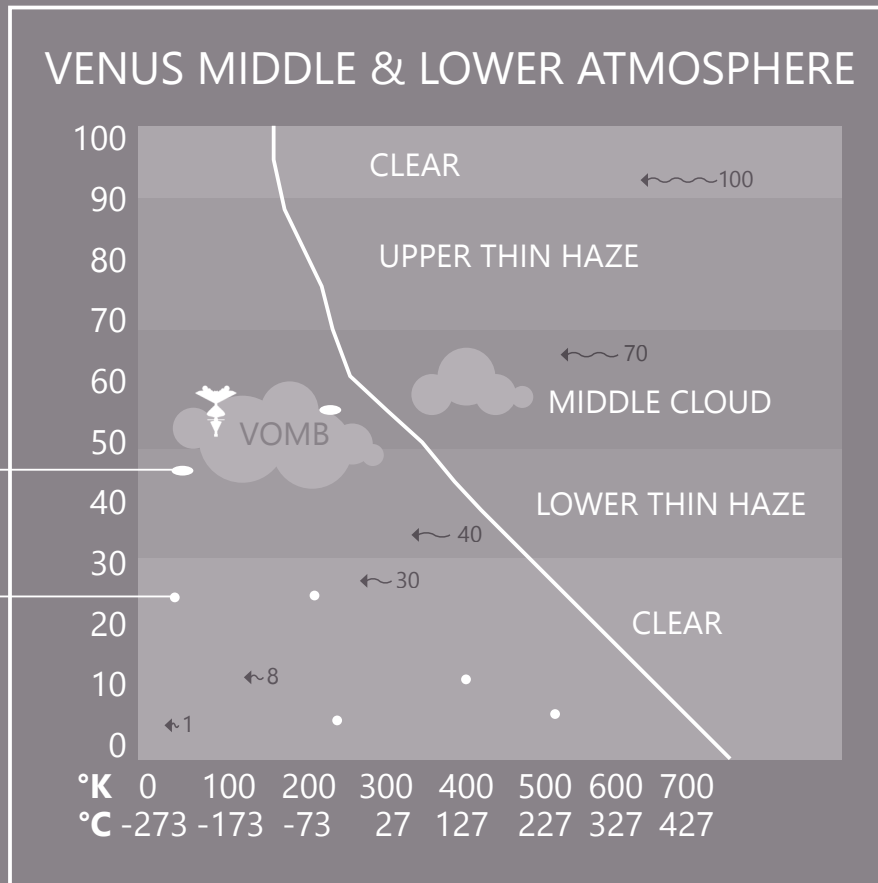
6. Fabric interiors

7. “Grove”, photo of inflatable fixtures by (Pneuhaus, N/D)

8. Goodyear Aerospace’s toroidal space station, ‘Moby Dick’ habitat module (NASA, 2017b)

9. Venusian habitat section by (Phillips-Hungerford, 2017, p.13)

SECTION OF VENUS



LOCAL CONDITIONS

Acidic rain

Just like Earth, Venus has clouds and precipitation, however, since Venus atmosphere partly consists sulfuric acid, the rain is acidic and highly corrosive (Britannica, 2023d).

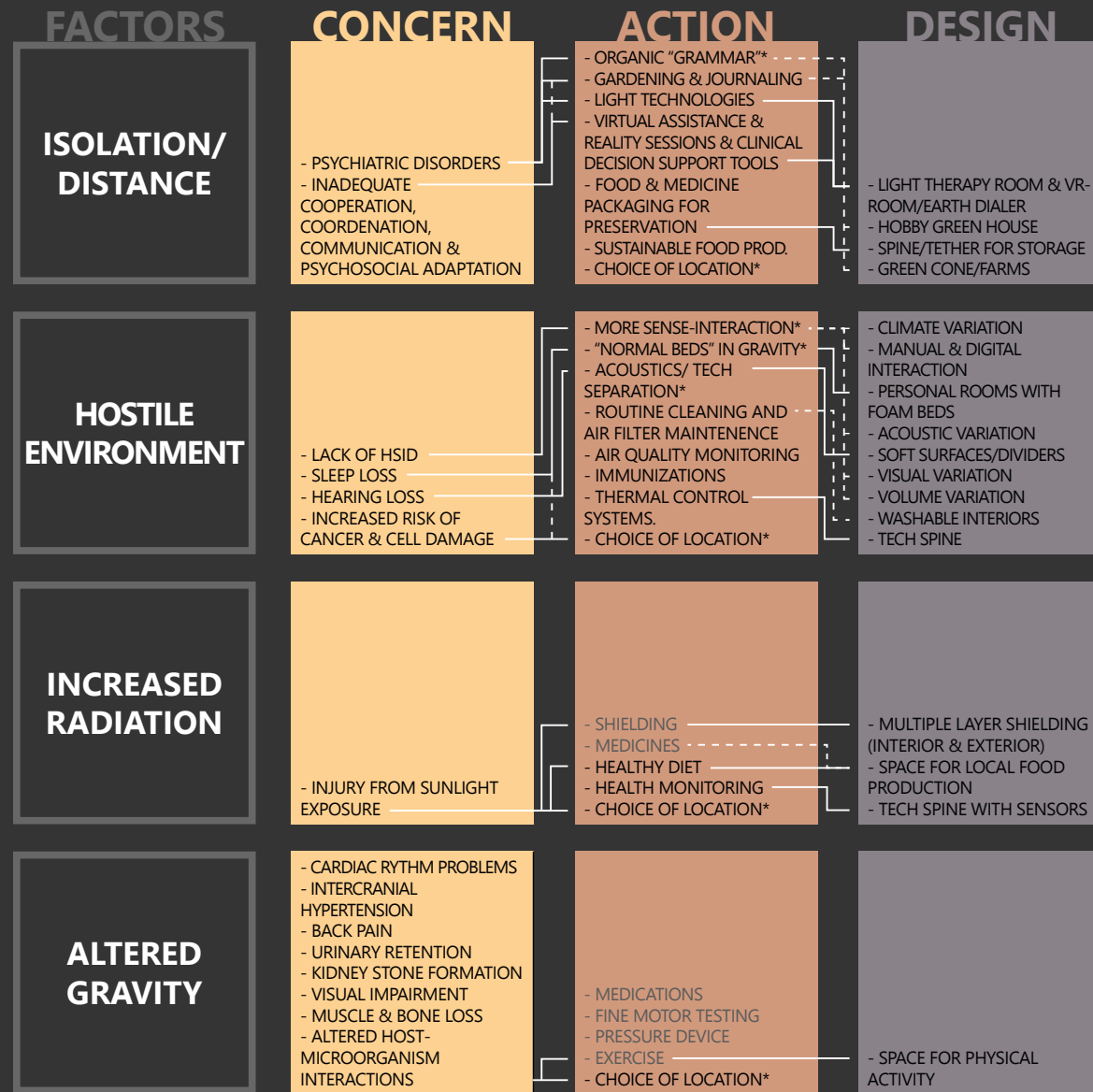
Wind

Depending on altitude, the windspeed on Venus can vary from 0-100 m/s. Infact, the atmosphere rotates faster than the planet. The most calm areas are remain close to the surface, while the most turbulent areas are at the higher altitudes (Britannica, 2023d).

Reflections

Because of the acidic conditions, a potential structure on Venus needs corrosive-resistance. Assuming the structure will be placed at the altitude of ca. 50 km, it also needs to be aerodynamic because of the winds. Taking potential changes in pressure and temperature into account, the structure also needs to be airtight & host climate regulators.

DESIGN FOR HEALTH



* Own action proposals, also see page 62-63. Greyed letters indicate less dependence as a result of location

ON VENUSIAN RESOURCES

The follow text explains some of the materials and resources related to VOMB and the planteray conditions.

Fertilizer from SO_x and NH₄⁺.

As of today, fertilizers can be produced by combining sulfuric acid and ammonia to create ammonium sulfate, used within agriculture (Britannica, 2019). By combining the sulfuric components in the Venusian atmosphere and ammonia (from e.g. biological by-products) it may be possible to create fertilizers in space (Bains et al., 2021). While presence of ammonia on Venus belongs to a transformative hypothesis, it's likely that fertilizers will be a part in space projects focusing on agriculture. According to ESA (N/Da), ammonium ions are a part of MELiSSA.

Microorganism products

According to NASA (2015), microorganisms in our guts might alter in microgravity. However, NASA (2020b) also states that the production of e.g. medicines might benefit from microgravity, as that can lead to fewer defects & better quality. That being said, such production still needs resources, something Venus, potentially, could provide (Phillips-Hungerford, 2017, p.17-18).

Fabrics/membranes & water

Because of acids and heat, the habitat needs different fabrics, membranes and materials for the facade & hubbles (see right image). While the first hubbles are produced close to Earth or on Earth, the second generation will be Venusian, produced using polymerization and carbondioxide from the atmosphere (Fraunhofer, 2021). Glass fiber, on the other hand, are derived from SiO₂, a mineral that exists on the Moon & Mars (Tucker & Ethridge, 1998). According to NASA (2019b) this mineral may also be combined with hydrogen to create water. Reversed chemical reactions of these elements may also be possible (ESA, N/Db).

Energy

Apart from solar power, the natural temperature at the altitude of 50 km provide a stable amount of heat energy (Jones & Arney et al., 2015). The hydrogen present in Venusian acids may also be used to create fuels (Bains et al., 2021) and lifting gas (Bains et al., 2021; Phillips-Hungerford, 2017, p.17-18).

Carbon fiber & conductors

Since minerals & metals may diffuclt to mine on Venus, VOMB's electric grid uses graphite & graphene, materials derived from carbon-based molecules. The graphite is used as conductor for electricity, but also within interior design in order to reduce static electricity.

JOURNEY IN SPACE

1. VOMB is partly pre-assembled on Earth. These parts are later sent to space by using a space tether, a hypothetical structure that can catch suborbital vehicles (Bogar, 2000; NASA SCIENCE, 2018), or a kinetic launch system, currently used to launch satellites into orbital and suborbital heights. using electric spinning tethers and vacuum (SpinLaunch, N/D).

2A. & 2B. Once the modules reaches space, autonomous in-space assembly is set in motion in order to bring the full structure together (2A) (NASA, 2019a). As an option, this can be done on the moon (2B).

An alternative is to develop the necessary materials in microgravity, as that can lead to products that are higher quality and more effective than when produced on Earth (2A) (NASA, 2020b), perhaps in close proximity of a space tether (Bogar, 2000; NASA SCIENCE, 2018).

3. After the completion of the shuttle encapsulation, the modules are launched from Earth's orbit to Venus.

4. Once arriving to Venus, the structure is prepared for atmospheric arrival.

5. VOMB is then deployed.

6. Departure back to Earth via Venus tether.

LOCOMOTION

Habitat traveling along day/night-line to mimic Earth days

VENUS
5.

4. TETHER
Potential node for medicine & food resupply

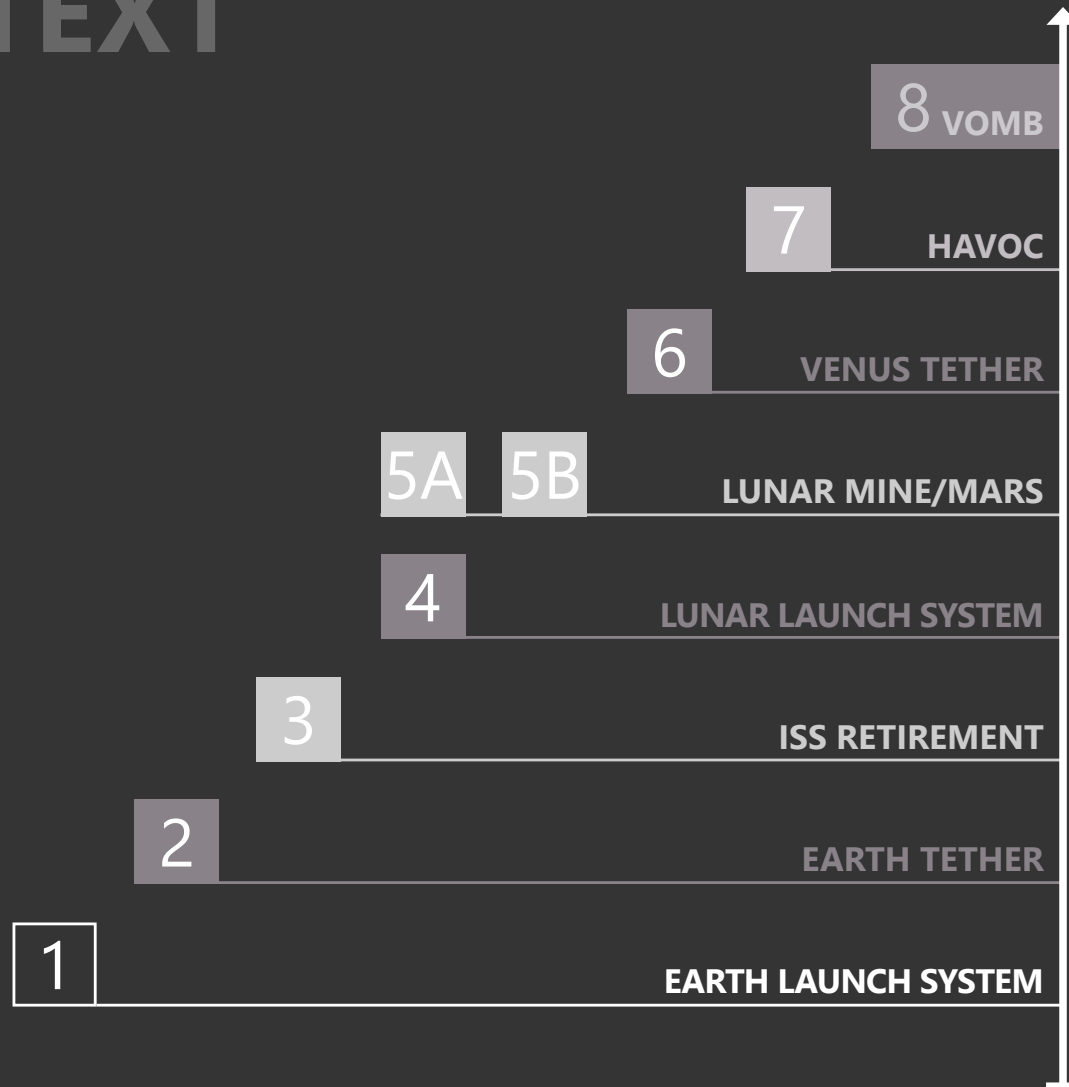
2B. MOON
Space assembly, lunar launch & materials

2A. TETHER
Space assembly

1.
EARTH

DEPLOYMENT
STRUCTURES BUILT BEFORE VOMB *NOT TO SCALE

PROJECT CONTEXT



THESIS (YEAR +2100)

NASA PROPOSAL

OWN SUGGESTION

NASA PROPOSAL

OWN SUGGESTION

NASA PROPOSAL

OWN SUGGESTION

IN PROGRESS (YEAR 2023)





... I remember my great grandpa telling me about previous space stations, how narrow they were and how little greenery there was. VOMB, on the contrary, is said to be spacious enough to have your own flourishing greenhouse.

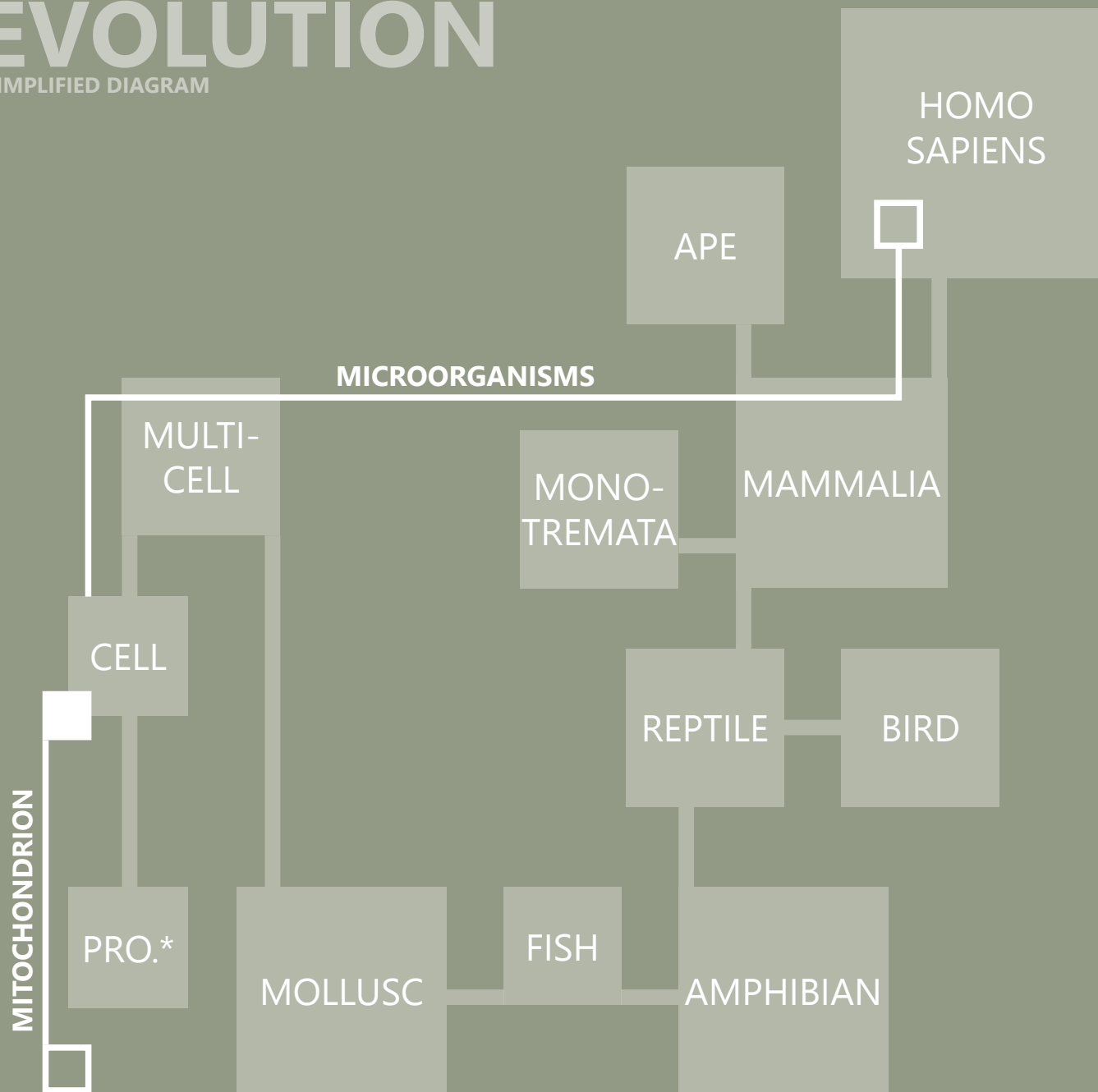
I glance at the wall handle, reflecting the green walls of the room.

According to previous visitors, even the “hubbles” of VOMB seem to grove and stretch...

III. STEM FROM NATURE

EVOLUTION

SIMPLIFIED DIAGRAM



THE "SUPRAORGANISM"

It's believed that journey of humans began in Africa, however, the modern human is, spread to a variety of environments, spanning from deserts, forests, islands and even ice-covered landscapes. Our attributes vary as well, including bone density and pigmentation among other features (Britannica, 2022d).

The cells in organisms, including us, may change, adapt and even merge with other organisms. The power house of the cell, also called the mitochondrion, is believed to be a reminence of such merged organism (Britannica, 2022h). Today, our body not only consists of our own cells, but several microorganisms. In other words, humans are "supraorganisms", consisting of various species of animals (Britannica, 2022e). According to a paper published in 2013, cohabiting family members even share microbiota with one another - and with their dogs (Lauber, C. et al. ,2013).

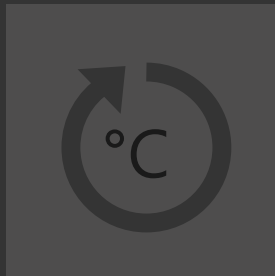
Reflections

Looking at a greater perspective, when we are affected by an environment, so might our internal ecosystem be, whether it's to a smaller or greater degree. Keeping that in mind, it's possible to assume that humans are dependant on a functioning body & environment, but also the coexistence of other species.

*Prokaryotes

FACTORS

TEMPERATURE &
SEASONS



RADIATION
INTENSITY



ATMOSPHERIC
COMPOSITION



GRAVITY

OUR ENVIRONMENT

The factors for our shape, form and creation vary in attributes. While some of them are created by humans, other factors stem long before the creation of humans.

Some of the most prominent factors on Earth include the atmospheric composition with its link to the biosphere (Britannica, 2020b; Sundin, 2021), radiation intensity, temperature (Doglioni et. al., 2016) and gravity (Dubinin, 1976). The current atmosphere/hydrosphere on Earth is connected with multiple ways of metabolisms, including cellular respiration and photosynthesis (Sundin, 2021). Looking at the effects of gravity, it's linked to bone density, vision and muscle mass among many other physiological features (NASA, 2015, p.19). Last but not least, the temperature range of Earth supports the existence of carbon based organisms and carbon based chemistry (Sundin, 2021), the backbone in every organism on Earth today (Sundin, 2021; NASA, N/Dd).

Reflections

The factors mentioned above are not the only environmental factors present in our environment today, however, because they exist as a foundation for our chemistry and the first organisms that we know of, they can be regarded as important aspects of our shape and living conditions of Earth - even before the existence of humans.



OUR SENSES

TOUCH

Through touch, the human body is capable of distinguishing textures, temperature & consistency of materials. Comparing the energy impact in our receptors, the skin requires close to 10 Billion times more energy than the eye & 100 Million times more energy than the ear (Britannica, 2022g).

SMELL

In humans, olfaction is said to be 10,000 times more sensitive than taste. Temperature and humidity influence the strength of an odour by affecting the emission of odorous particles from the source (Britannica, 2022f).

TASTE

While we normally avoid “tasting” our surrounding today, early humans used their gustatory sense as a way to detect calorie rich foods with less effort (Britannica, 2022a). Taste adaptation affect the next flavour we detect, e.g., when consuming a lot of salt, the sensitivity for saltiness decreases, while it increases for sour flavours. (Britannica, 2022b).

HEARING

The vestibular sense of humans, also known as “hearing”, most easily detects frequencies of 1K-4K hertz, but the entire audible range of sounds can extend from ca. 20-20 000 hertz (Britannica, 2022c).

VISION

According to Britannica, vision is one of the most used senses in humans. However, our eyes cannot detect ultra violet and infrared rays (2022h).

SENSORY DEPRIVATION

According to Britannica (2023b) isolation/sensory deprivation may cause reduced information input via the senses (such as sight and hearing). The same source also states that a person who remains alert during periods of isolation is likely to experience vivid fantasies, including hallucinations.

In a paper published at NASA Johnson Space Center, Houston, TX, by Lauren Leveton, Katharine Ridgway O'Brien Bachman and Christian Otto (2012) it's stated that isolated, confined, and extreme (ICE) environments may cause sensory deprivation. As suggested in the discussion section, this could be a result of sensory monotony, such as visual monotony or mechanical constraints (p.2), referencing to the main sources of Lotfi B. Merabet et al. (2004) and John Rasmussen (1973).

As countermeasures, the publication by Lauren Leveton et al. (2012) suggests novelty, virtual reality (VR) and a greenhouse, where the introduction of novelty is underlined as the most critical countermeasure (p.6). In the conclusion, the publication suggests tests in high-fidelity environments in order to counter potential concerns related to social isolation & sensory deprivation. It also suggests that both sensory deprivation and social isolation must be planned as a part of space missions, rather than being treated as optional or auxiliary operations (p.13).

“...the body is the soul's prison unless the five senses are fully developed and open.”

— Jim Morrison

*Singer, poet and songwriter
(Wanis, P. 2014)*

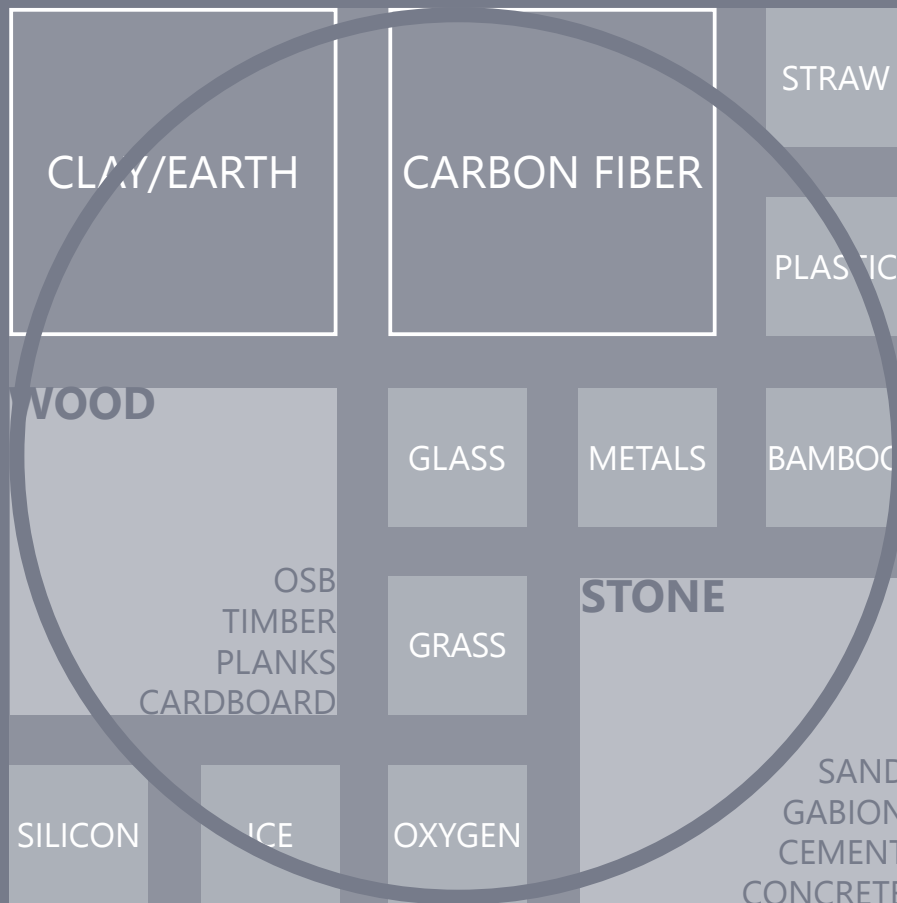




... If it wasn't for the previous space stations, VOMB would never exist. It's an answer to the health concerns my great grandpa experienced and for future astronauts to come.

The sky starts to clear up in a neutral hue...

IV. APPLY SPACE RESEARCH



EARTH RESOURCES

SIMPLIFIED DIAGRAM

A PART OF EARTH

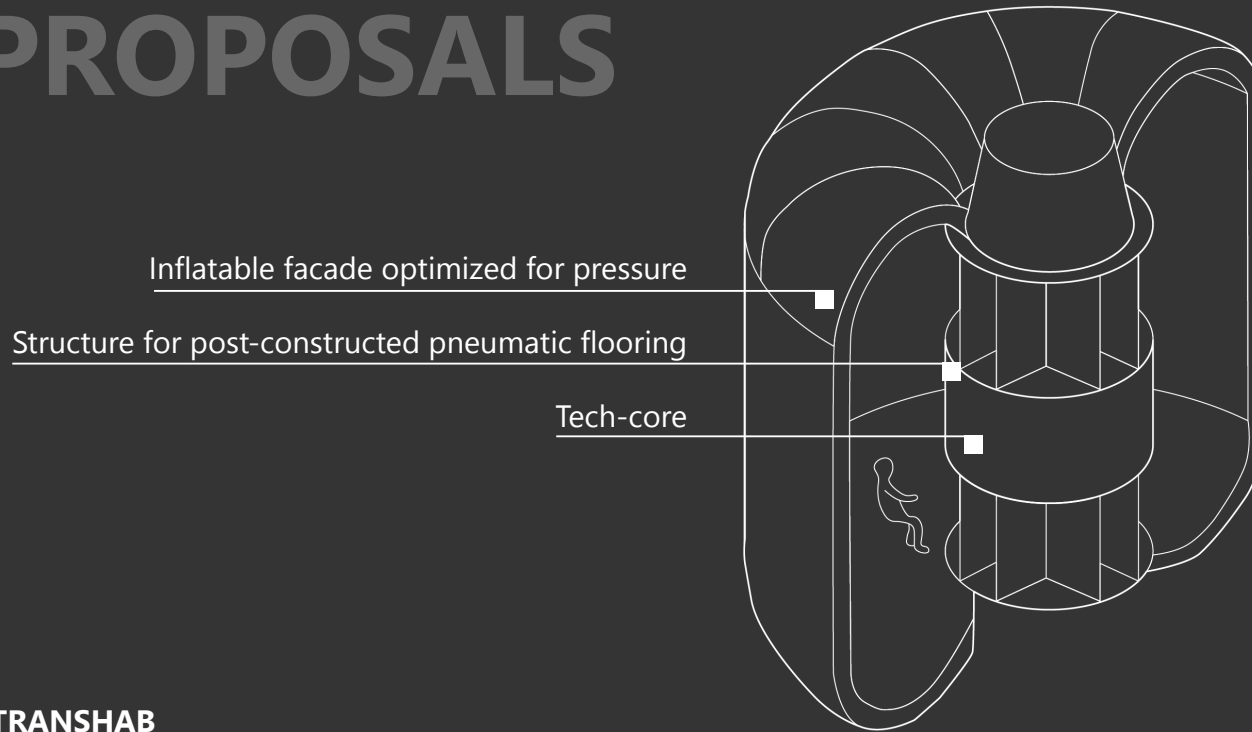
While some resources may be directly extracted and utilized, other resources need processing or refinement, sometimes by using other chemicals as catalysts. This is both common on Earth and in space projects.

For space projects, metals are highly valuable as it has multiple applications. According to a NASA (2020a) and a document by ESA named “ESA Space Resources Strategy” (N/Db), some metals are even used as minerals in fuel. Apart from that, titanium, Kevlar, ceramic fabrics and high-grade steel are common materials in the ISS (NASA SCIENCE, 2001). In the diagram to the left we are presented to some common building materials and used within architecture today, some of which are by-products and several which are poor material options in space projects.

Reflections

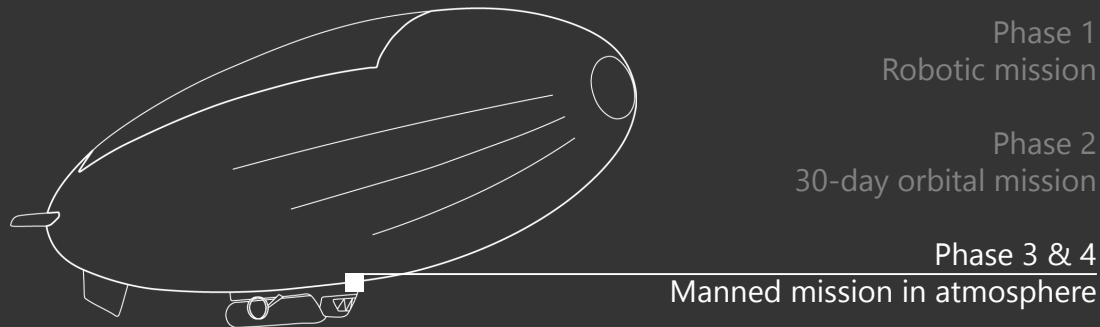
The primary resources in our environment aren't necessarily the only resources used within construction today. Some resources are refined to create new materials. From that perspective, the discovery, refinement and use of new materials is natural for humans, both historically and today. In order to live in space, material refinement may also be a must.

SPACE ARC. PROPOSALS



TRANSHAB

NASA project (OUTER SPACE/MARS/MOON)



HAVOC

High Altitude Vehicle Operational Concept (VENUS)

Phase 5
Habitat

TO BUILD BEYOND EARTH

Since outer space lack some of the most basic conditions of our natural environment, not to mention radiation shielding and spatial conditions, buildings beyond Earth might require an additional set of features than buildings on Earth. Exeptions to this statement include foldability, which is present in tents/emergency shelters (Bertoldi et al., 2021), as well as space structures, e.g. BEAM (currently attached to the ISS) (NASA, 2022b) HAVOC (Jones & Arney et al., 2015) and TransHAB (Litteken et al., 2019).

The following list includes some of the challenges specifically related to space architecture. Note, this is not a complete list of possible conditions. The list is derived from existing architectural concepts and own research. For more information on human health in space, see chapter VI.

POTENTIAL CHALLENGES

- Strong acidic rain
- Global sandstorms (MARS)
- Celestial dust
- Extreme pressure
- Extreme temperature
- Micrometeorites
- Energy production
- Material extraction

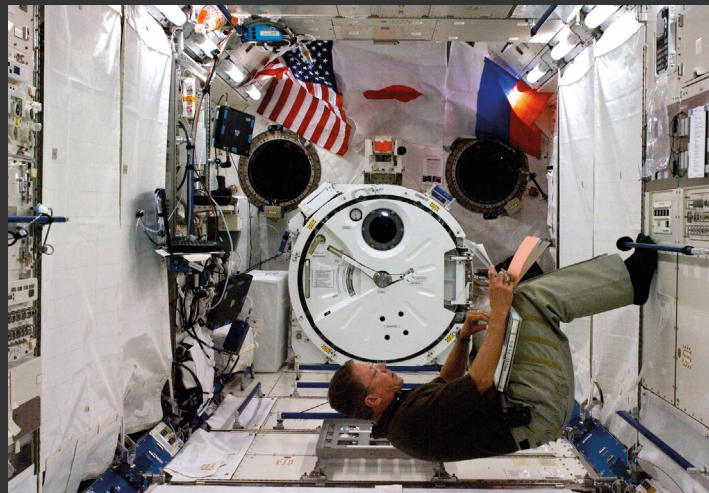
EXISTING SPACE PROJECTS

SELECTION OF THREE EXISTING SPACE HABITATS/MODULES



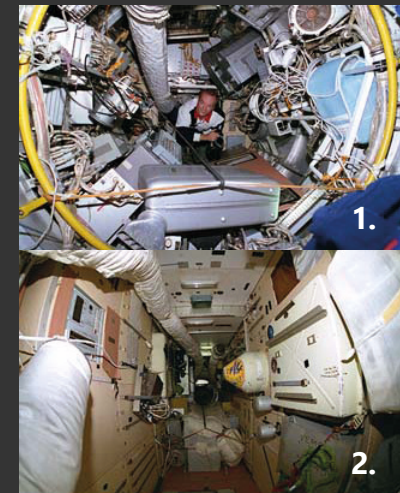
**ISS: FLIGHT ENGINEER PYOTR DUBROV
ZVEZDA SERVICE MODULE**

(NASA, 2021a)



**ISS: ASTRONAUT MIKO FOSSUM
THE KIBO JAPANESE PRESSURIZED MODULE**

(ESA, 2008)



**MIR SPACE STATION: ORBITER
PATHWAY & KRISTALL MODULE**

1. (NASA HEADQUARTERS HISTORY, 2001a)
2. (NASA HEADQUARTERS HISTORY, 2001b)

SENSE ANALYSIS

EXAMPLES FROM PREVIOUS PAGE (NOTE: BASED ON SOURCES & IMAGE OBSERVATION)

TOUCH 

SMELL 

TASTE 

HEARING 

VISION 

ZVEZDA SERVICE MODULE

Manual/digital interaction
Hard/plain surfaces of mostly cold metal and plastics. Room temperature.

Smells of various foods and odors. No access to fresh air. (NASA, 2017d)

Variating food selection (NASA, 2020d). Crew bored with food selection (Leveton et al., 2012).

Noise from machines & electronics. Voices from earphones and crew-members. Music is optional (ESA, 2019).

White & light grey. Green contrast. Grey handles. Rectangular expression, circular vaults. Labels/cables/tech everywhere. Centered flat light. Lit, although appears darker. A small corridor's visual distance, few windows, no greenery.

THE KIBO MODULE

Manual/digital interaction
Hard/plain surfaces of mostly cold metal and plastics. Fabric elements. Room temperature.

-"-

-"-

-"-

White. Blue contrast & handles. Rectangular expression, circular vaults. Labels/cables/tech everywhere, some of which are conceal behind blinds. General light focused on working areas. Well-lit. A medium size room's visual distance, windows, no greenery.

MIR SPACE STATION

Manual/digital interaction
Hard/plain surfaces cold metal. Fabric surfaces, a lot of cables & soft pipes. Room temperature.

-"-

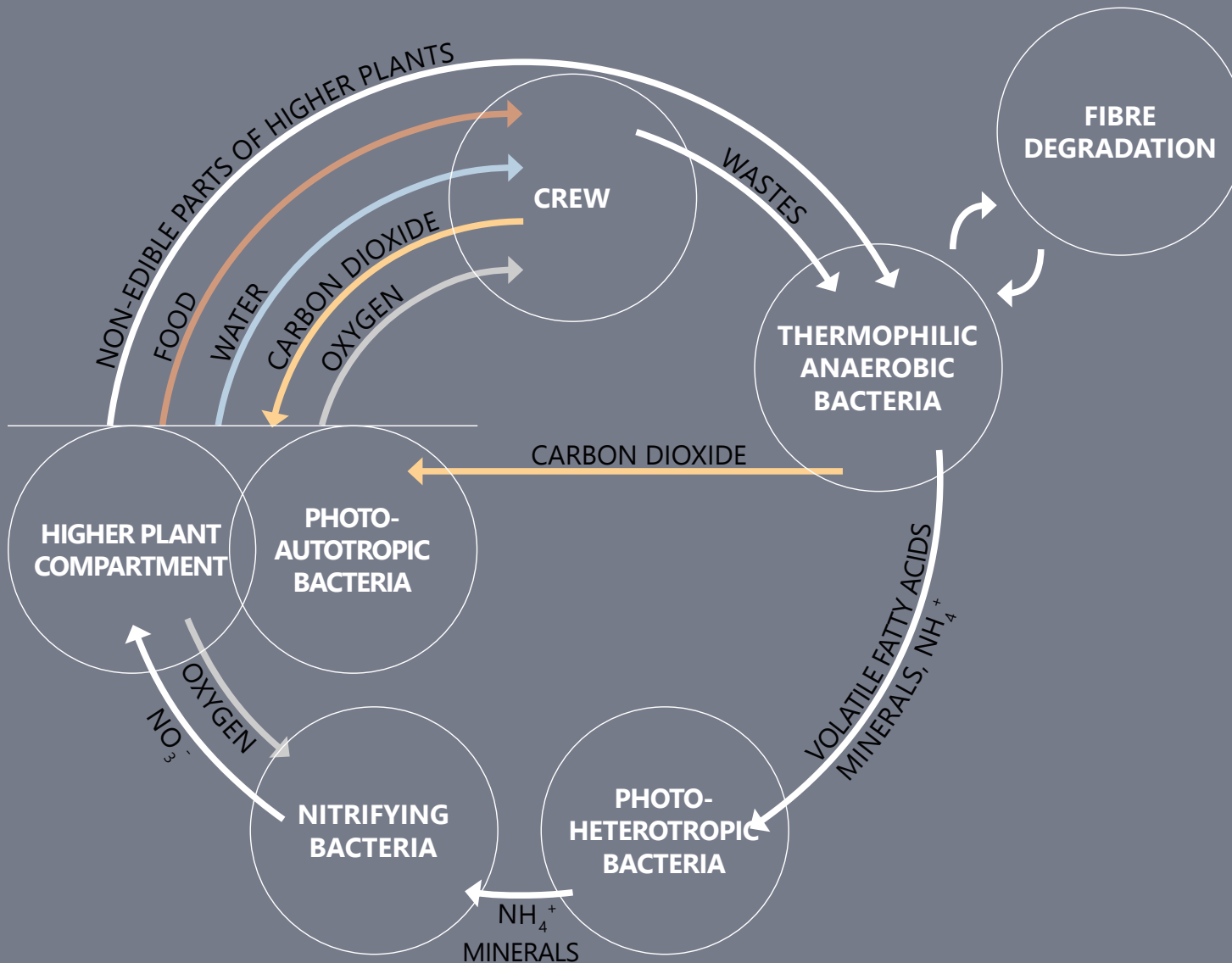
-"-

-"-

Beige/brown/grey/white. Yellow contrast & handles. Rectangular & irregular expression, circular vaults. Surfaces covered in buttons & tech. Small general light sources. Quite dark/narrow. A small room's visual distance, few windows, no greenery.

LIFE SUPPORT SYSTEM

THE CLOSED ECLS-SYSTEM MELISSA BY ESA



MELISSA

The diagram to the left shows a diagram of MELISSA by ESA (N/Da). In comparison with the ISS ECLS-system, MELISSA is a closed loop system, implying that e.g. bacterias, waste, water etc. must be a part of the loop in order to create functional life support system.

In the source by ESA (N/Da) system size requirements remain unspecified, meaning MELISSA or the habitat in question may need adjustments in order to fit its infrastructure.

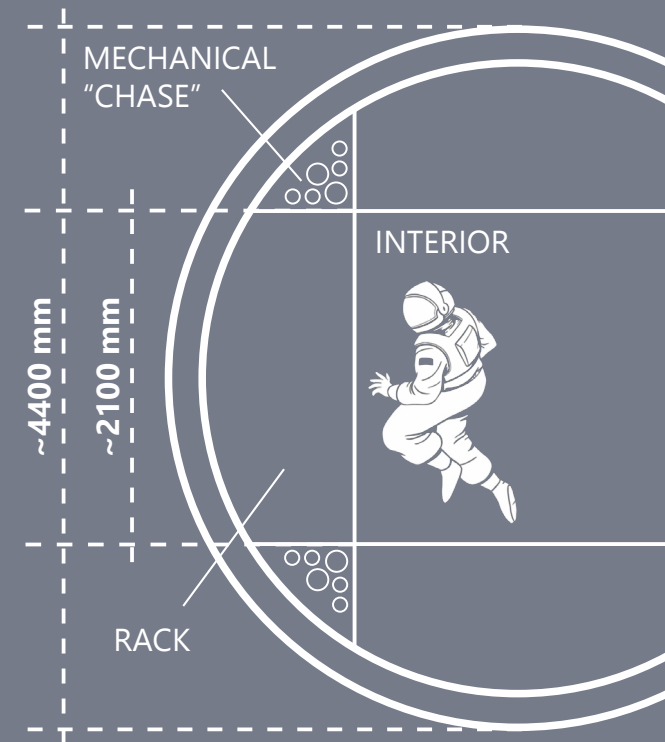
MODULAR THINKING

Just like building standards on Earth, the ISS has its own modules and measurements, such as the ISPR-system, customized for humans in microgravity (Uri, 2007). Since the launch of the ISS, modules have been added, moved and even modified to sustain necessary conditions for visitors (see illustration) (Uri, 2007; NASA, 2022b; NASA, N/Db).

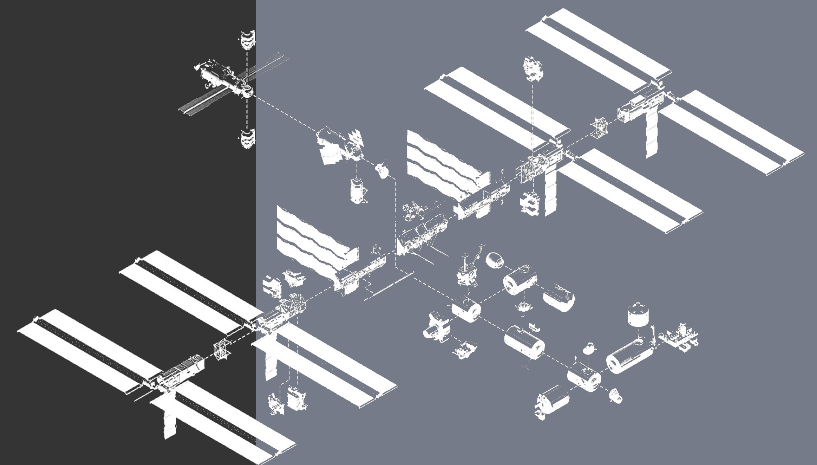
While many of these additions are planned through modular thinking, some changes requires special mating adapters in order to link Today, the ISS can be divided into several modules with varying functions. (NASA, N/Db). Despite these different functions, previous sense analysis (see previous chapter) indicate that each module also provide similar stimuli in terms of interaction, volume, visual expression & microgravity-workflow.

Reflections

Although the modules of the ISS satisfies far from every need of the human body and mind, they are designed to maintain our basic biological functions, even if evolution never provided physiological features to live outside Earth. In a sense, the modules works as an extension of the human body and evolution. That being said, it's reasonable to think that the design enveloping us in space should be symbiotic with the grammar of organic life, since this is the creation we wish to sustain and the entanglement we are created for. This is something that may be combined with modular thinking.

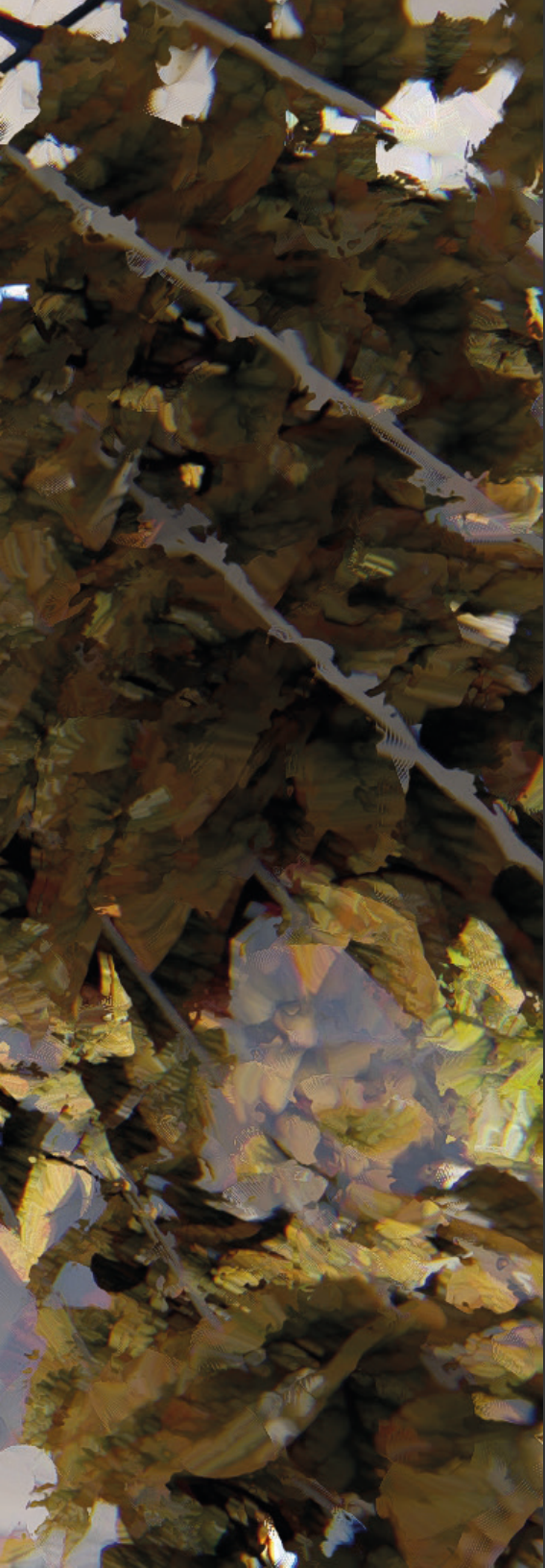


*Section of an ISS-module
Own sketch*



*3D-illustration of the ISS
Source of information: (NASA, 2022b)*

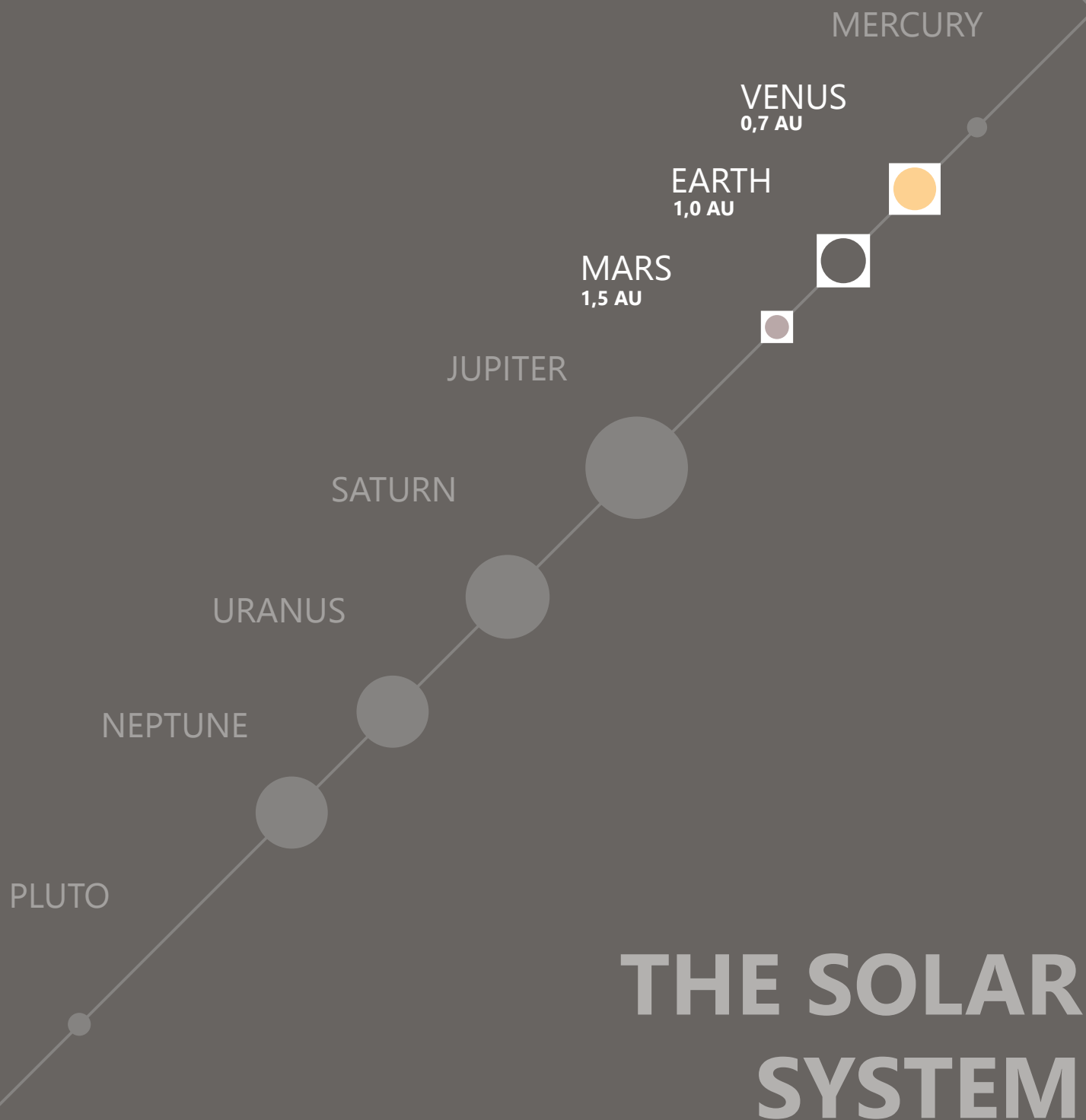




... Since VOMB is a sister project of the Martian project, the data collected by our team is compared with their colony, including weather, plant growth and resource extraction. That's how the project will develop from now on.

Unfortunately, it's unlikely that we will ever meet the Martian team. The traveling time is simply too long...

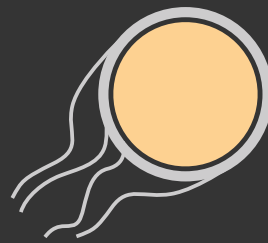
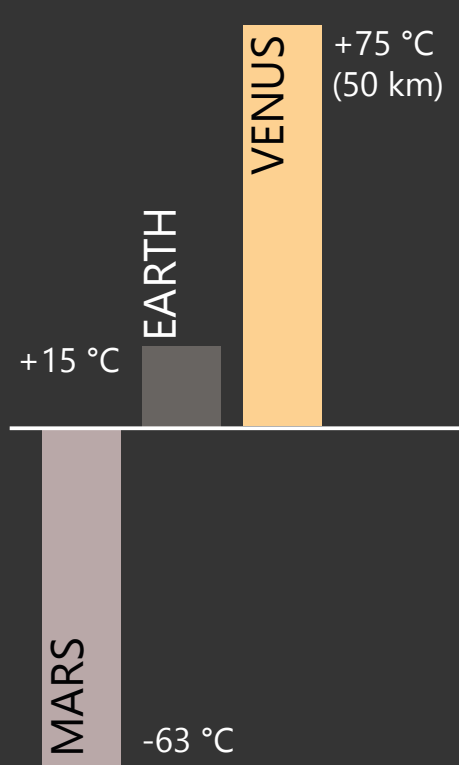
V. OUR NEIGHBOURS



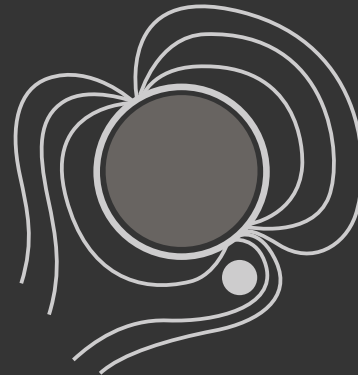
DISTANCE

In terms of astronomical units (AU) Mars, Venus and Mercury are our closest neighbours in the solar system. However, when taking orbital movement into account, Venus is the closest option. It would take roughly 7 months to travel to Mars (NASA SCIENCE, N/D), while it would take 3-4 months to travel to Venus (Jones & Arney, 2015, p.16).

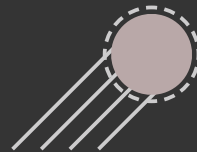
Since one year on Venus (the orbital time around the sun) is shorter than a year on Mars, traveling back and forth to Earth would be easier. This is because Venus is, on average, closer to Earth than Mars is to Earth. An exploration of potential round trip trajectories for Venus are as short as 14 months, compared to 26 months or more for Mars (Jones & Arney et al., 2015, p.2).



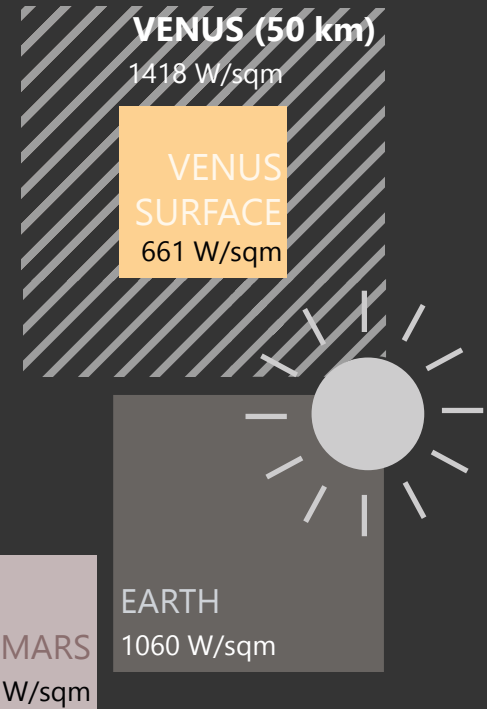
VENUS
THICK ATMOSPHERE
OF CARBONDIOXIDE,
IONIC TAIL



EARTH
MAGNETOSPHERE &
OZONE



MARS
THIN ATMOSPHERE
OF CARBONDIOXIDE,
IONIC TAIL



Source of information: (Jones & Arney, 2015)

MEAN TEMPERATURE

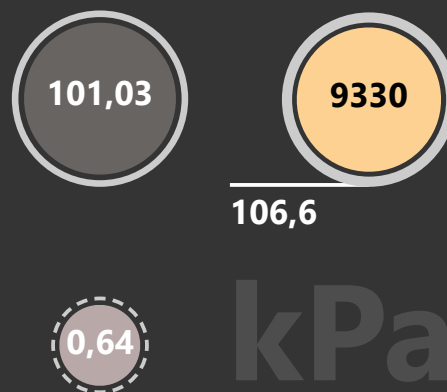
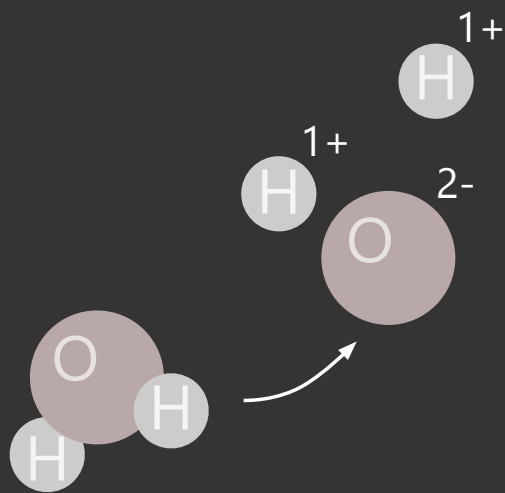
According to Christopher A. Jones & Dale Arney (2015) the surface temperature of Venus is around 462 °C, comparing to Earth's 15 °C & Mars' -63 °C (see above). Britannica (2023c) even estimates it can reach 464 °C. Both 462 °C & 464 °C are beyond the melting point of lead (Phillips-Hungerford, 2017, p.5).

RADIATION SHIELDING

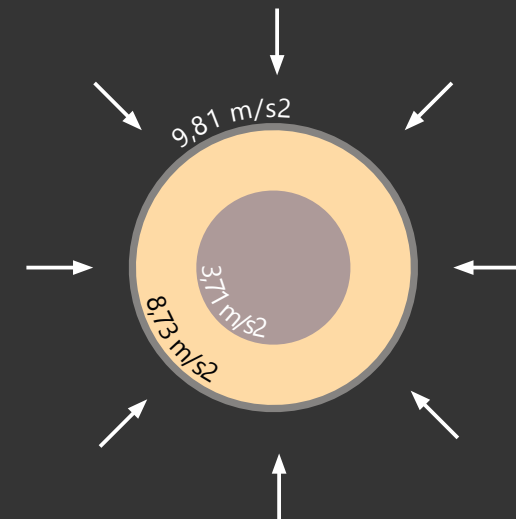
Comparing radiation shielding, Mars has a significantly less protective atmosphere. In fact, both Mars and Venus lack magnetospheres. However, thanks to the thick atmosphere of Venus, the planet has similar radiation shielding as Earth, even at the altitude of 50 km (Jones & Arney, 2015, p.6).

PHOTOVOLTAIC POTENTIAL

Despite the thick atmosphere of Venus, the photovoltaic potential at the Venusian surface is higher than that on the Martian surface. At the altitude of 50 km, Venus could harvest about 33%-40% more solar energy than the average amount on Earth (Jones & Arney, 2015, p.6; Phillips-Hungerford, 2017, p.5).



Source of information: (Jones & Arney et al., 2015)



ELECTRIC FIELD & MINING

Unlike Earth and Mars, Venus has an electric field with a potential of about 10 V. Water molecules reaching the upper atmosphere are broken down into hydrogen & oxygen ions (see illustration). The ions are then carried away into space by the electric field (Britannica, 2023d). In terms of resources, the Martian soil consists mostly of silicate, aluminium, iron, magnesium and calcium (NASA, 2012). However, the Martian atmosphere is thin, while the Venusian atmosphere is thick (Britannica, 2022j). According to Taylor Phillips-Hungerford (2017), the Venusian atmosphere is that thick it may be mined and later used in space industry (p.17-18). The Venusian core, on the contrary, is difficult to reach and likely consists of minerals similar to Earth minerals (Britannica, 2023d; 2023c).

ATMOSPHERE & PRESSURE

Taking a closer look at the atmospheric composition, Mars and Venus share some characteristics, including similar percentage of carbon dioxide present in the atmosphere; Mars 95 % & Venus 96 % (Britannica, 2022j).

One major difference between Venus and Mars is the amount of sulfuric chemicals. According to Britannica (2023d) Venusian precipitation is highly corrosive as it contains sulfuric acid. In addition to that, the thickness of Venus' atmospheres can be compared to the pressure of 90-96 Earth atmospheres. That is roughly 9330 kPa (kilo Pascal). Though, at the altitude of 50 km, the pressure is similar to that of Earth's (Jones & Arney, 2015, p.6; Phillips-Hungerford, 2017, p.5).

GRAVITY

When presented a comparison of Mars and Earth, it's not uncommon that the planets are depicted with a similar size. Exceptions to this statement include a presentation by Christopher A. Jones & Dale Arney at NASA (2015) as well as seminars by Maria Sundin, docent in theoretical physics at the University of Gothenburg, (2021).

In reality, the diameter of Mars is close to half that of Earth's while the gravitational pull is close to a third, as demonstrated above. Venus, on the contrary, has a gravitational pull ~95 % that of Earth's, even at altitudes of 50 km (Jones & Arney, 2015, p.6).

COMPARISION

Judging from the information from previous sections, Venus and Earth are more alike than Mars and Earth. While Mars may have strong visual resemblance with Earth (for example polar ice caps, deserts, dunes, canyons and traces of water), it's evident that the planetary characteristics lack several conditions, fundamental to the a majority of organisms on Earth (see previous chapter). These conditions include stronger gravitational pull, atmospheric pressure and radiation shielding.

When comparing surface resouces, the Martian composition is well-known, while the Venusian soil most likely offer similar minerals to those on Earth. Though, as seen the example by Taylor Phillips-Hungerford, the Venusian atmosphere may be mined without heavy machinery, instead using filtering methods. The molecules present in the Venusian atmosphere may later be used to various materials important to space industry, although probably different materials than the one produced from Martian soil.

Though, it's worth to point out that just because a site is more appropriate for mining, doesn't mean it'suitable for habitats. Venus just happens to suit both activities rather well, atleast hypothetically

“About 50 km (~30 mi.) above the surface of Venus, the environment changes to the most Earth surface-like conditions within the Solar System”

- *SACD*
Systems Analysis and Concepts
Directorate at NASA's Langley
Research Center (SACD, 2022)





... As we travel in space, our bodies encounter a number of health concerns. While treatment for many of these concerns exists, social distance seems to tear us the most, even with light therapy and virtual assistance.

*Outside a jet passes by close to the neighbouring colonies.
I tilt my head towards the window and sigh....*

VI. SPACE & HEALTH

SPACE HEALTH CONCERNS

PSYCHIATRIC DISORDERS

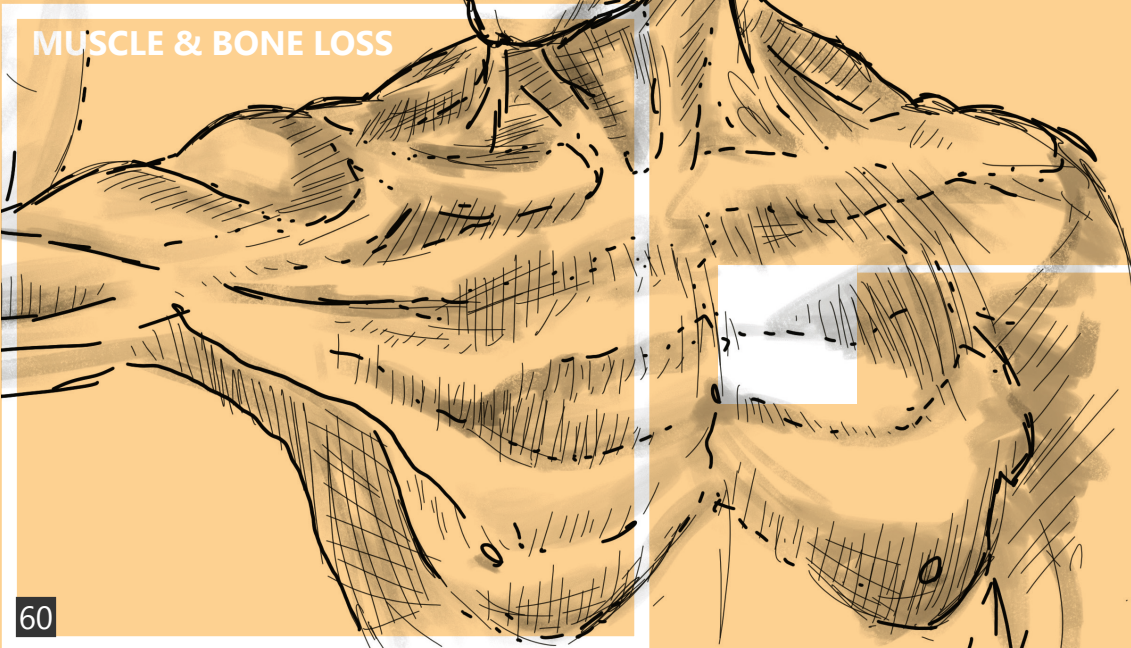


INTERCRANIAL HYPERTENSION



VISION IMPAIRMENT

MUSCLE & BONE LOSS



CARDIAC RYTHM PROBLEMS

FACTORS

ISOLATION/
DISTANCE

HOSTILE
ENVIRONMENT

INCREASED
RADIATION

ALTERED
GRAVITY

LACK OF
HSID

HUMAN-SYSTEM
INTERACTION DESIGN

=

REDUCED CREW
PERFORMANCE

HEARING LOSS

SLEEP LOSS

DUE TO E.G. GRAVITY
(GONFALONE, 2018, P. 83-84)
& LINKED TO HALLUCINATIONS (BRITANNICA, 2023b)



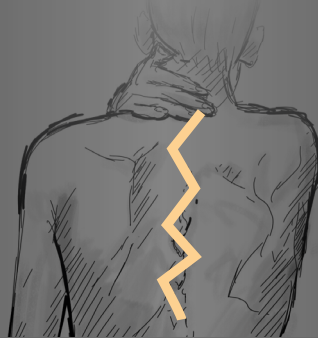
INCREASED RISK OF CANCER &
CELL DAMAGE



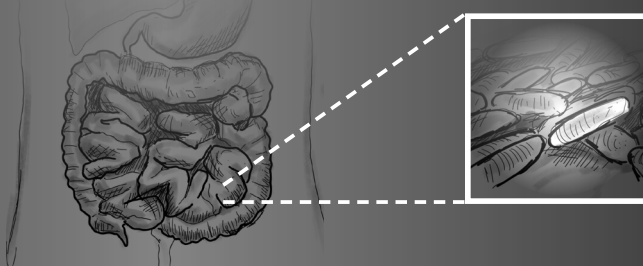
INJURY FROM
SUNLIGHT
EXPOSURE



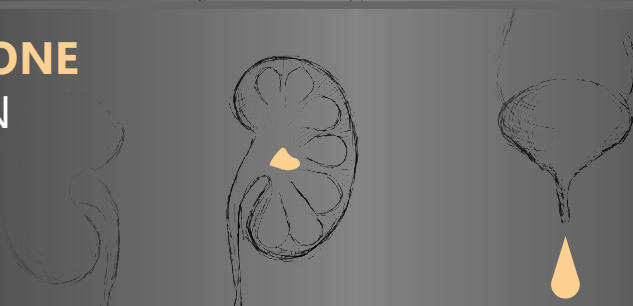
BACK **PAIN**



ALTERED HOST-
MICROORGANISM
INTERACTIONS

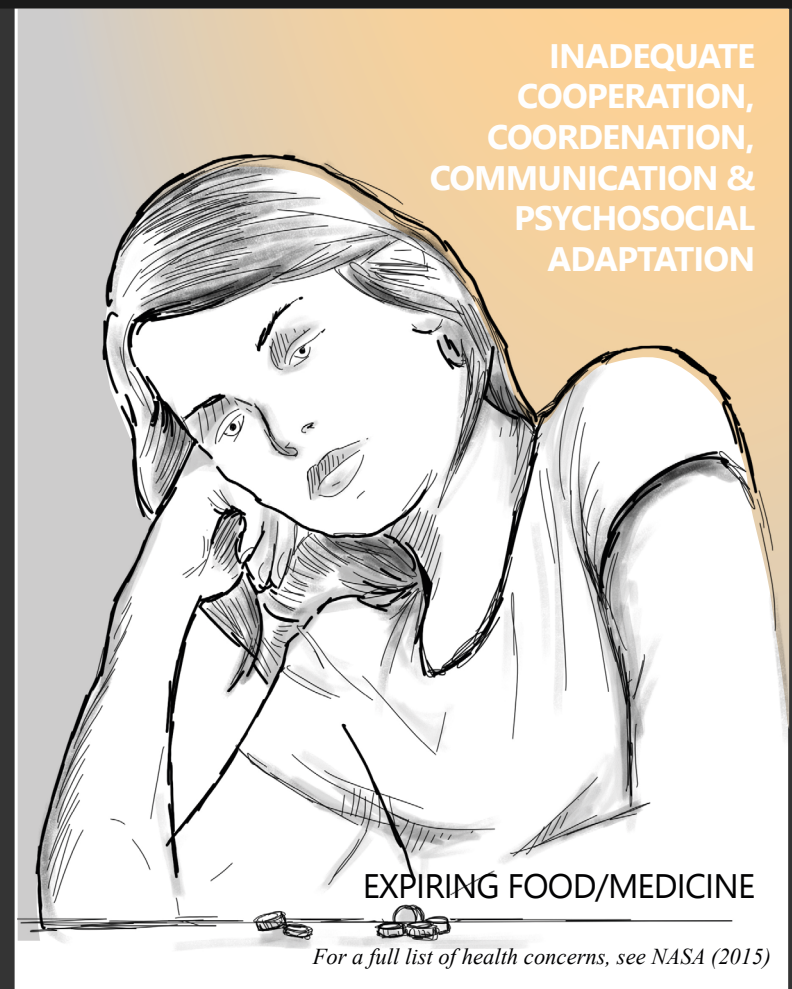


KIDNEY STONE
FORMATION



URINARY
RETENTION

INADEQUATE
COOPERATION,
COORDINATION,
COMMUNICATION &
PSYCHOSOCIAL
ADAPTATION



For a full list of health concerns, see NASA (2015)

COUNTERMEASURES

NASA PROPOSALS

Increased radiation

Health monitoring, medicine, healthy diet, shielding.

Isolation/distance

Gardening & journaling, light technologies, self-assessments, virtual reality sessions. Food & medicine packaging for preservation, sustainable food systems, virtual assistants, clinical decision support tools.

Altered gravity

Exercise, medications, pressure device, fine motor testing.

Hostile environment

Routine cleaning and air filter maintenance, air quality monitoring, immunizations, thermal control systems.

Source of information: (NASA, 2021b)

OWN PROPOSALS

Increased radiation

Choose a location with natural radiation protection.

Isolation/distance

Propose & construct a space-based framework for production of food, medicine and materials. Choose a closer location than e.g. Mars to enable faster interplanetary communication.

Altered gravity

Choose a location that is the most Earth-like in terms of mass.

Hostile environment

Choose a safer location. Work with acoustics, easy-to clean surfaces & elements which may enhance the psychological/physical state, perhaps organic design as a novelty. By the reflections from chapter II, this could, perhaps partly, be done through more sense interaction in the habitat.

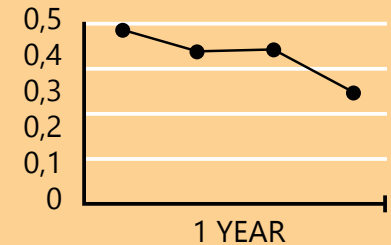
ON ADAPTATION

Because of our biology, adaptation in humans and the human DNA, driven by the newly applied environmental conditions, may take long time to develop in comparison with e.g. bacterias. However, as previously stated in chapter II, we work around many of these biological constraints by using technology & architecture.

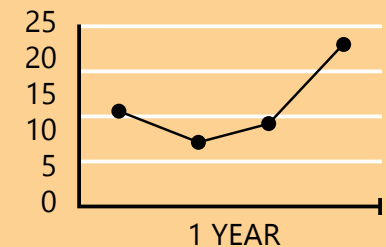
Yet, despite being capable of hosting astronauts for months, space architecture, such as the ISS, has not been able to eliminate several health concerns related acoustics, sleep deprivation, social concerns (see graphs to the right) and microgravity among others (NASA, 2015; NASA, 2022c; Leveton et al. 2012).

Reflections

Architecture has the capability to provide many solutions for our survival, yet, there are still needs that remain unaddressed, crucial for carrying out longer space missions. Hence, if we plan to expand beyond the boundaries of Earth, where technical solutions may be non-existent, it's reasonable to question the approach of solving everything with a compensation or building. By choosing a location that is most similar to that of Earth's, our genetic makeup may have more time for adaptation. We may also have time to understand the changes we are exposed to and how it molds us as humans. Merging this reflection with previous comparison of planetary conditions in chapter IV, that location is Venus.




ISS Group Interaction Positivity Ratings by mission quarter (244 entries)



ISS Journal entries on conflict by mission quarter





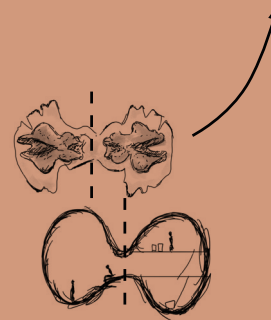
... The previous Mars team suffered many health issues, especially when traveling to the planet. Now they are on their way to the space shuttle, transferring cargo for lunar refinement.

In a couple of months we will also be sending our materials from the gas mining stations and rigid balloons... or... atleast that's the plan...

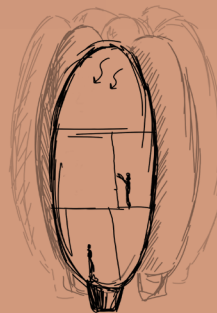
VII. DESIGN INVESTIGATIONS

AQUATIC STUDIES & SKETCHES

INTER-
CONNECTIONS?



"REPRODUCTION"
CAPABILITIES?



OWN SKETCHES, 2023

COMMENTS:

Because water is quite similar to air as a medium, form studies were partly based on aquatic morphologies. Above are a selection of sketches, some of which were derived from observations of phyto- & zooplankton.

GENUS: *Tabellaria*
Source of information: (AlgaeBase, 2023)



OWN PHOTOGRAPHY, 2015



OWN PHOTOGRAPHY, 2015

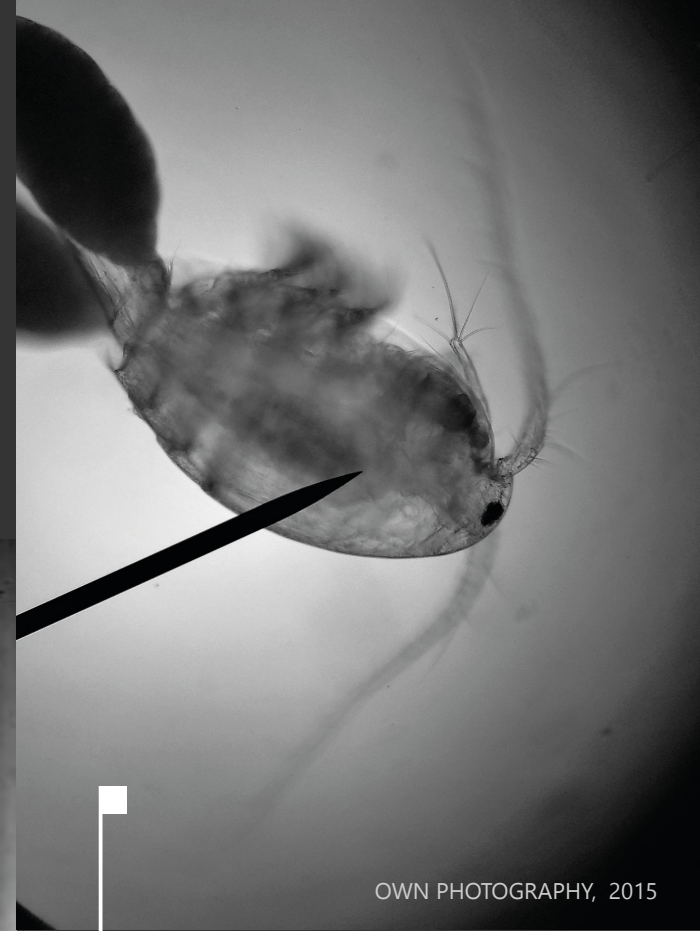
GENUS: Desmidium
Source of information: (AlgaeBase, 2023)

COMMENT:
By observing the morphology of plankton, it was possible to link geometry to certain features e.g. aerodynamics, area for photosynthesis, reproduction or stability.



OWN PHOTOGRAPHY, 2015

GENUS: Cyclops (copepod)
Source of information: (Bydén et al., 2003)



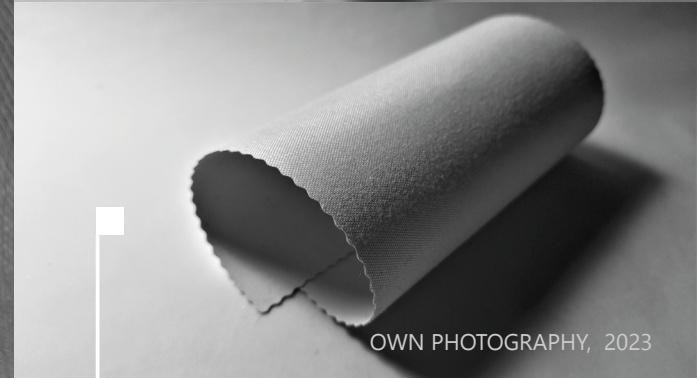
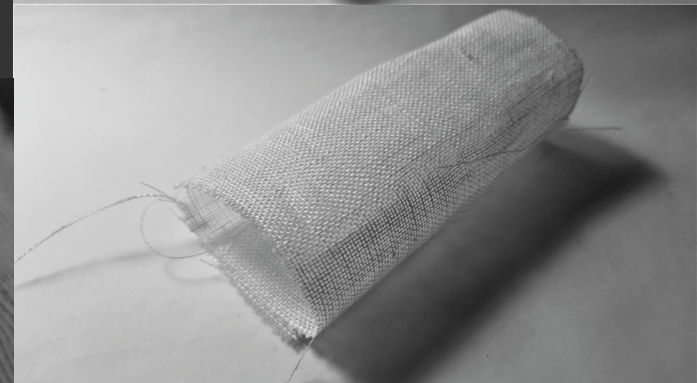
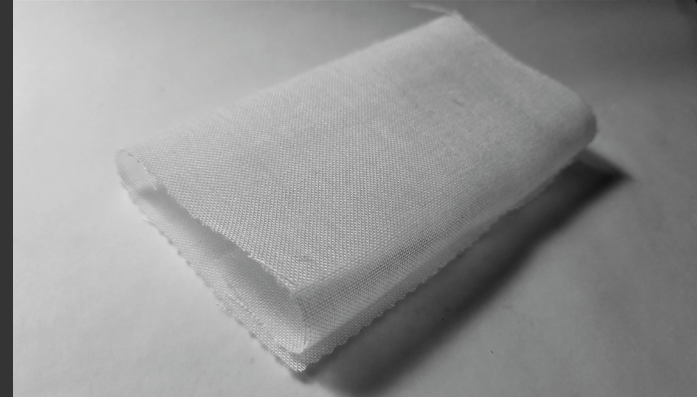
OWN PHOTOGRAPHY, 2015

GENUS: Micrasteria
Source of information: (Bydén et al., 2003)

STUDYING SOFT SHAPE



FABRIC INTERIORS FORM STUDY



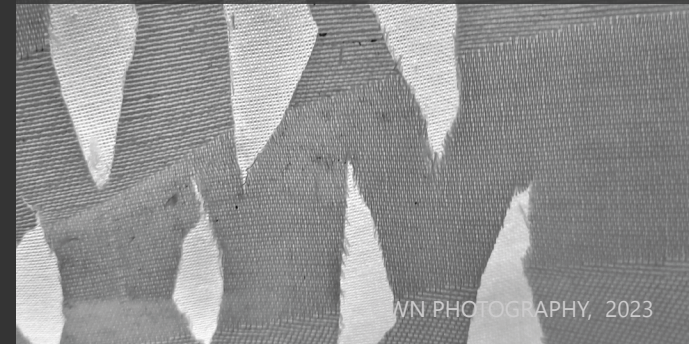
OWN PHOTOGRAPHY, 2023

OBSERVATION:

Spherical/irregular shapes with soft light created a more organic environment, rhyming with the biology of humans and, perhaps, a sense of being inside a safe "egg" & "womb".

SURFACE A

LIGHT STUDY, MEMBRANE COVERED BY MESH



OWN PHOTOGRAPHY, 2023

SURFACE B

LIGHT STUDY, MESH COVERED BY MEMBRANE



OWN PHOTOGRAPHY, 2023



EXTERIOR

INTERIOR

OWN PHOTOGRAPHY, 2023



EXPLORING FOLDS

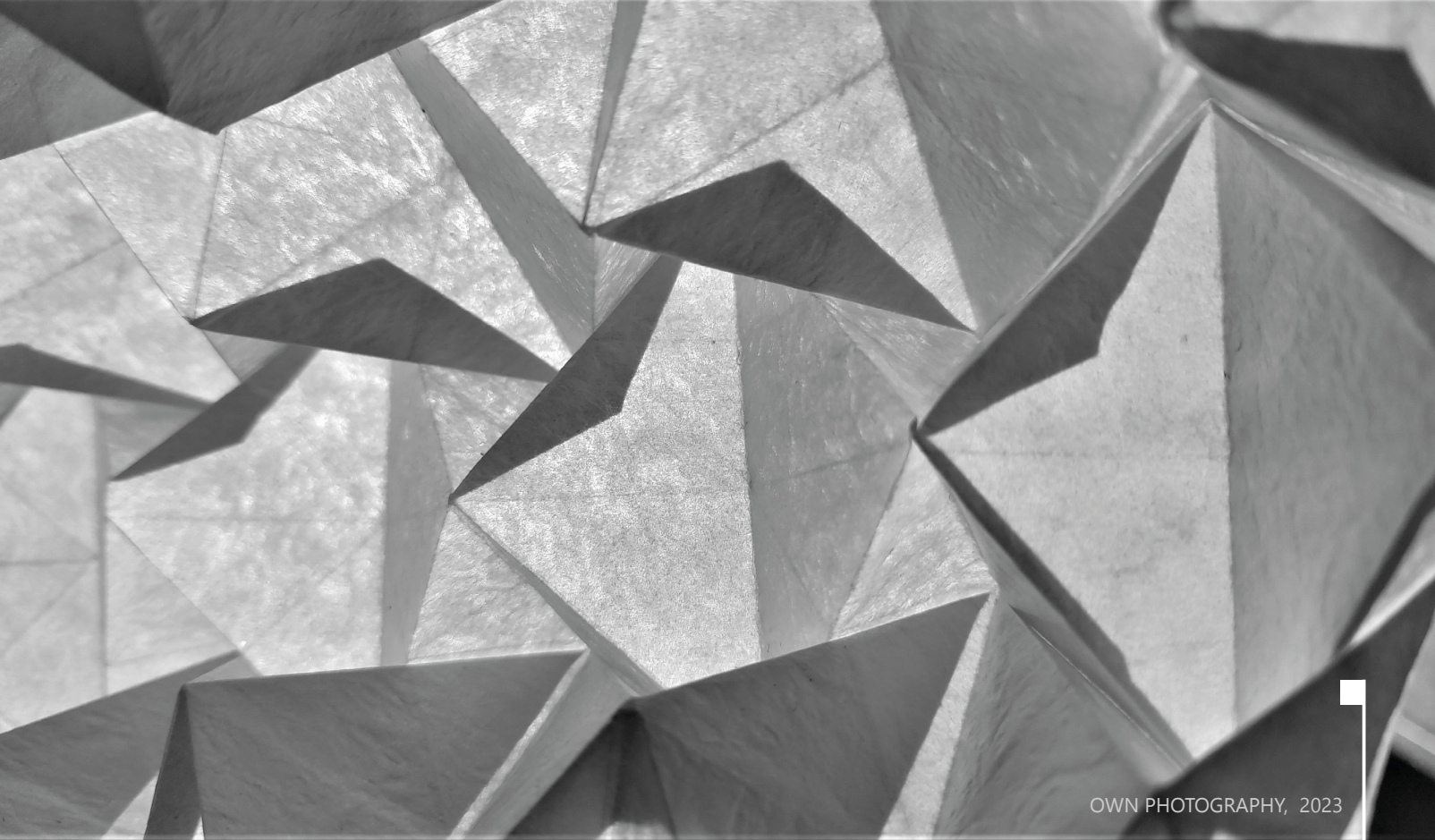


FABRIC INTERIORS FORM STUDY

COMMENT:

While spherical shapes contributed to better form factor and less thermal bridges, they seemed more difficult to use when creating internal divisions/ structures in comparison with e.g. origami.





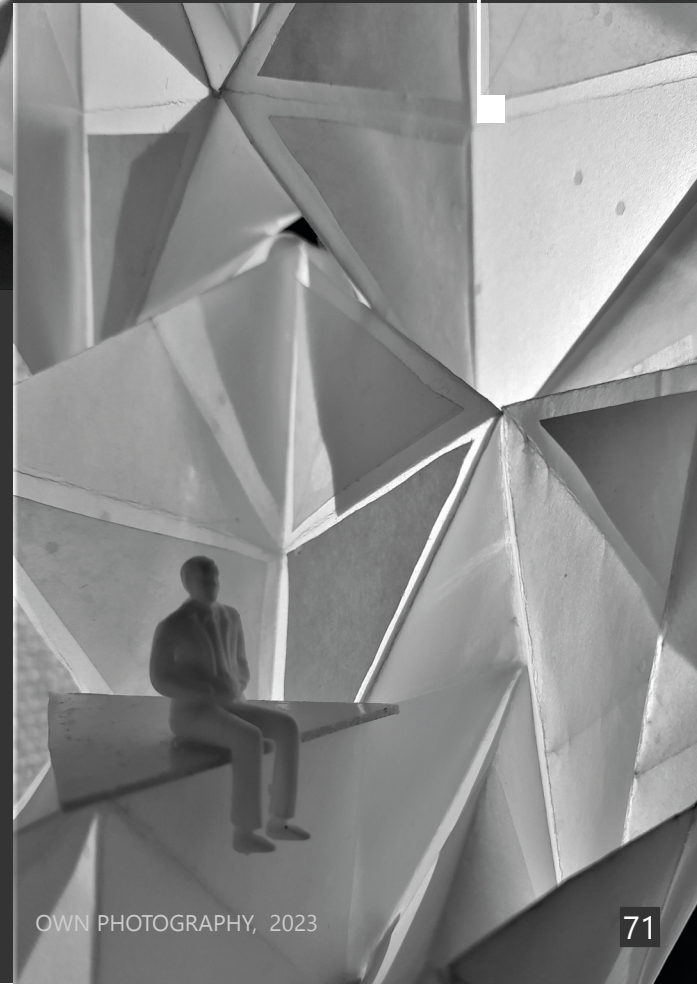
OWN PHOTOGRAPHY, 2023

COMMENT:

Space architecture has used origami to make structures more compact & limit deformation, while increasing the surface area. Because of this, the studies included origami shape/light study.

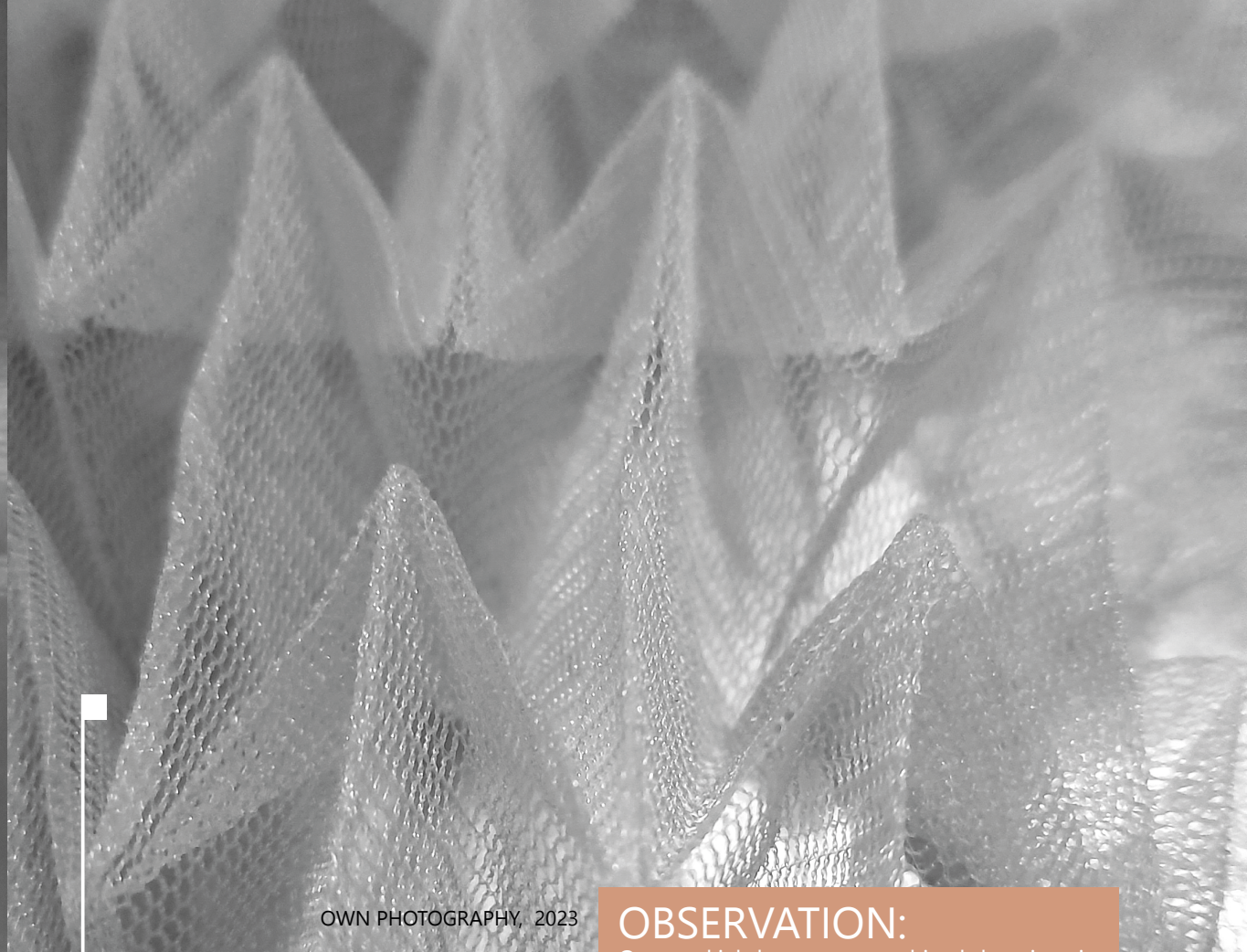
WATERBOMB ORIGAMI
LIGHT & FORM STUDY

WATERBOMB ORIGAMI
LIGHT & FORM STUDY



OWN PHOTOGRAPHY, 2023

SOFT ORIGAMI



OWN PHOTOGRAPHY, 2023

OBSERVATION:

Once multiple layers were combined, the origami folded more poorly or adjusted individual layers. However, unlike a transhab-fold, the faces tended to avoid bending deformation.

WATERBOMB ORIGAMI

BOBBINET FABRIC, MATERIAL & FORM STUDY

OBSERVATION:

The fabric version of origami seemed to add lost features of flexibility. Layering both a rigid and soft version evoked a similar vibe as surface B (p.69) or translucent skin/membranes.



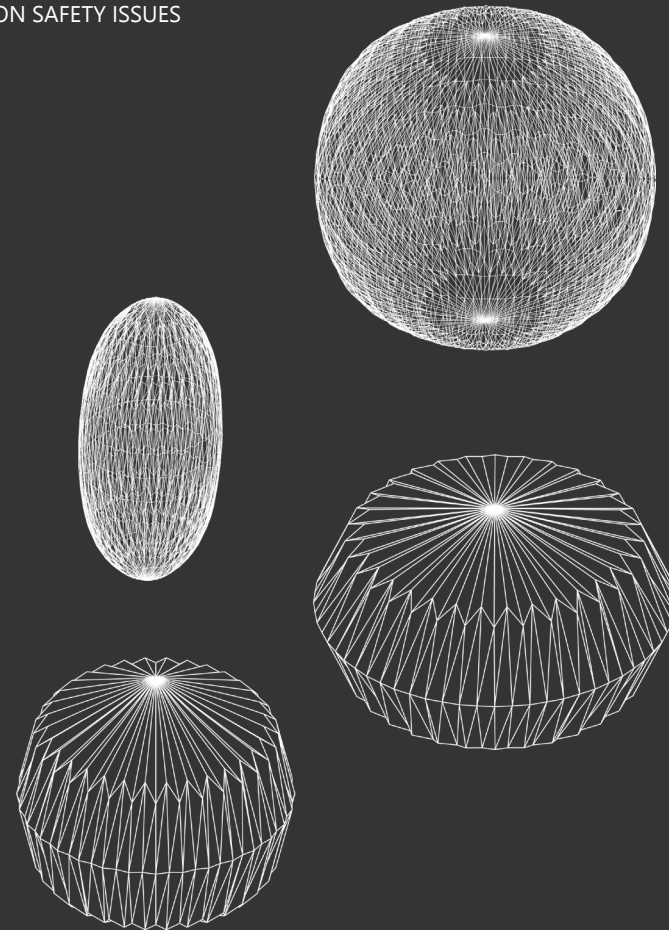
OWN PHOTOGRAPHY, 2023



SIMULATING SHAPE

ELASTIC

- +/- ADAPTABLE FOLDS
- +/- ELASTICITY THROUGH MATERIAL
- + SOFTER COLLISIONS
- DIFFICULT TO ATTACH RIGID SHAPES
- DEFORMATION SAFETY ISSUES



COMMENT:

Elastic principles seemed to damage or stretch coatings essential to the survival of a Venusian structure, while rigid/sharp shapes could cause more collision damage.

RIGID

- +/- PLANNED FOLDS
- +/- ELASTICITY THROUGH SHAPE
- + CONTROLLED DEFORMATION
- + EASIER TO ATTACH RIGID SHAPES
- + VITAL LAYERS SUFFER LESS STRESS

CYLINDER STRUCTURE PHASES
 RESTRAINT FABRIC, LIGHT & FORM STUDY, INSPO FROM SIPHONOPHORES

OBSERVATION:

A cylindric/ring structure supported a vertical tech-system & modules (inspired by siphonophores), however, it also posed structural challenges, as the restraint layers landed on a soft bent "floor".

OWN PHOTOGRAPHY, 2023

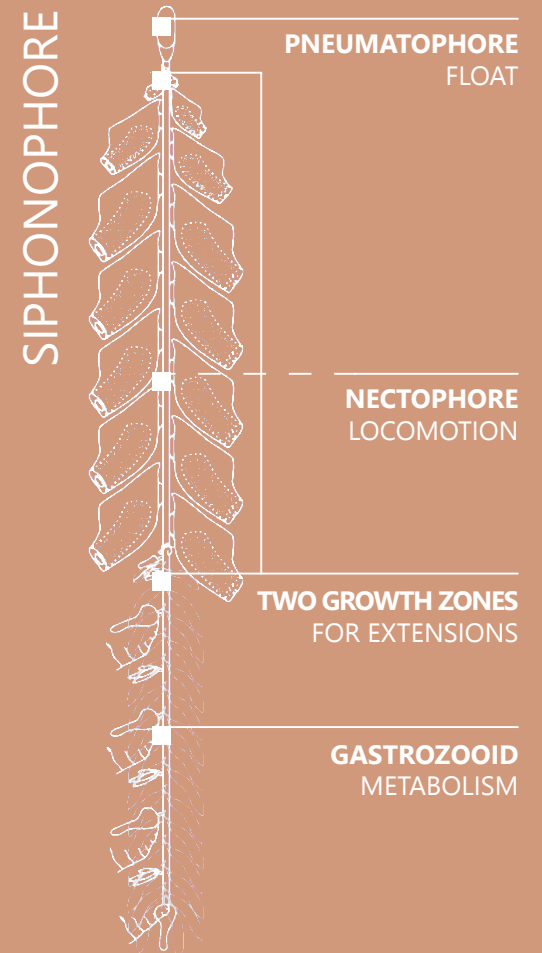
LANTERN STRUCTURE

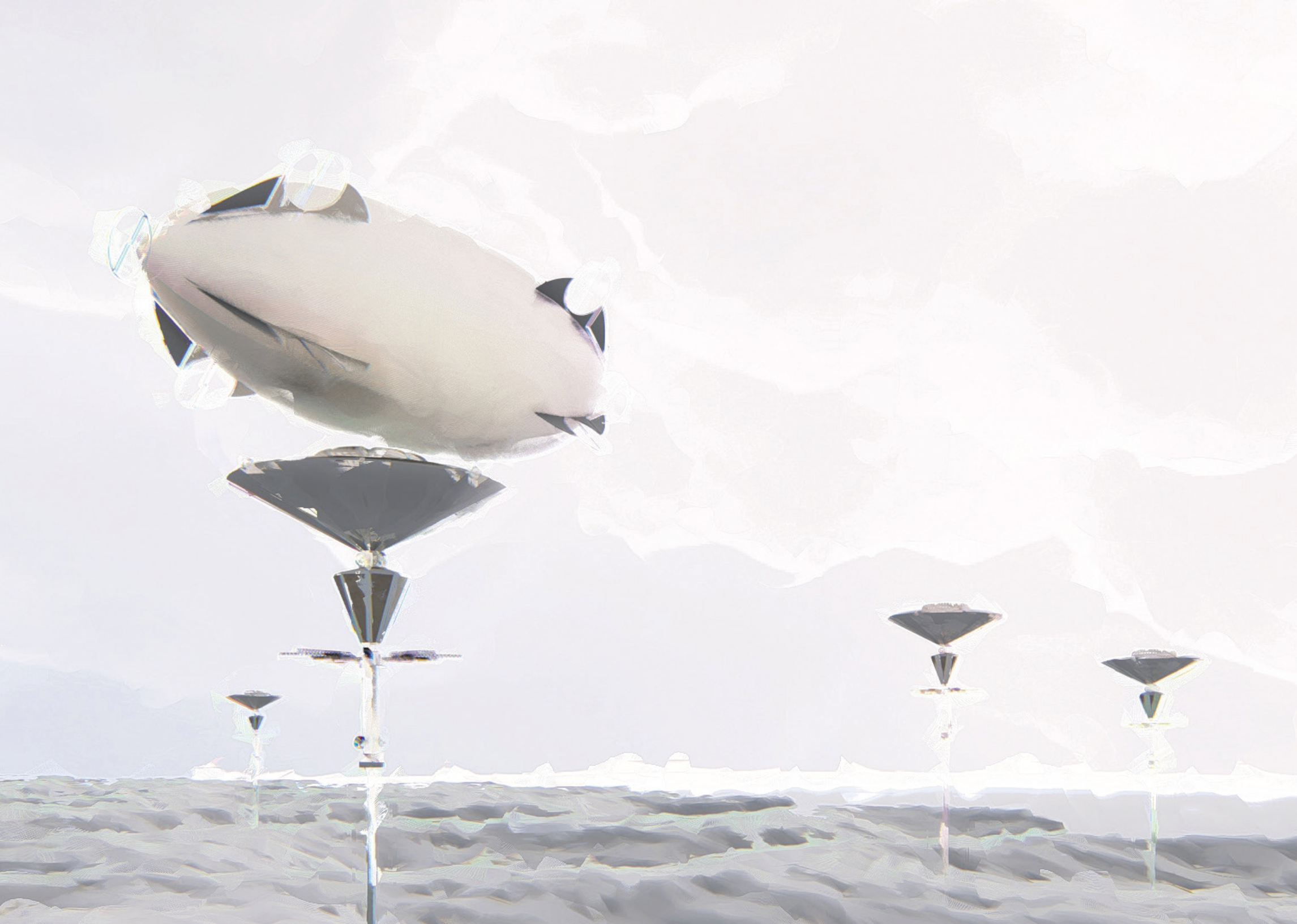
RESTRAINT FABRIC, LIGHT & FORM STUDY

OWN PHOTOGRAPHY, 2023

FORM COMBINATIONS

The final form became a hybrid of most design investigations. Ultimately, the umbrella principle combined with siphonophore structure became the leading shape, as it merged softer and stiffer geometries with a logical order of functions, articulating the strength in each principle. Interiorwise, this lead to volumes ephasizing the unique character of each cone.







*... Suddenly, a signal can be heard from the corridor.
The blimp is docked now.*

*I grab the cold metal handle on the wall and make my way towards
the habitat pathway, connected to the top of the structure.*

*Close to the top, the air turns more humid as scent of greenery
embodies the pathway. It's different from the scent of Earth, but a
pleasant addition for a space station.*

*I know that, even this place has flaws, our research here will
provide a better place for coming generations, not just on Venus, but
anywhere we decide to live in the future.*

VIII. SUMMARY & SOURCES

CRITICISM

On human health

Even if altered gravity is removed as a health factor, it doesn't imply that every health concern related to that factor will go away, e.g. altered host-microorganism interaction may be a result of something else rather than microgravity. Another example is cardiac rhythm problems, which may be genetic. Apart from health problems on site, it's likely that health problems or conflicts might occur in space before the arrival to Venus.

When it comes to space travel, it's worth noticing that the travel duration to Venus aligns with Earth-reliant missions of 6-12 months (NASA, 2015, p.20, 35) and that health concerns related to social behaviour start to accelerate after 3/4 of a year (NASA, 2015, p.30), a time frame which a Venus mission could match with 3-4 months (Jones & Arney et al., 2015; Phillips-Hungerford, 2017, p.19), considering many of the natural factors present on Earth (see chapter II & IV) would "return" once arriving to Venus.

As proven by previous existing space projects, it's difficult to build away every problem, not to mention those linked to human health. Assuming future projects will provide every solution by consuming/producing resources and turn into something built may thus be regarded as ambitious. It's also worth to question whether missions need to be manned or not.

On folds

The fold sequences displayed in this thesis are only meant to display rough principles. Considering available information about details & materials necessary for the survival of a Venusian structure, VOMB is based on a rough estimation of the fold morphology and facade layers, derived from simple 3D-simulations and information from Doug Litteken, Thomas Jones & Gerard Valle (2019), Taylor Phillips-Hungerford (2017) and Christopher A. Jones & Dale Arney et al. (2015).

On needs vs "wants"

It's difficult to judge whether some design features in this thesis are answers to needs or "wants", although they can, perhaps, be distinguished in the following way; a need is something that may be more related to a larger group of individuals, while a "want" is on a more personal scale, although not always. A need may also belong more to our primal needs, rather than a personal hobby. Surely, even a "want" may support our well-being for a larger group, but the "want" may usually be something of a luxury and rather insignificant in the total context, instead of a tool to counter psychological/physical problems. For VOMB, gardening is, in a sense, both a need and a "want". Judging from the list of health concerns by NASA, gardening is a need from a human health perspective.

SUMMARY

This thesis presented a conceptual architectural proposal, featuring design elements which may support human health and human well-being in space. By applying space research and stemming from biology, this thesis also argued where a potential extraterrestrial habitat would be located and what its morphology may look like. As a hypothetical proposal, VOMB did not demonstrate the ultimate solution for all health problems related to human space exploration, rather it displayed a hypothetical answer to currently identified health concerns related to space travel. The thesis questions were answered as follows:

Where would we settle first and why, from a health perspective?

We would settle at Venus, because of its proximity, resources and Earth-like features.

What can space architecture do for longterm resilience in space, both for human well-being and the human being as a species?

Space architecture can work more with sense stimulation and variation, deriving tools from targeted health concerns. Choice of location should also be a crucial part in space project, as it affects the very function of the building and its inhabitants. This may, hypothetically, contribute to better a understanding about human health, our needs, as well as the development of space economy.



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