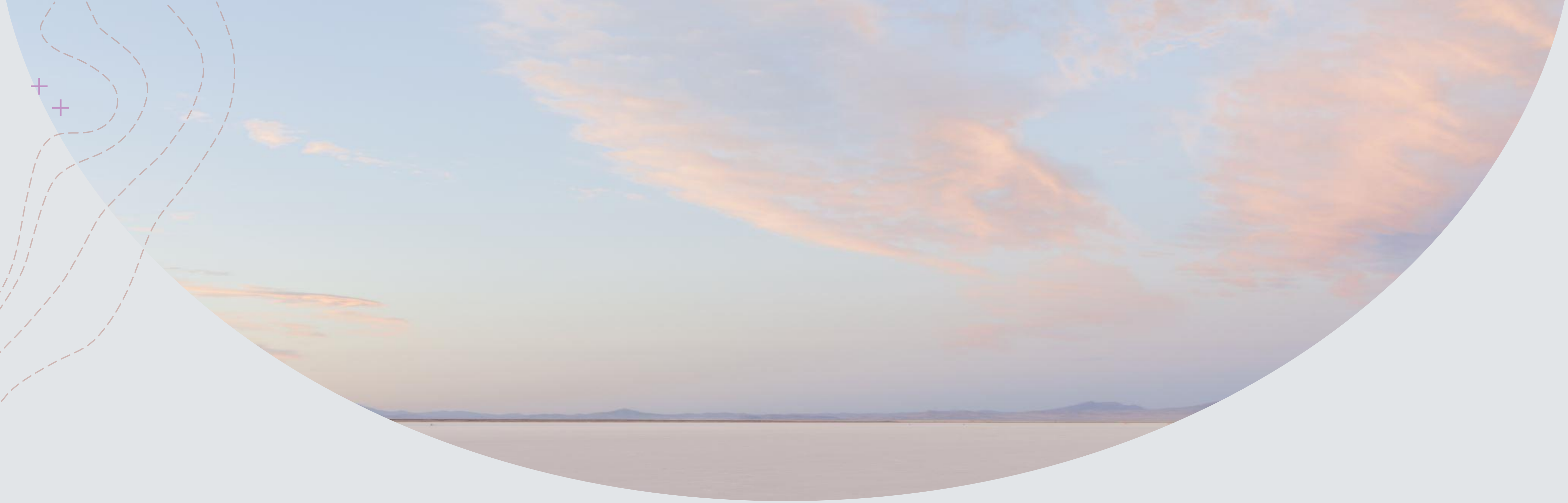


HUMAN PERFORMANCE & ARCHITECTURE IN EXTREME ENVIRONMENTS

Presented by: Pranita Khedkar

M.S. in Space Architecture
Spring 2022

UNIVERSITY of HOUSTON
CULLEN COLLEGE of ENGINEERING
Department of Mechanical Engineering

SICSA

Problem

- Lack Participatory Architectural Design Process
- Lack of spatial habitability supporting both working & social activities
- Crew Autonomy, Democracy & Teamwork
- Machine Support, human creativity for exploration and discovery
- Equipments and workstation design for productivity, not packaging
- Workplace design shapes the quality of work life

Vision & Mission

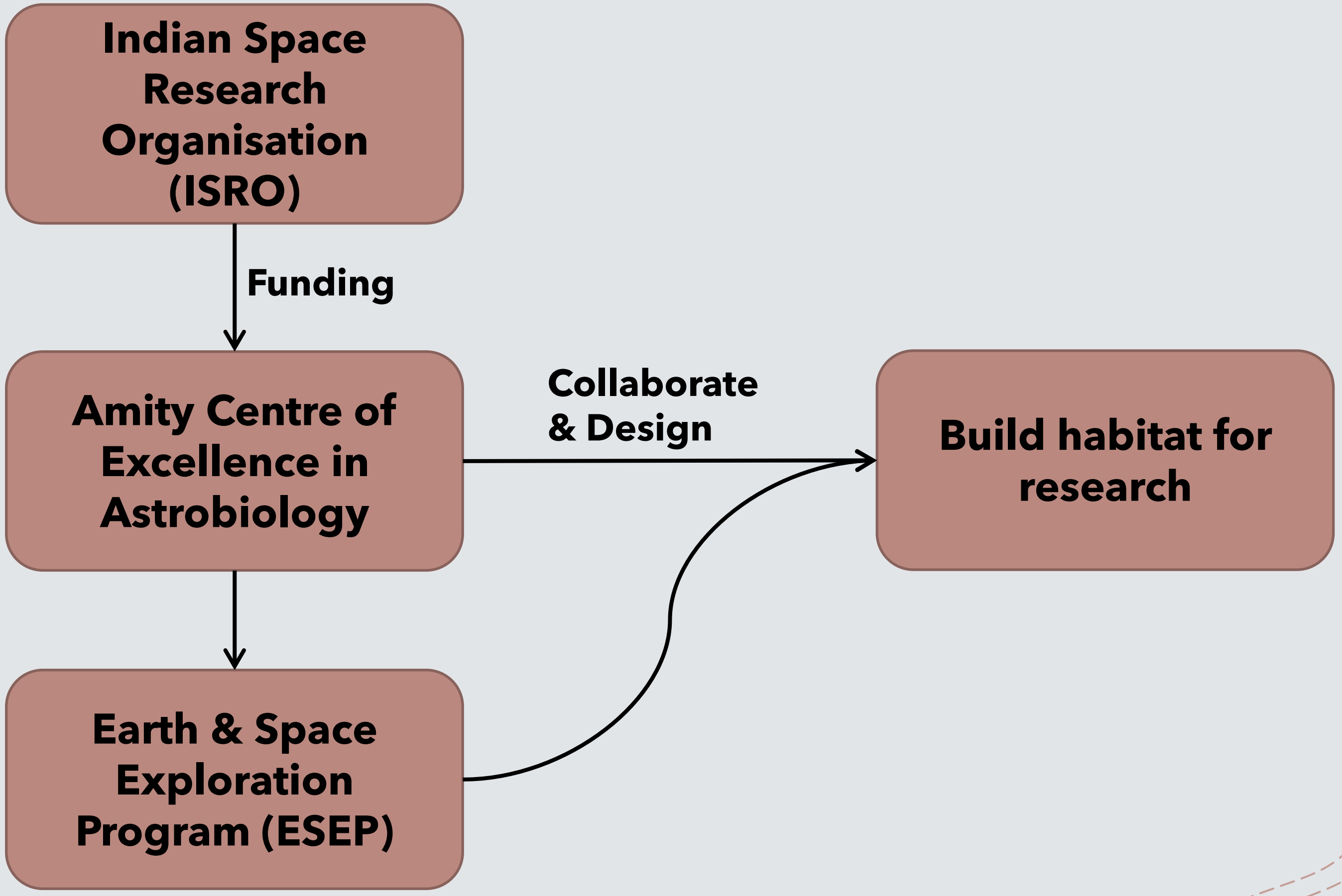
- To design and provide safe and self-reliable habitation capable with fully-integrated systems for autonomous operations

- Investigating mission architecture that would help in decreasing crew training time, adaptability to new conditions in extreme environments.
- Design/Develop most efficient and effective habitat for Mars-like environment on Earth.

Goals

- An effective testbed for field operations
- The prototype will be practical, realistic, and adaptable to future.
- Serve as a useful research facility at analog sites on Earth.
- The research facility will generate public support for sending humans to Mars to settle.

Budget

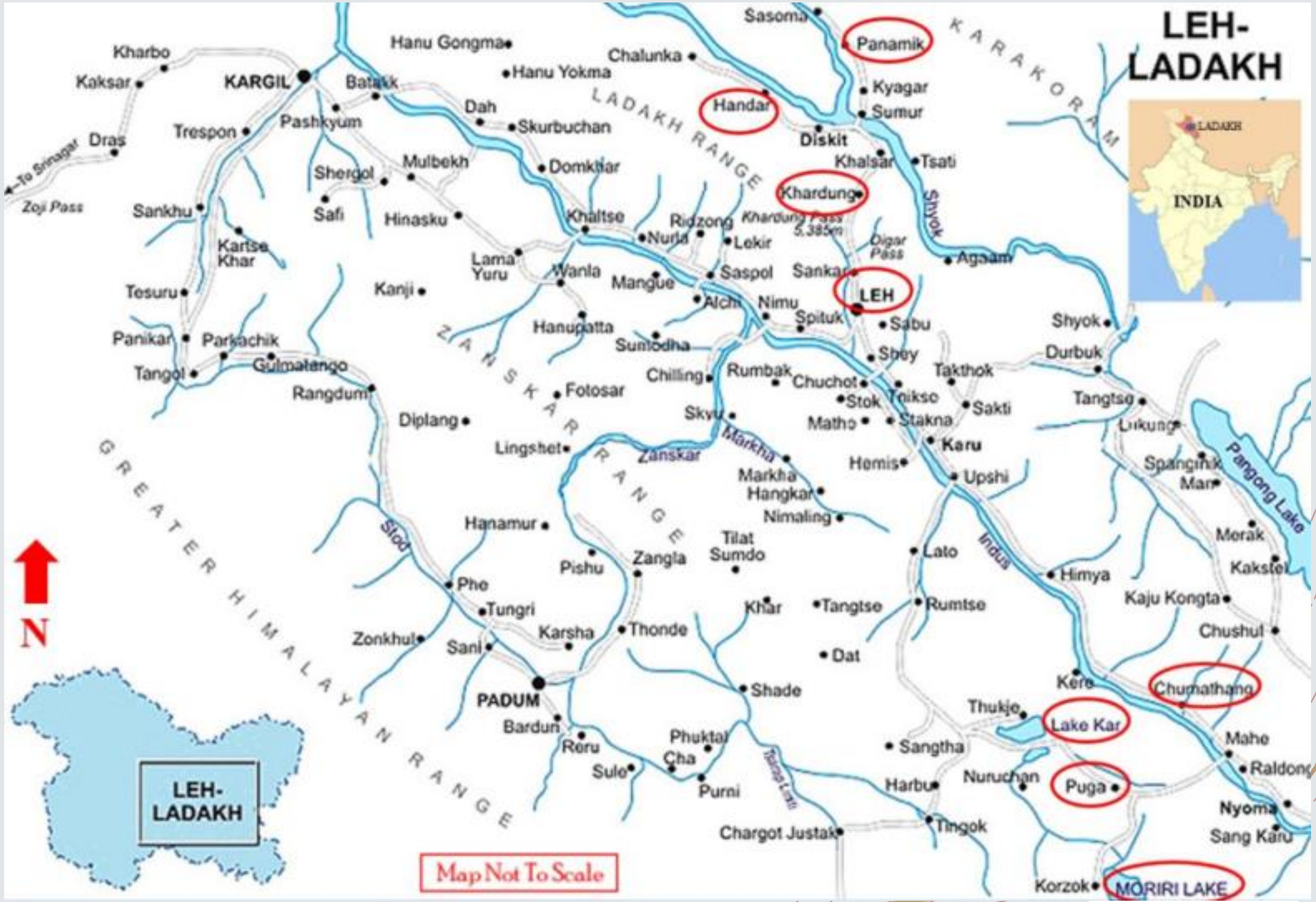

Indian Space Research Organisation (ISRO)
Funding
Amity Centre of Excellence in Astrobiology
Collaborate & Design
Build habitat for research
Earth & Space Exploration Program (ESEP)


LADAKH
MARS

Potential Sites

Ladakh is cold, high altitude desert region located in the Himalayas. With a diverse range of extreme environments (boron rich hot springs, glacial deposits, saline lakes and permafrost regions).

Ladakh is located in the easternmost section of Himalayas (3500-5500 meters above sea level). With cold temperatures and high ultraviolet exposure due to its elevation, Ladakh has unique topological features that are of particular interest to scientists and analog explorers alike.

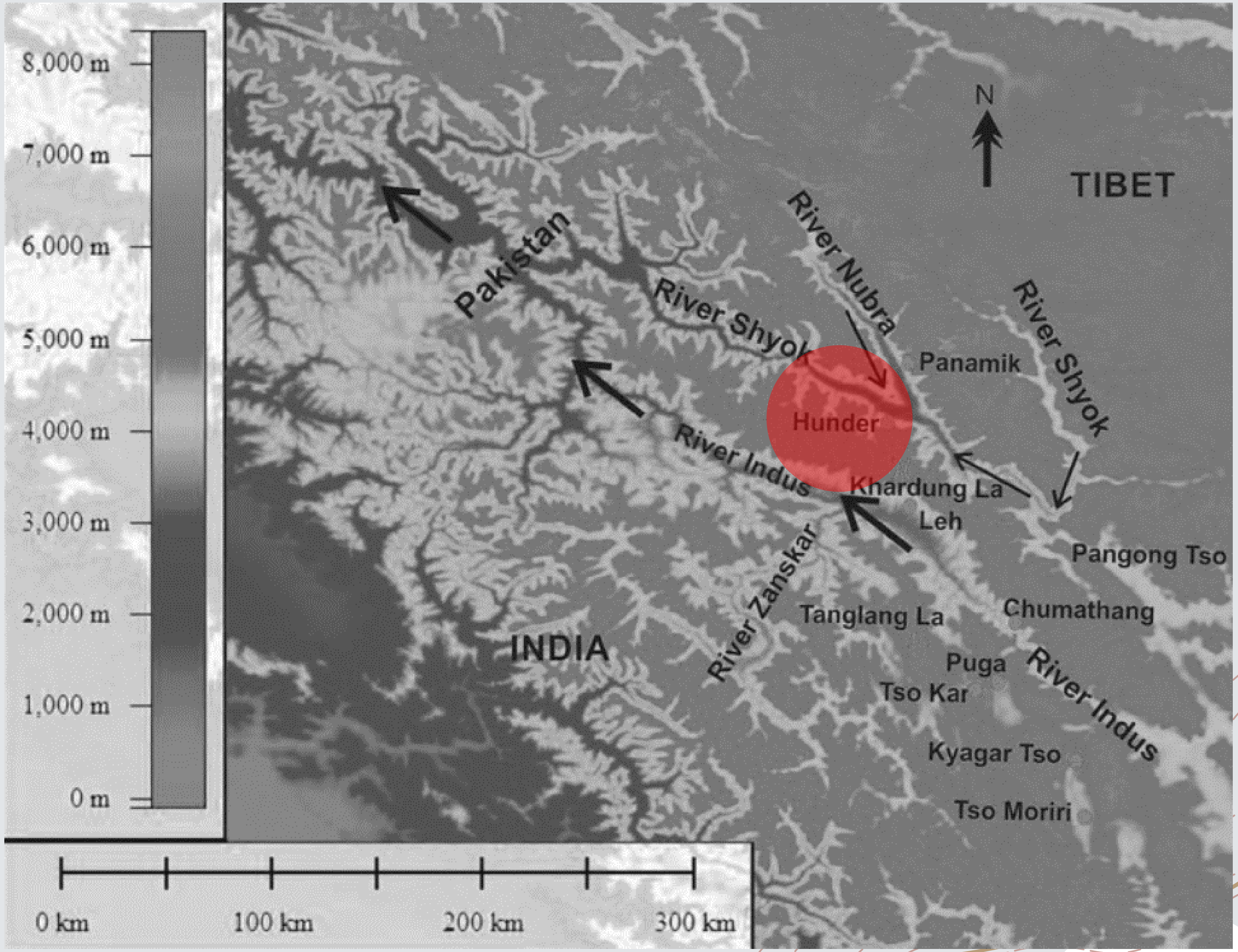


Selected Site for Analog Mission

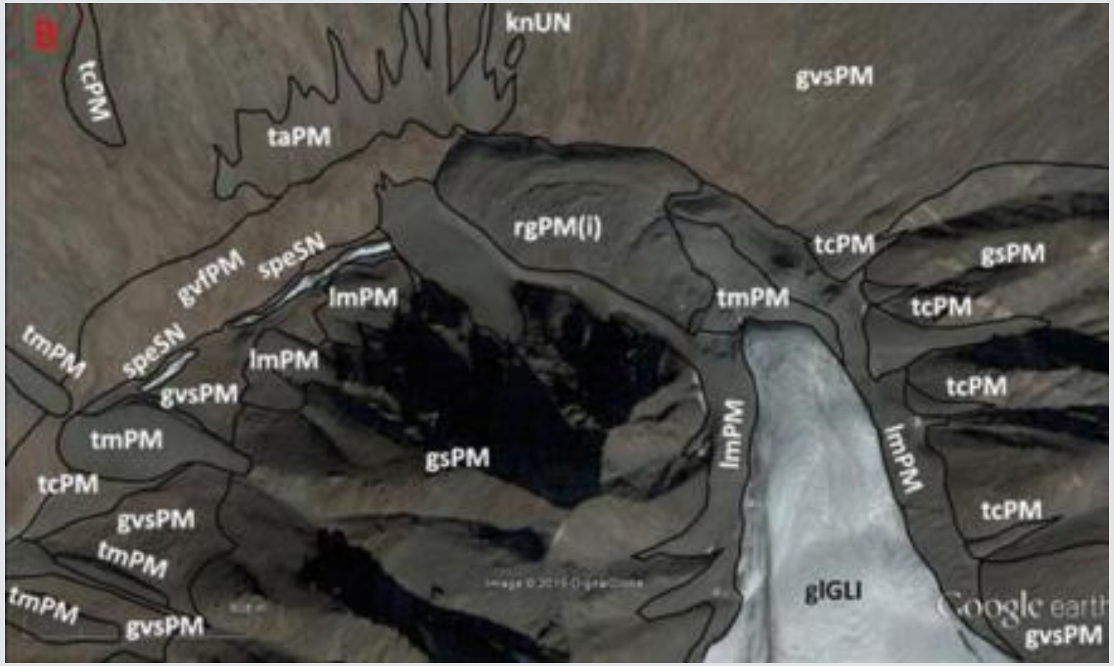
Site Types	Glacial High Passes		Sand Dune and Ponds	Hot Springs			Saline Lake		Permafrost
Activity	**Kardung La**	**Taglang La**	**Hunder**	**Panamik**	**Chumathang**	**Puga**	**Sumdo**	**Tso Kar**	**Tso Kar**
Regolith Landform Mapping	x	x	-	-	-	-	-	-	-
Comparative Planetology	x	x	x	x	x	x	x	x	x
Instrument Testing	x	x	x	-	-	-	x	x	x
Life Detection Analytical Protocols	-	x	x	x	x	-	x	x	x
Biomass Distribution	-	x	x	x	x	-	x	x	x
Microbial Diversity/ Metabolism	-	-	-	x	x	x	-	-	-

Potential Site for Analog mission - Hunder

- It has natural hot springs filled with microbial organisms adapted to reduced oxygen levels and atmospheric pressure.
- Salty lakes coexist with arid desert, making Ladakh in many ways possibly similar to ancient Mars.
- Data sourced by rovers points that liquid water and warmer temperatures were maybe present on the Martian surface.
- Under such extreme conditions, physical and mental fatigue sets in, aggravated by lower oxygen levels.
- The mission can bring to conclusion of individual productivity, health, and emotional well-being with group dynamics



Site-scale regolith-landform units mapped onto a ground-level photograph from Phyang glacier terminus, Ladakh



Regolith-landform map of the Phyang glacier in Ladakh on Google Earth base image

Photo Credits referred from Amity Centre of Excellence in Astrobiology

Wind eroded inter-dune sediments in Hunder

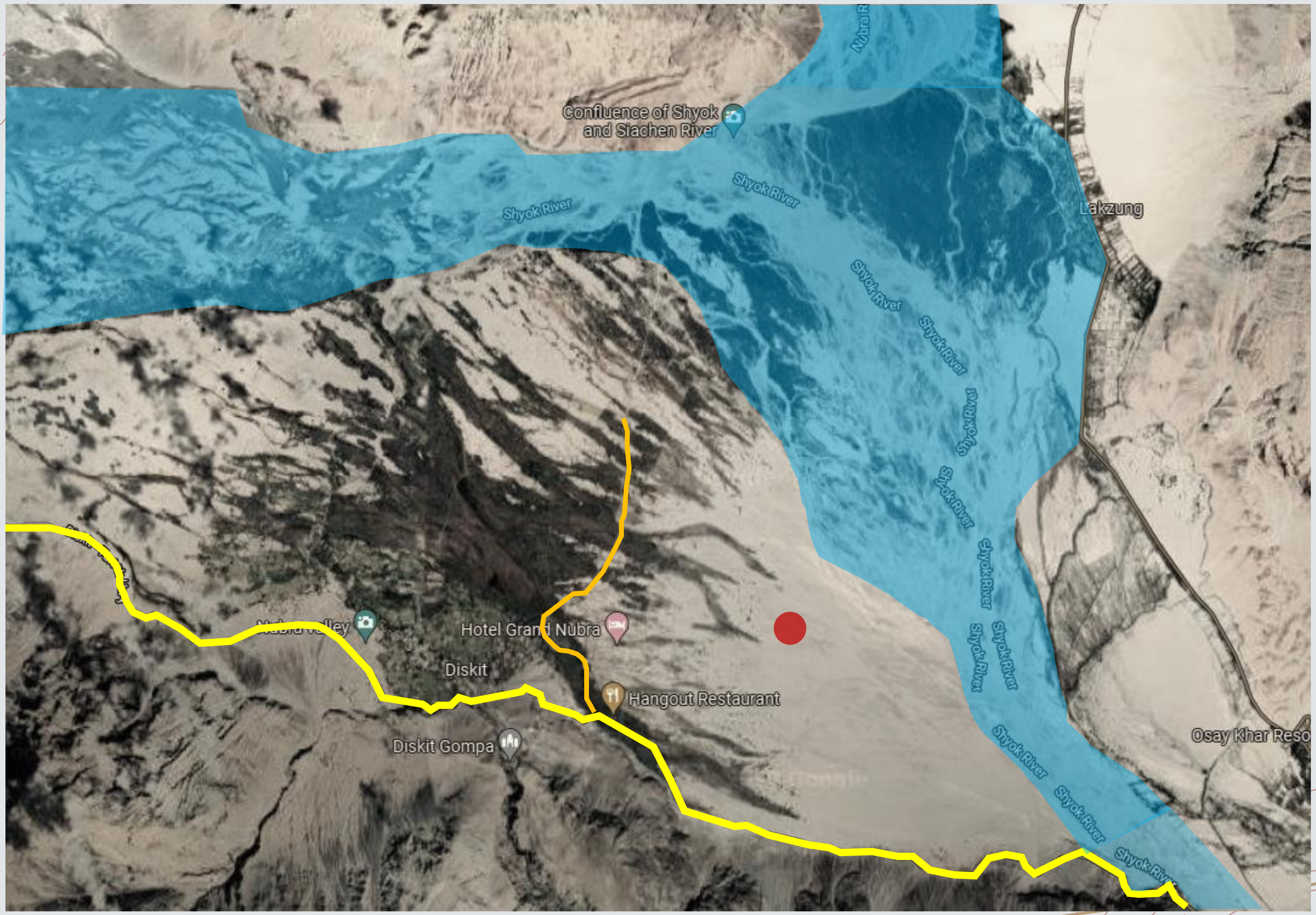
Inter-dune Pond, Hunder

For comparison, a dune field inside Endurance crater on Mars

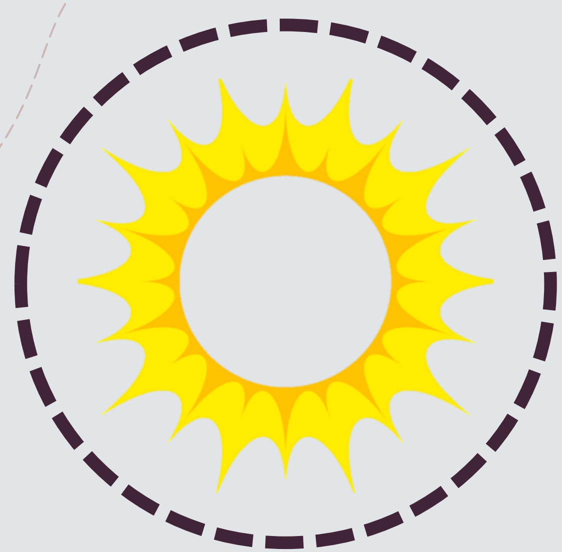
Stack inverted dune swale deposits

Photo Credits referred from Amity Centre of Excellence in Astrobiology

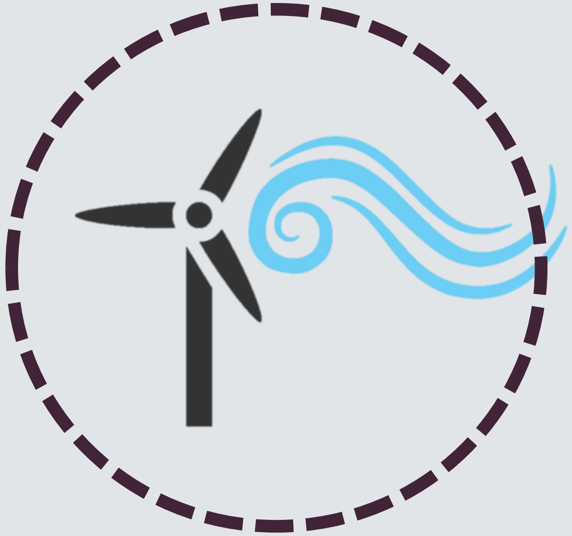
Potential Site for Base



Climate



Summers are extreme & UV radiation is high due to high-altitude and clear sky



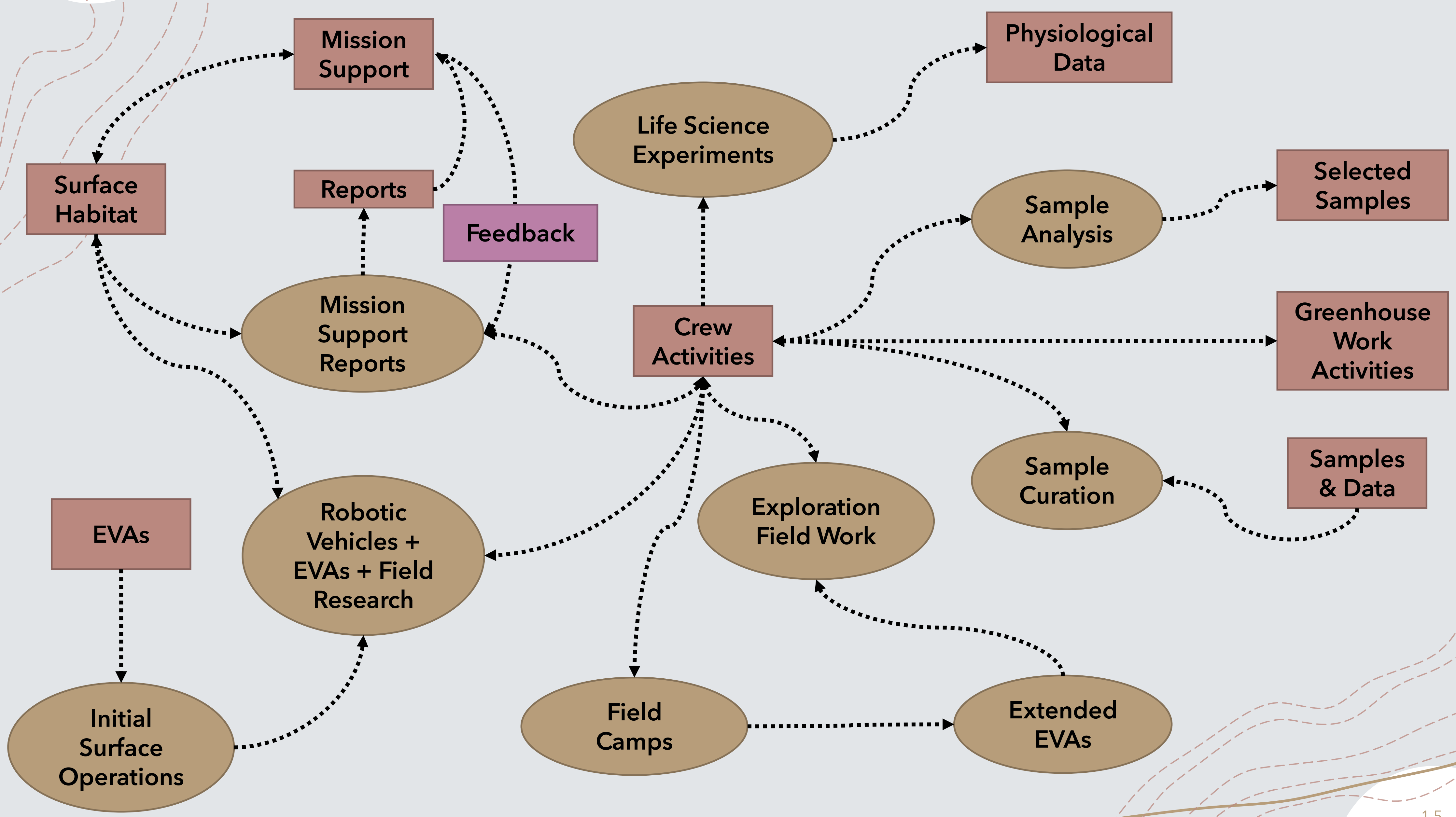
Wind speed is relatively intense throughout the year with 50% cloud coverage

Snowfall tends to be low, but temperature ranges from -14° C to 0° C

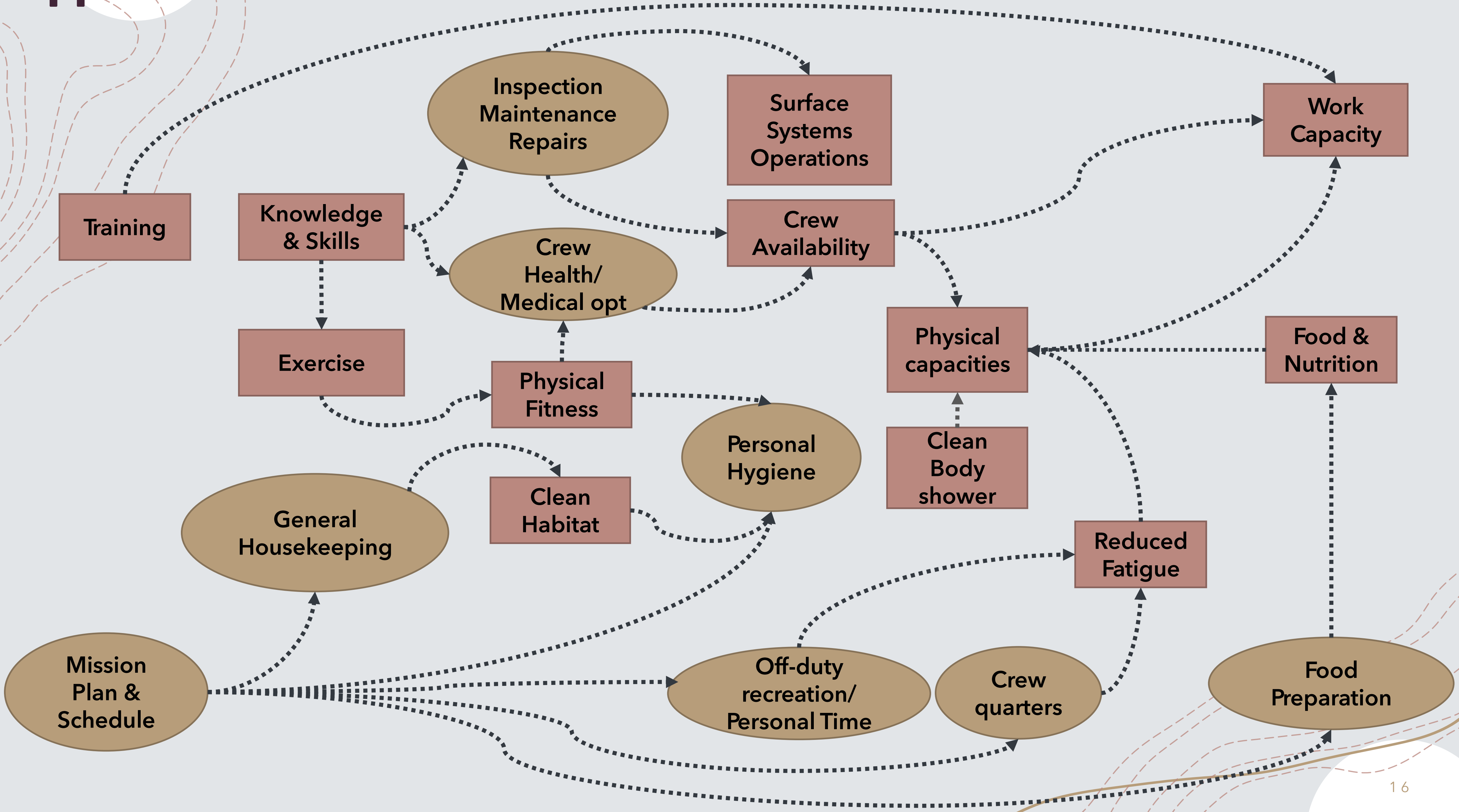
Habitation Research Assements

Aspects	Characteristics
Environmental constraints	Wind Storm Snow Radiation Dust
Human considerations	Psychology Physiology
Habitation systems	Internal subsystems External systems and Interfaces
Design trade studies	Environmental Human Subsystem
Application	Planetary surface Extreme environments

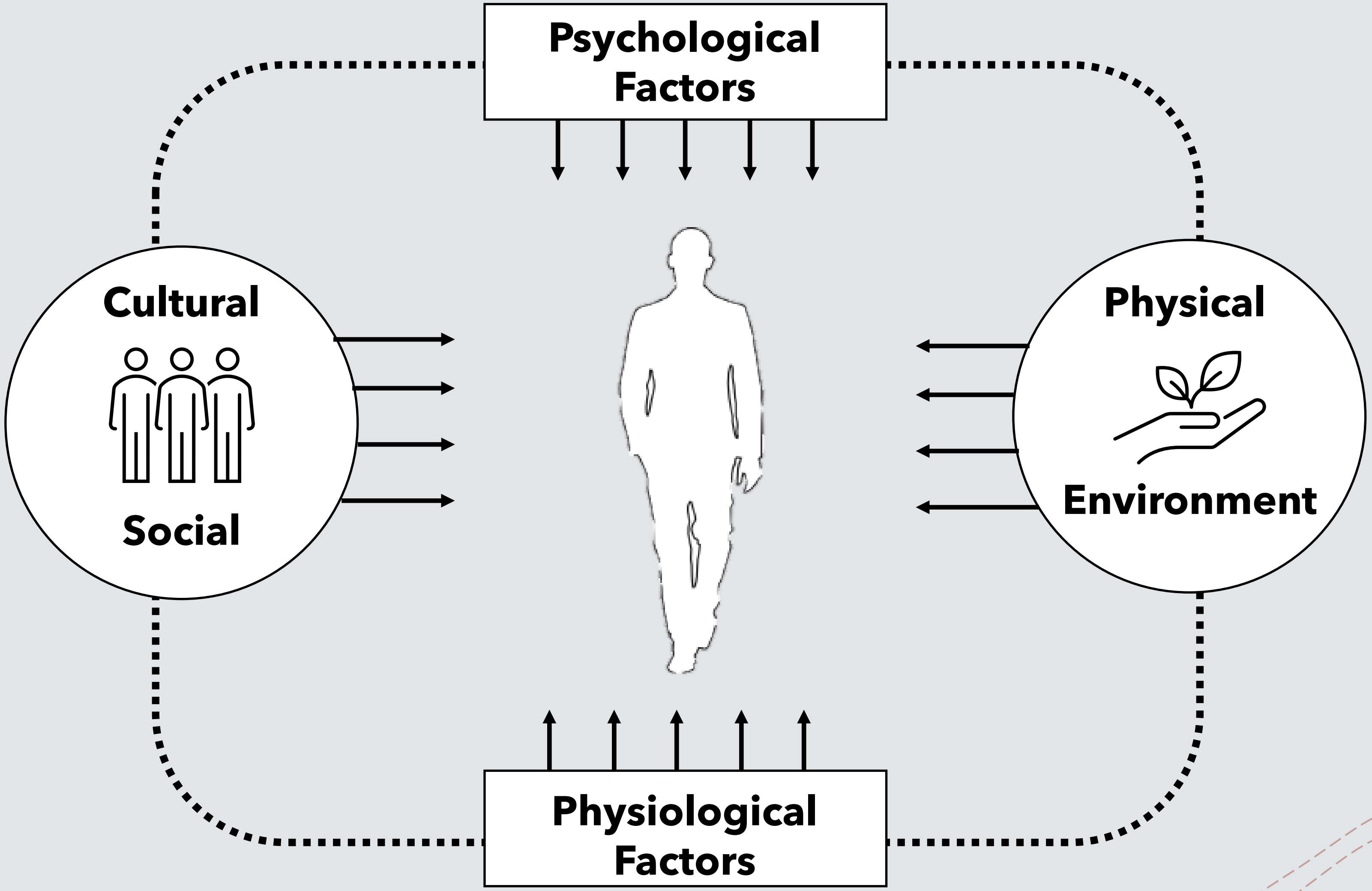
Crew Activities



Support Activities



Behavior Architecture



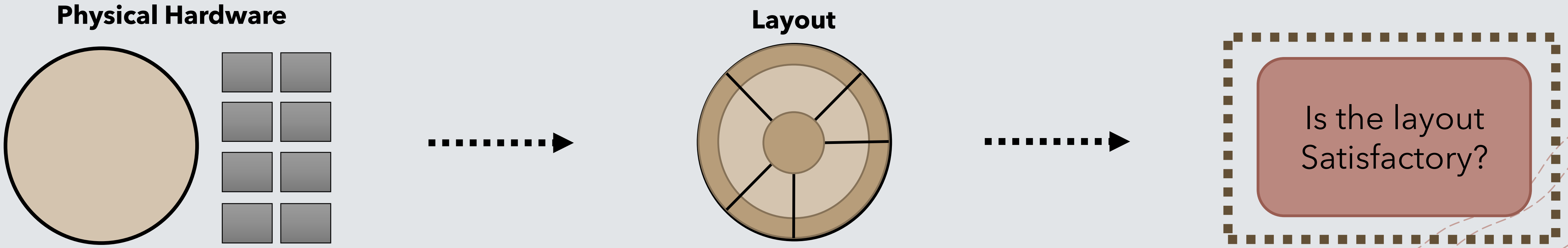
Mission Requirements for Habitat Design

Geometry
- Required Volume
- Hatches/ Entry-Exit
- Transition Paths

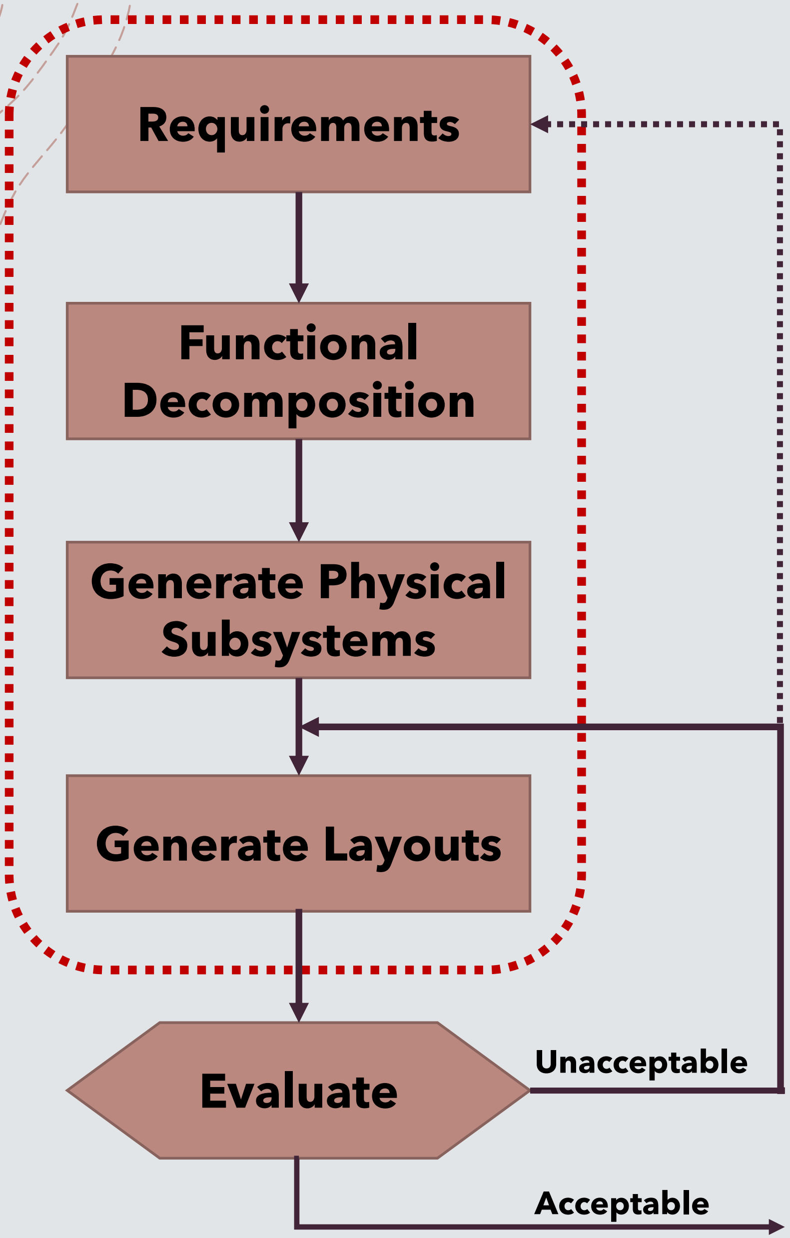
Habitat Functions
- Life Support
- Food
- Sleep
- Exercise
- Waste & Hygiene
- Thermal

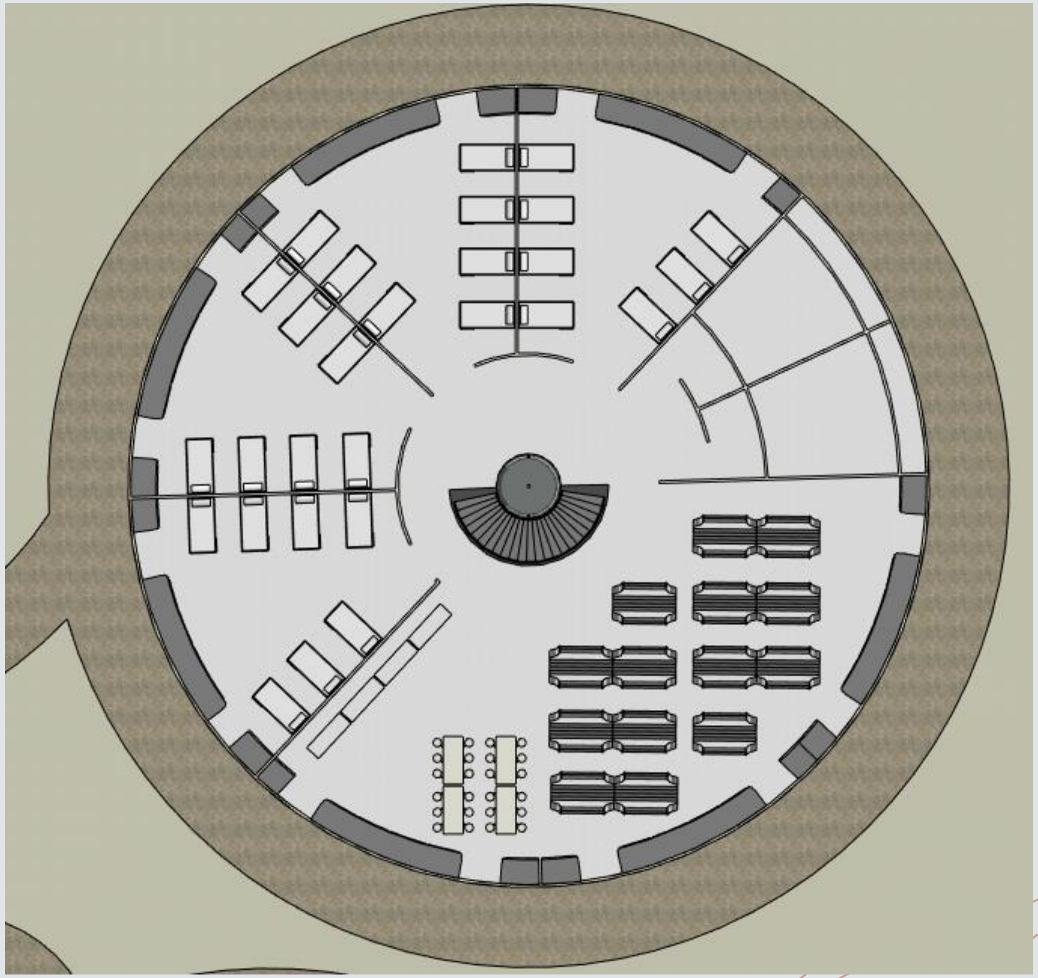
Mission Functions
- Communication Delay
- Command & Data Handling
- Science
- Power

Layout Generation & Evaluation



Interior Layouts Generation Process





Crew Activity Schedule

Intensity Level (High) › Intensity Level 5 › Intensity Level 4 › Intensity Level 3 › Intensity Level 2 › Intensity Level 1

Exercise
- Physical Exercise General
- Physical Exercise Treadmill
- Physical Exercise Ergonomic

Maintenance
- Testing
- Utility Check
- Inspection
- Inventory
- Stowage
- Sample Analysis

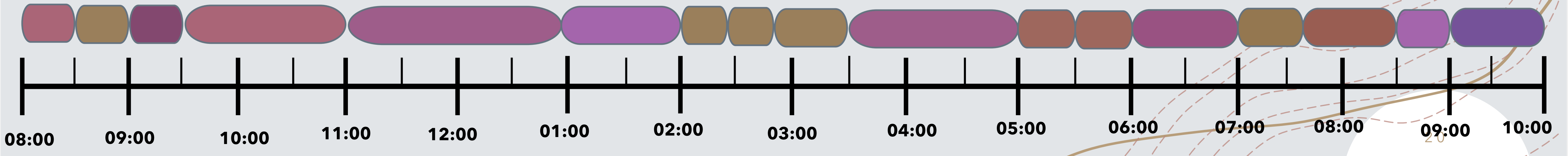
Preparation
- Conference
- Planning
- Food Preparation
- Data Preparation
- Work Preparation
- Sample Preparation

Experimentation
- Research
- Photography

Food
- Breakfast
- Lunch
- Dinner

Sleep
- Pre Sleep
- Sleep
- Post Sleep

Crew Schedule for Researchers, Scientists



Activity Schedule

Intensity Level (High) > Intensity Level 5 > Intensity Level 4 > Intensity Level 3 > Intensity Level 2 > Intensity Level 1

Exercise

- Physical Exercise General
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- Physical Exercise Ergonomic

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- Testing
- Utility Check
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- Stowage
- Sample Analysis

Preparation

- Conference
- Planning
- Food Preparation
- Data Preparation
- Work Preparation
- Sample Preparation

Experimentation

- Research
- Photography

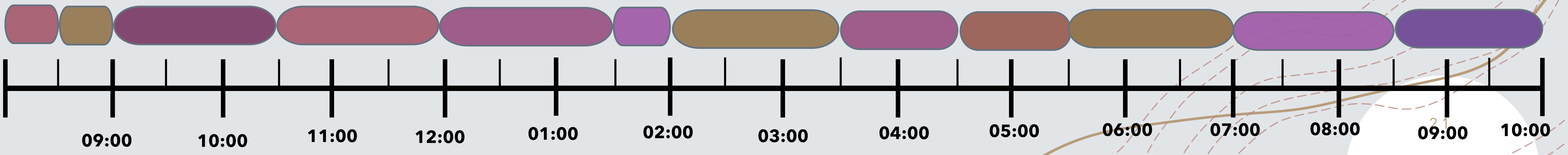
Food

- Breakfast
- Lunch
- Dinner

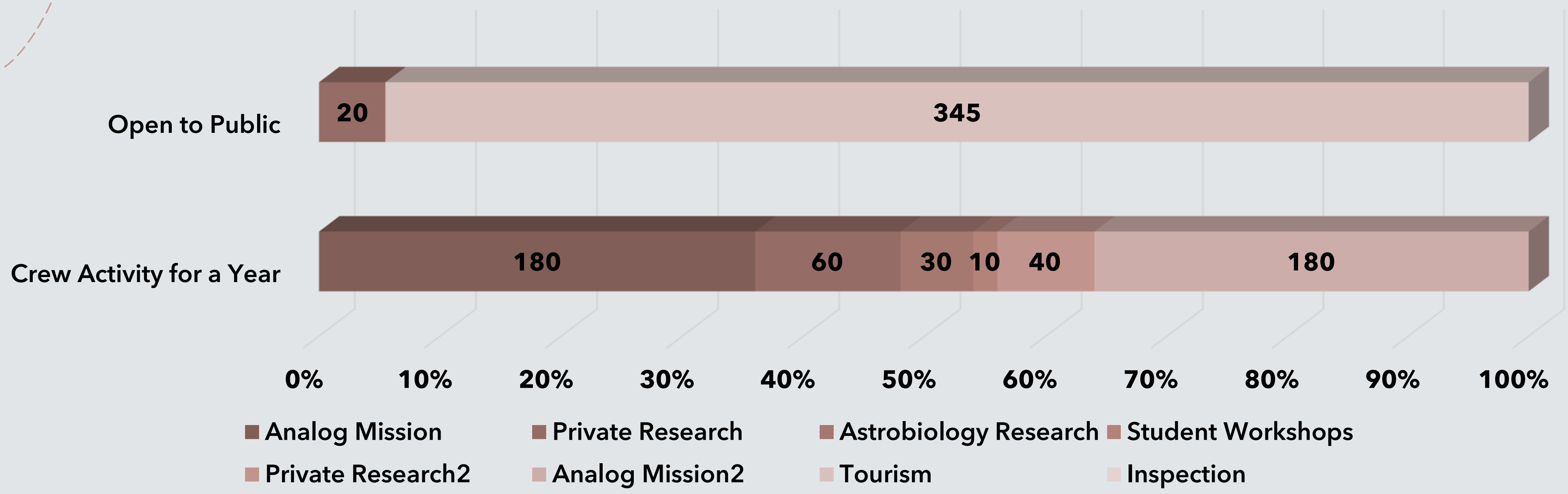
Sleep

- Pre Sleep
- Sleep
- Post Sleep

Schedule for Students



Human Activity over a year



New Technologies for Psychological Support in long duration missions

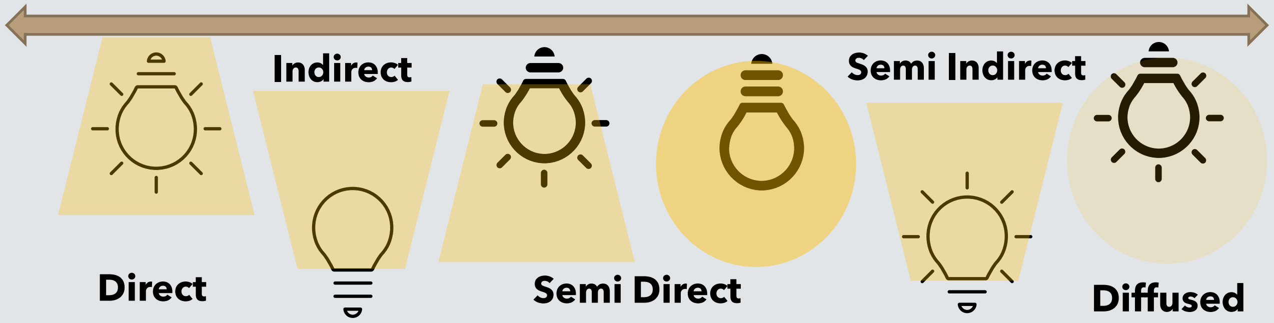
Favourite corner of the house portrayed in VR environment to feel at home

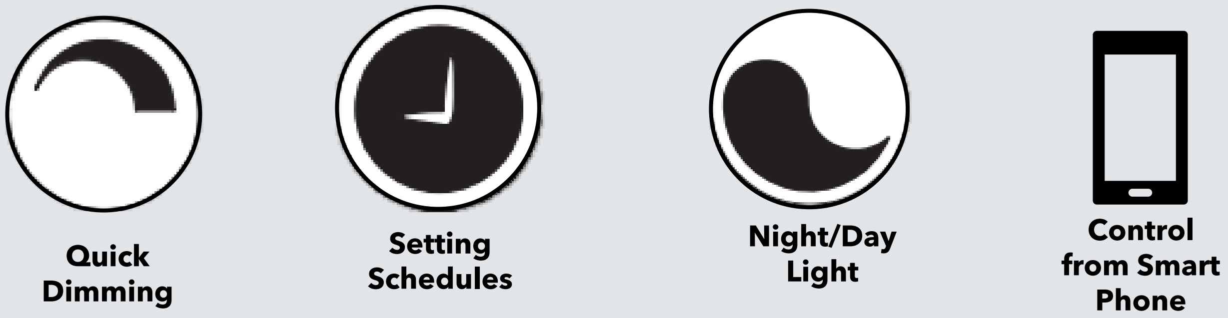
New Technologies for Psychological Support in long duration missions – Greenhouse

Closed life support system effective for psychological relaxation

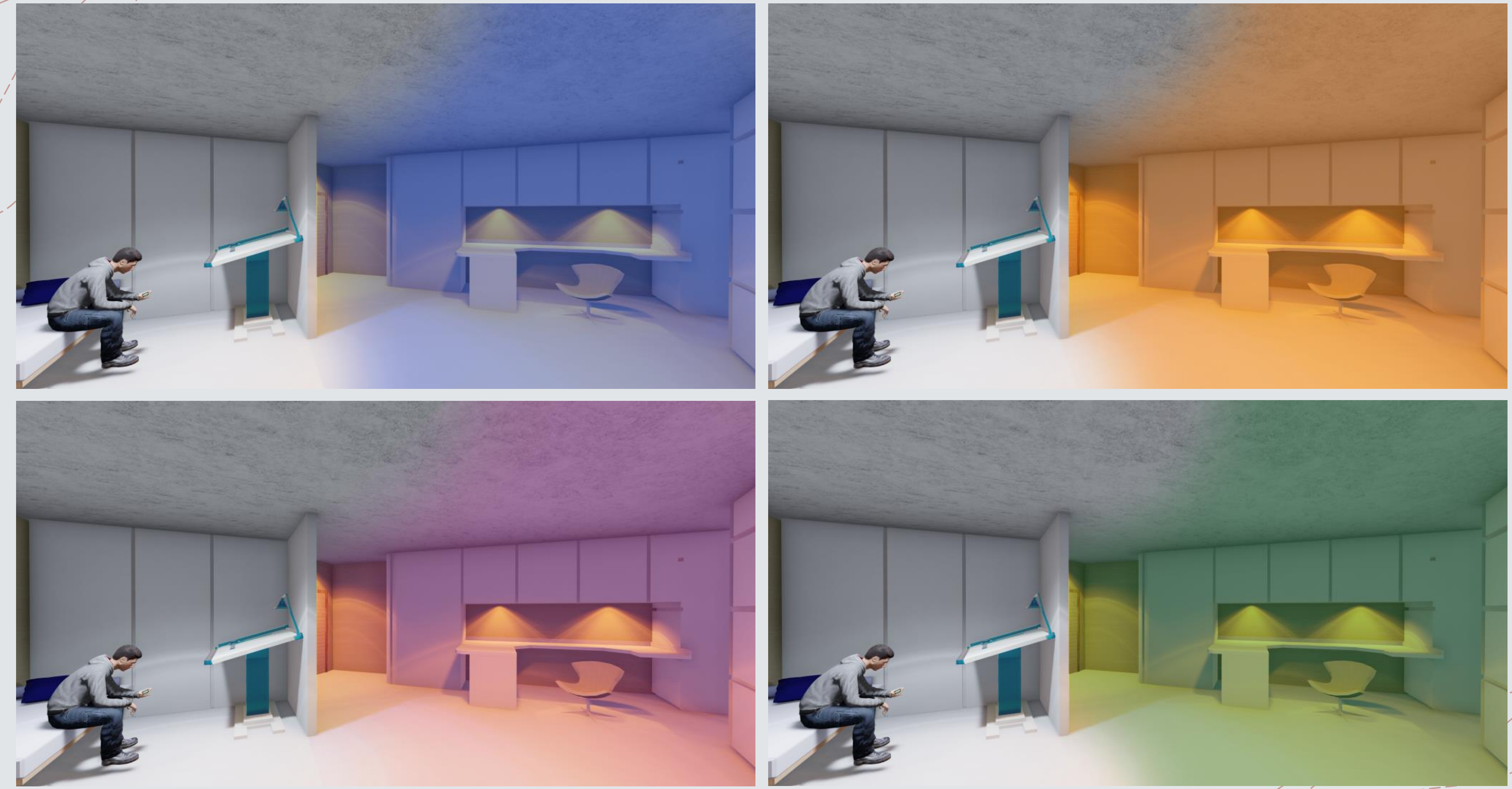
New Technologies for Psychological Support in long duration missions – Personal Activities

New Technologies for Psychological Support in long duration missions – Light Play

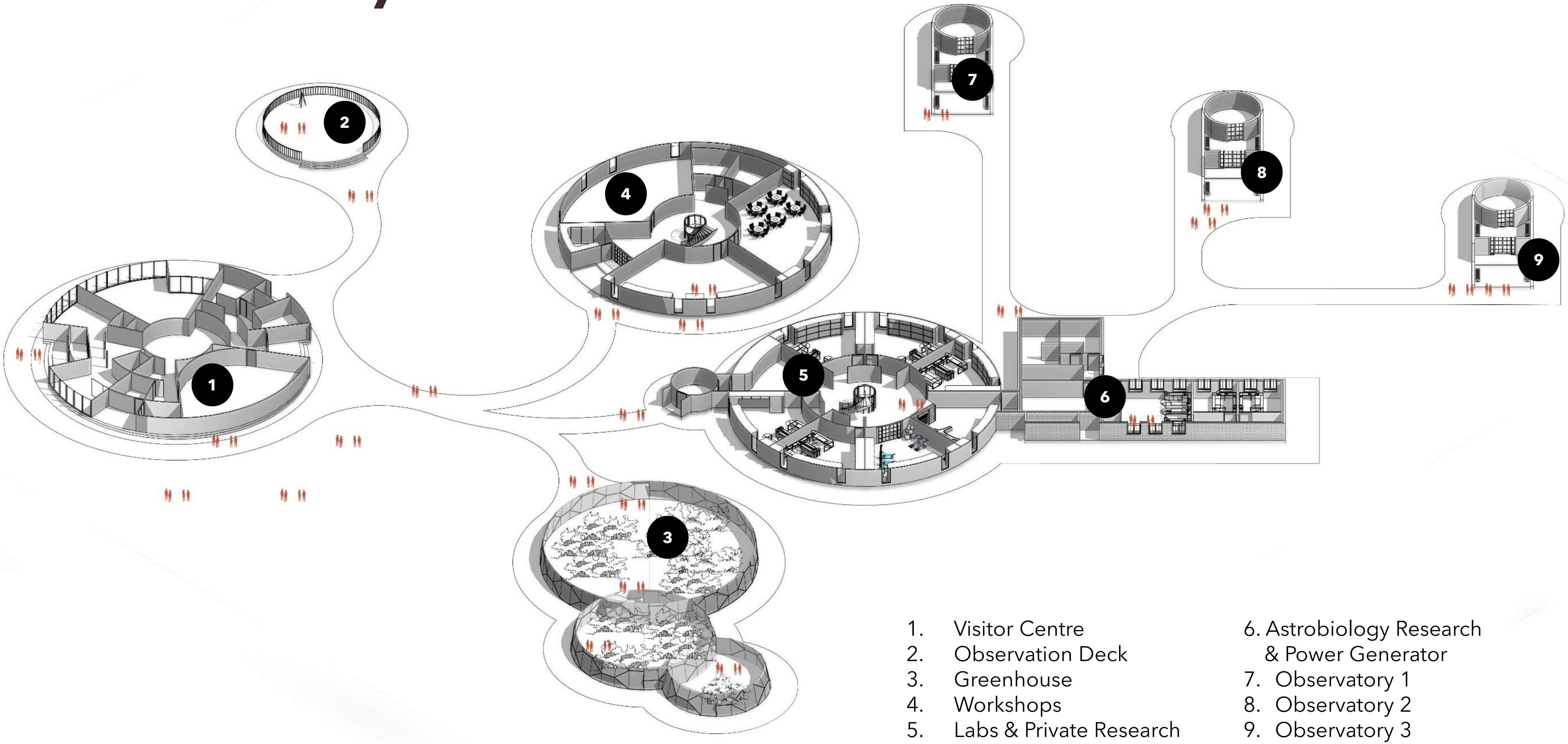




New Technologies for Psychological Support in long duration missions – Light Play



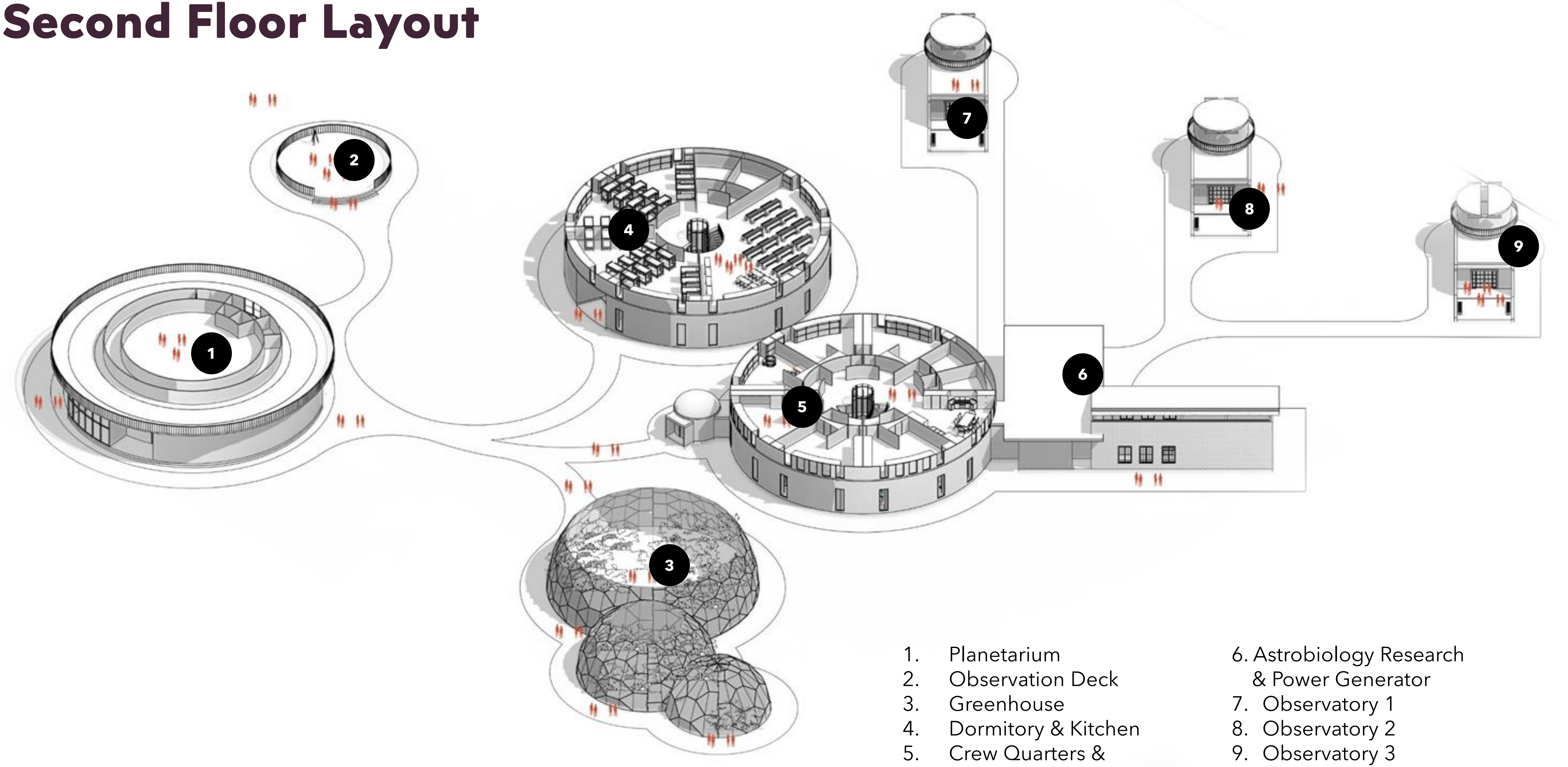
Ground Floor Layout



1. Visitor Centre
2. Observation Deck
3. Greenhouse
4. Workshops
5. Labs & Private Research
6. Astrobiology Research & Power Generator
7. Observatory 1
8. Observatory 2
9. Observatory 3

Scale – 1:100

Second Floor Layout

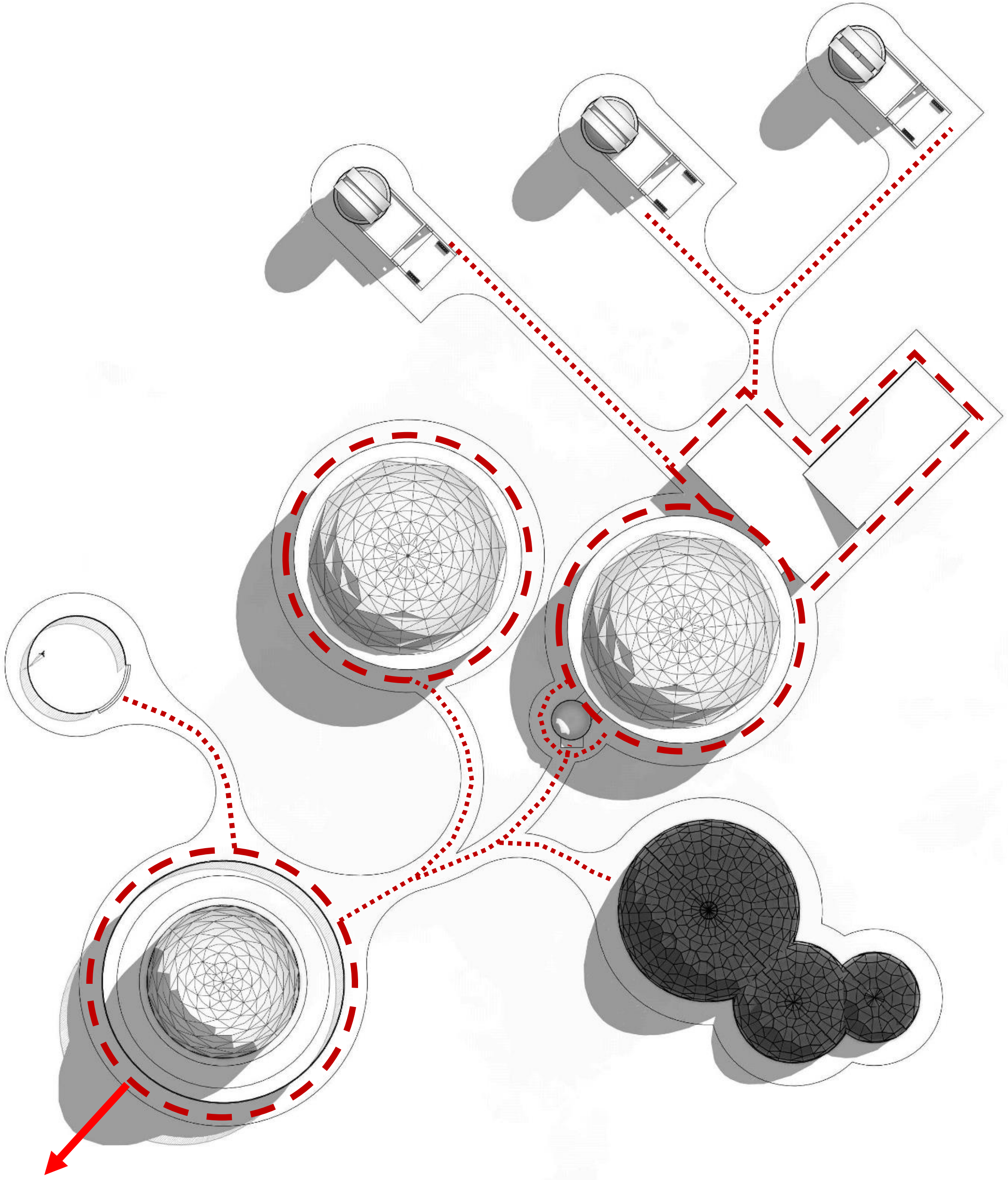


1. Planetarium
2. Observation Deck
3. Greenhouse
4. Dormitory & Kitchen
5. Crew Quarters & Workstation

6. Astrobiology Research & Power Generator
7. Observatory 1
8. Observatory 2
9. Observatory 3

Scale – 1:100

Schematic Layout – Emergency Exits



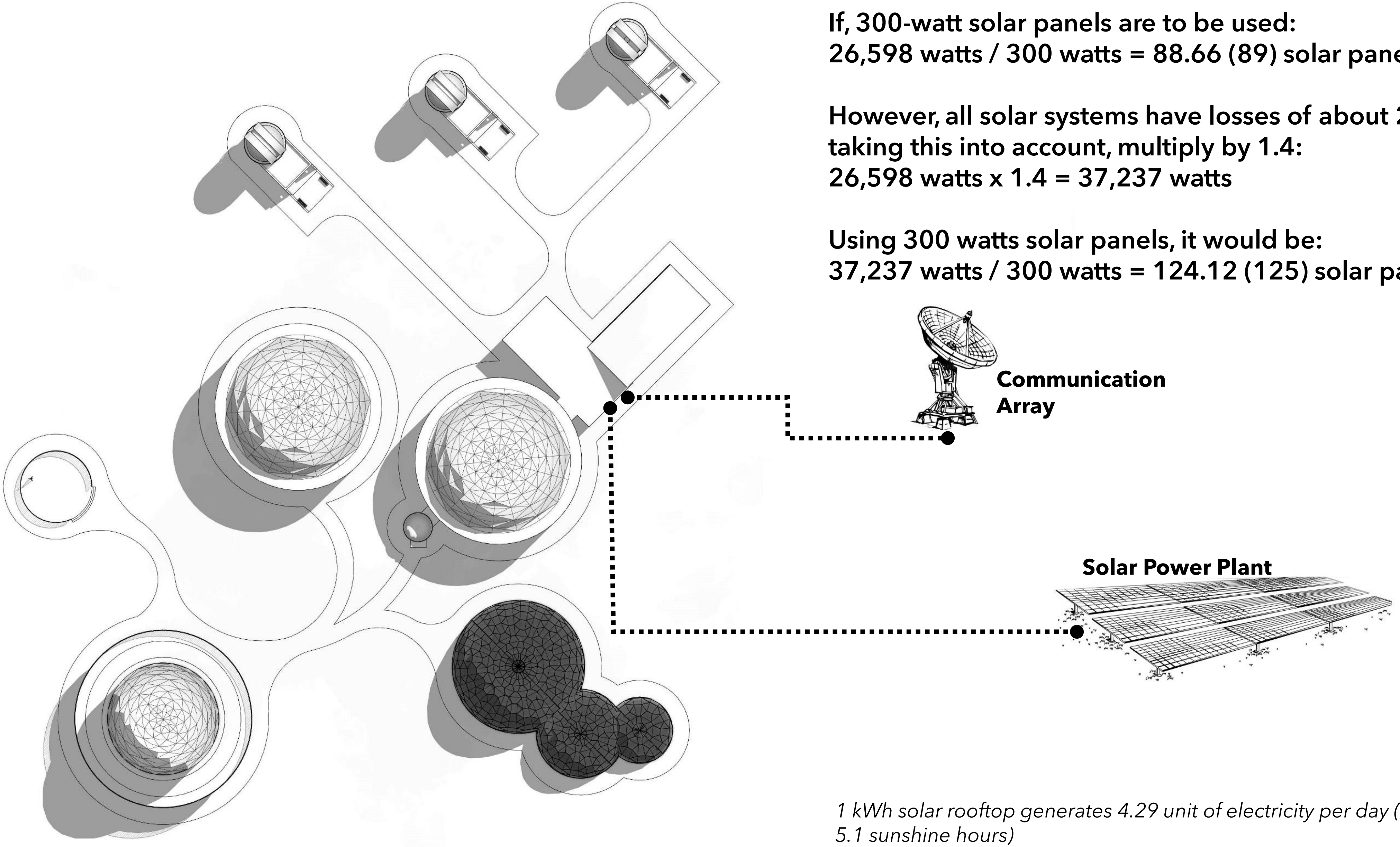
Schematic Layout

Solar Power Required :
6200 sq.m x 4.29 = 26,598 solar watts

If, 300-watt solar panels are to be used:
26,598 watts / 300 watts = 88.66 (89) solar panels

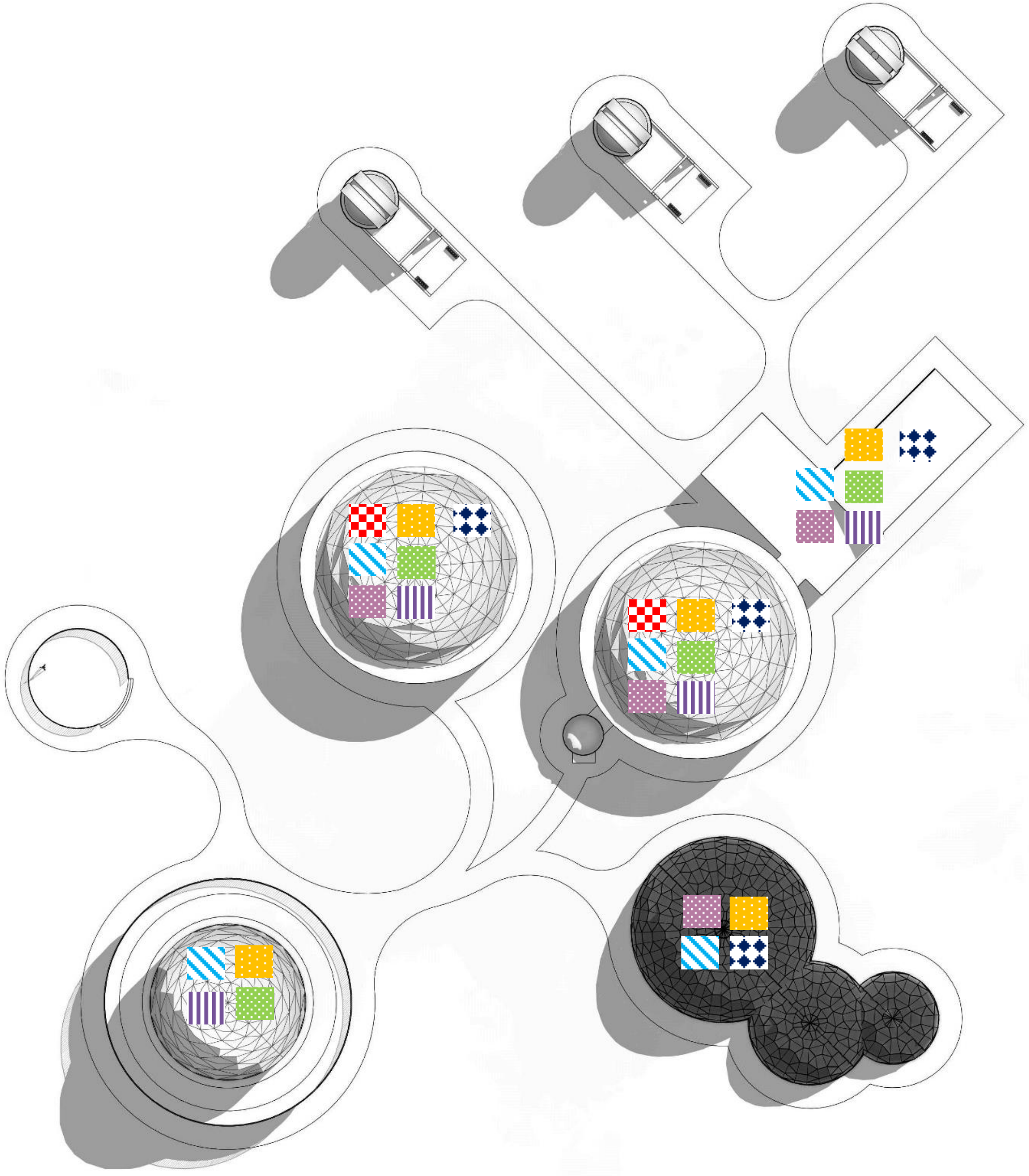
However, all solar systems have losses of about 23%, taking this into account, multiply by 1.4:
26,598 watts x 1.4 = 37,237 watts

Using 300 watts solar panels, it would be:
37,237 watts / 300 watts = 124.12 (125) solar panels



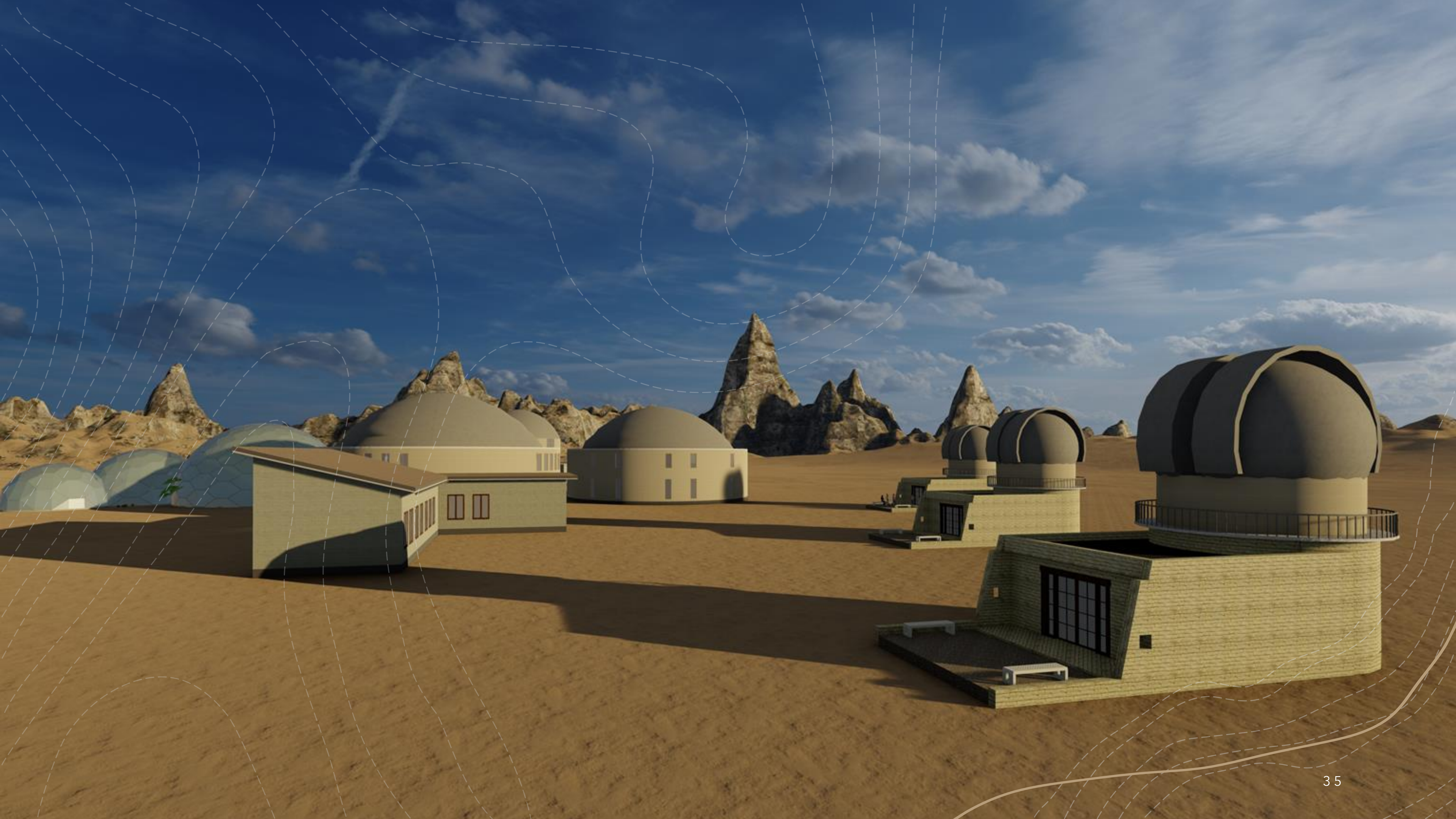
1 kWh solar rooftop generates 4.29 unit of electricity per day (considering 5.1 sunshine hours)

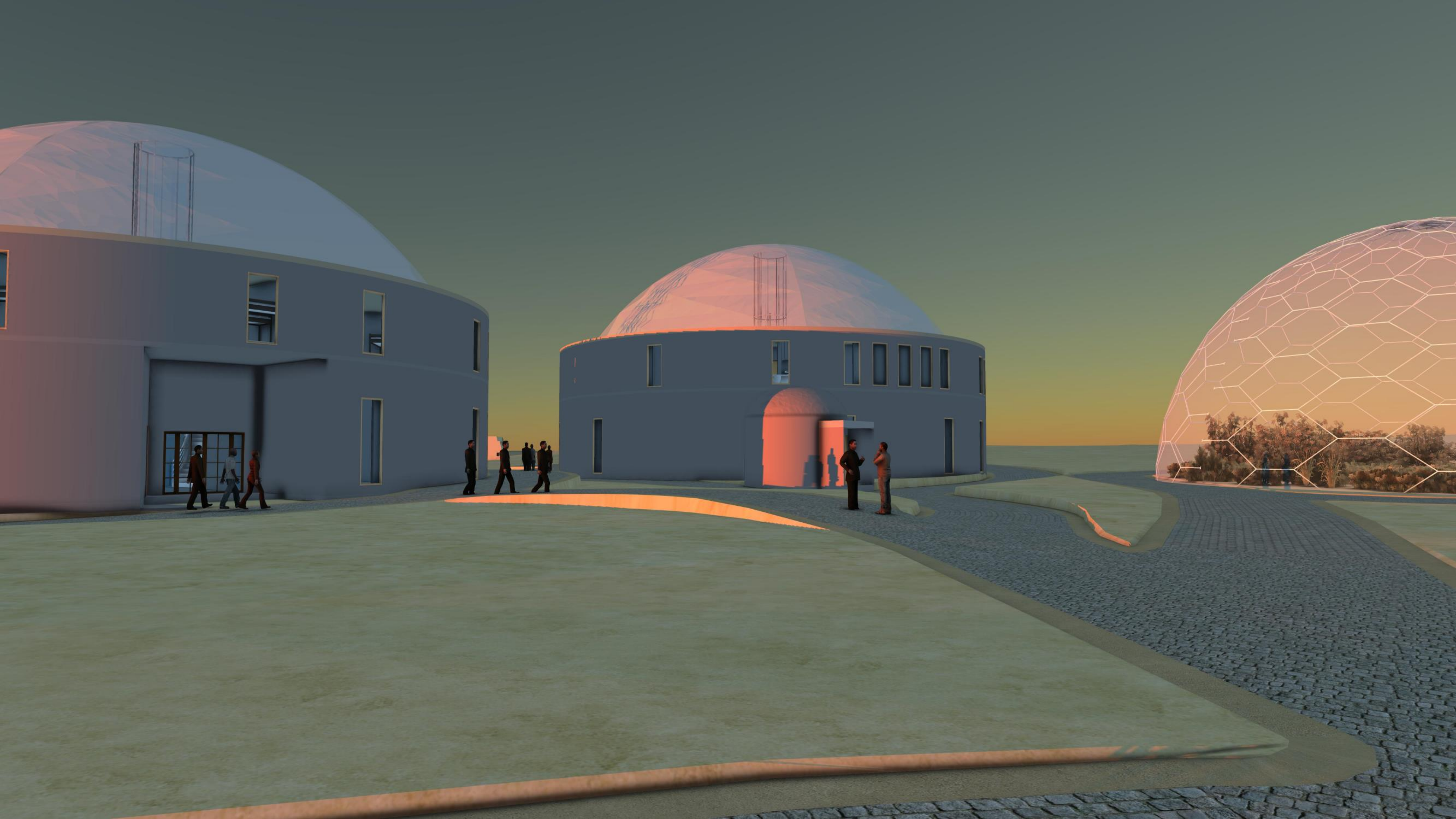
Schematic Layout – System Distribution

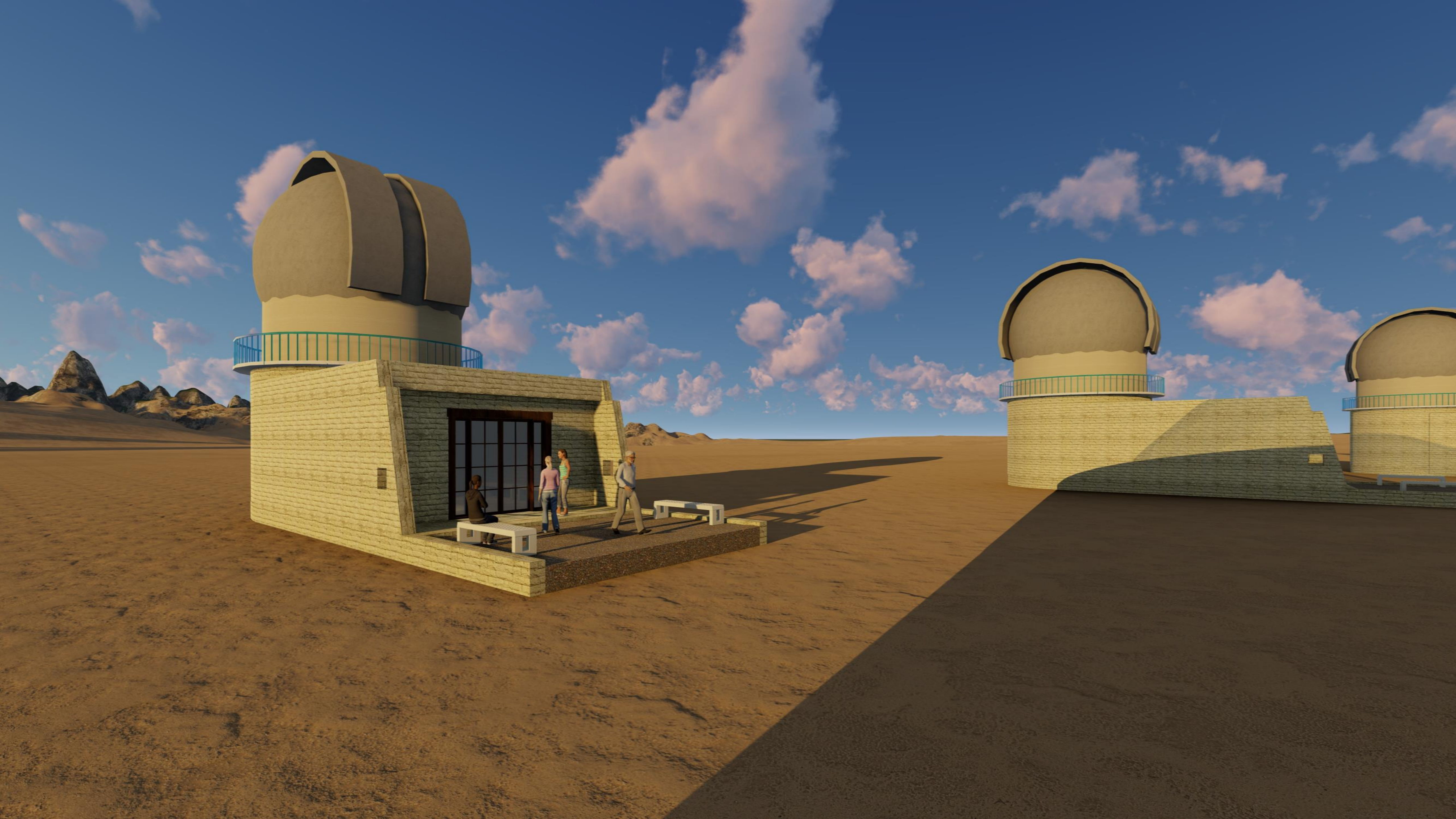


- EVA Prep Room
- Temperature Control
- Water Source & Processing
- Communication Array
- Hygiene
- Contamination Control
- HVAC

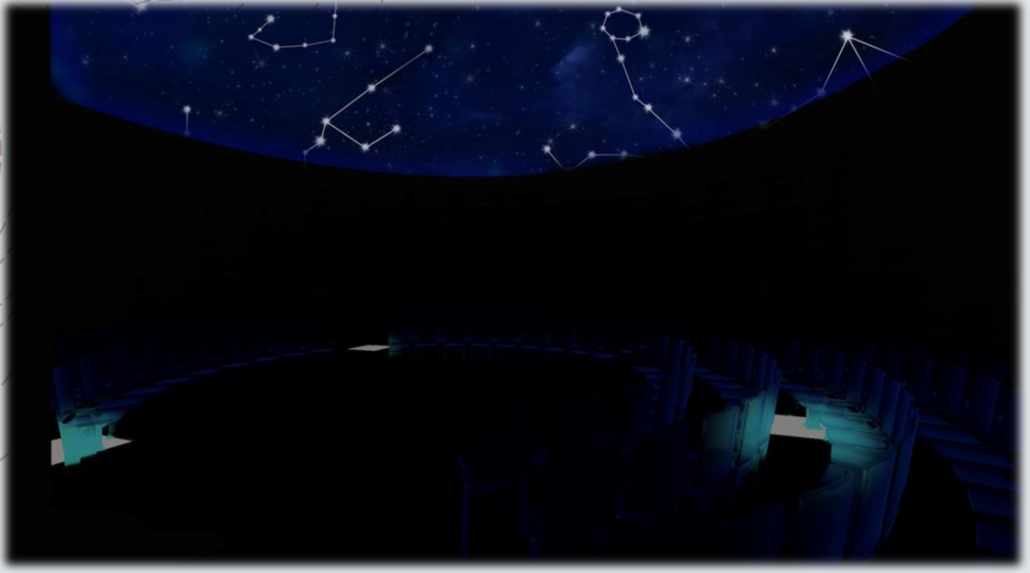
Analog Mission Research Station





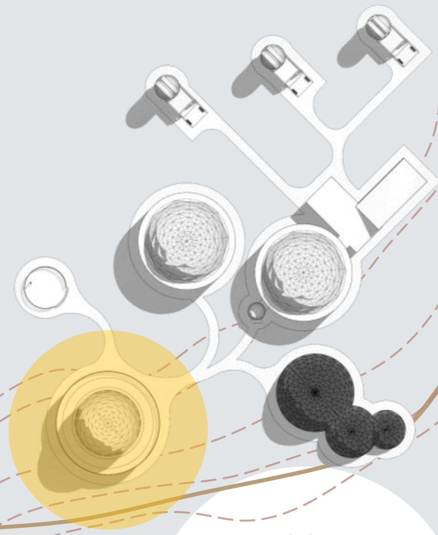


Visitor's Centre



Key Features:

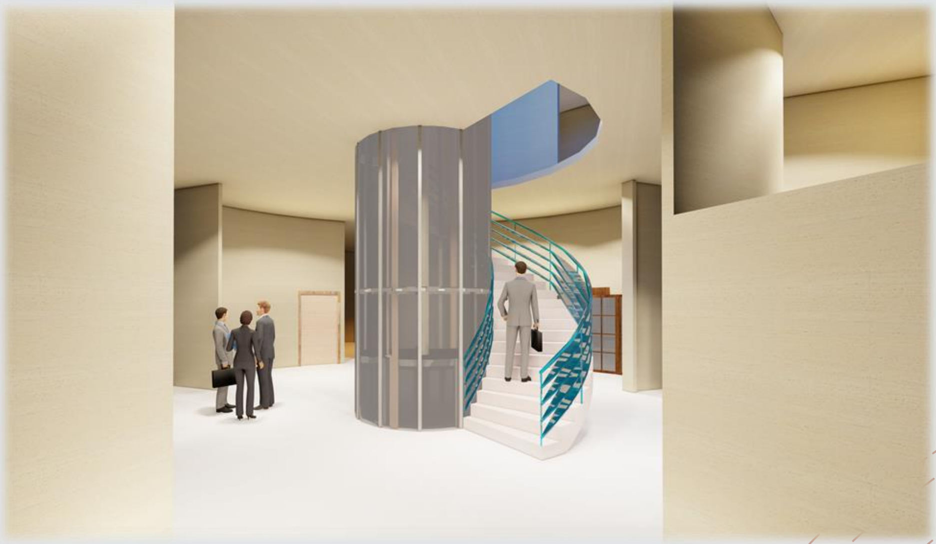
1. Planetarium
2. Curiosity & Space Exploration

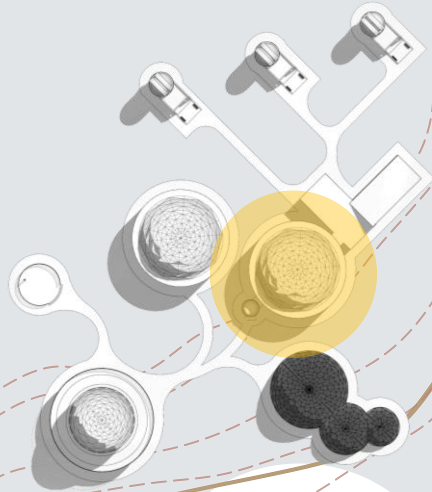


Crew Quarters & Common Areas

Key Features:

1. Common area – Open Library
2. Private Crew Individual Research Labs & Workstation





Crew Quarters & Common Areas

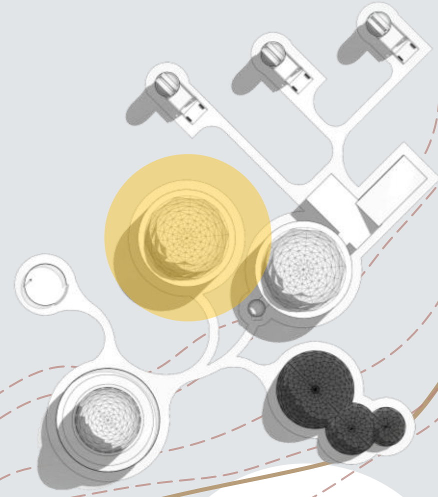
Key Features:

1. Common Areas – Kitchen, Gym
2. Private Crew Quarters & Personal Activity Space

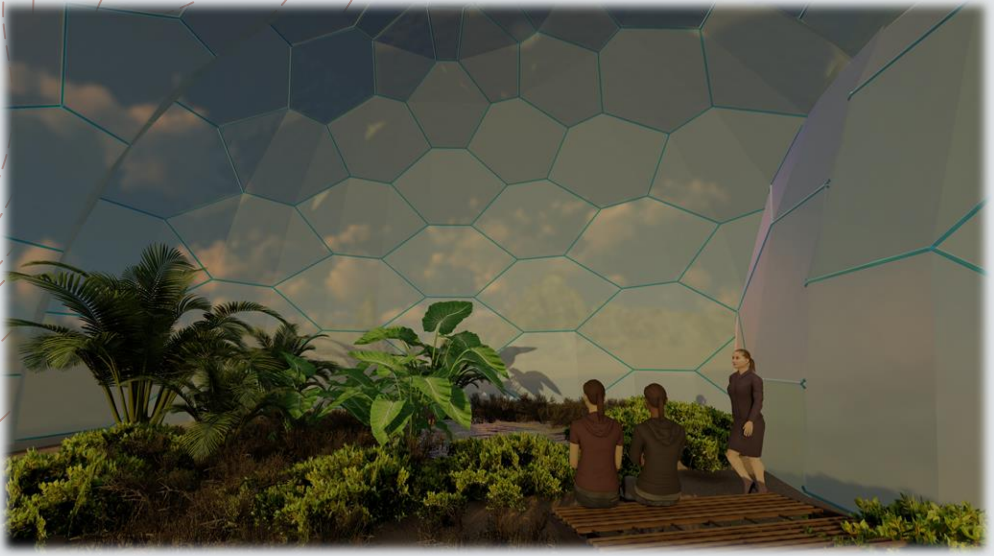
Workshops & Dormitory

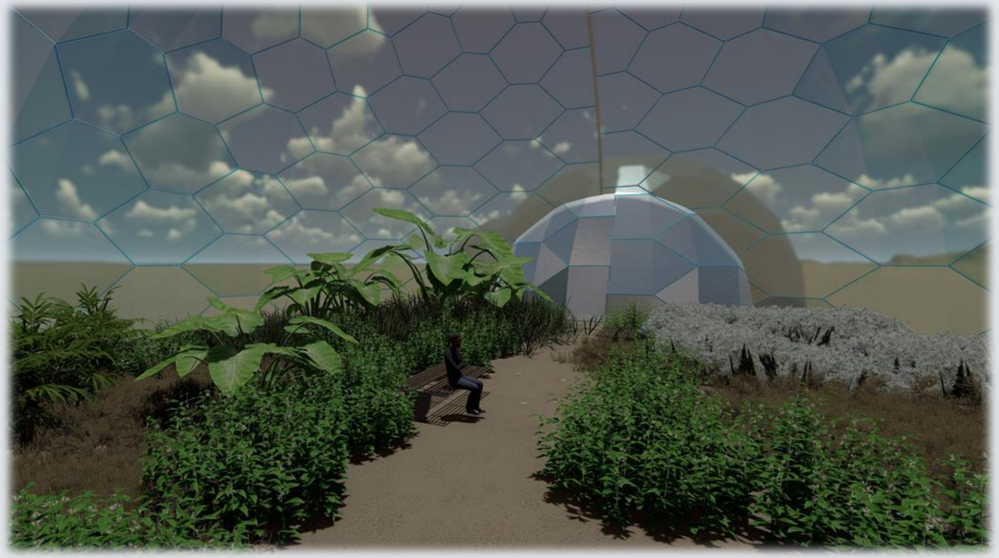
Key Features:

1. Workshop spaces for students
2. Dormitory



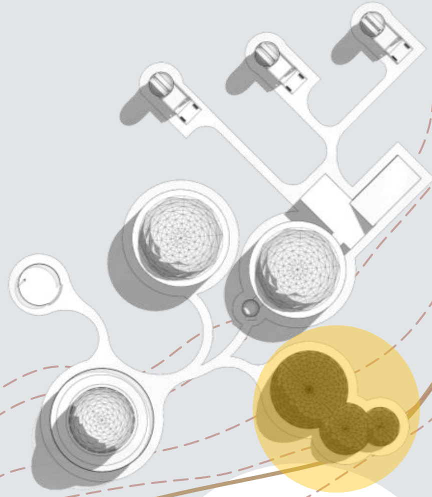
Greenhouse



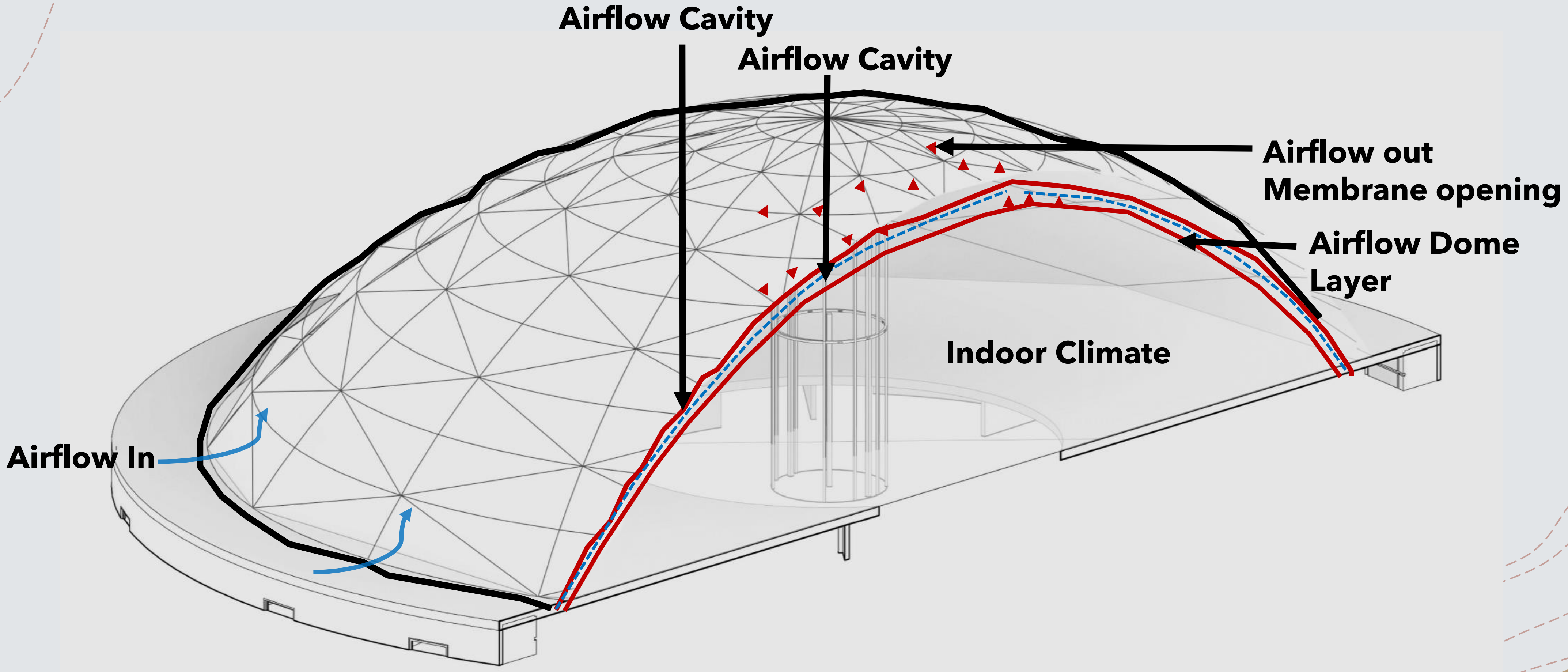


Key Features:

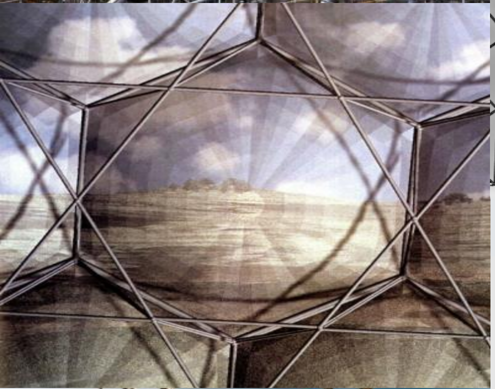
1. Psychologically helpful
2. Plant research

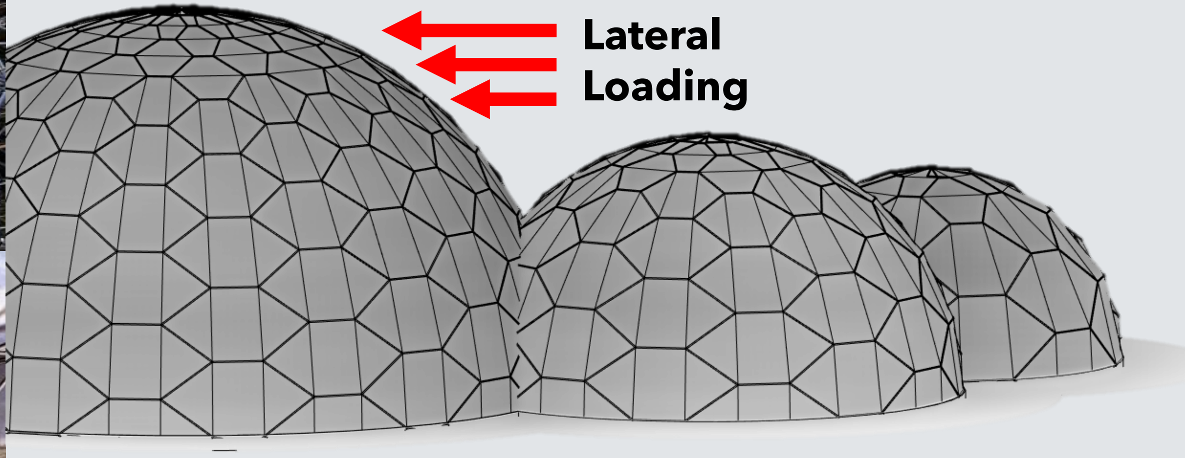


Functional Diagram for Inflatable Domes

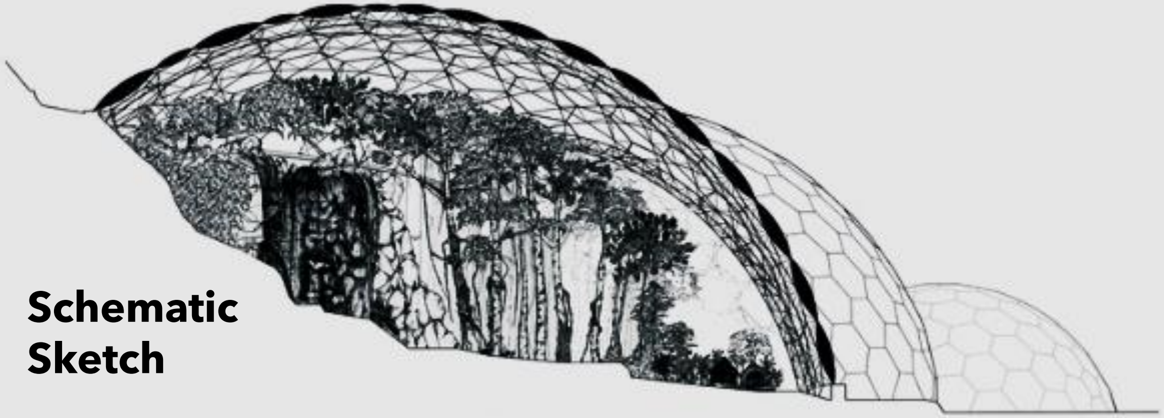


Structural Components – Greenhouse

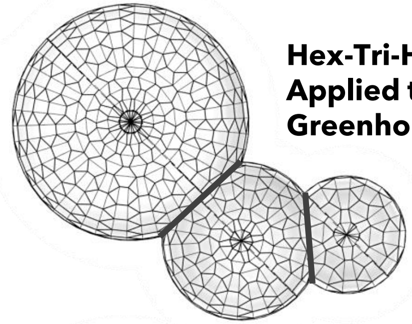




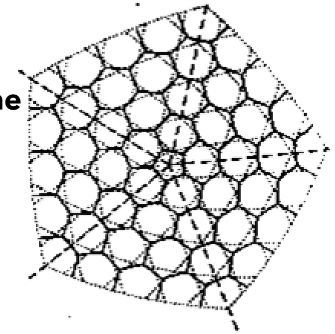
Lateral
Loading

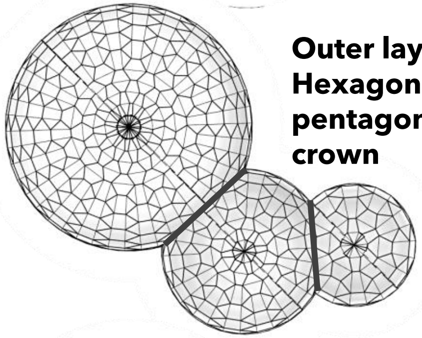


Schematic
Sketch

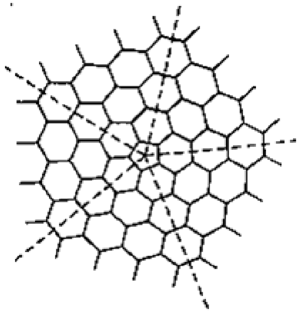


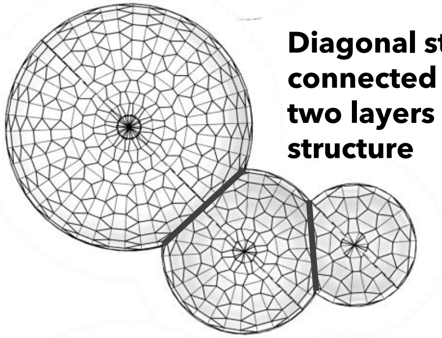
Hex-Tri-Hex
Applied to the
Greenhouse



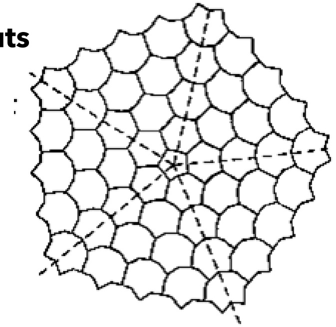


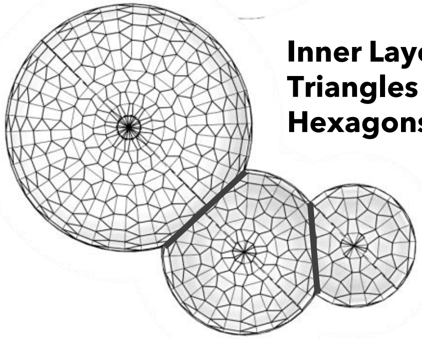
Outer layer of
Hexagon with
pentagon at
crown



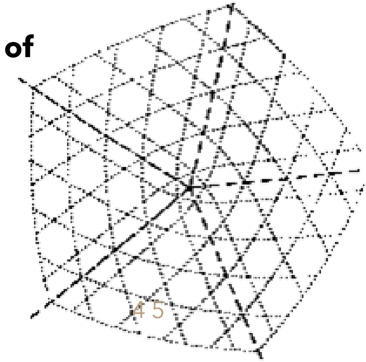


Diagonal struts
connected to
two layers of
structure

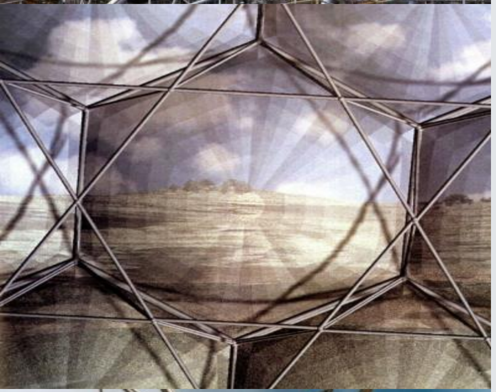


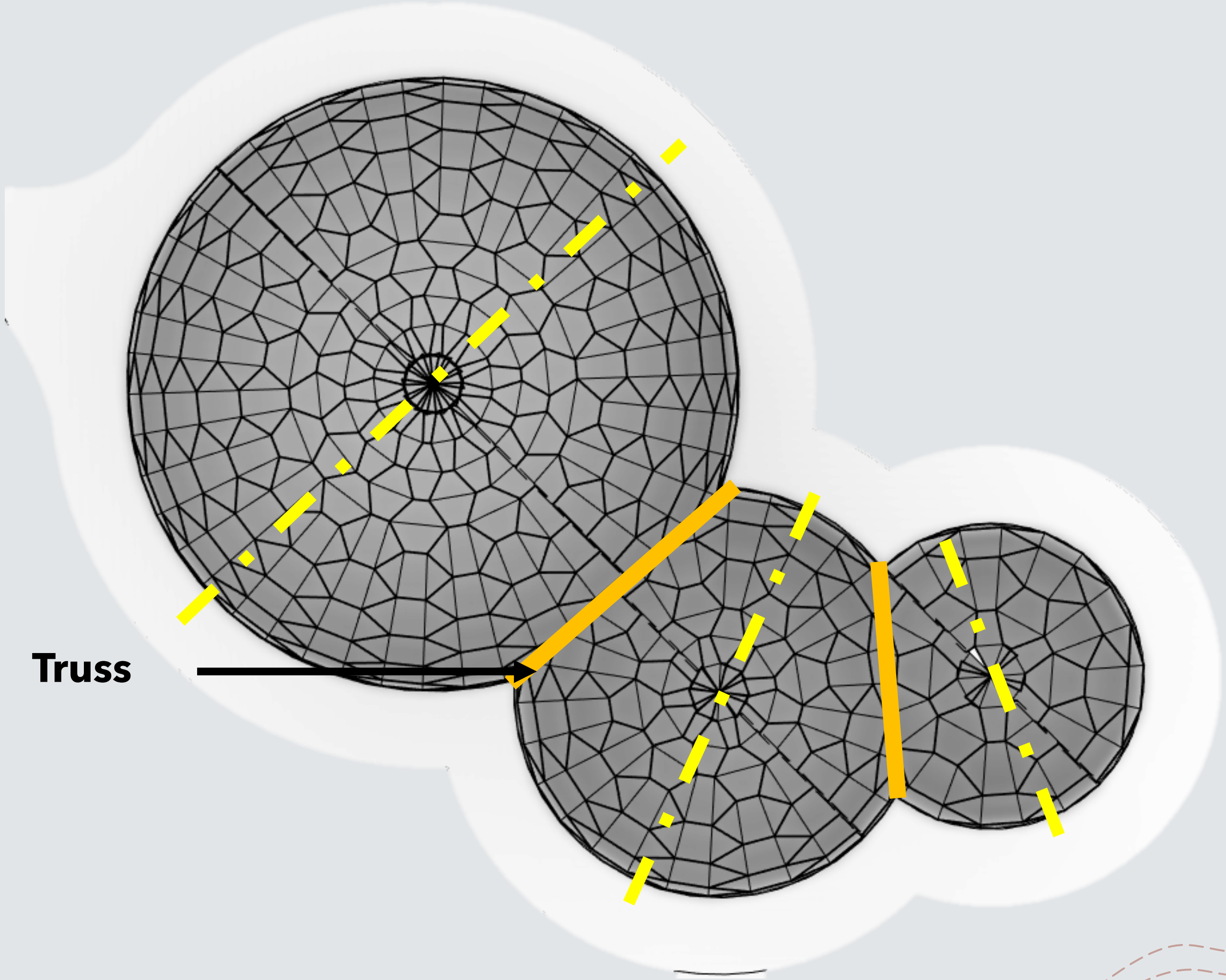


Inner Layer of
Triangles &
Hexagons

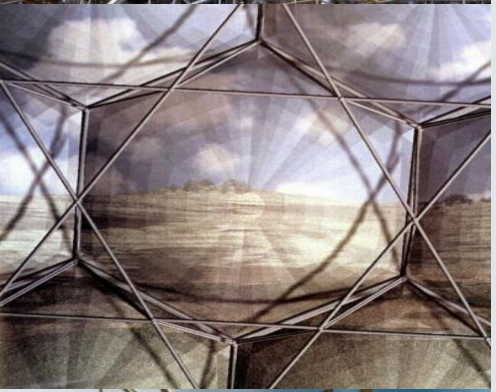


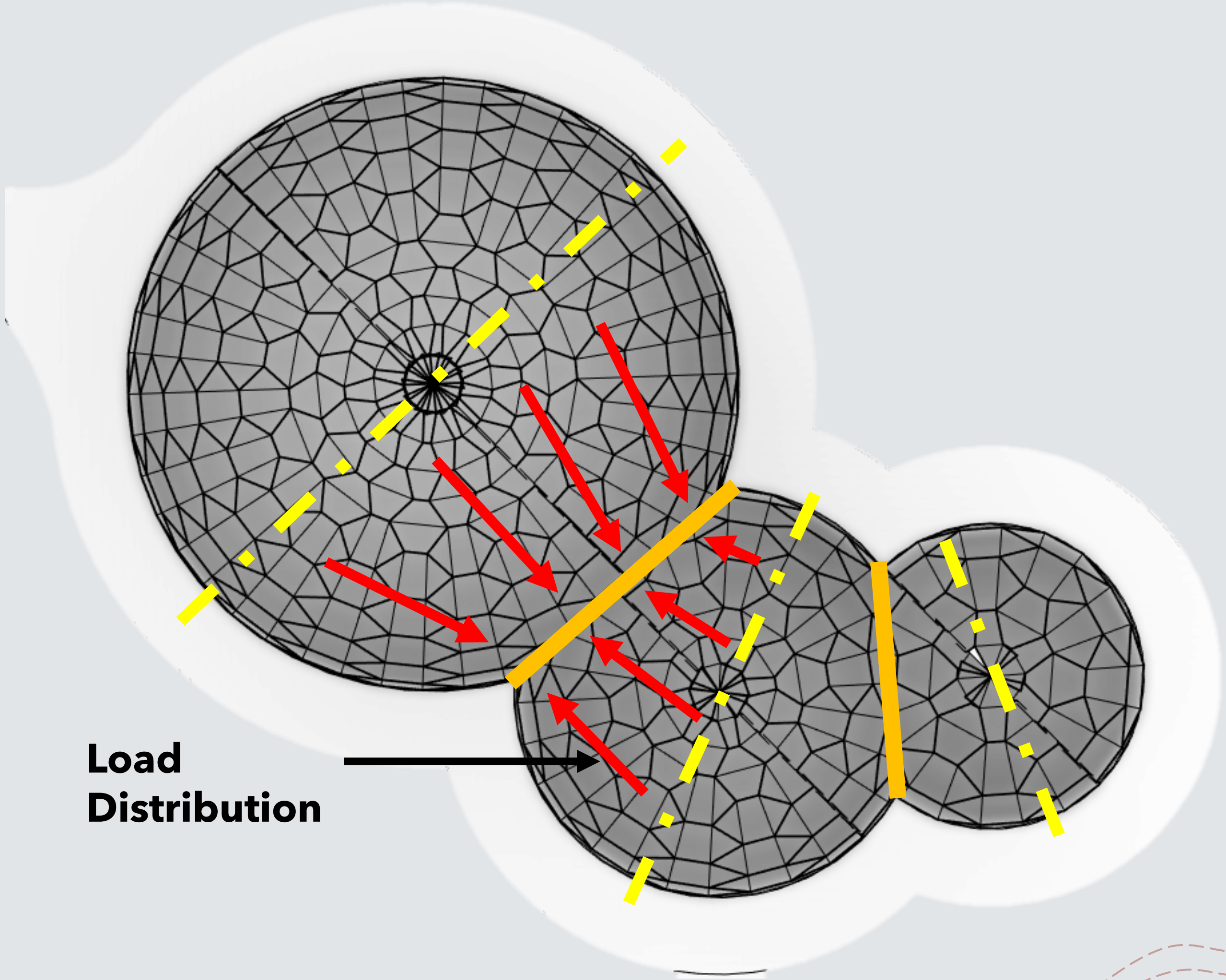
Structural Components





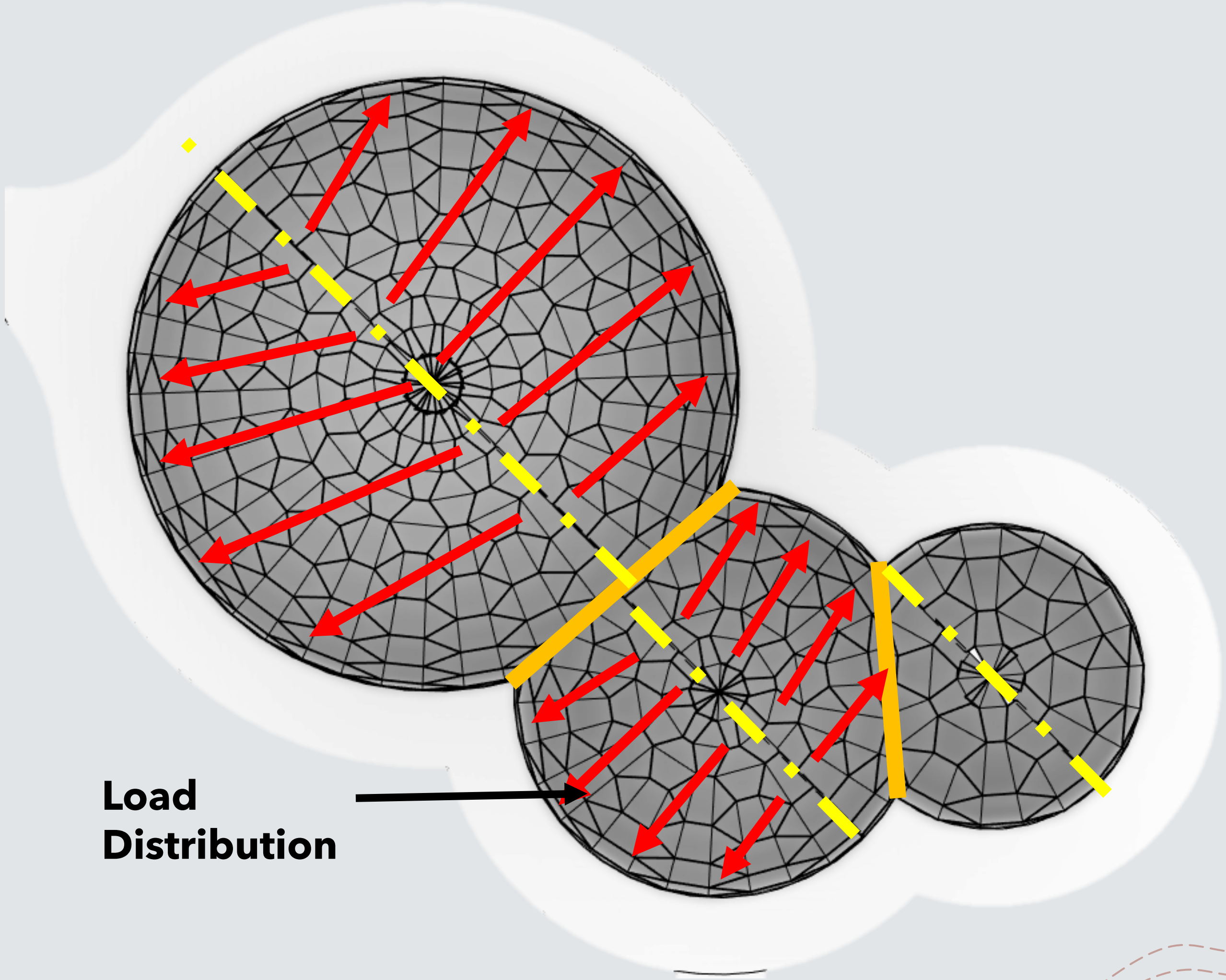
Structural Components



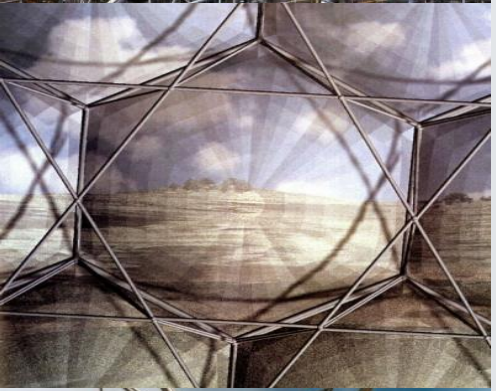


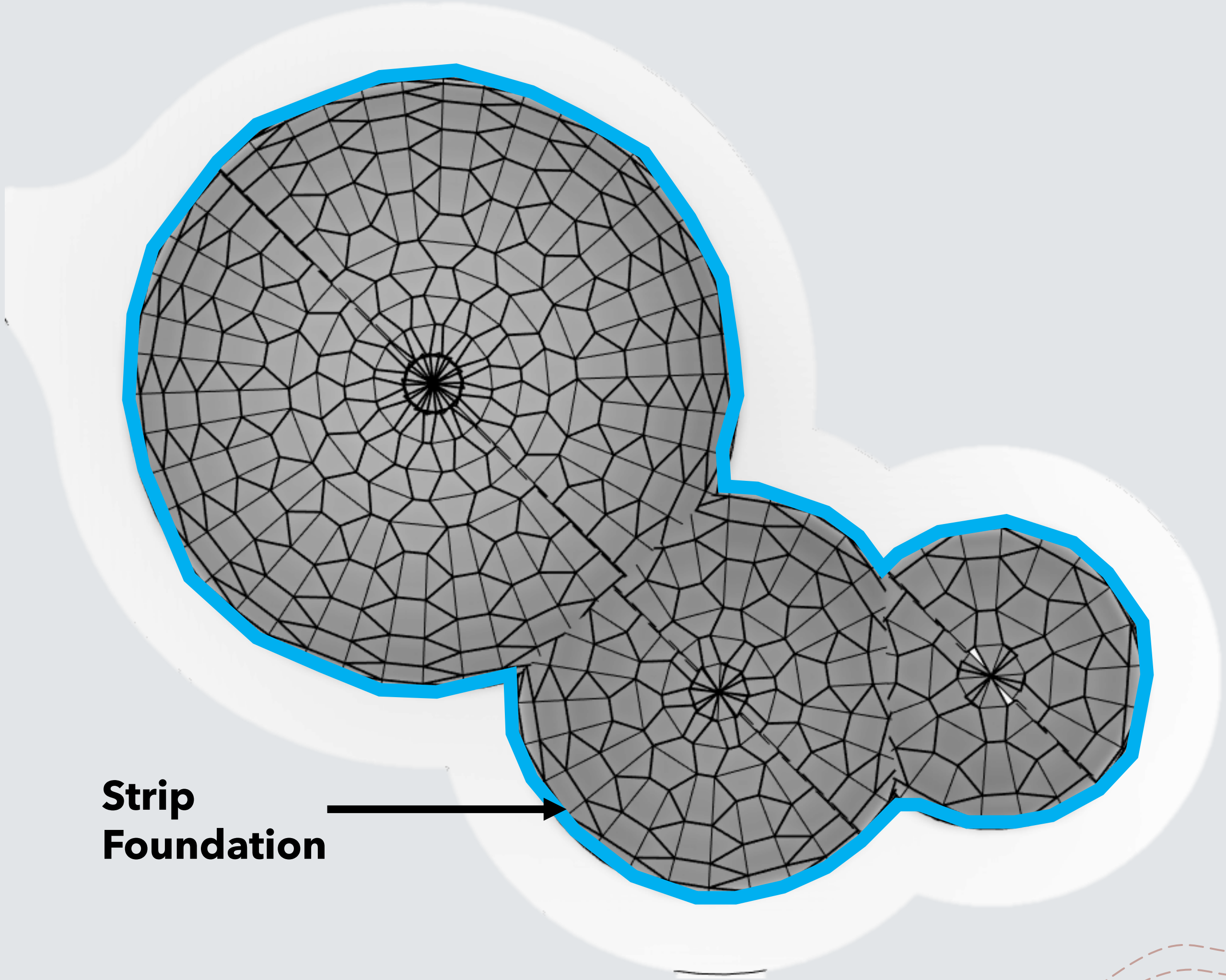
Load Distribution

Structural Components

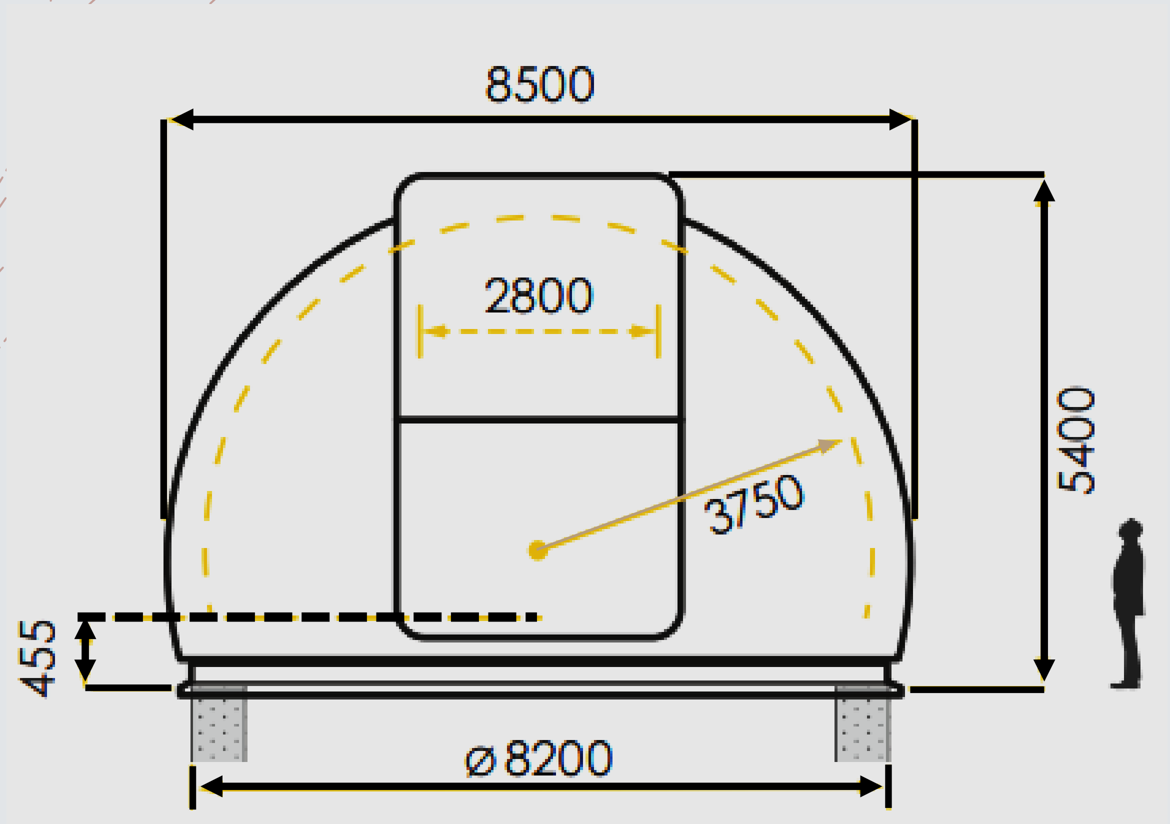


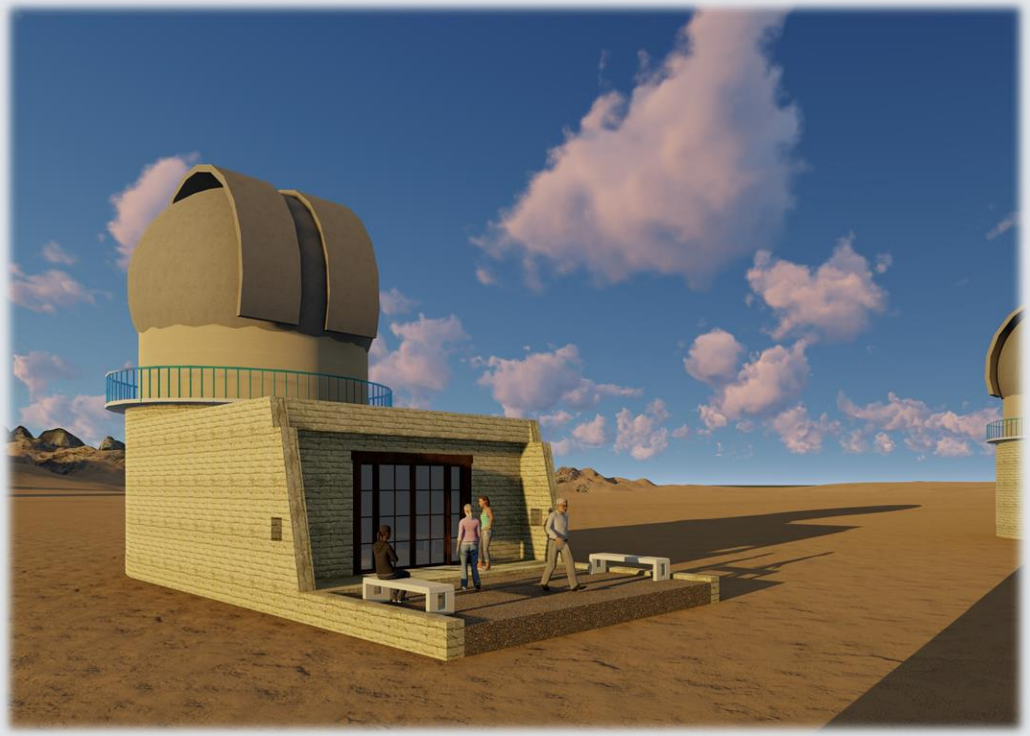
Structural Components





Observatory Dome





Use of Advanced Slit Domes

https://drive.google.com/file/d/1HMfjFU4tbJE0x6ylGhM0vV9WCHyV34Cc/view?usp=sharing

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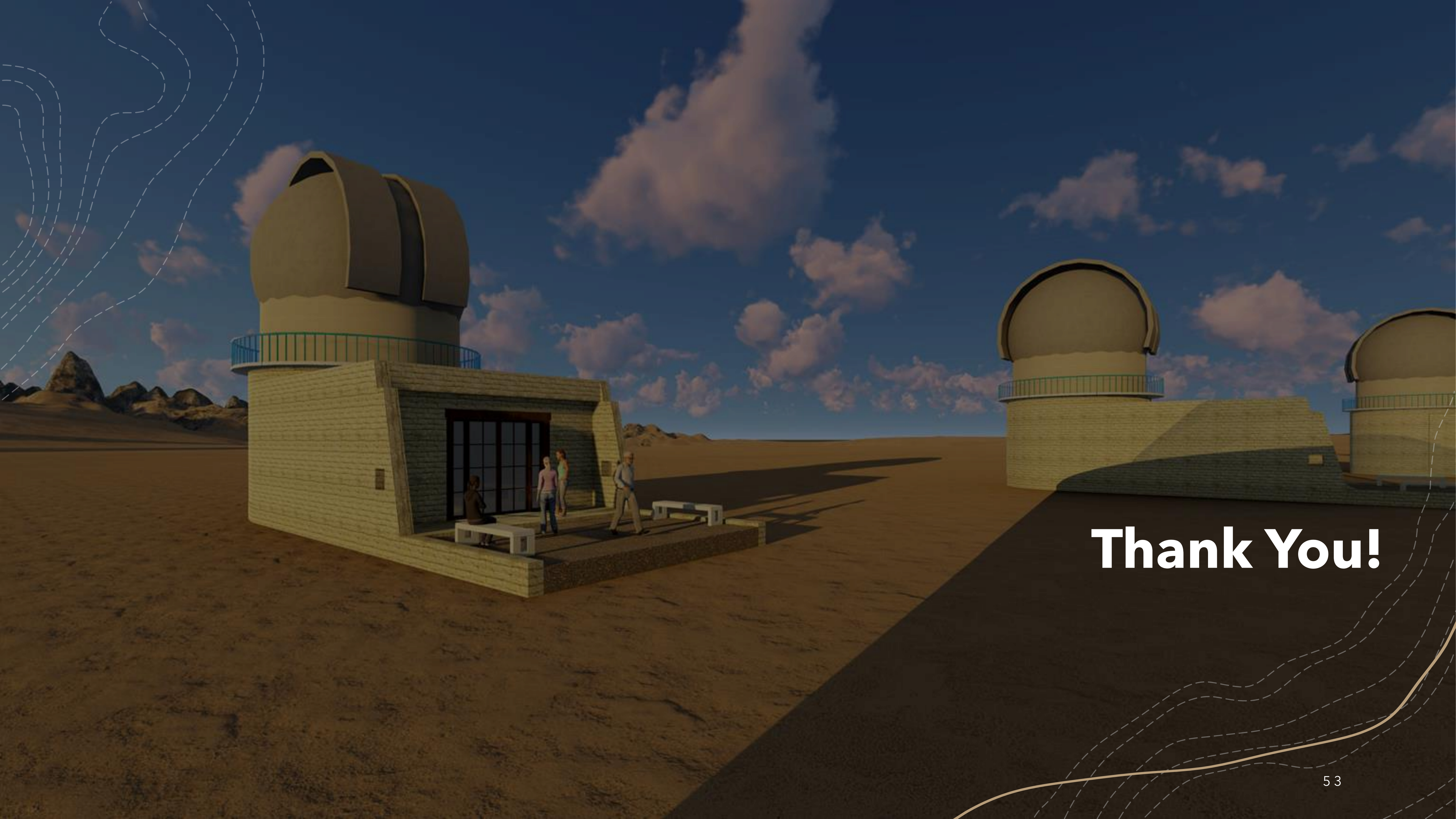

Thank You!