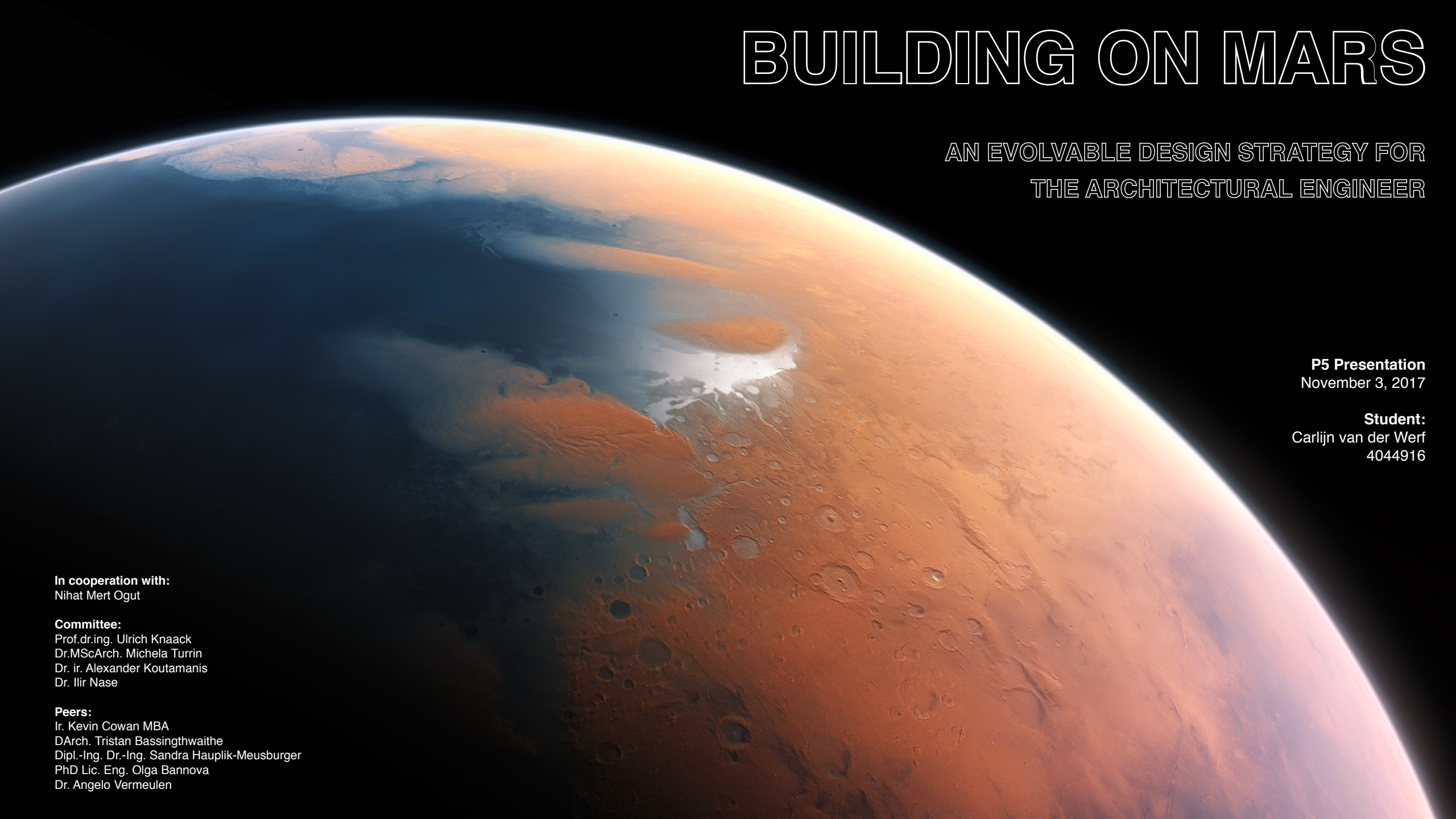
BUILDING ON MARS

AN EVOLVABLE DESIGN STRATEGY FOR THE ARCHITECTURAL ENGINEER



P5 Presentation
November 3, 2017

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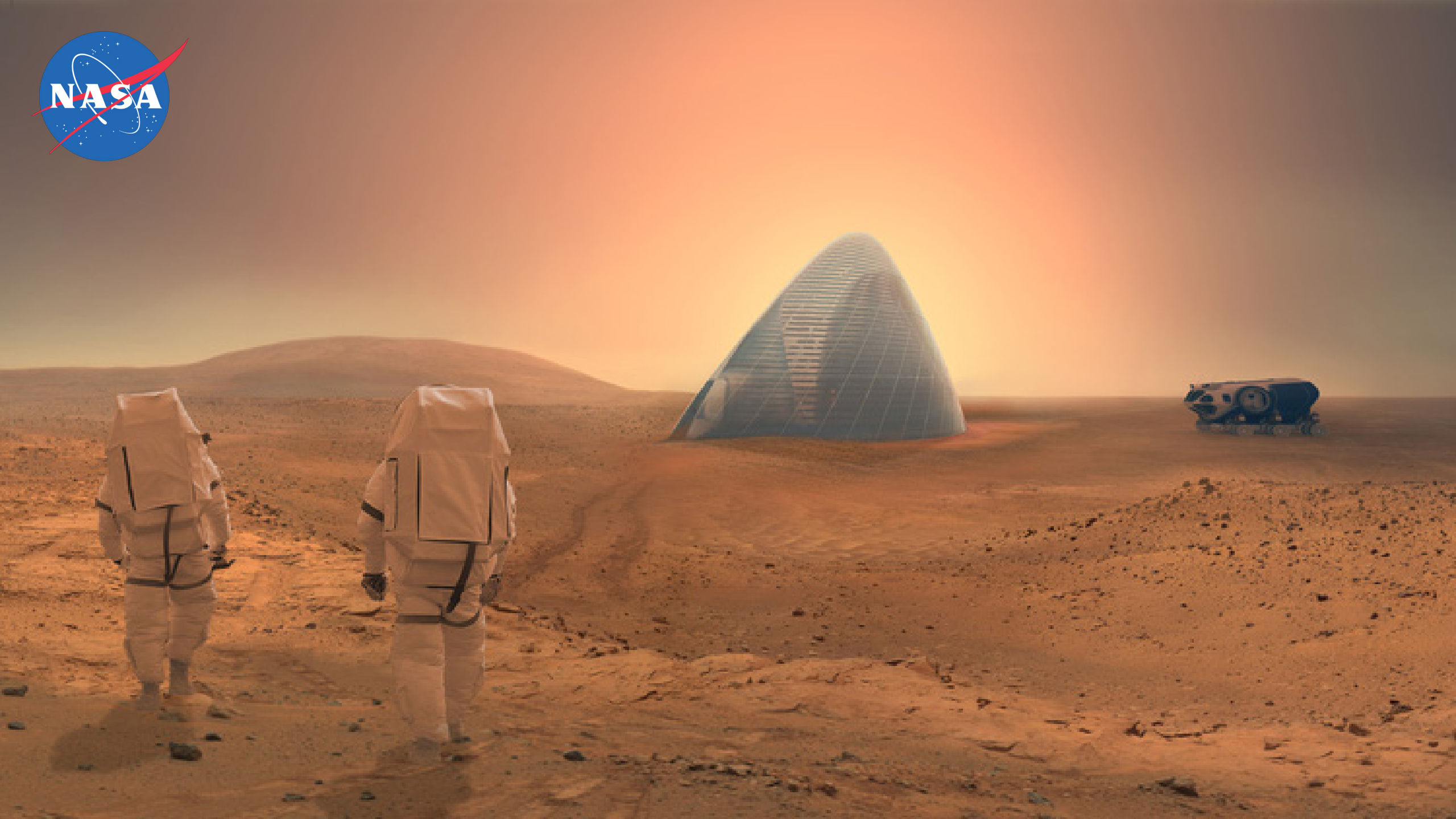
Dr. Angelo Vermeulen

MAHLI image mosaic from April 27, 2014 (Sol 613)
Credit: NASA/JPL-Caltech/MSSS
Edited by Jason Major


NASA

STRUCTURE

1. INTRODUCTION

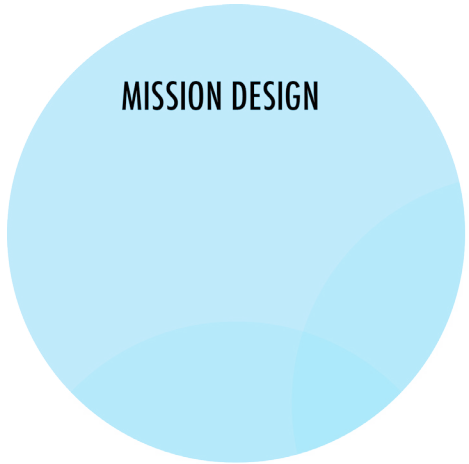
2. PLANET MARS

STRUCTURE

1. INTRODUCTION

2. PLANET MARS

3. MISSION DESIGN



STRUCTURE

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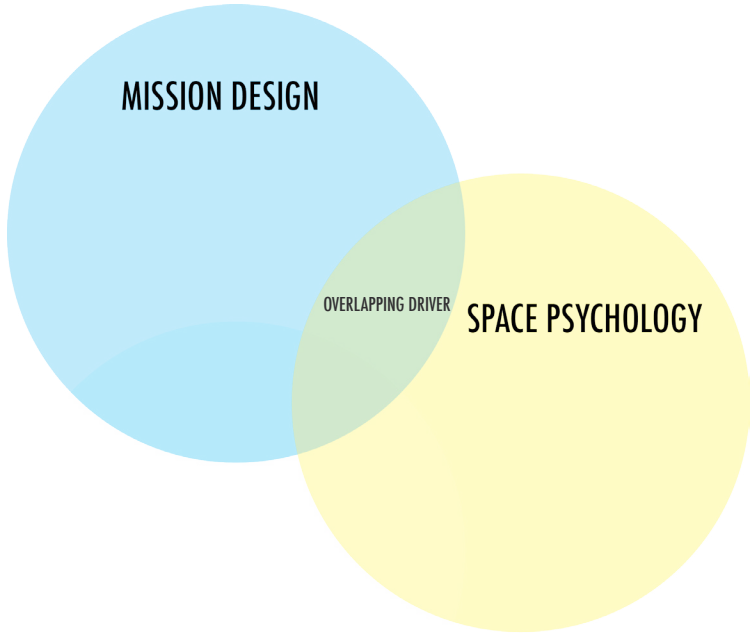
3. MISSION DESIGN

4. SPACE PSYCHOLOGY



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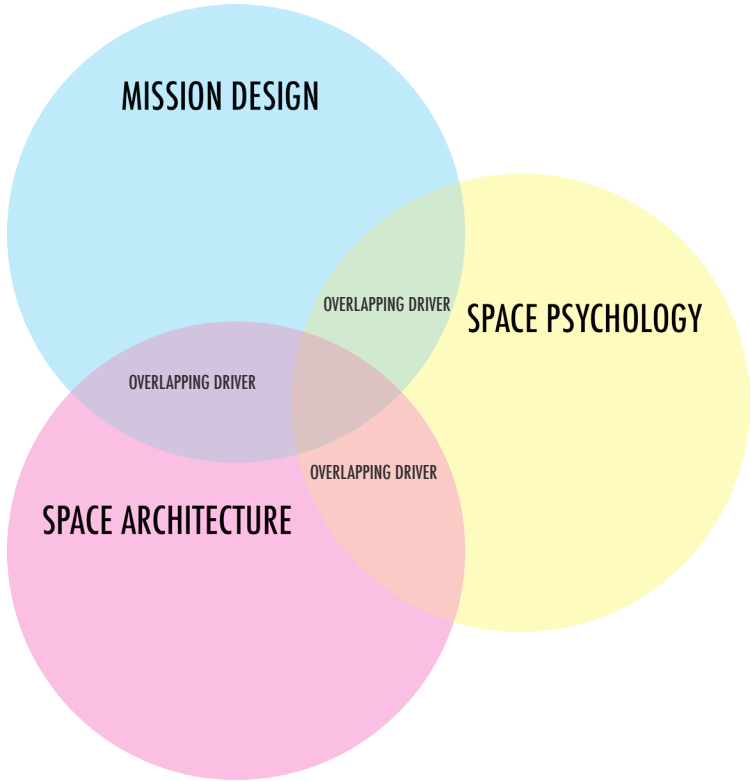

STRUCTURE

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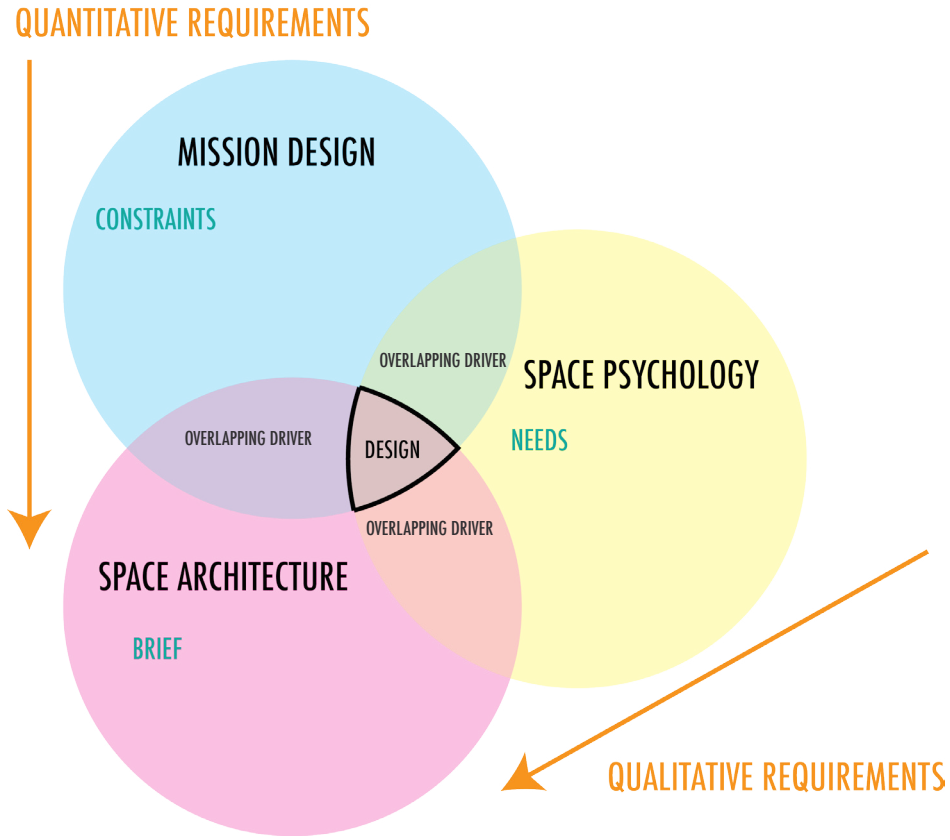
5. SPACE ARCHITECTURE
6. **DESIGN**



STRUCTURE

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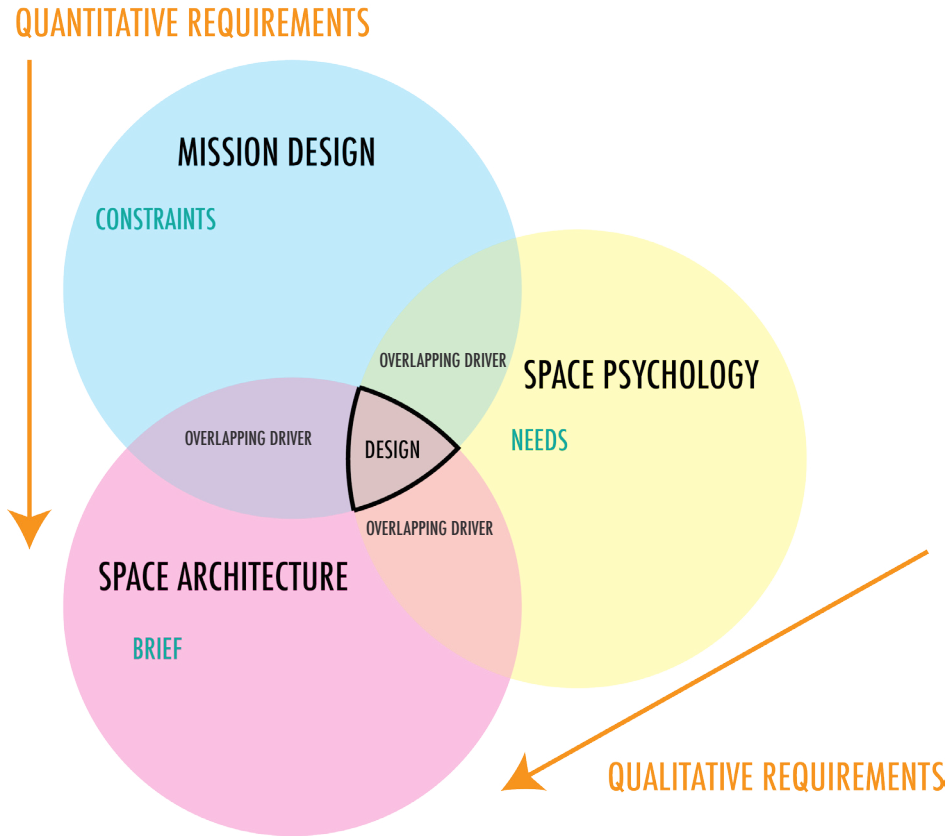
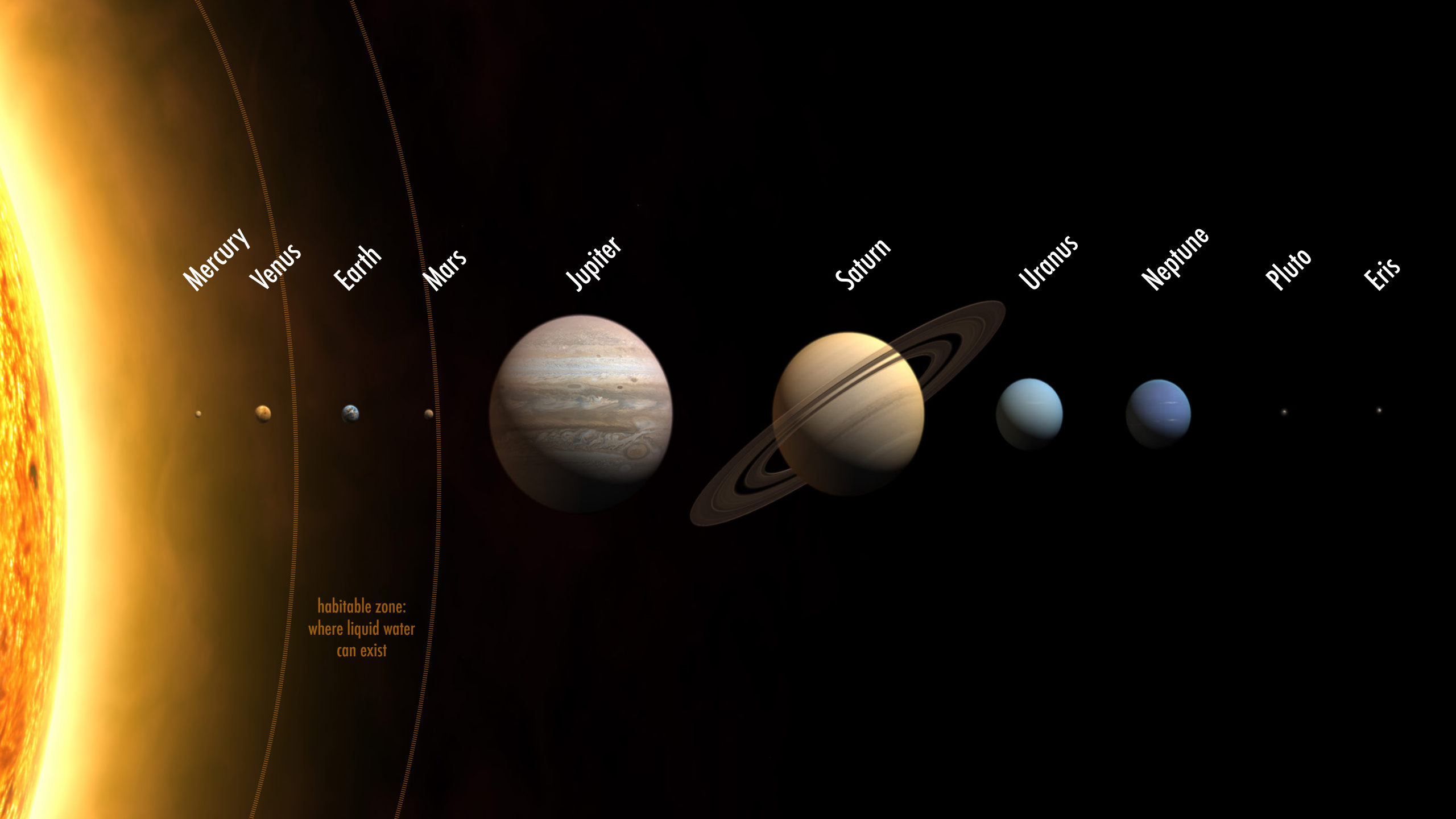
5. SPACE ARCHITECTURE
6. DESIGN
7. CONCLUSION

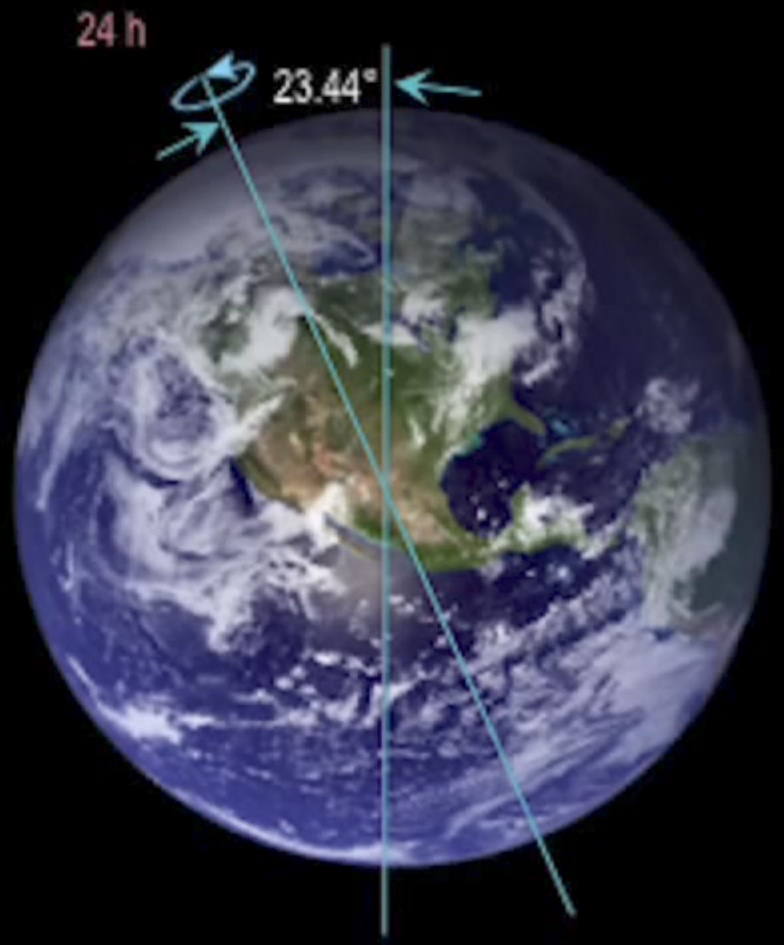


02

PLANET MARS


Mercury
Venus
Earth
Mars
Jupiter
Saturn
Uranus
Neptune
Pluto
Eris
habitable zone:
where liquid water
can exist

EARTH



COMPARISON

YEAR

365 Days

686 Days
(667 Sols)

GRAVITY

38% of earth

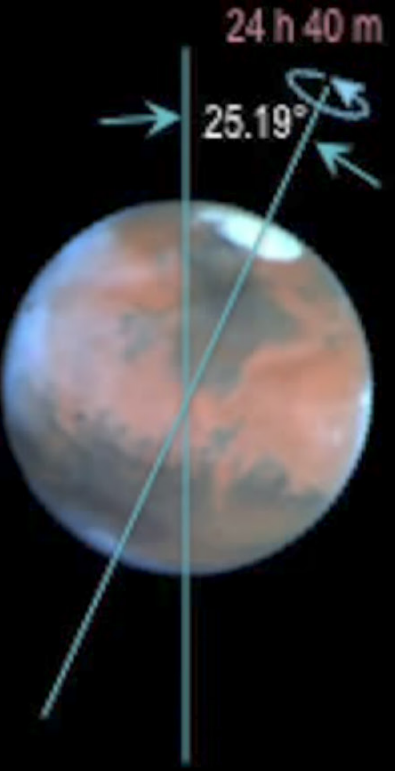
SUNLIGHT

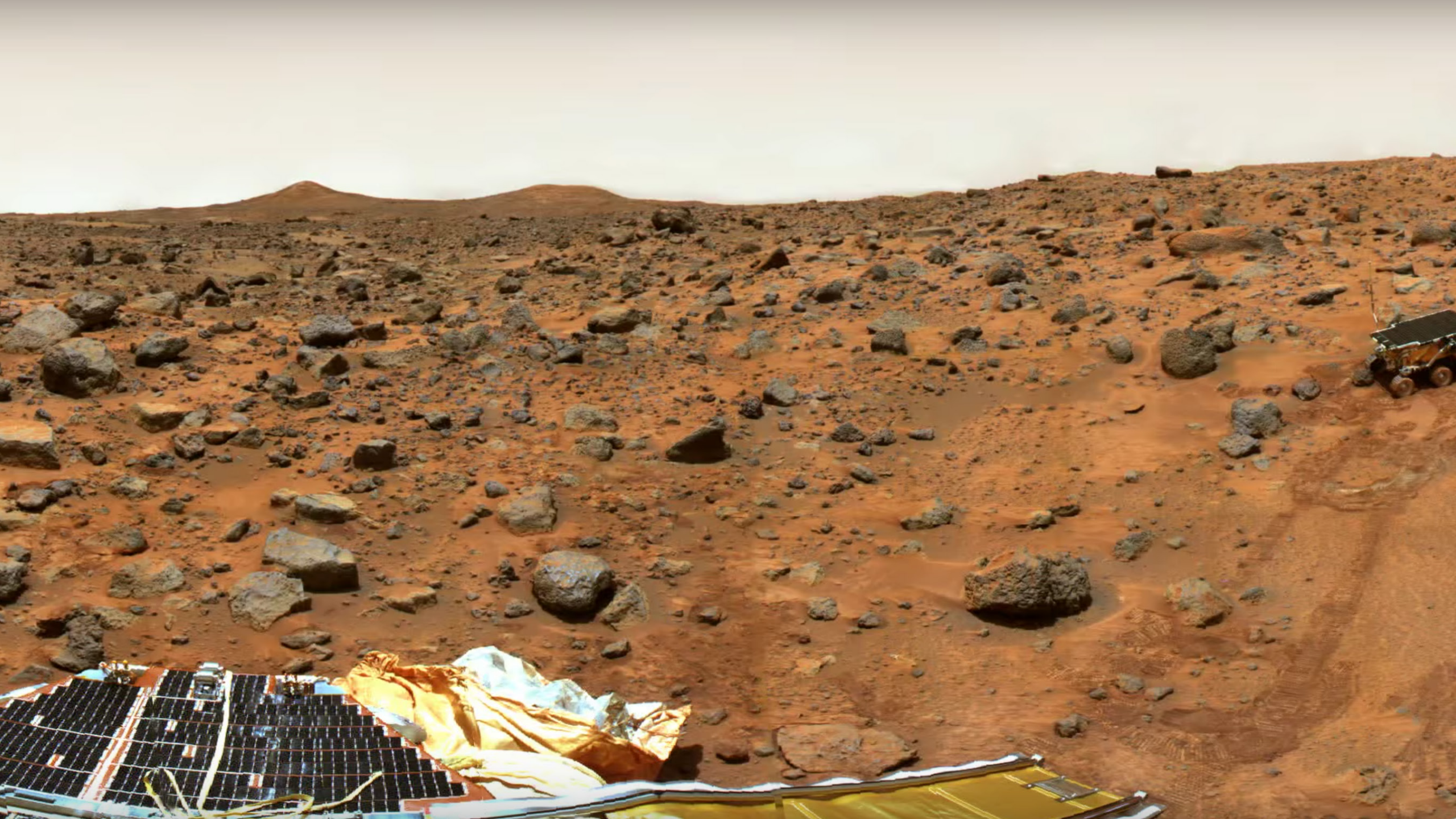
44% of earth

ATMOSPHERE

1013 mb	Total	7.6 mb
0.00035	CO_2	0.95
0.781	N_2	0.027
0.210	O_2	0.0013
0 to 0.04	H_2O	0 to 0.00021
0.0093	Ar	0.016

MARS

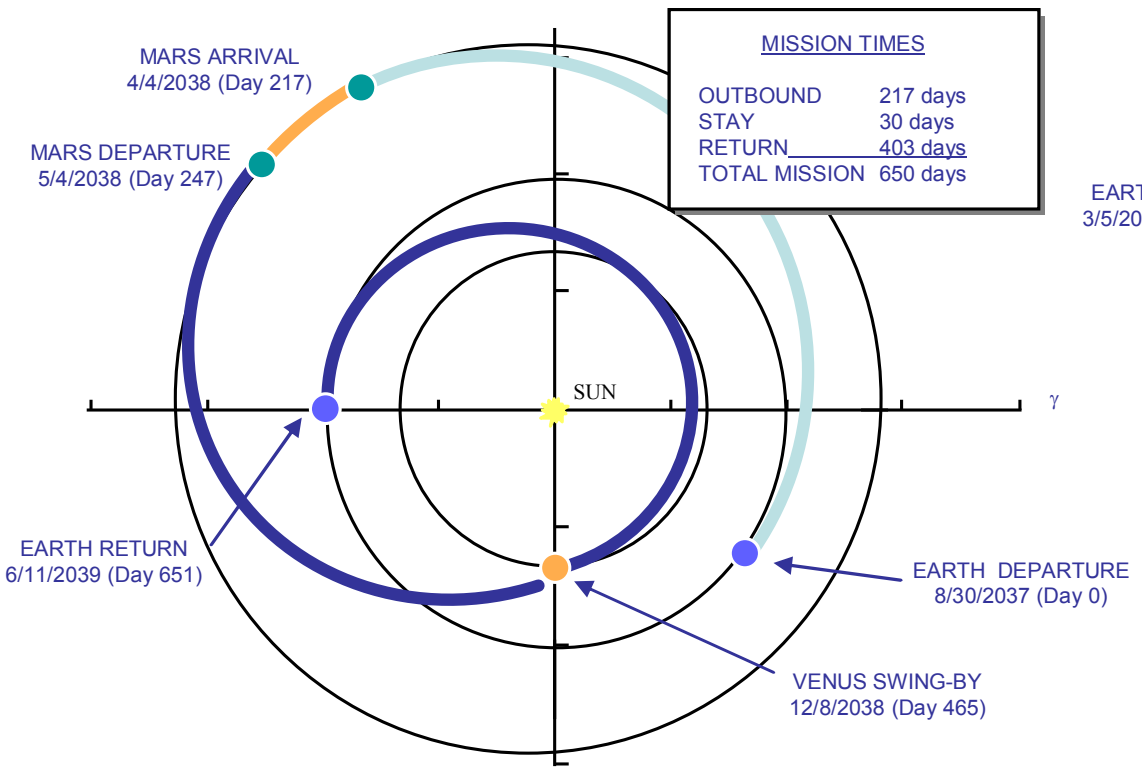




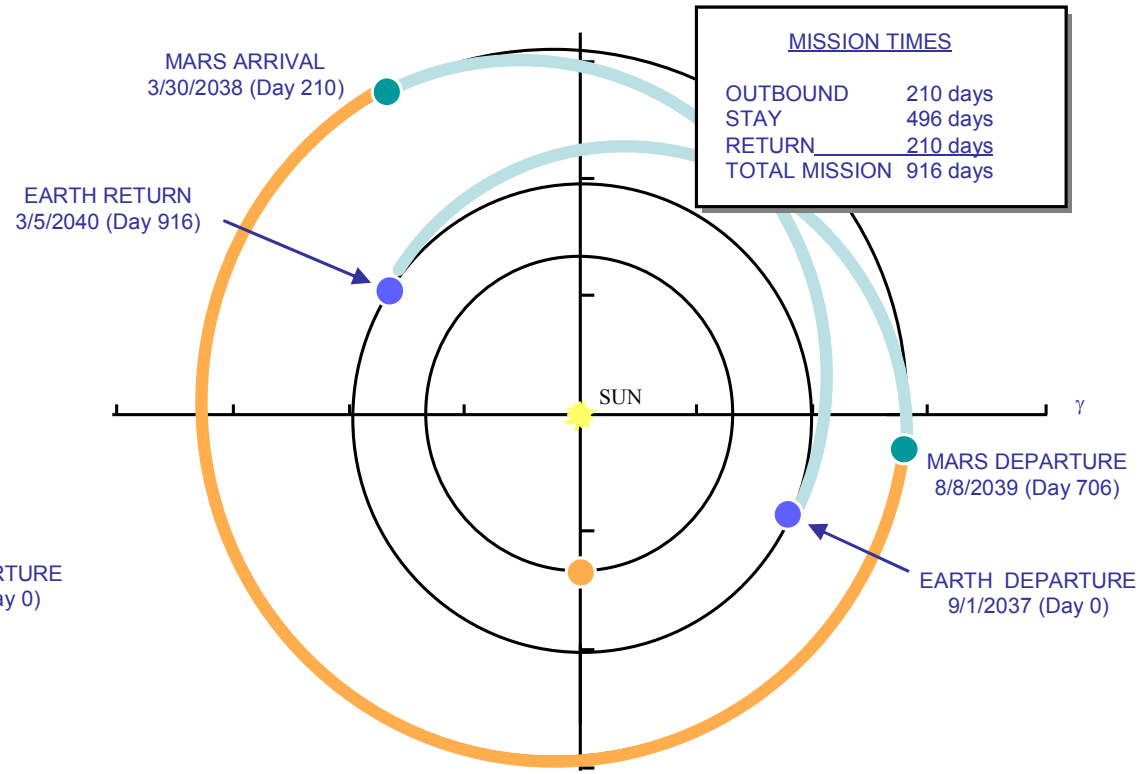
03

MISSION DESIGN

TRAJECTORY

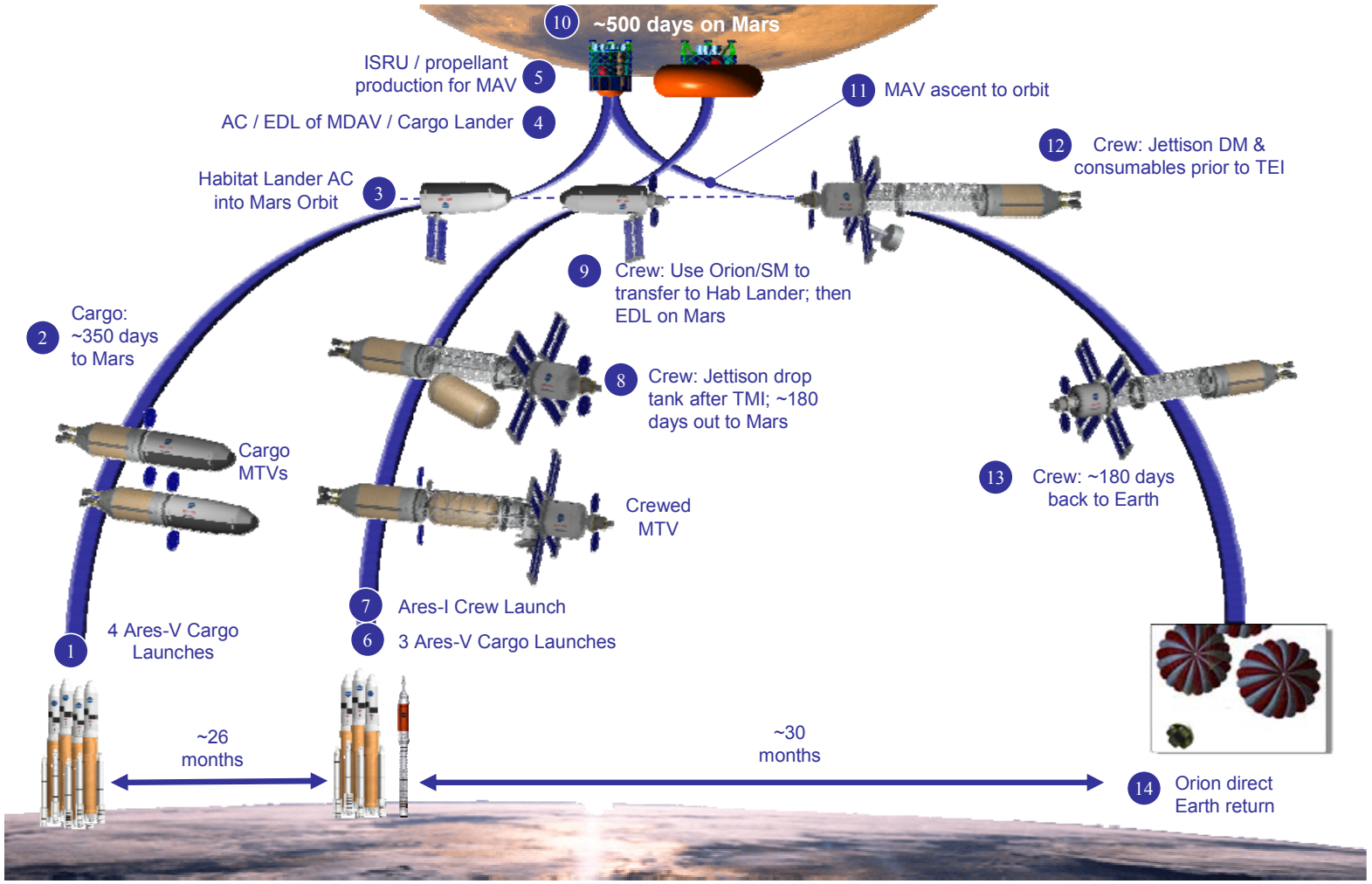


a) Opposition Class: Short-Stay Mission

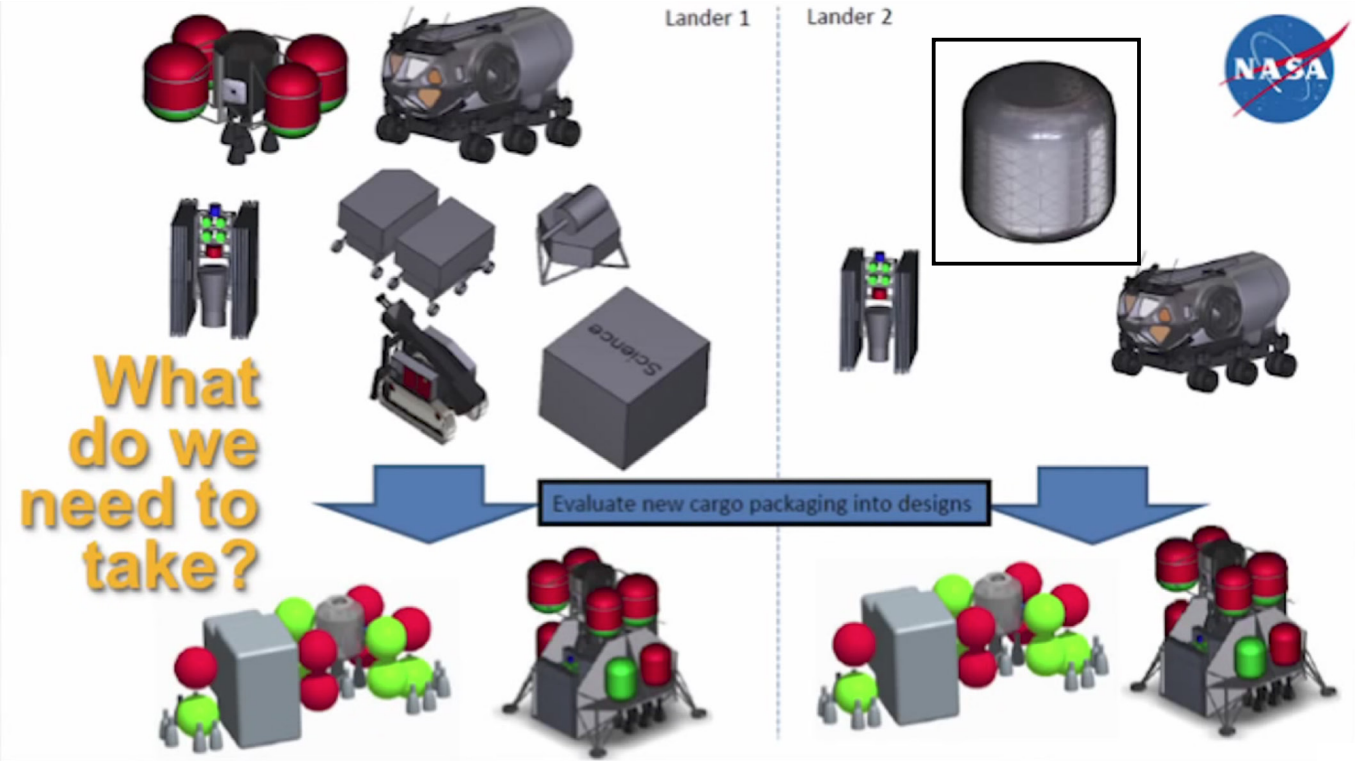


b) Conjunction Class: Long-Stay Mission

MISSION ARCHITECTURE : DRA 5.0



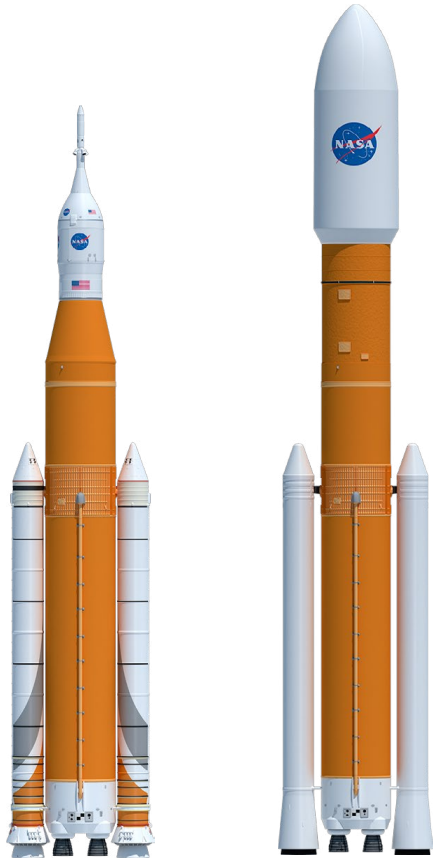
MISSION SYSTEM ELEMENTS: 20 mt for habitat



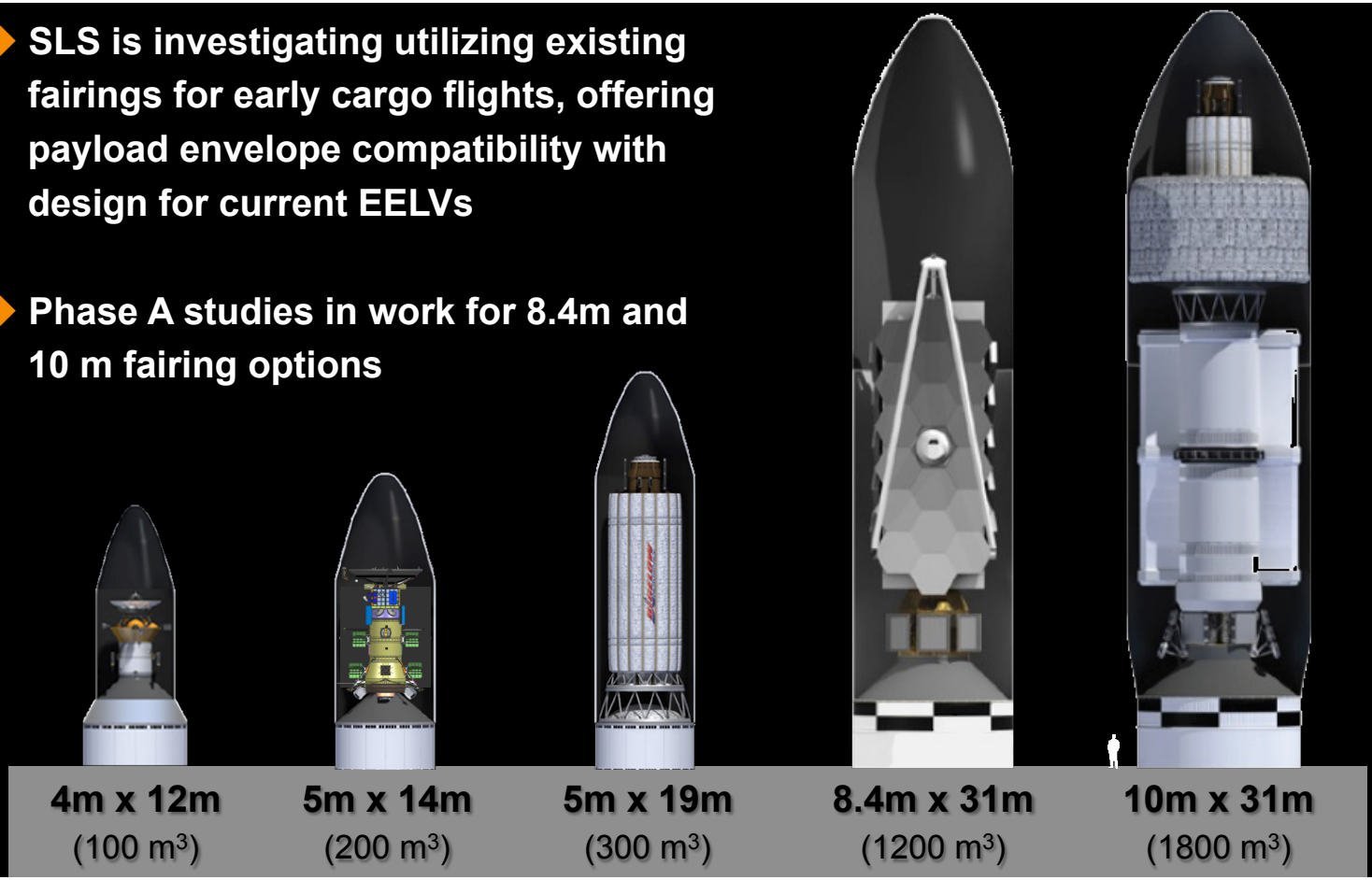
Surface Systems	Quantity	Habitat Lander System Mass (kg)	DAV Lander System Mass (kg)
Crew Consumables	-	1,500	4,500
Science	-	-	1,000
Robotic Rovers	2	-	500
Drill	1	-	1,000
Unpressurzed Rover	2	-	500
Pressurized Rover	2	8,000	-
Pressurized Rover Growth	-	1,600	-
Pressurzed Rover Power	2	-	1,000
Traverse Cache	-	-	1,000
Habitat	1	16,500	-
Habitat Growth	-	5,000	-
Stationary Power System	2	7,800	7,800
ISRU Plant	2	-	1,130
Total Surface Systems	-	**40,400**	**18,430**

Lander Systems	Quantity	Habitat Lander System Mass (kg)	DAV Lander System Mass (kg)
Ascent Stage 1 (no LOX)	1	-	12,160
Ascent Stage 2 (no LOX)	1	-	9,330
Descent Stage (wet)	2	23,760	23,760
Aeroshell	2	42,900	42,900
Total Wet Mass (IMLEO)	-	**107,060**	**106,580**

PAYLOAD DIMENSIONS: VOLUME AND MASS



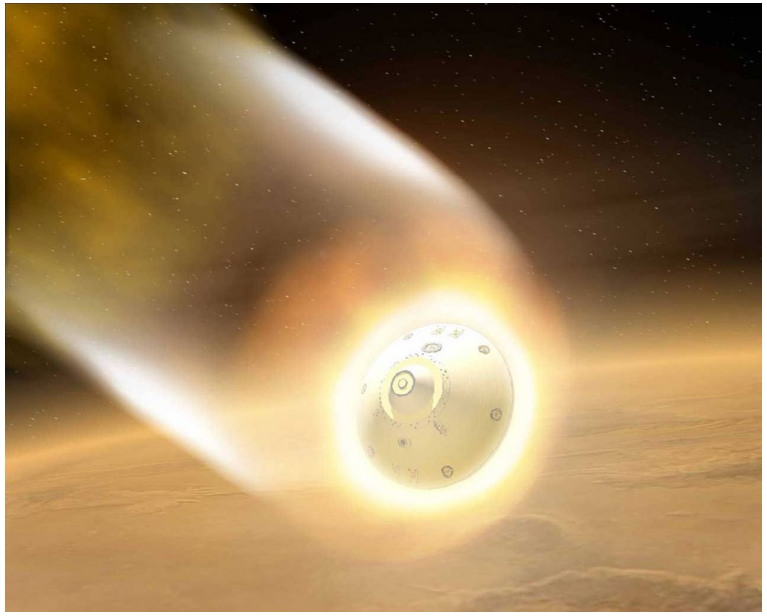
- SLS is investigating utilizing existing fairings for early cargo flights, offering payload envelope compatibility with design for current EELVs
- Phase A studies in work for 8.4m and 10 m fairing options



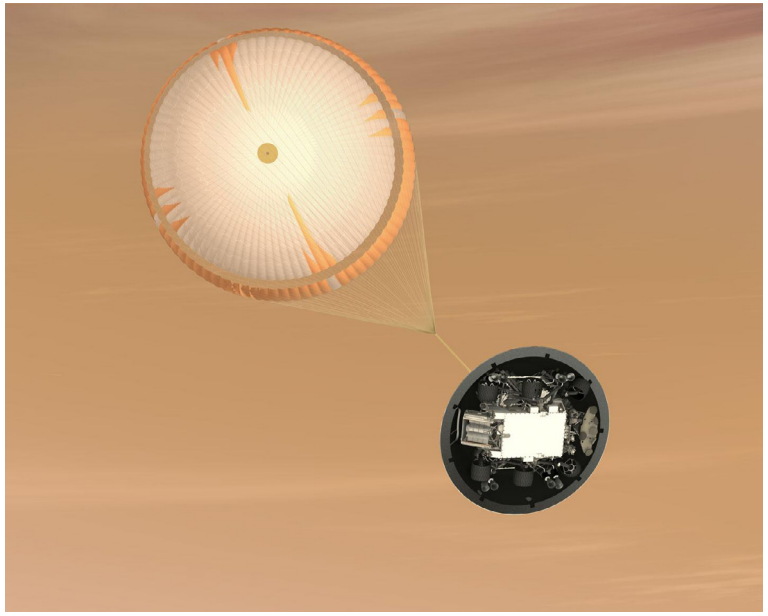
ENTRY, DESCENT AND LANDING

EDL MER A & B
0:38 to 3:34 min
https://youtu.be/7zpojhD4hpI?t=38s

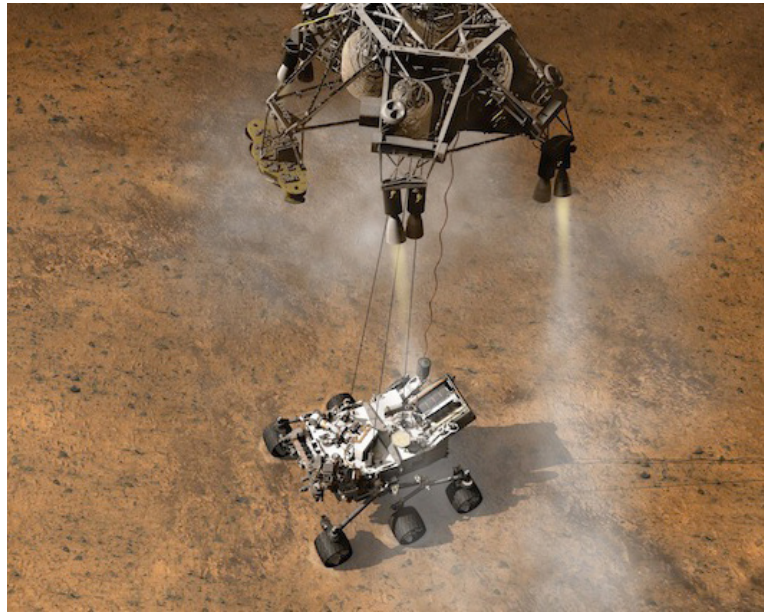
EDL MSL
11:20 to 13:20 min
https://youtu.be/7zpojhD4hpI?t=11m20s



Hypersonic deceleration

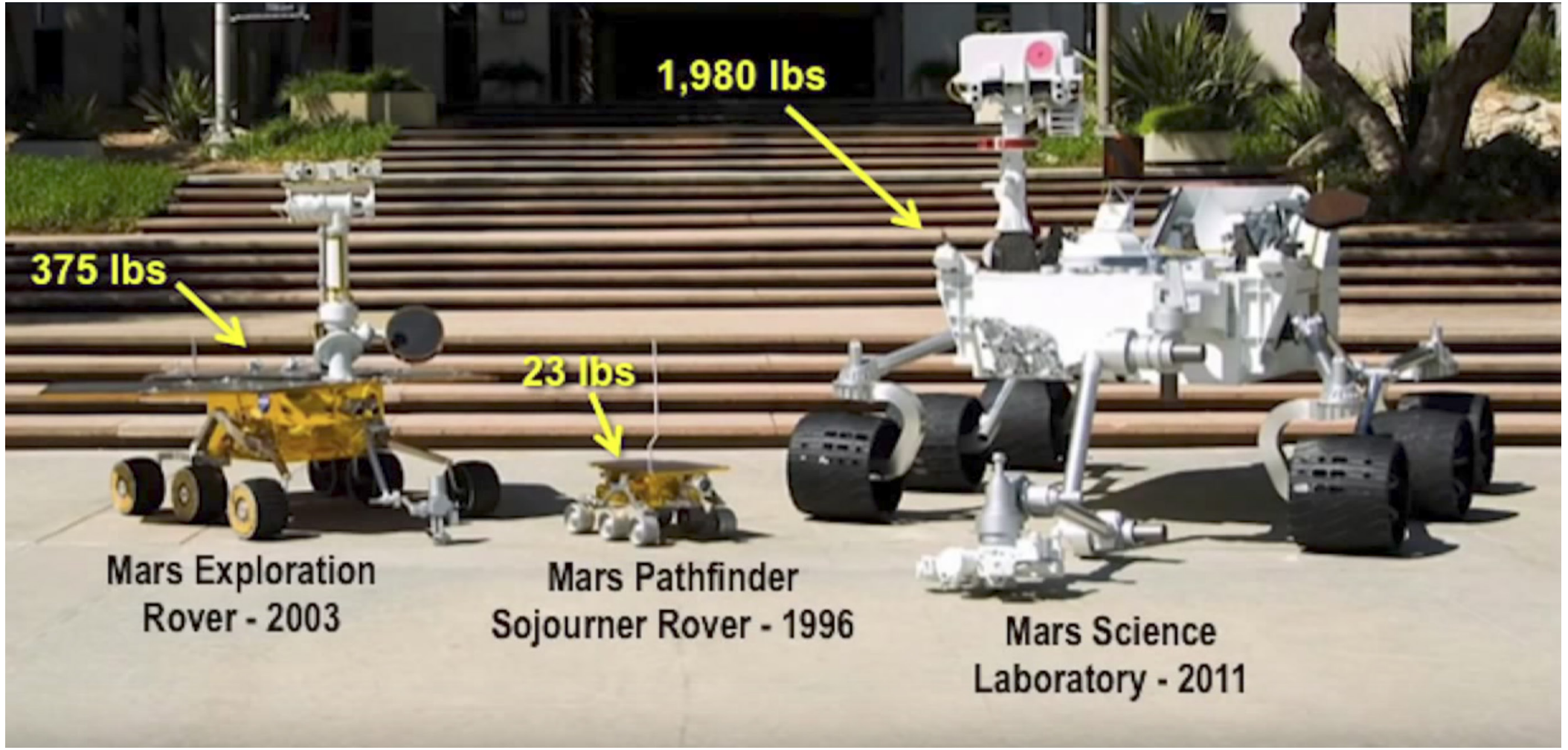


Supersonic deceleration

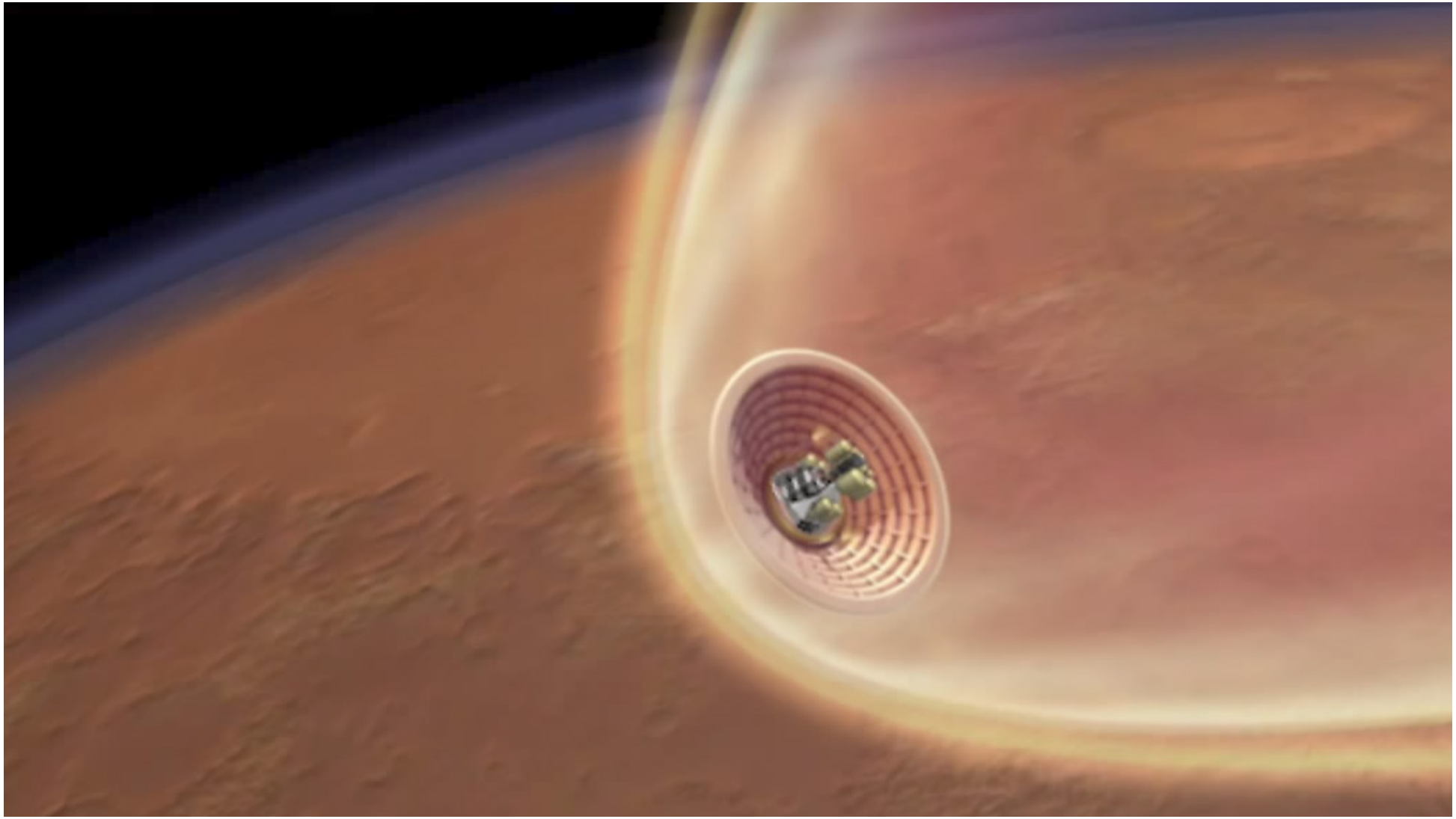


Subsonic deceleration

BOTTLENECK: SYSTEM SIZING AND MASS

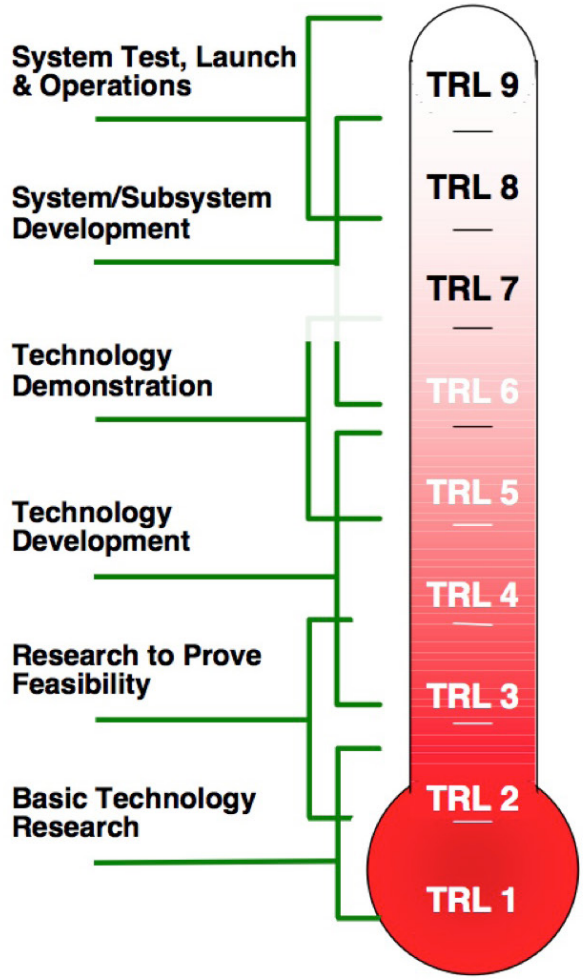


LOGISTICS: HYPERSONIC INFLATABLE AERODYNAMIC DECELERATOR (HIAD)



TECHNOLOGY READINESS LEVEL (TRL)

NASA/DOD Technology Readiness Level



TRL 9 — Actual system "flight proven" through successful mission operations

TRL 8 — Actual system completed and "flight qualified" through test and demonstration (Ground or Flight)

TRL 7 — System prototype demonstration in a space environment

TRL 6 — System/subsystem model or prototype demonstration in a relevant environment (Ground or Space)

TRL 5 — Component and/or breadboard validation in relevant environment

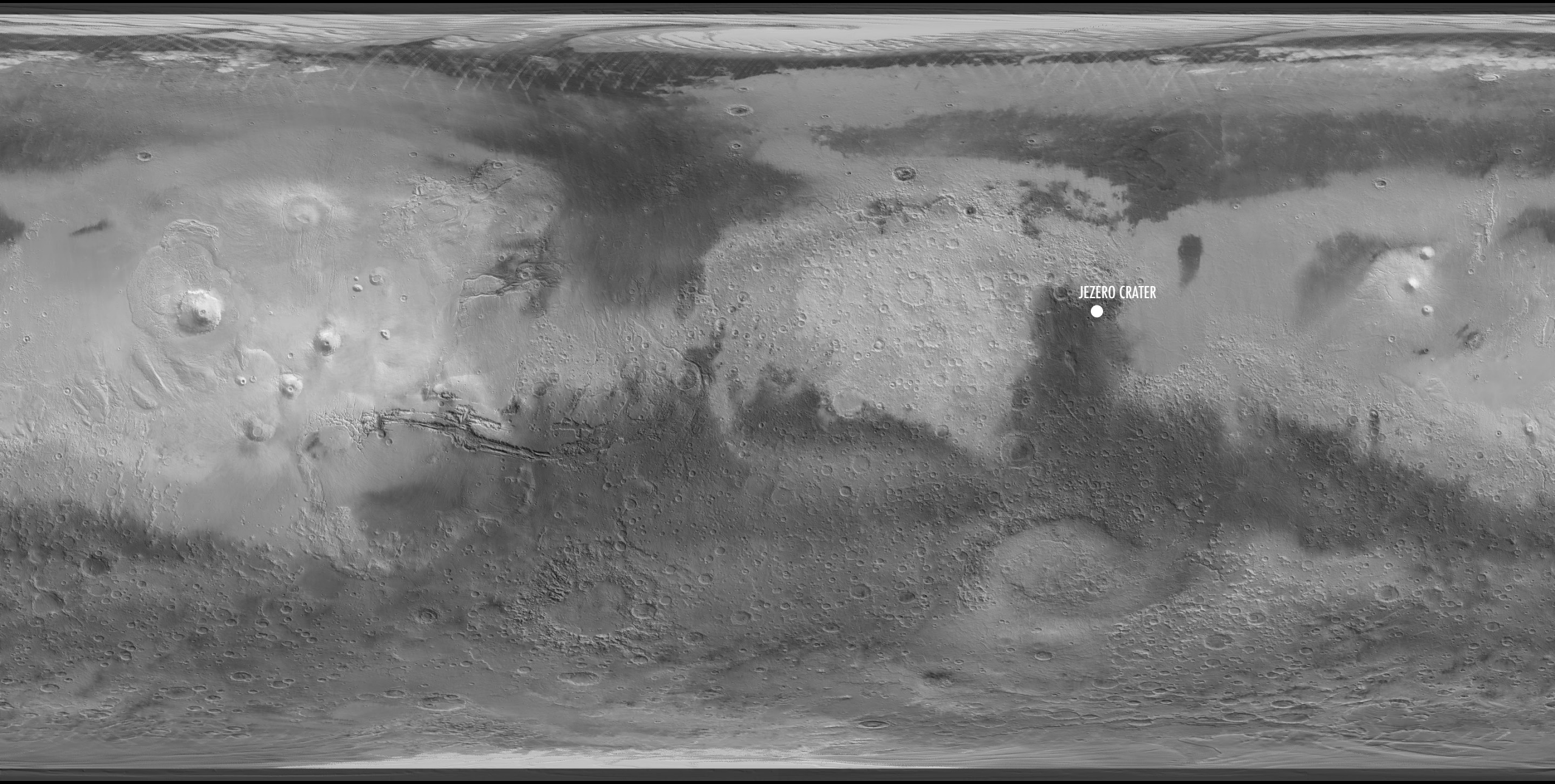
TRL 4 — Component and/or breadboard validation in laboratory environment

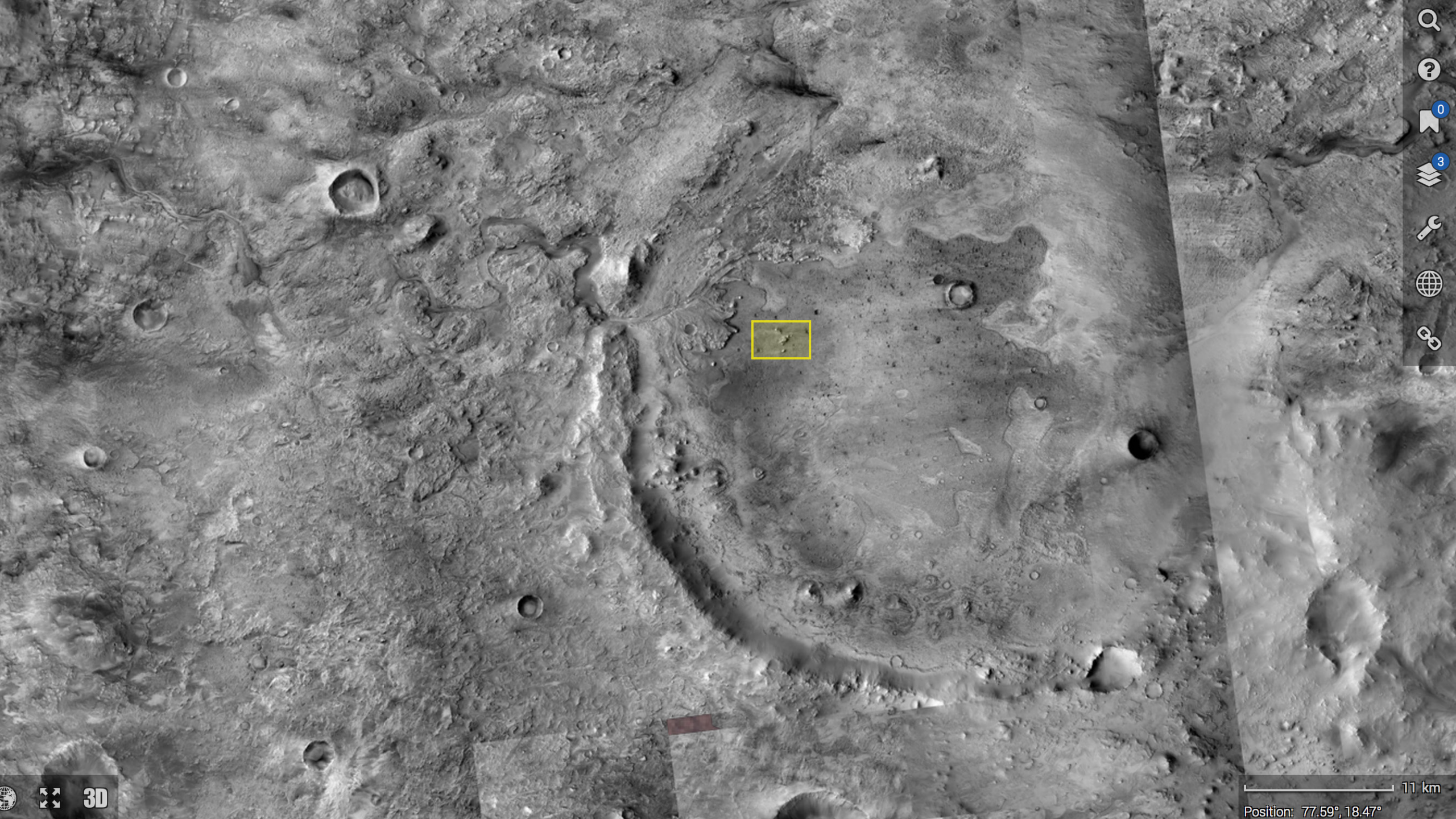
TRL 3 — Analytical and experimental critical function and/or characteristic proof-of-concept

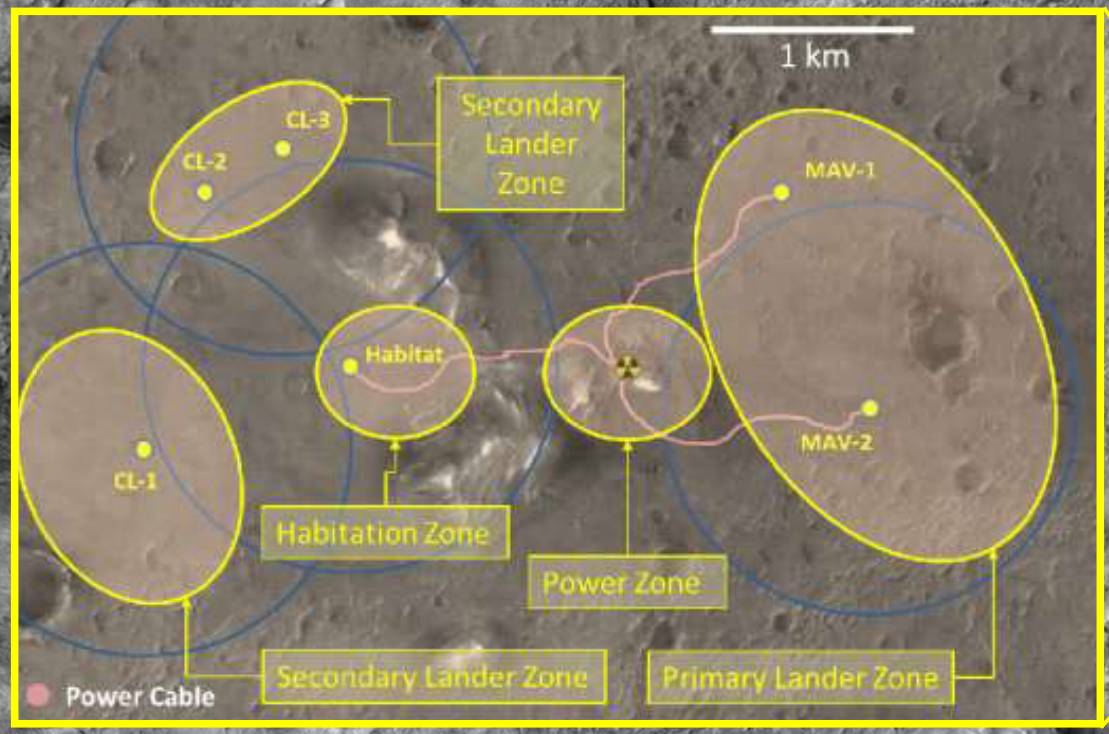
TRL 2 — Technology concept and/or application formulated

TRL 1 — Basic principles observed and reported

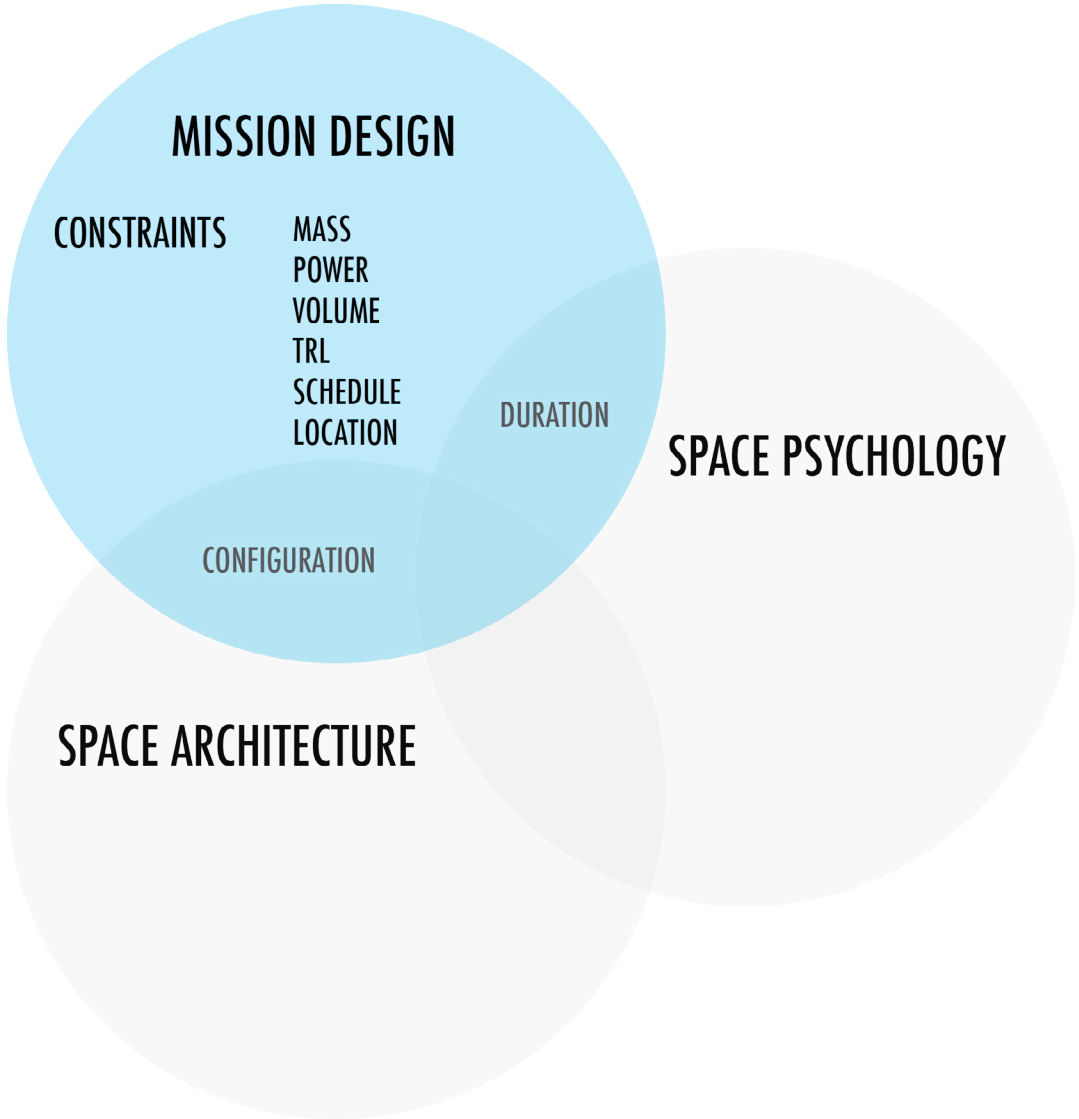
LOCATION JEZERO CRATER




0
3
3D
11 km
Position: 77.59°, 18.47°



CONCLUSION: ASPECTS FOR MISSION FEASIBILITY



04

SPACE PSYCHOLOGY

RISK AS A DRIVER

Three major categories defined for Human Health and Performance Risks concerning a mission to Mars:

1. Physiological risks

2. Psychological risks

3. Radiation exposure risks

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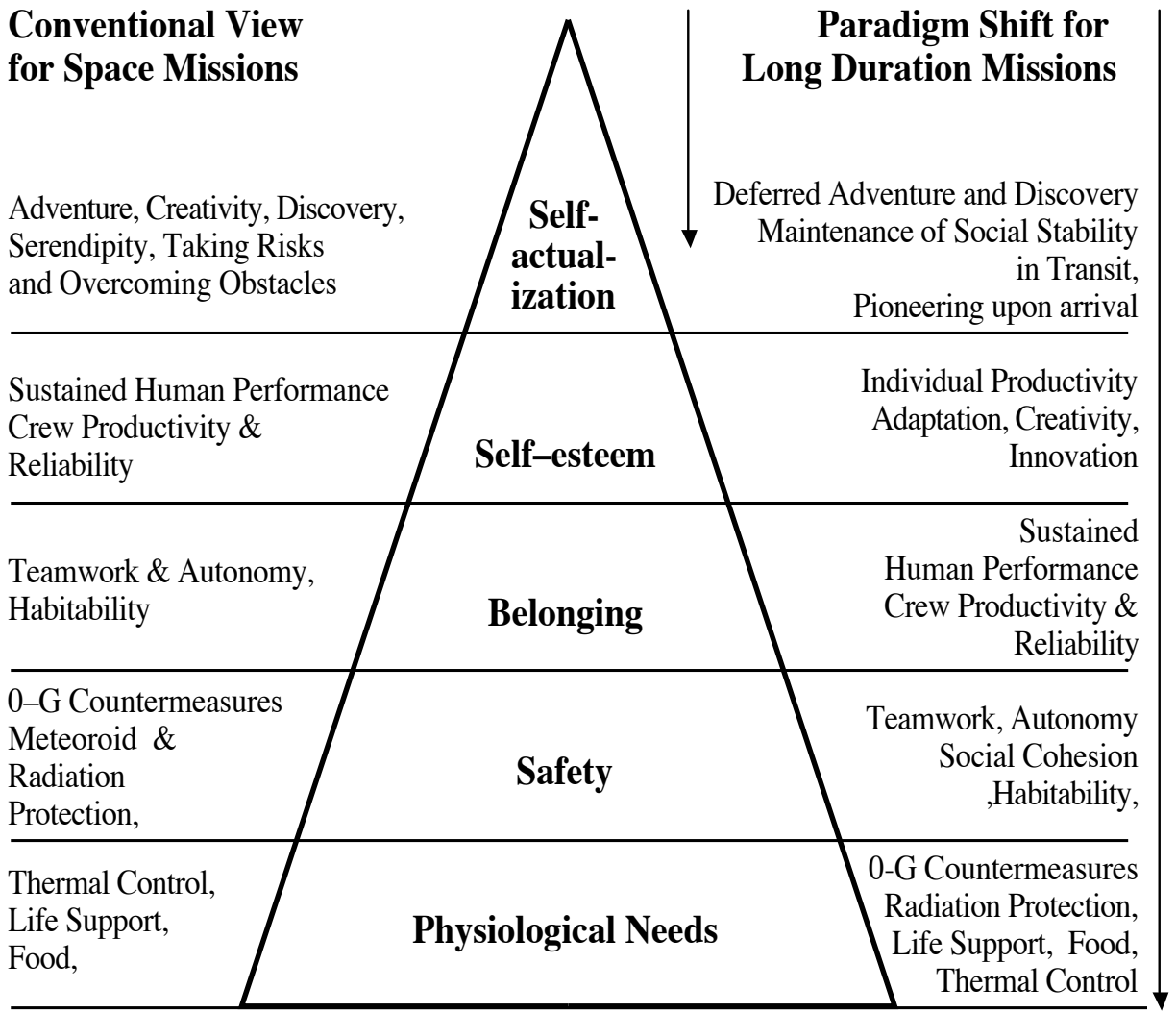
Main Human Health and Performance Risks for Exploration	Not mission limiting GO	Not mission limiting, but increased risk GO	Mission limiting NO GO	Mission			
				ISS (6 mo)	**Lunar** (6 mo)	**Deep Space** (1 yr)	**Mars** (3 yr)
Musculoskeletal: Long-term health risk of early onset osteoporosis Mission risk of reduced muscle strength and aerobic capacity							
Sensorimotor: Mission risk of sensory changes/dysfunctions							
Ocular Syndrome: Mission and long-term health risk of microgravity-induced visual impairment and/or elevated intracranial pressure							
Nutrition: Mission risk of behavioral and nutritional health due to inability to provide appropriate quantity, quality and variety of food							
Autonomous Medical Care: Mission and long-term health risk due to inability to provide adequate medical care throughout the mission (Includes onboard training, diagnosis, treatment, and presence/absence of onboard physician)							
Behavioral Health and Performance: Mission and long-term behavioral health risk							
Radiation: Long-term risk of carcinogenesis and degenerative tissue disease due to radiation exposure—Largely addressed with ground-based research							
Toxicity: Mission risk of exposure to a toxic environment without adequate monitoring, warning systems or understanding of potential toxicity (dust, chemicals, infectious agents)							
Autonomous Emergency Response: Medical risks due to life support system failure and other emergencies (fire, depressurization, toxic atmosphere, etc.), crew rescue scenarios							
Hypogravity: Long-term risk associated with adaptation during intravehicular activity and extravehicular activity on the Moon, asteroids, Mars (vestibular and performance dysfunctions) and postflight rehabilitation							

PSYCHOLOGY IN LONG DURATION SPACE MISSIONS



Cohen, 1991

DESIGN FOR HABITABILITY

The term **habitability** describes
the physical suitability
and subjective value of
a built habitat for its inhabitants
within a specific environment.

Hauplik-Meusburger, 2017

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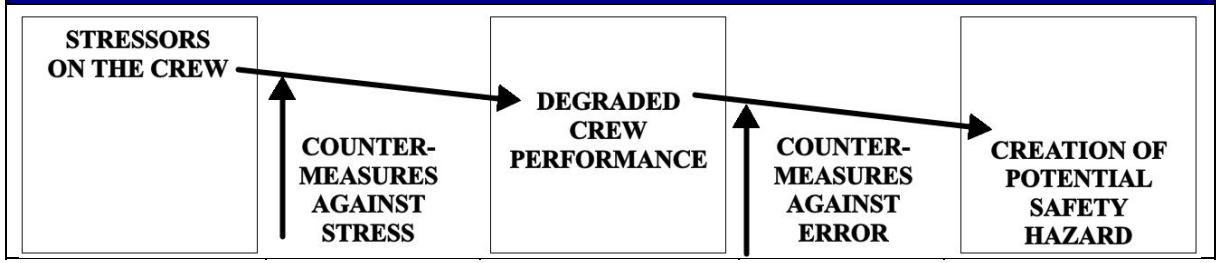
The term **habitability** describes
the physical suitability
and subjective value of
a built habitat for its inhabitants
within a specific environment.

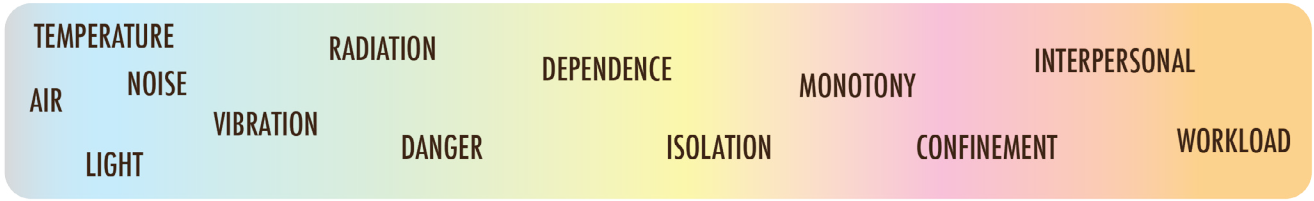
Hauplik-Meusburger, 2017

TABLE 1. CRITICAL HABITABILITY I[7]

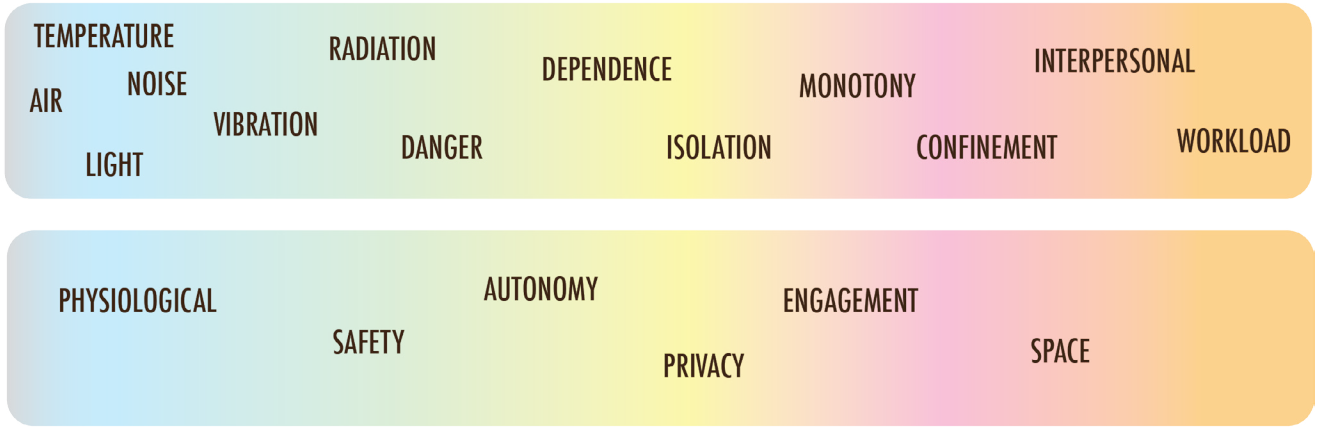


Cohen, 2015

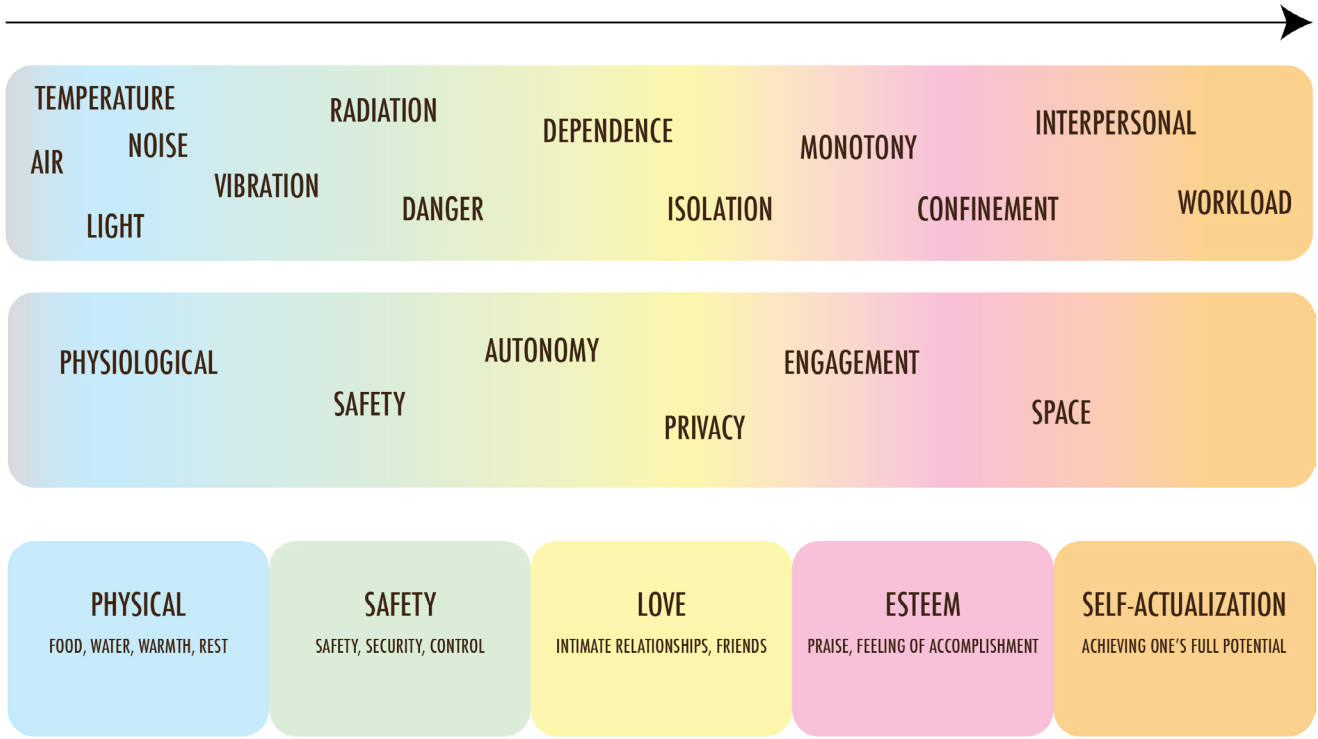
STRESSORS WERE CATEGORIZED

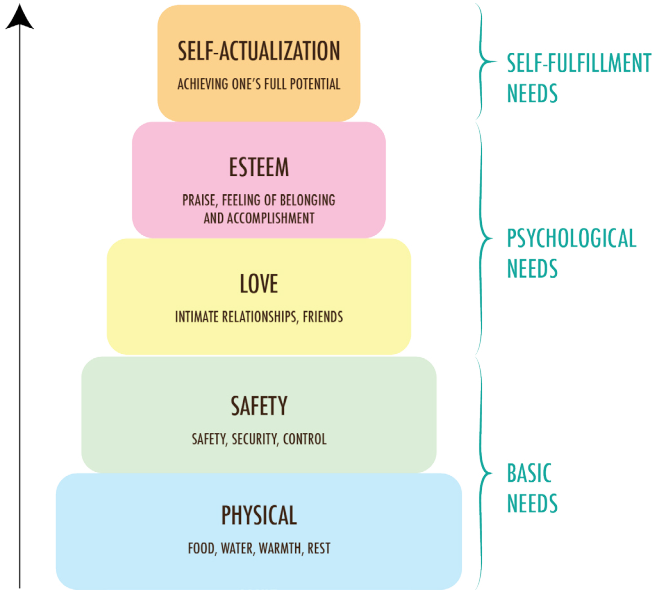


THEMATIC NEEDS WERE DERIVED

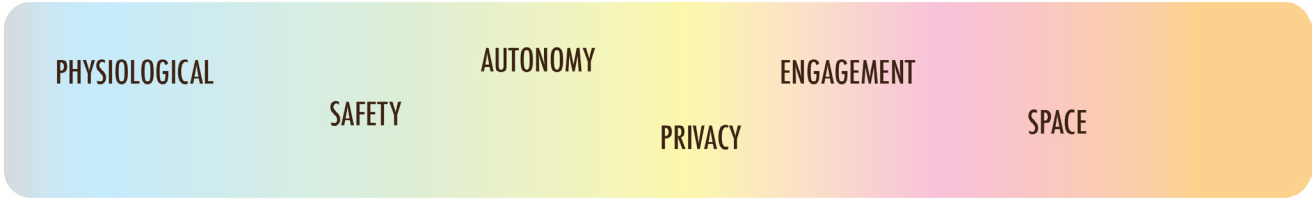


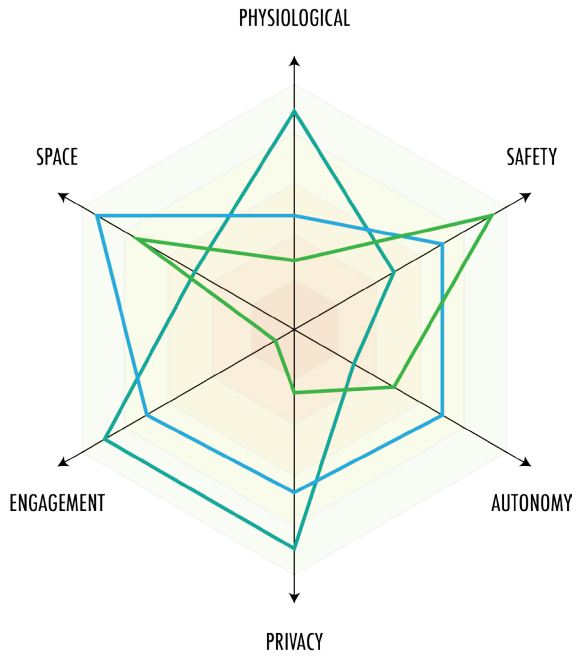
NEEDS RELATED TO MASLOW: DURATION INCREASES IMPORTANCE



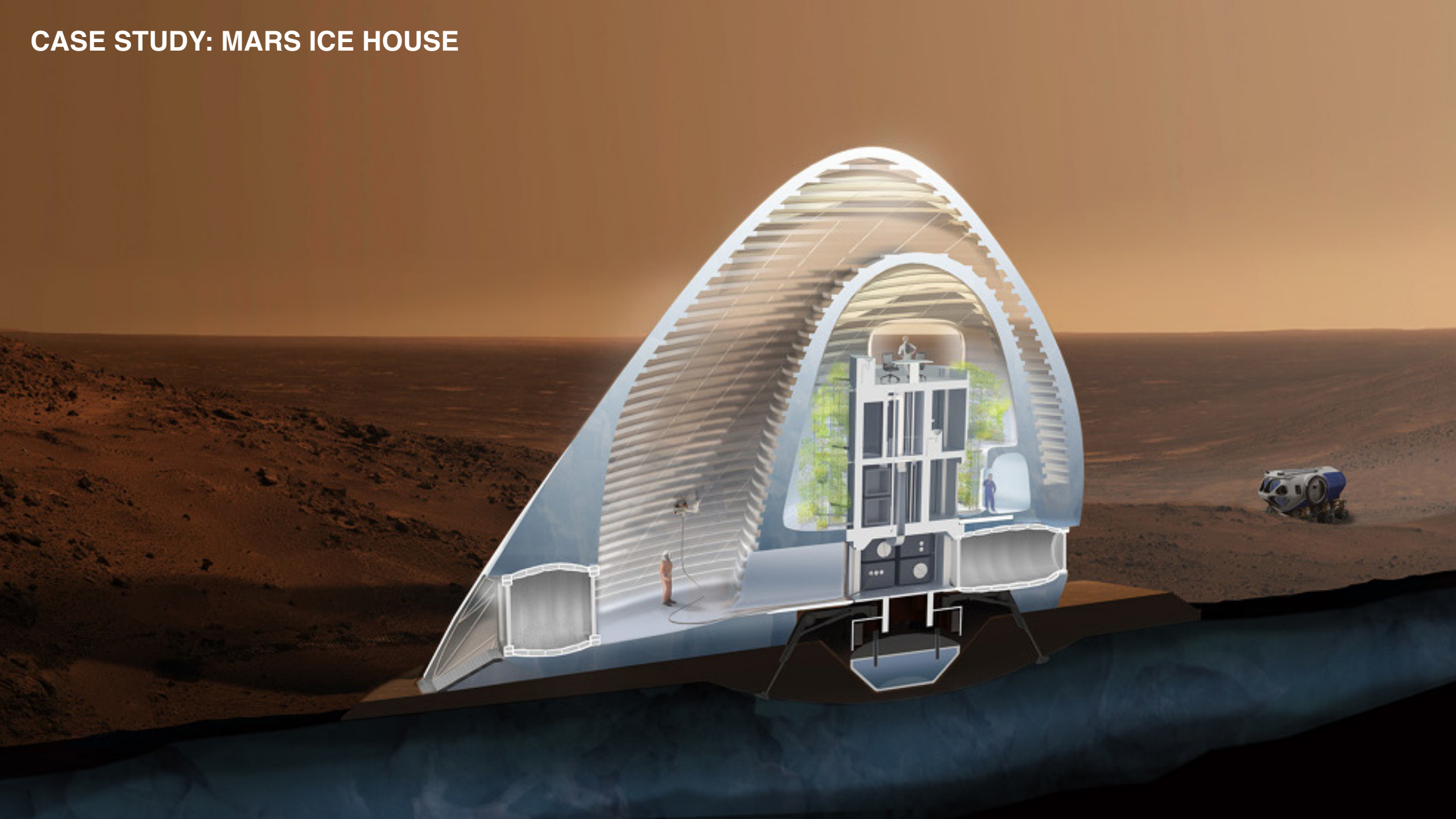


BALANCE QUALITATIVE REQUIREMENTS WITHIN DESIGN ORGANIZATION



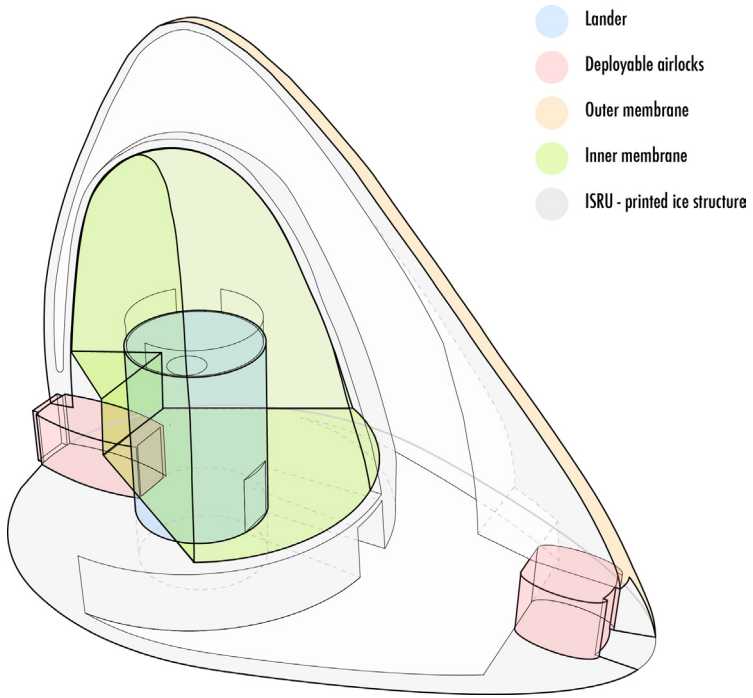


CASE STUDY: MARS ICE HOUSE

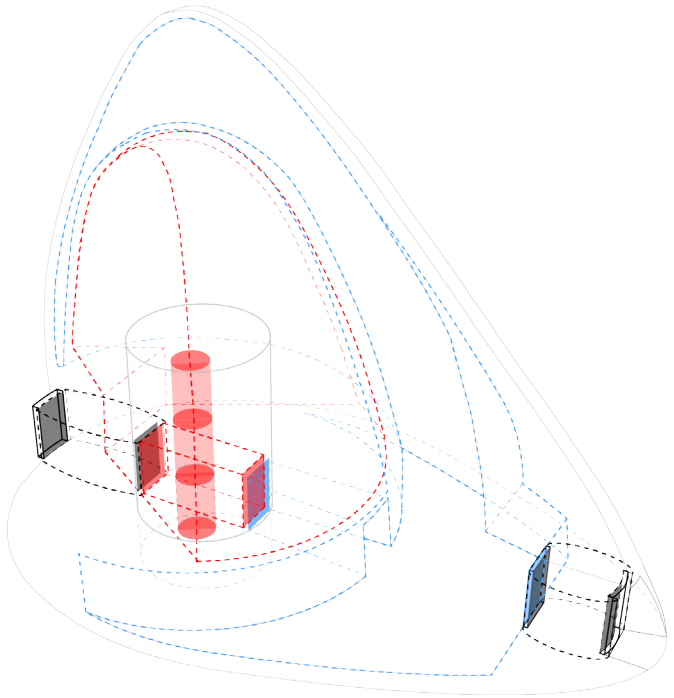


CASESTUDY: MARS ICE HOUSE

Configuration elements

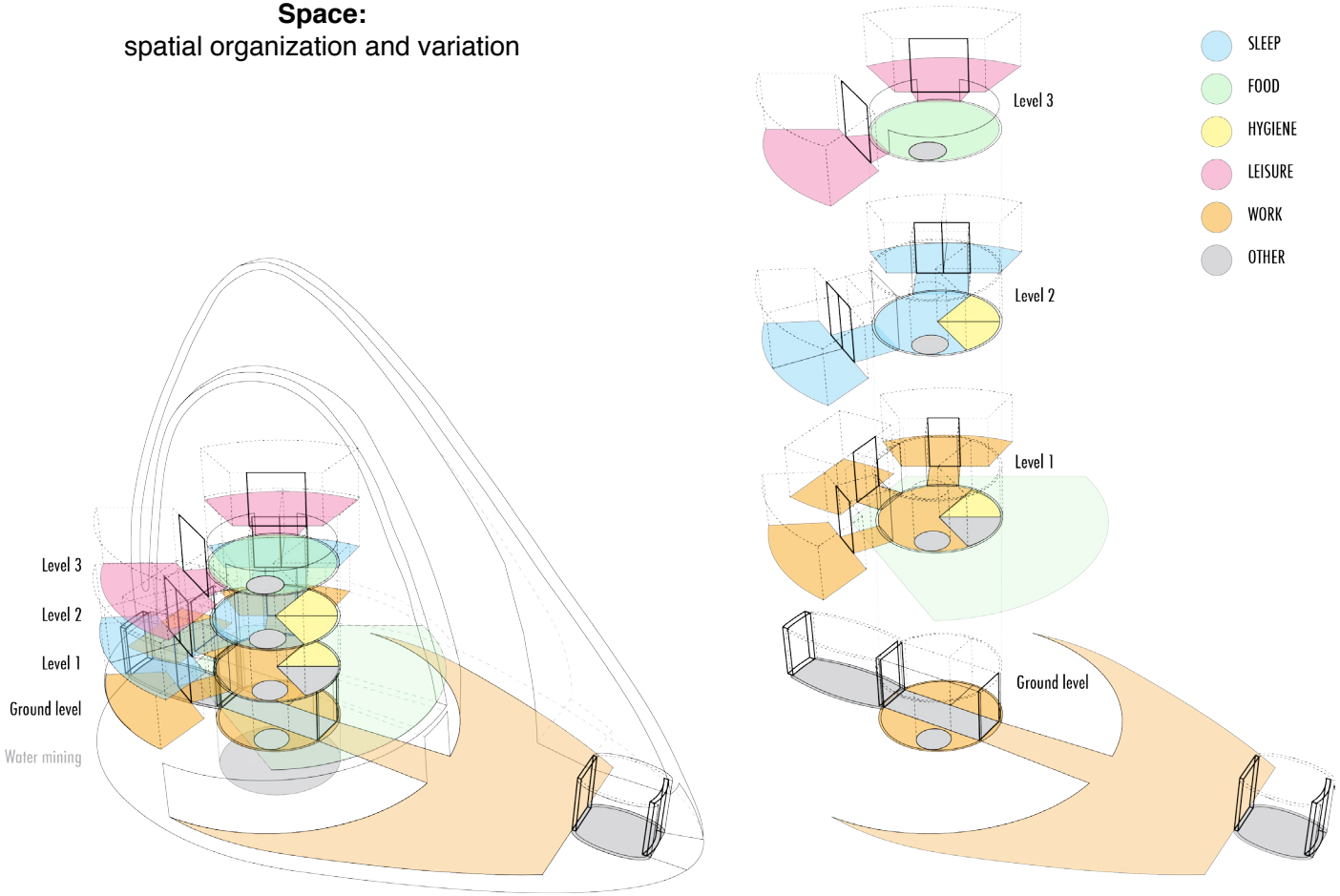


Safety:
zoning and double egression routes



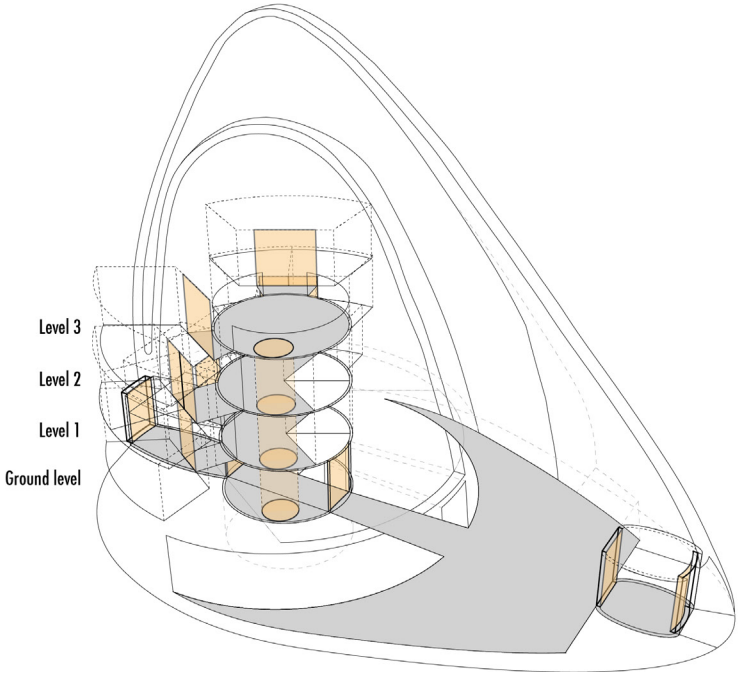
CASESTUDY: MARS ICE HOUSE

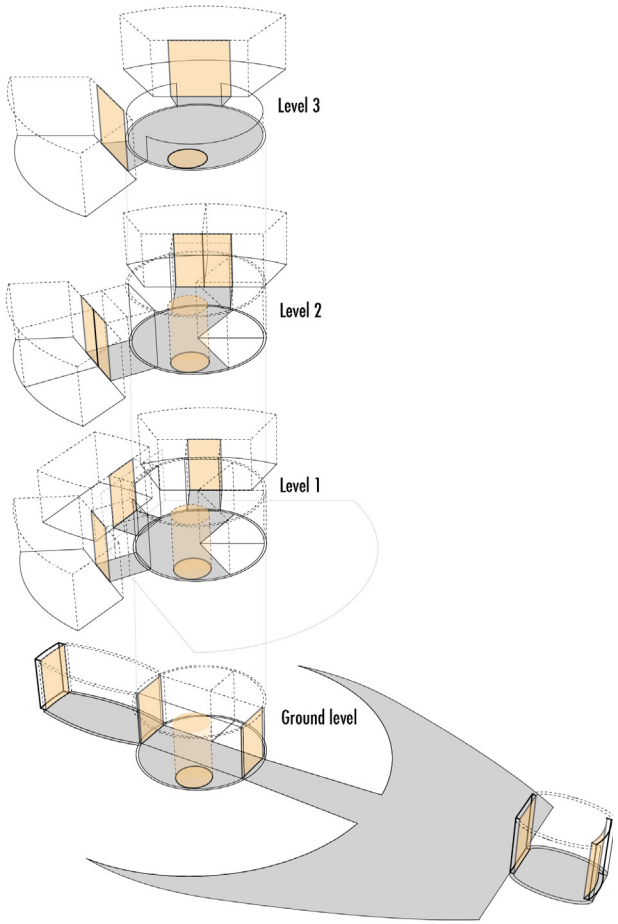
Space:
spatial organization and variation



CASESTUDY: MARS ICE HOUSE

Autonomy and Engagement:
Translation paths, windows, doors and hatches





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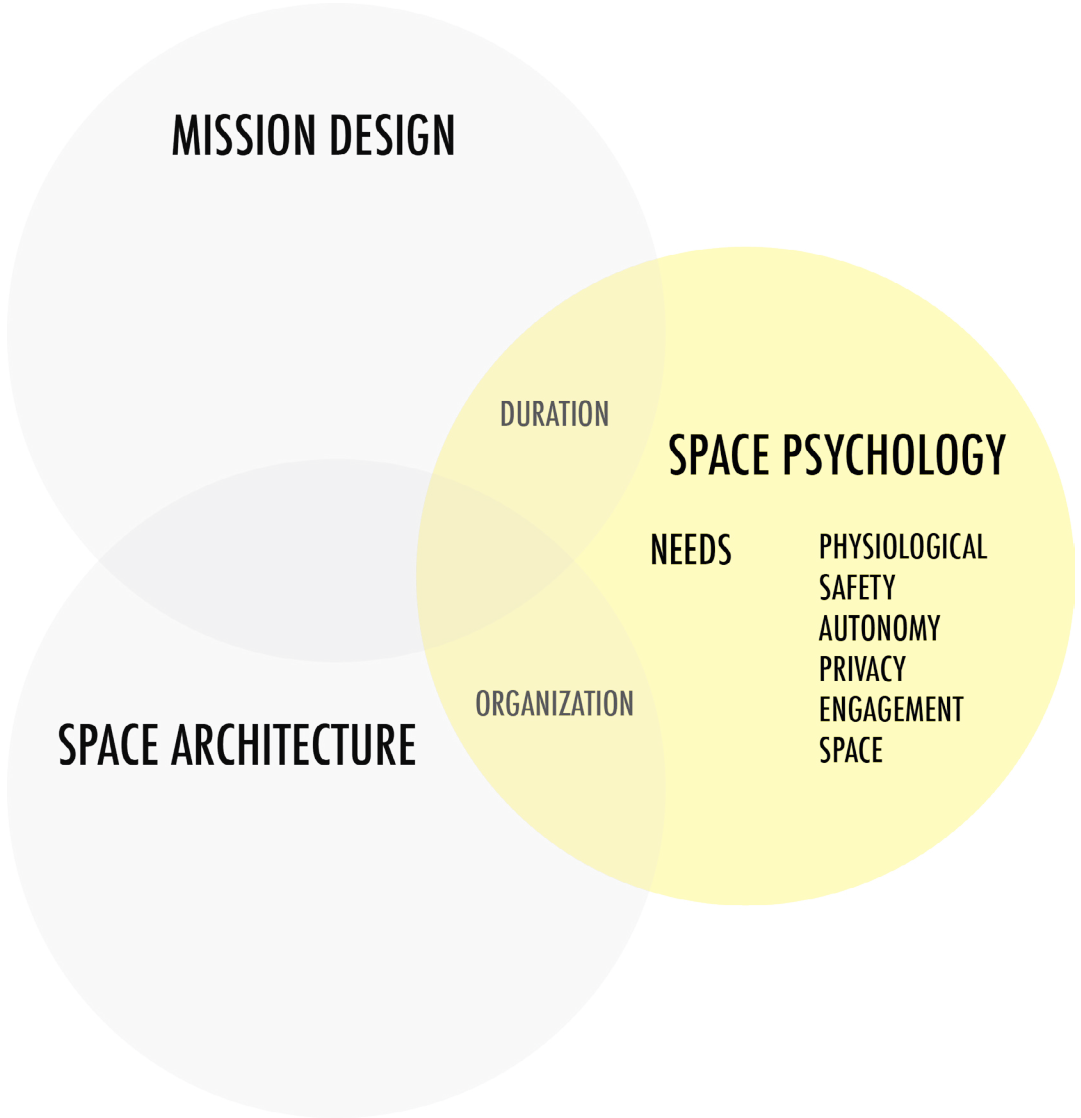
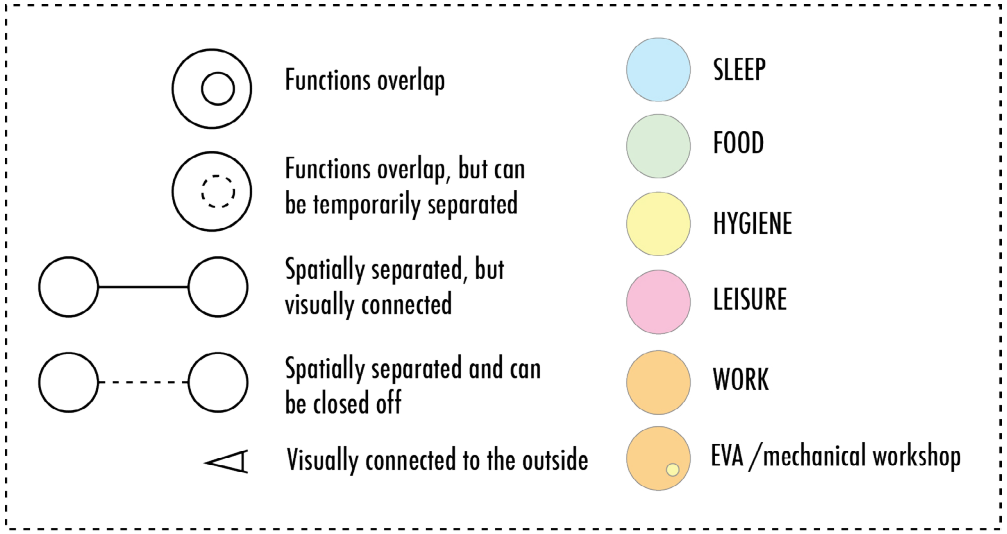
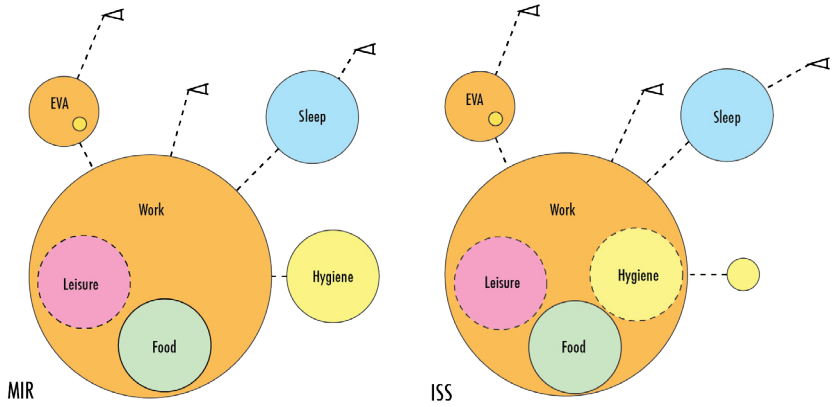


05

SPACE ARCHITECTURE

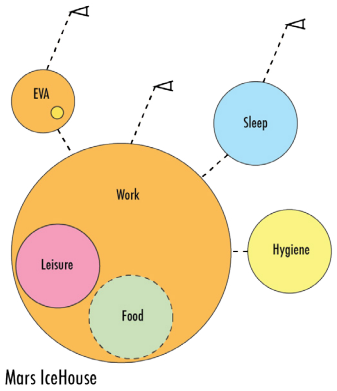
SPATIAL ORGANIZATION OF FUNCTIONAL ACTIVITIES



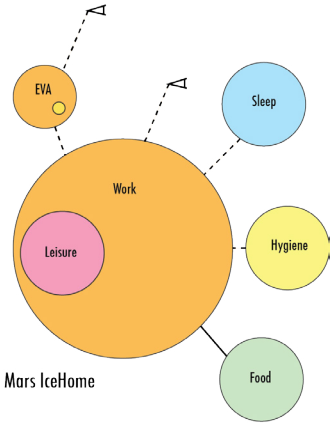


Hauplik-Meusburger, 2011

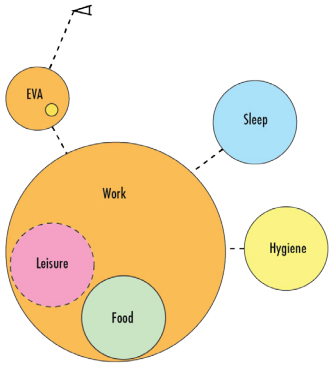
ORGANIZATION IN CASE STUDIES



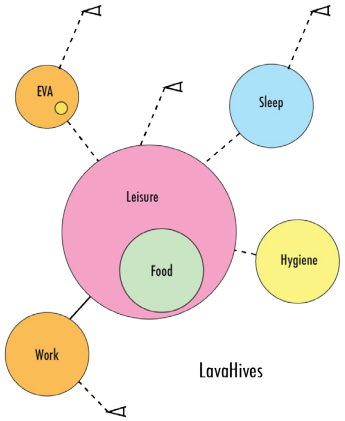
Mars IceHouse



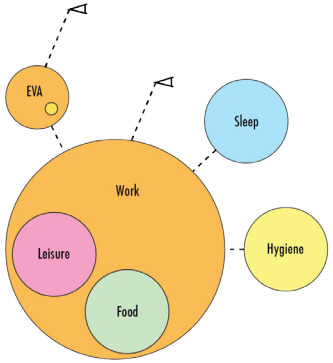
Mars IceHome



Team GAMMA



LavaHives



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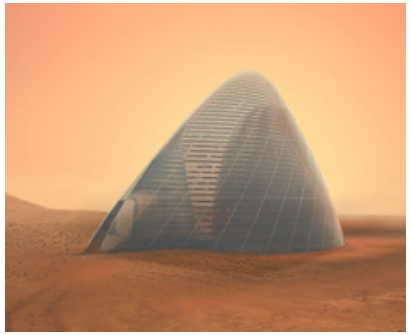
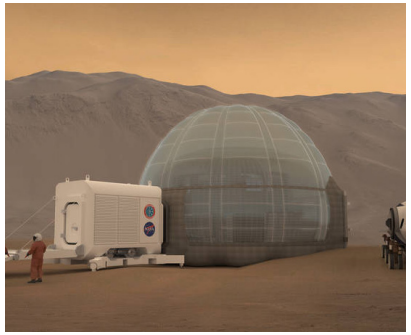
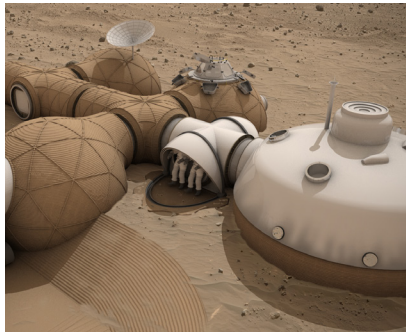
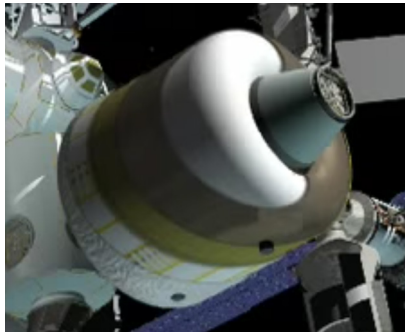
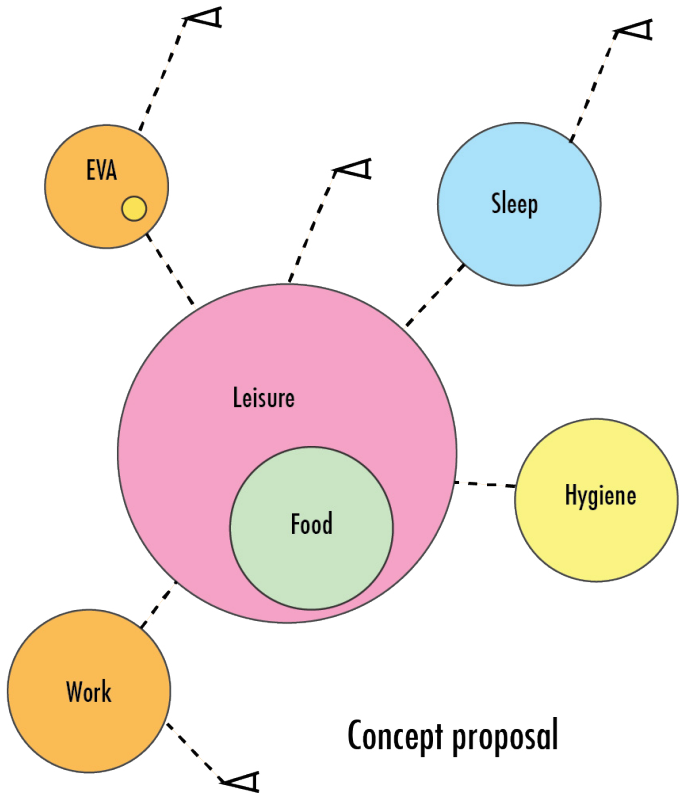




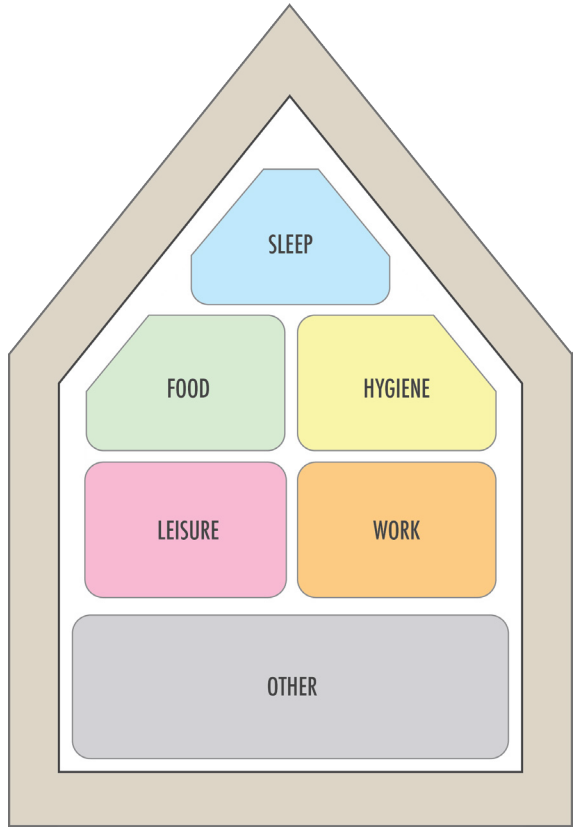




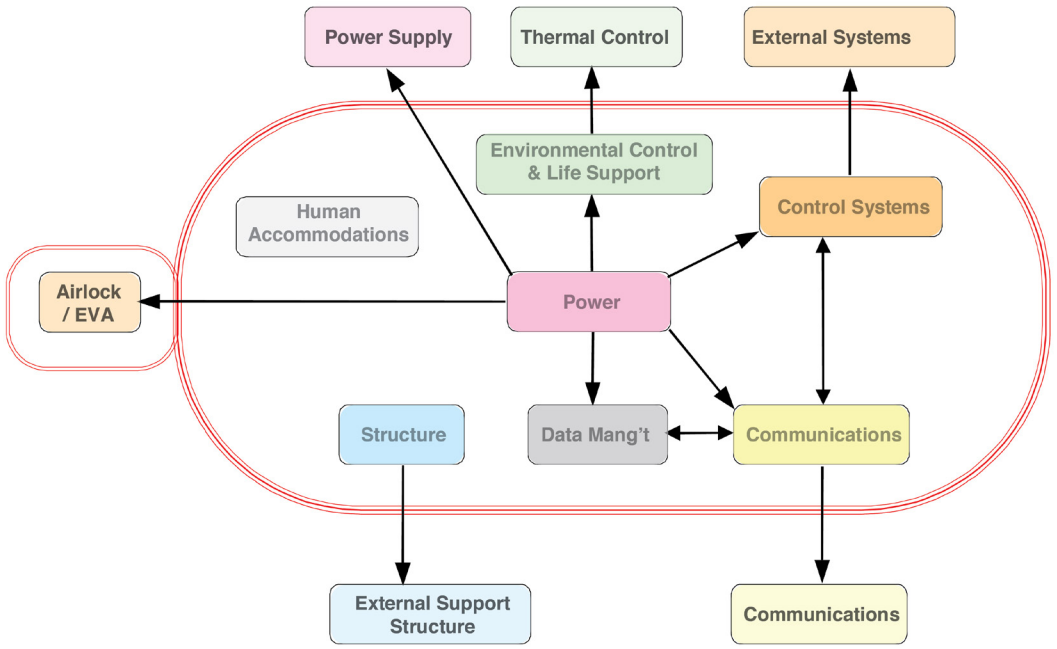
FINDINGS



Concept proposal

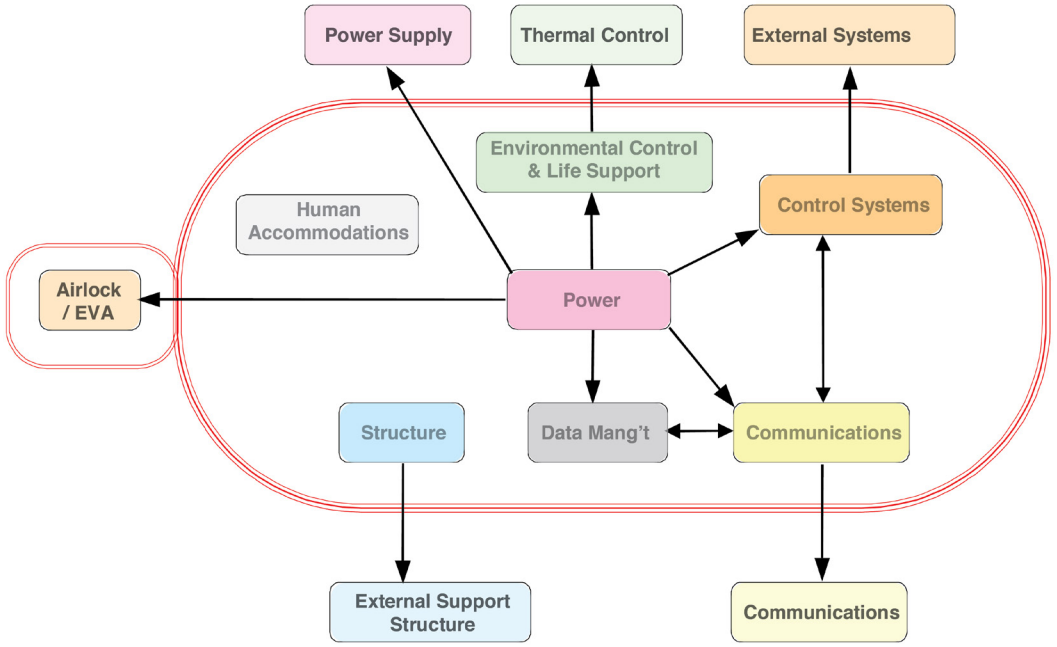


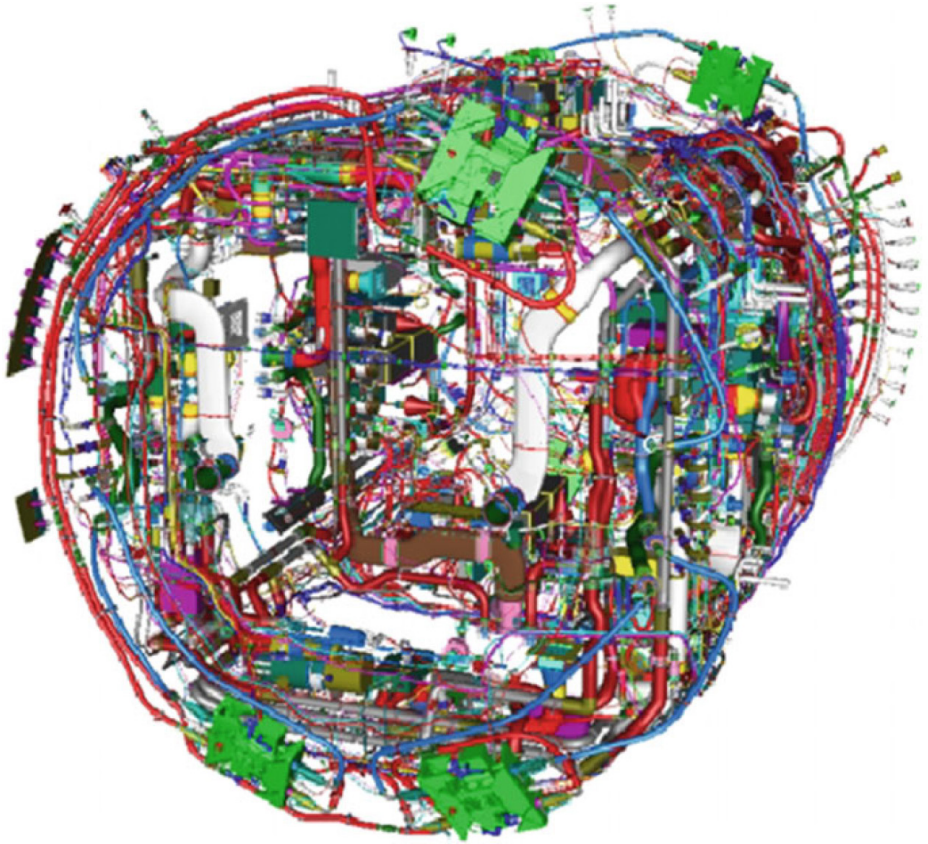
HABITAT SYSTEMS AND ELEMENTS



Kennedy, 2002

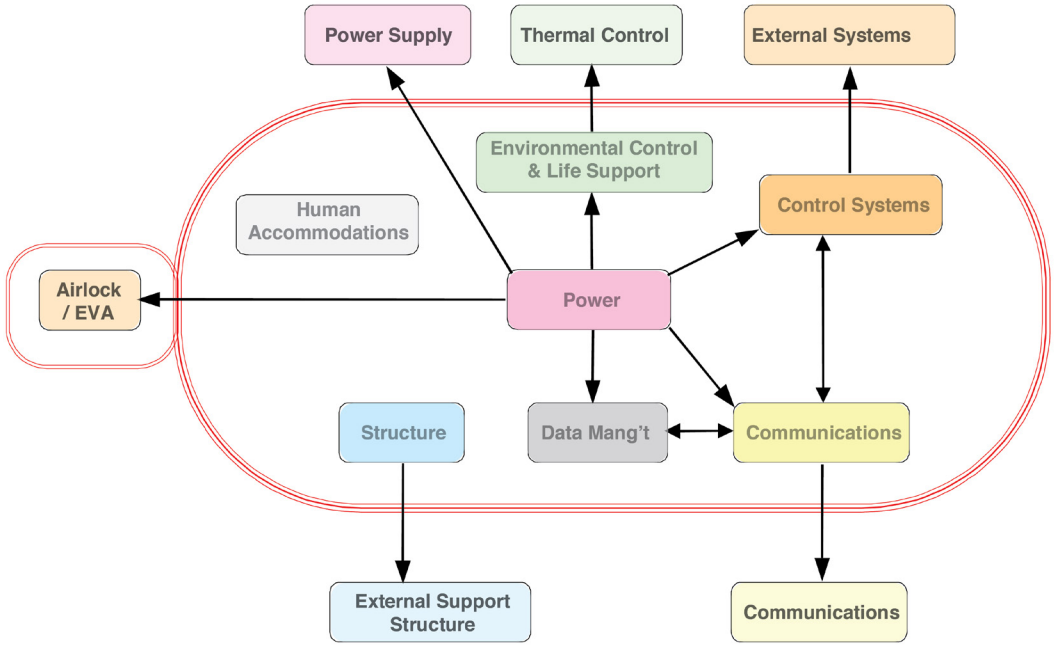
SYSTEM COMPLEXITY: PRE-FAB MODULE



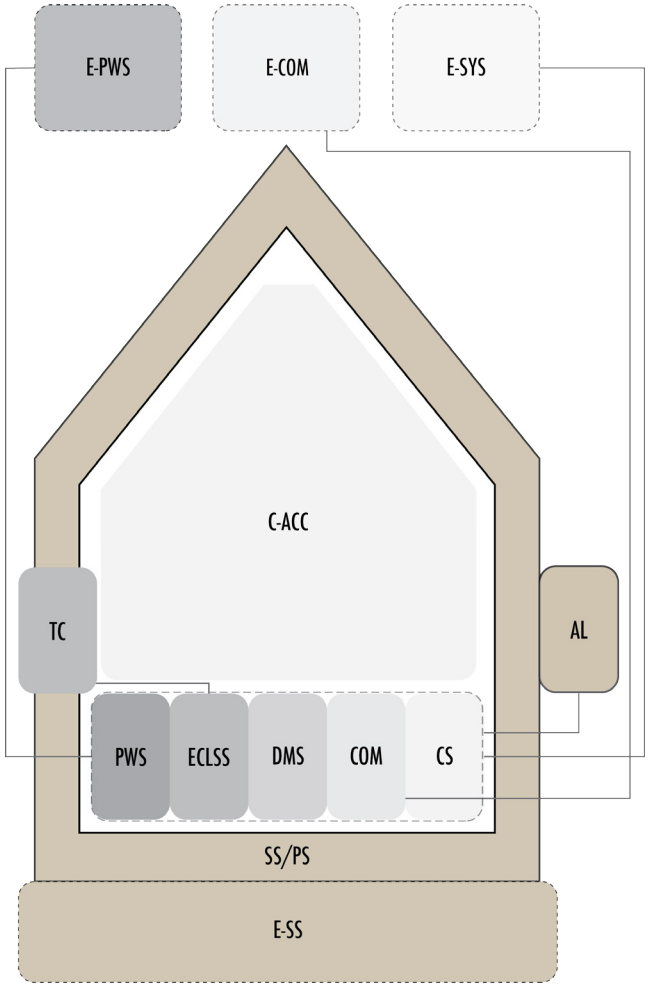


Kennedy, 2002

HABITAT SYSTEM ELEMENTS CONFIGURATION

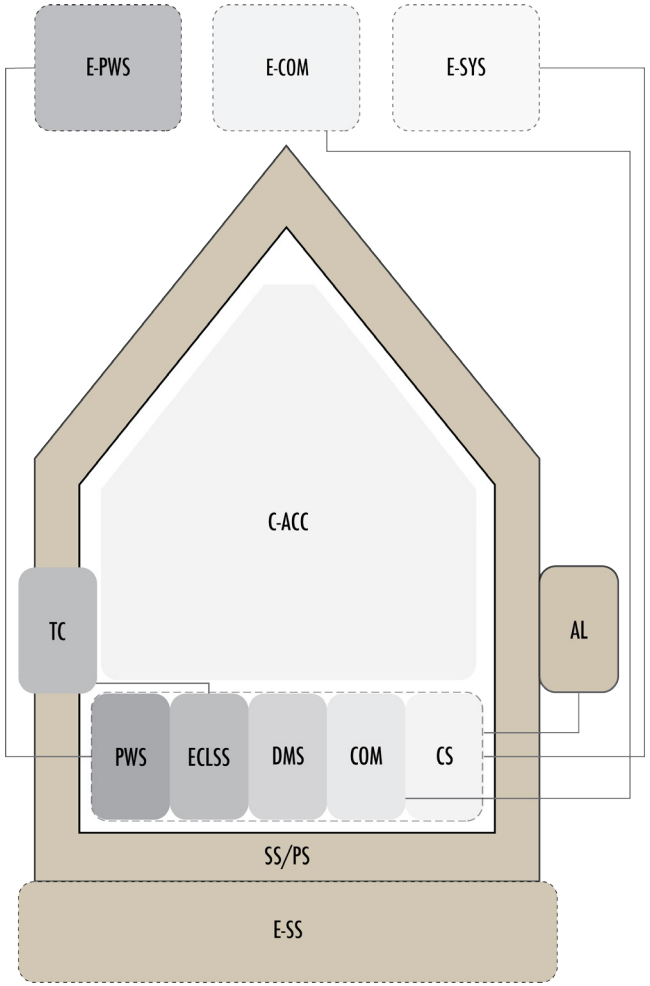


Kennedy, 2002

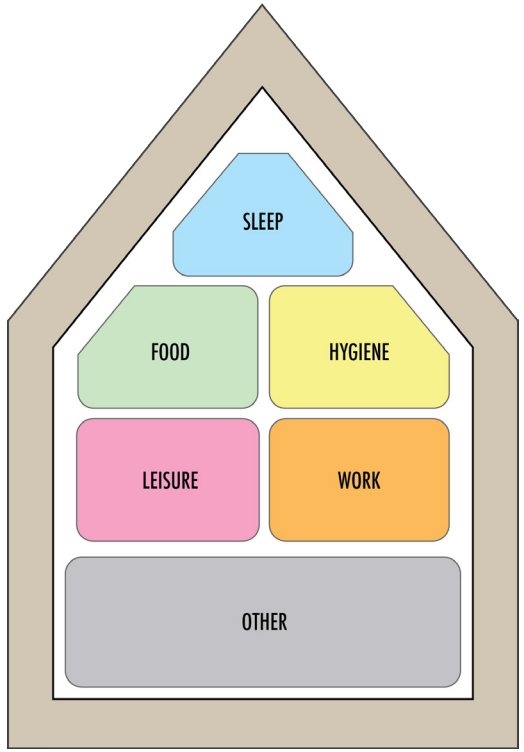


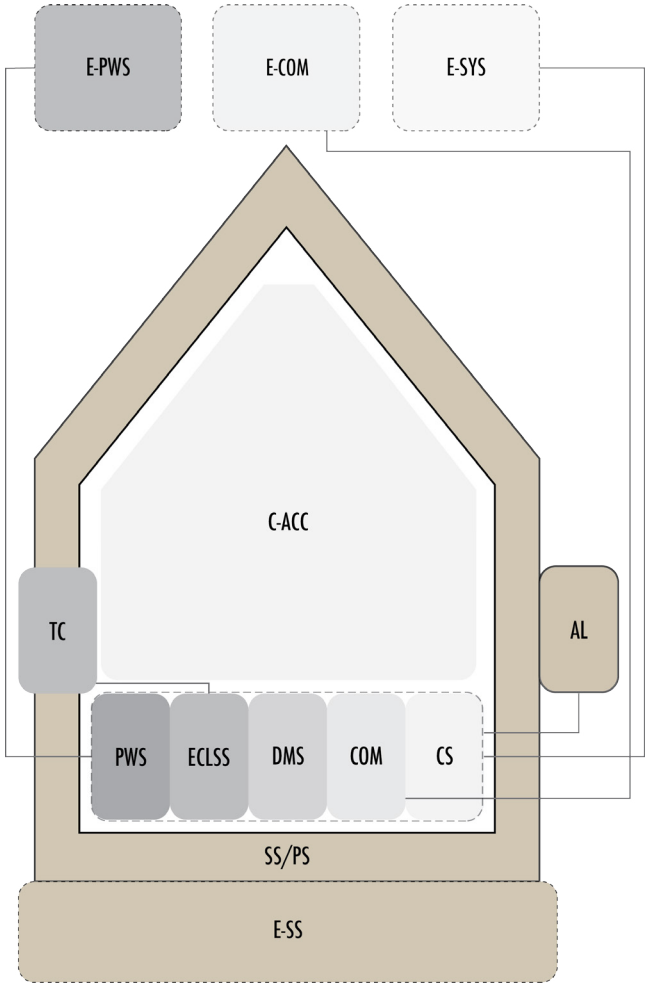
SYSTEM CONFIGURATION

icon	description	mass (kg)
C-ACC	Crew Accomodations	tbd
SS/PS	Support Structure/ Pressure Shell	7500
ECLSS	Environmental Control and Life Support System	2500
PWS	Power Supply System	1250
CS	Control Systems	200
COM	Command and communications Systems	200
DMS	Data Management and Storage	100
TC	Thermal Control System	1500
E-SS	External Support System	tbd
AL	Airlock and EVA systems	1500
E-PWS	External Power Supply System	5000
E-SYS	External Surface Systems	7000
E-COM	External Communication Systems	N/A

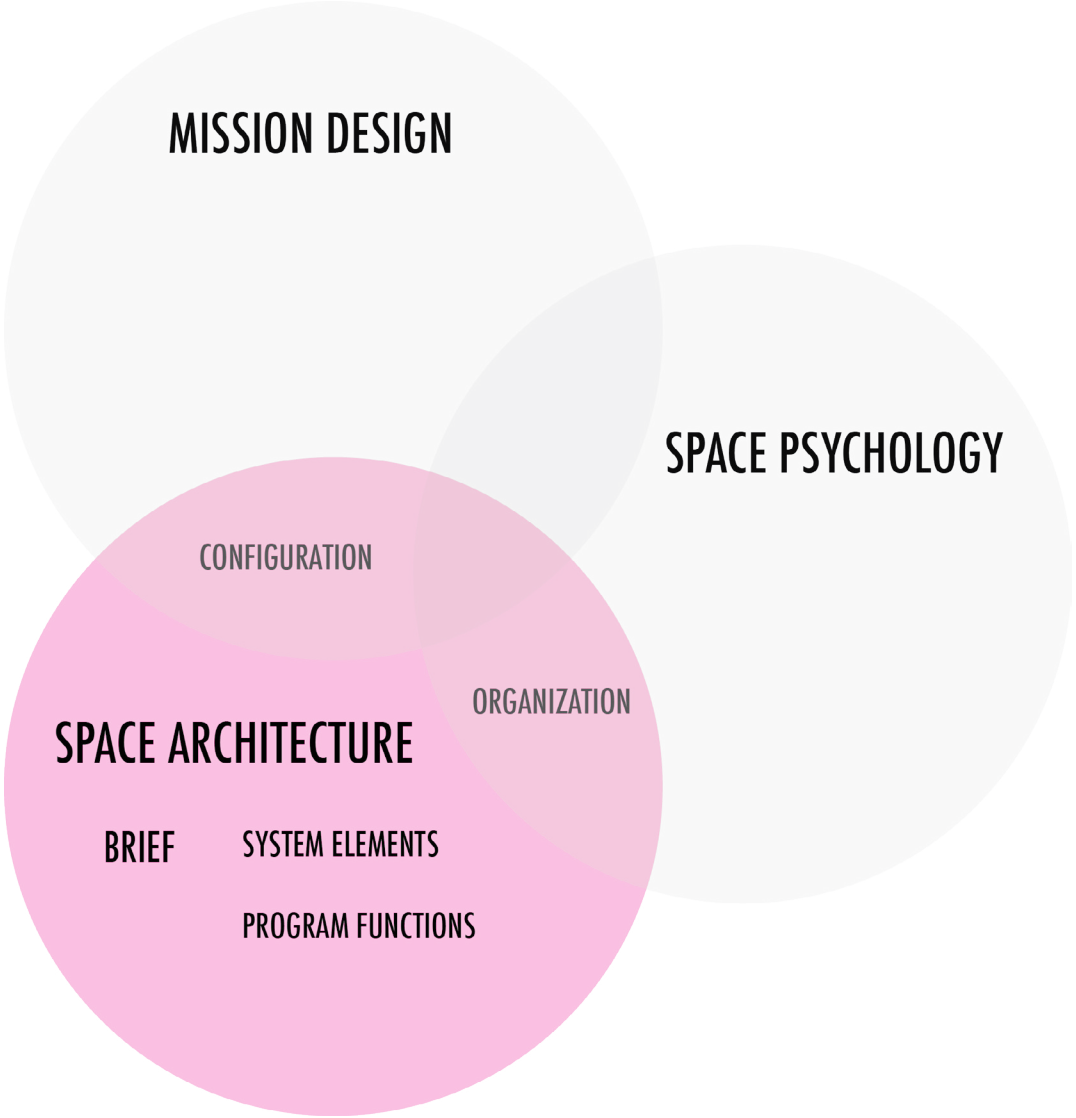


ORGANIZATION AND CONFIGURATION





CONCLUSION: ASPECTS FOR PSYCHOLOGICAL FEASIBILITY



06

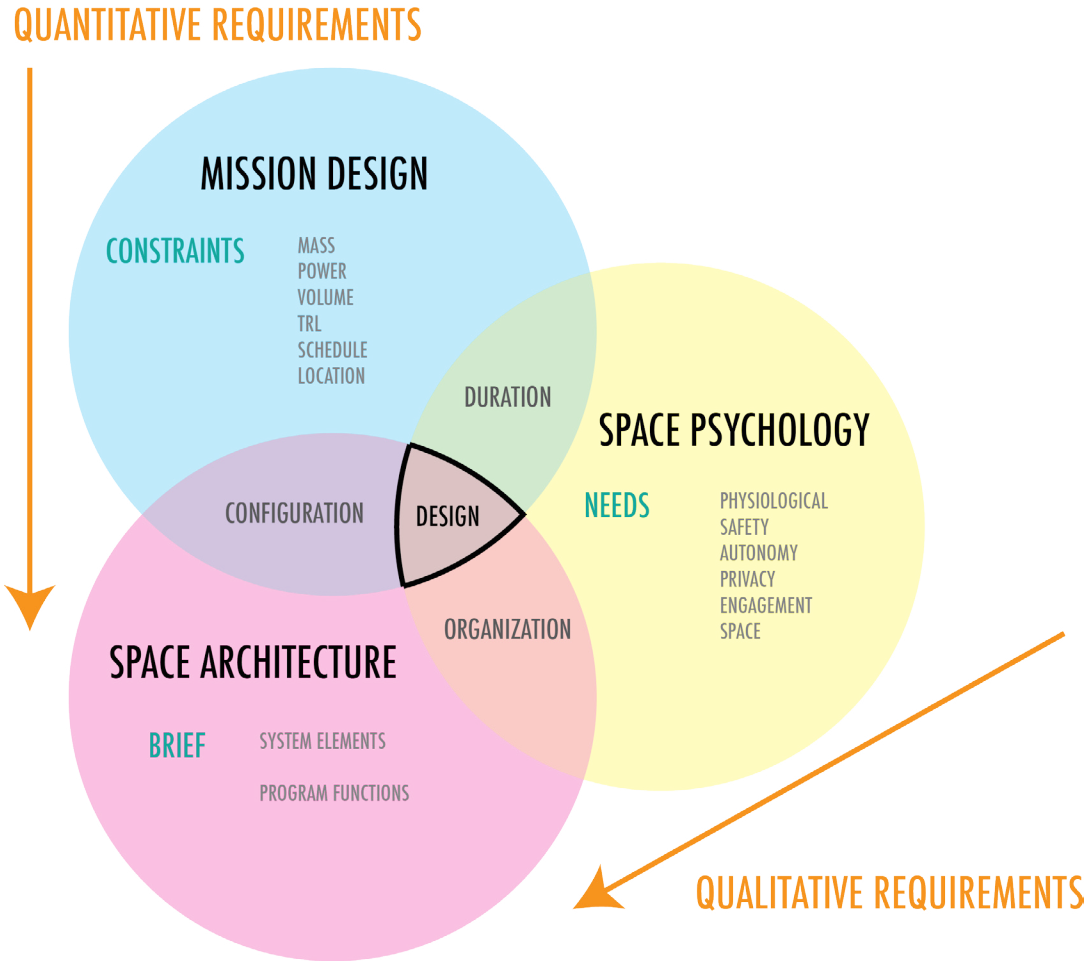
DESIGN

BRIEF REQUIREMENTS

Design Process

- Establish Goals
  Engineers | Mission Science | Client | Users
- Collect & Analyse Data
  Engineers | Architects | Researchers | Client | Users
- Determine Needs
  Engineers | Architects | Client | Users | Mission Objectives
- Test Concepts
  Engineers | Architects | Arts | Life Sciences
- Review Design
- Final Design

Bannova et al., 2016



DESIGN EXERCISE

Design Process

Establish Goals Engineers | Mission Science | Client | Users
Collect & Analyse Data Engineers | Architects | Researchers | Client | Users
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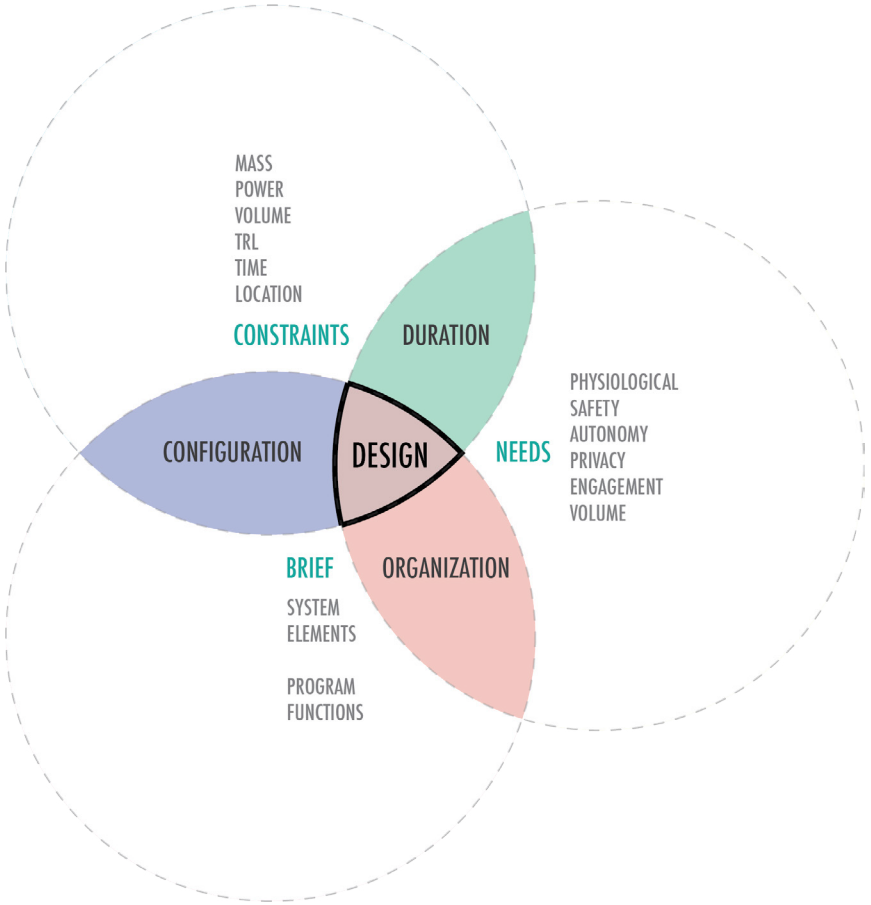
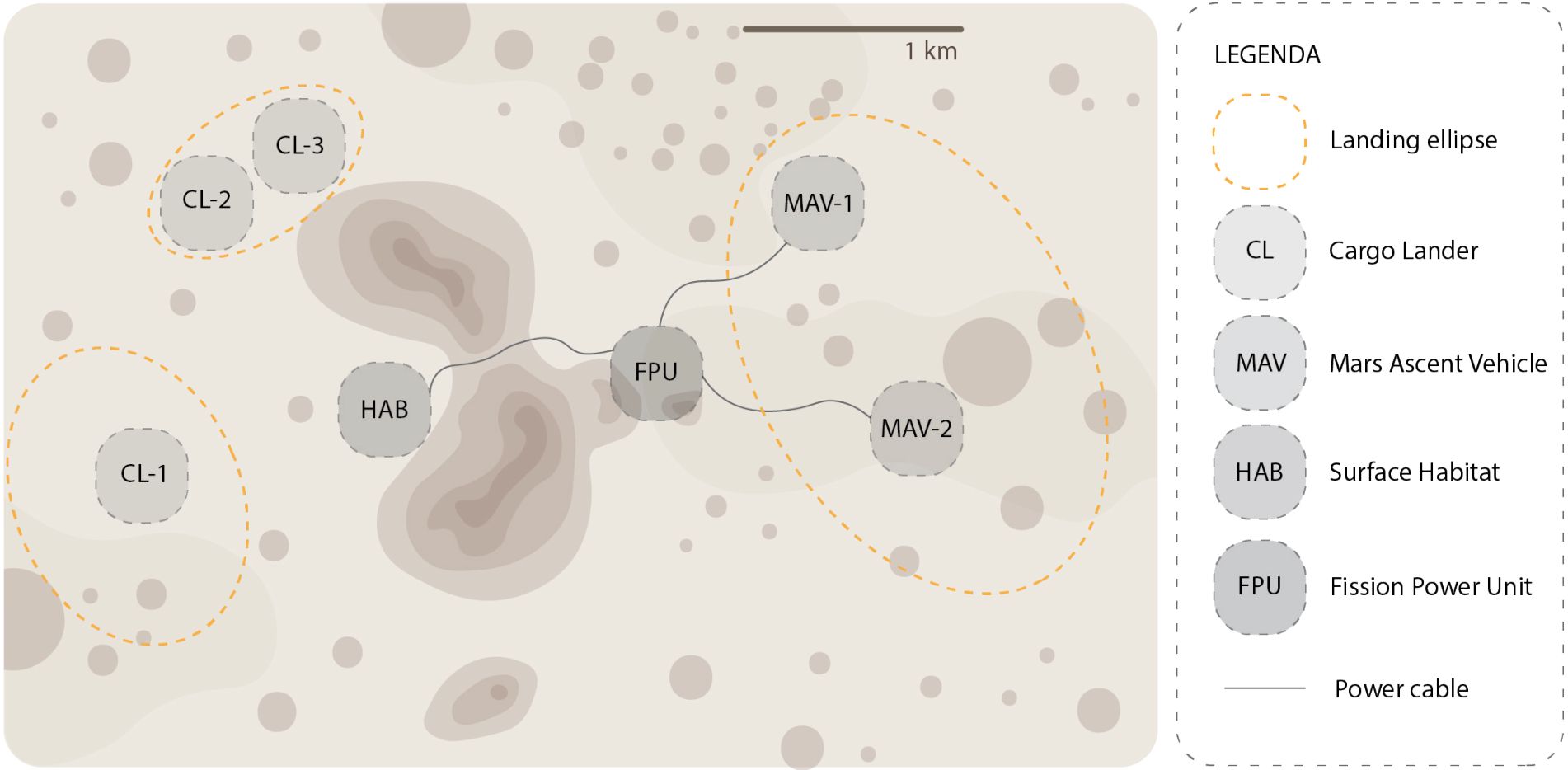
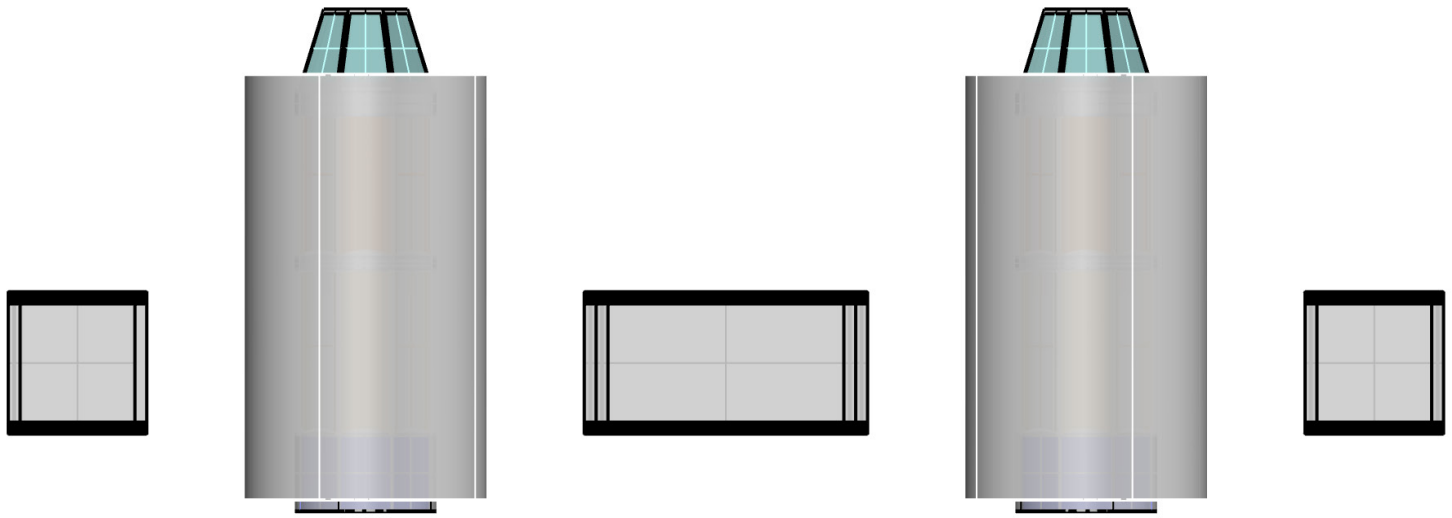


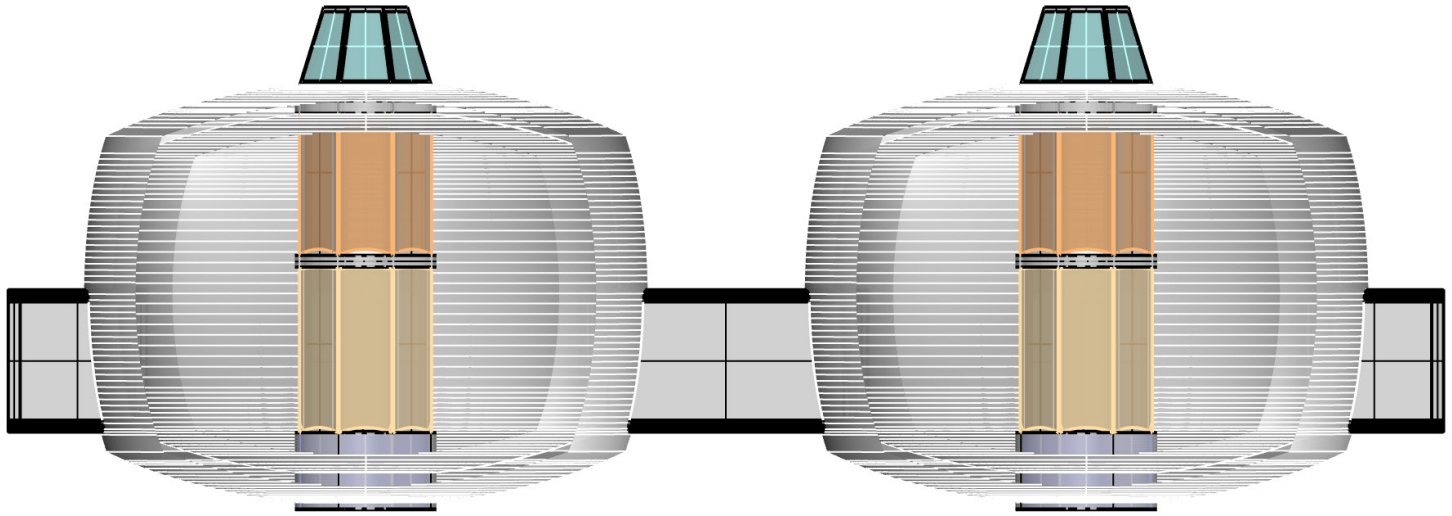
SITE PLANNING



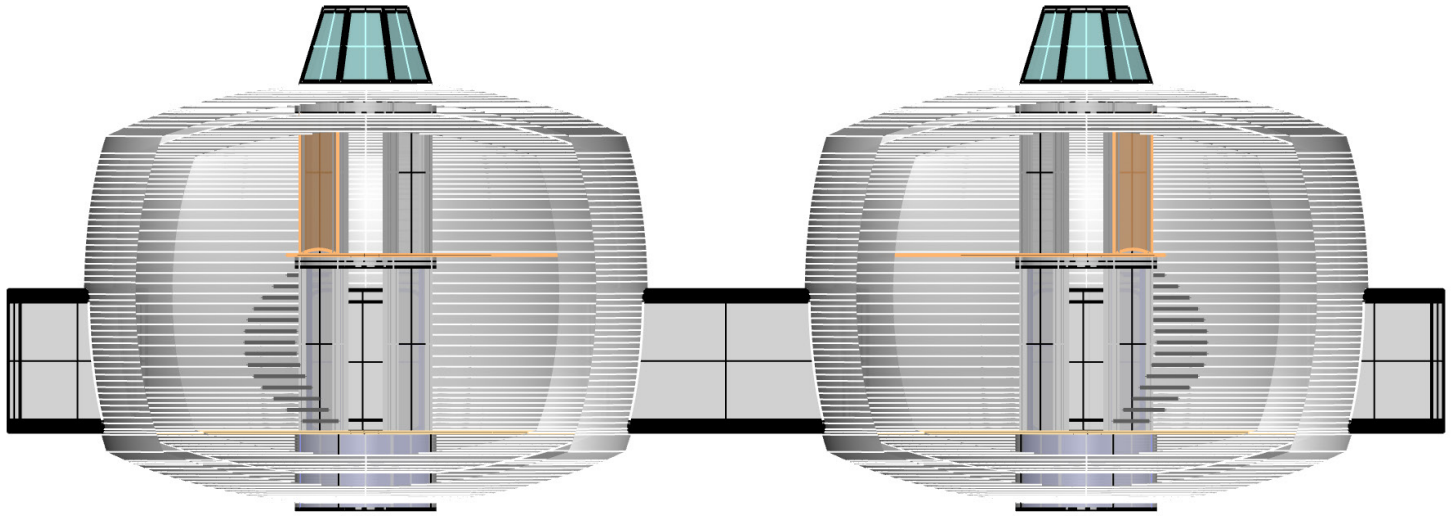
1. POSITION MODULES, CONNECT TO POWER SUPPLY



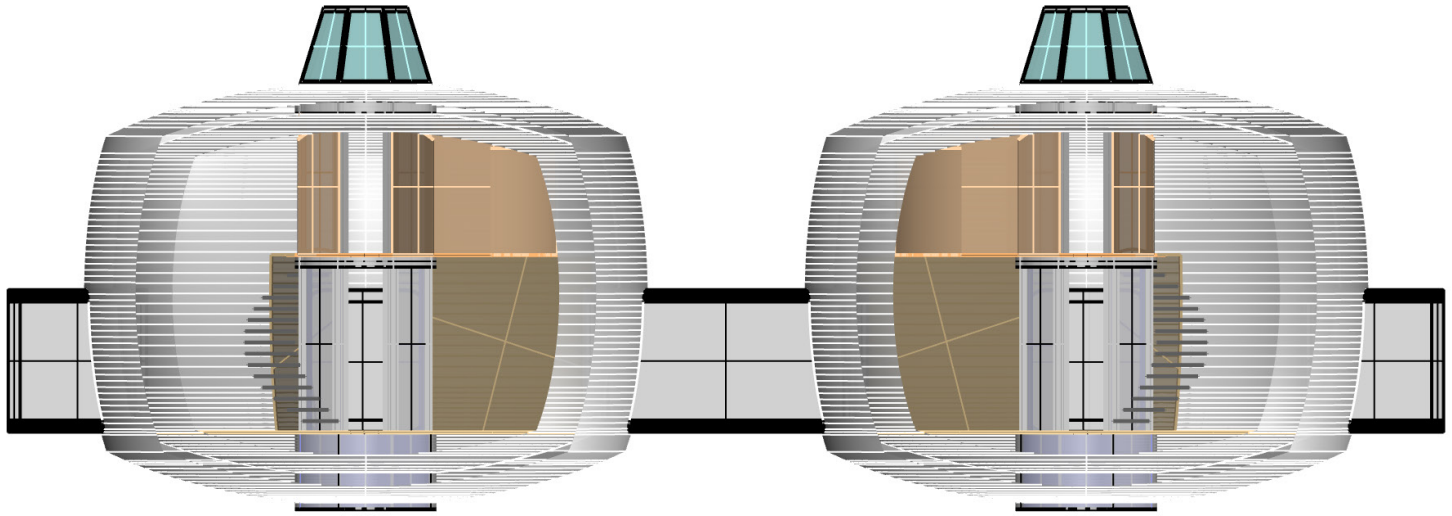
2. INFLATE DOMES, CONNECT MODULES THROUGH HATCHES



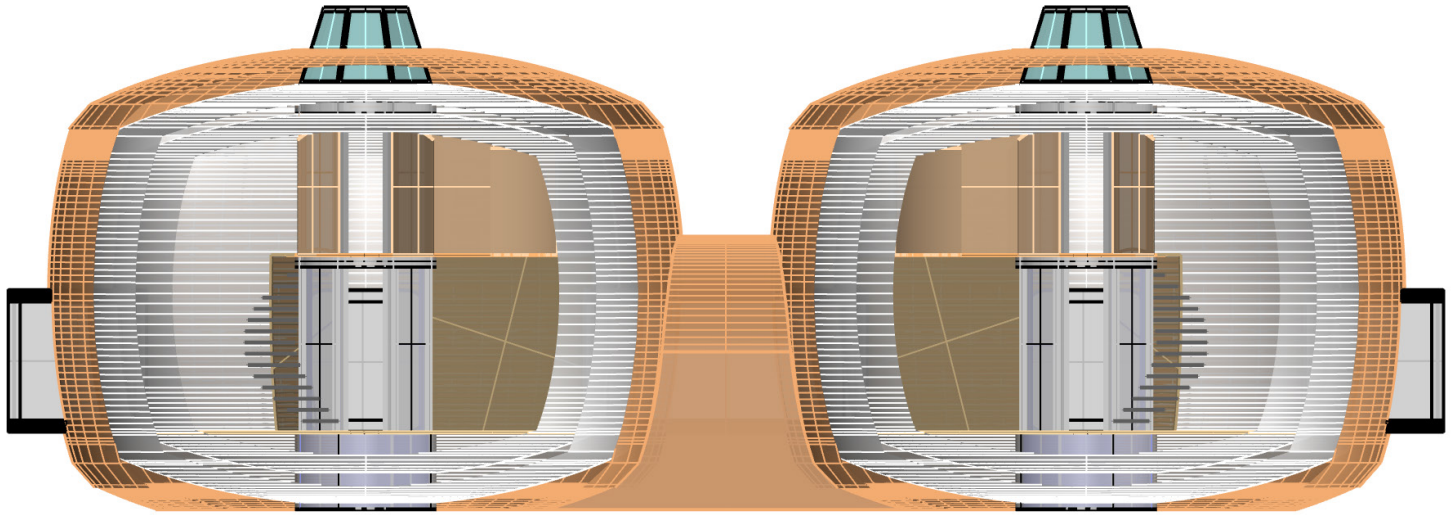
3. UNFOLDING OF FLOORS AND STAIRS, TEST EXTERIOR SYSTEMS



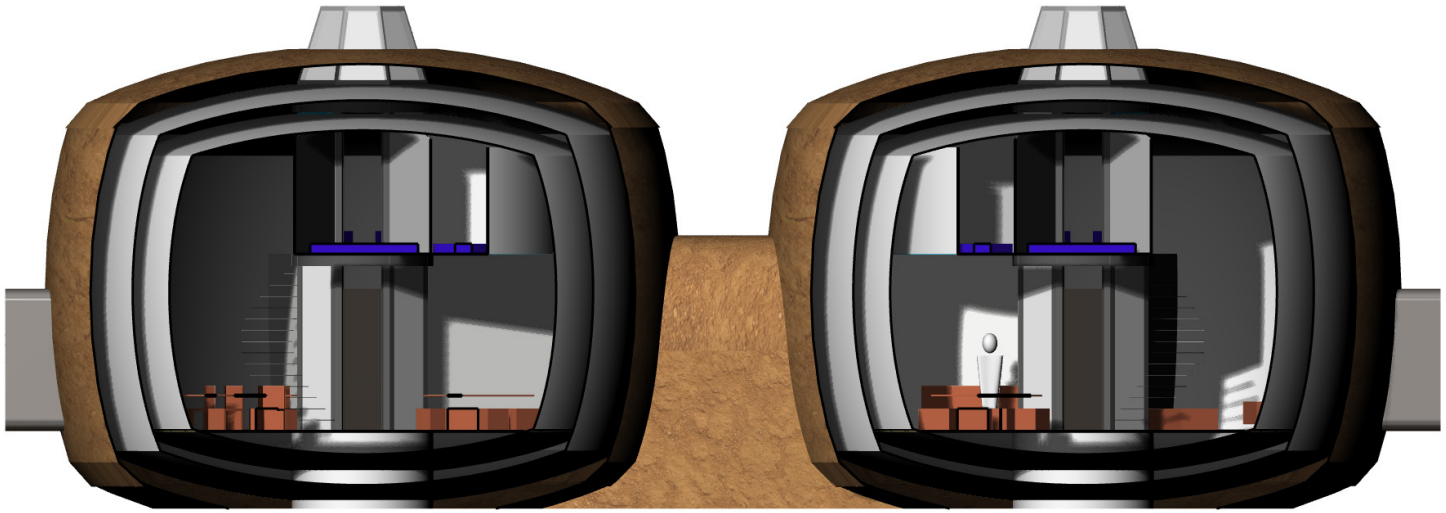
4. UNROLL SEPARATION WALLS, TEST INTERIOR SYSTEMS



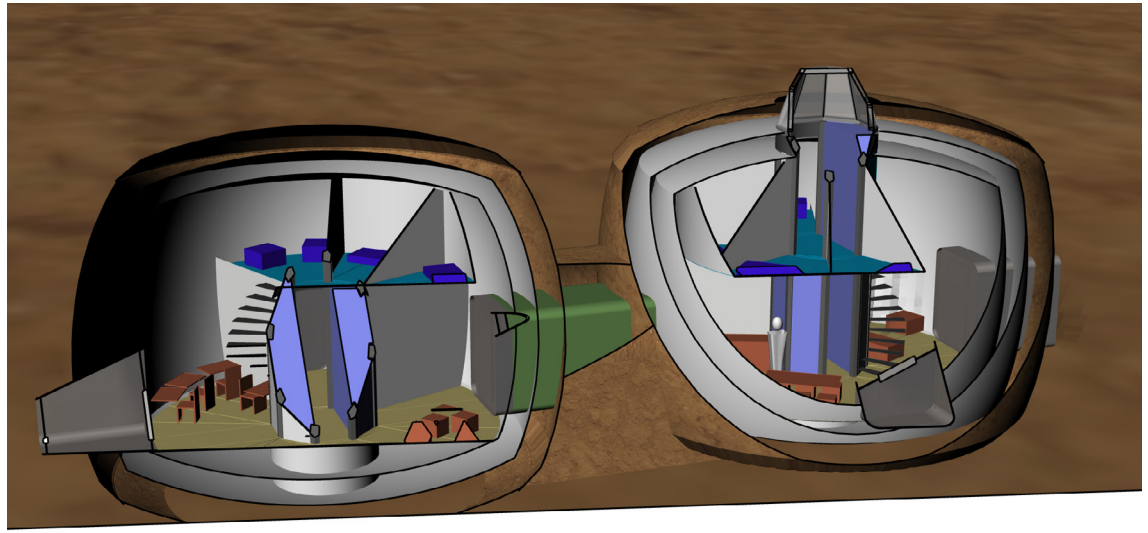
5. COVER WITH REGOLITH AND TEST FOR RADIATION SHIELDING



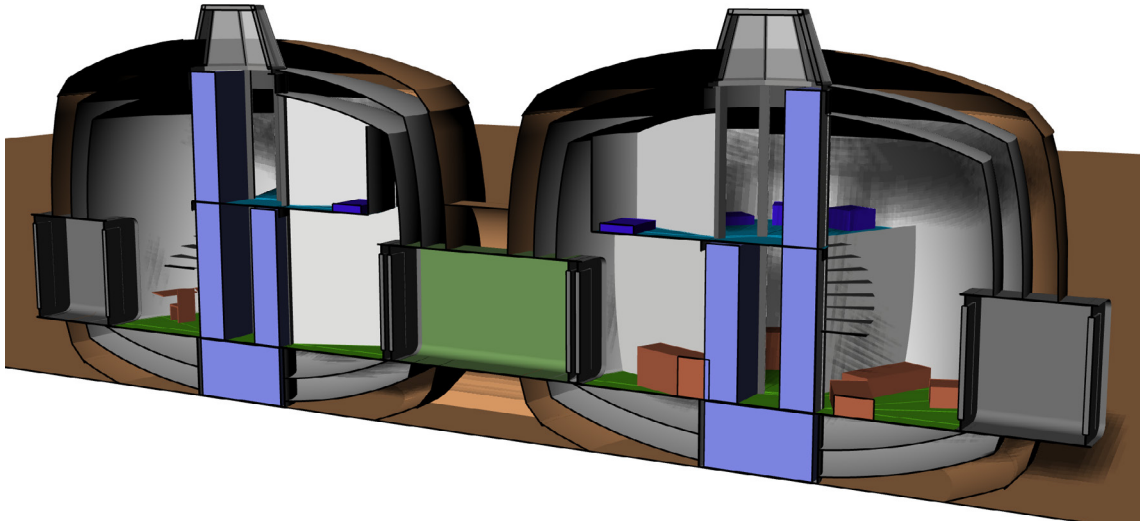
CONFIGURATION



ORGANIZATION



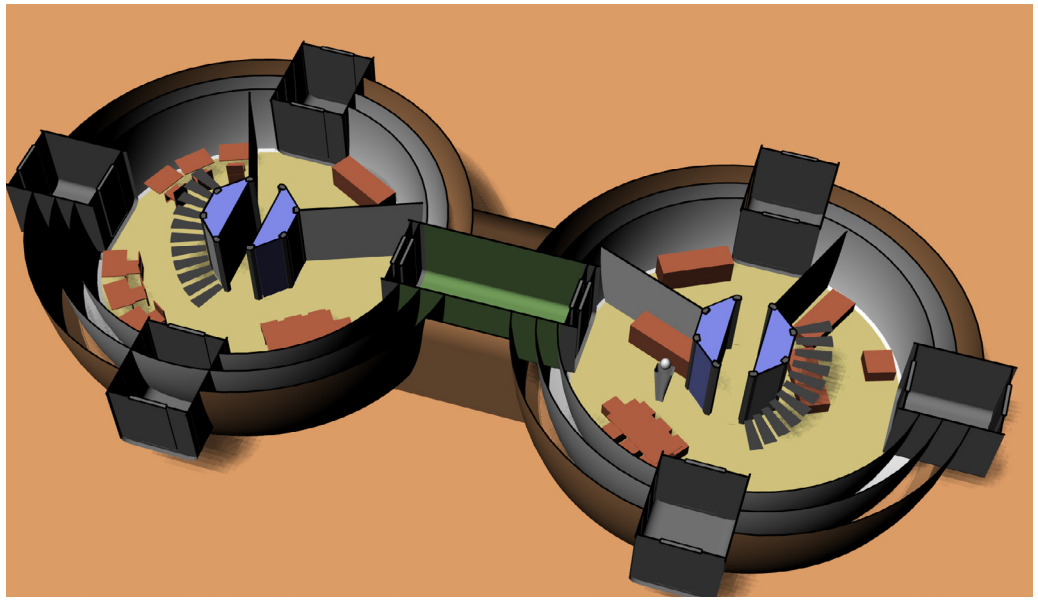
Technical Support Systems are integrated in the central module



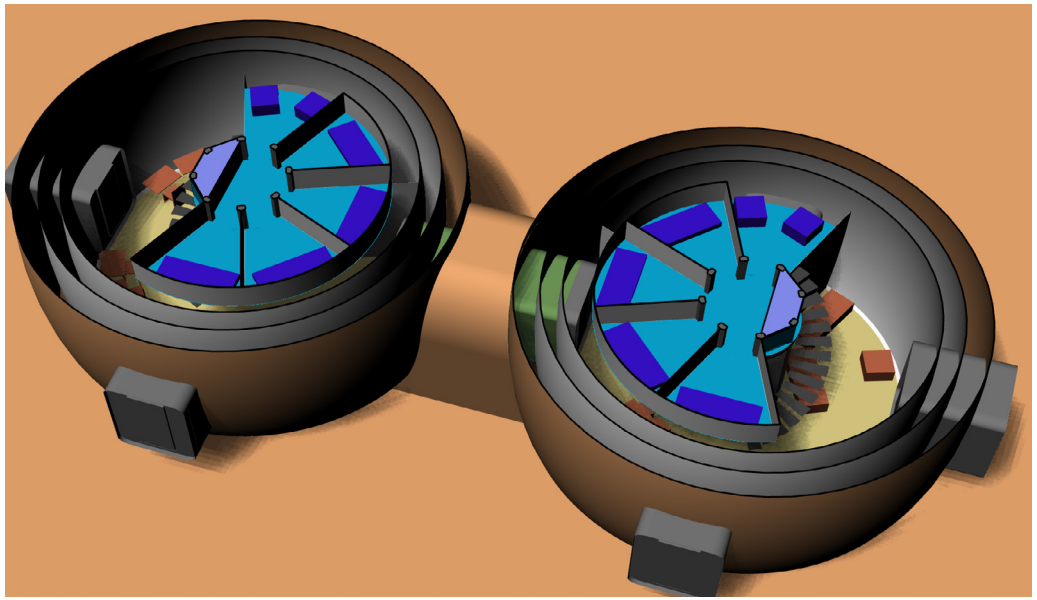
Greenhouse serves a double purpose as radiation storm shelter

ORGANIZATION

First floor

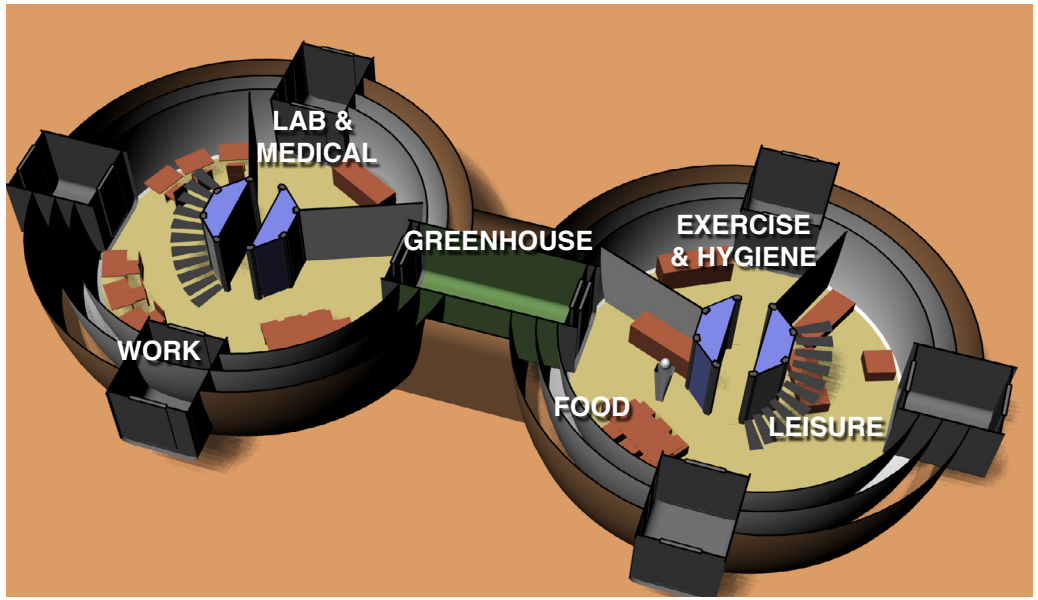


Second floor

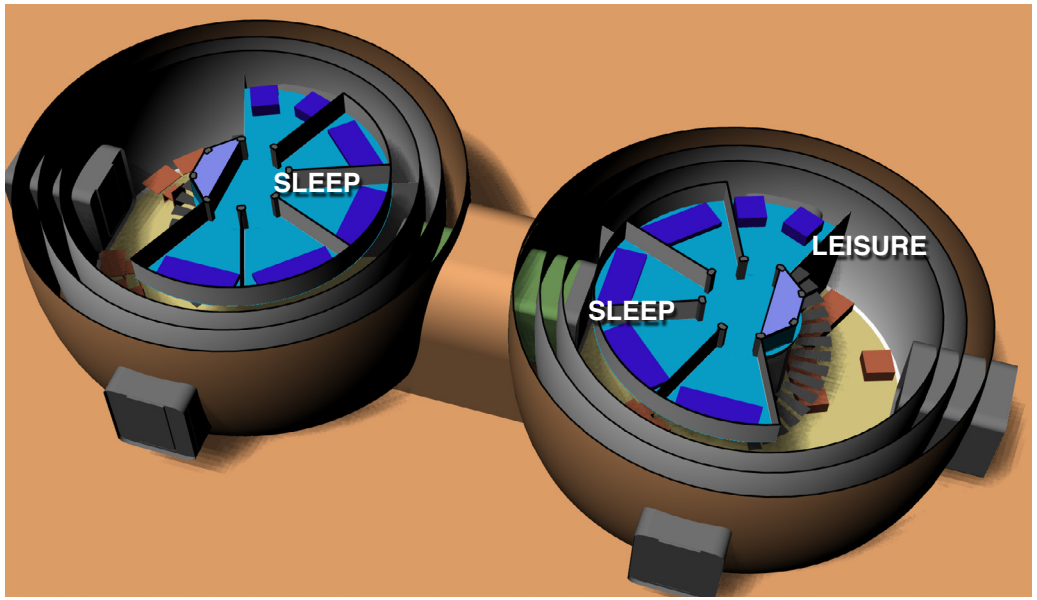


ORGANIZATION

First floor



Second floor



ORGANIZATION

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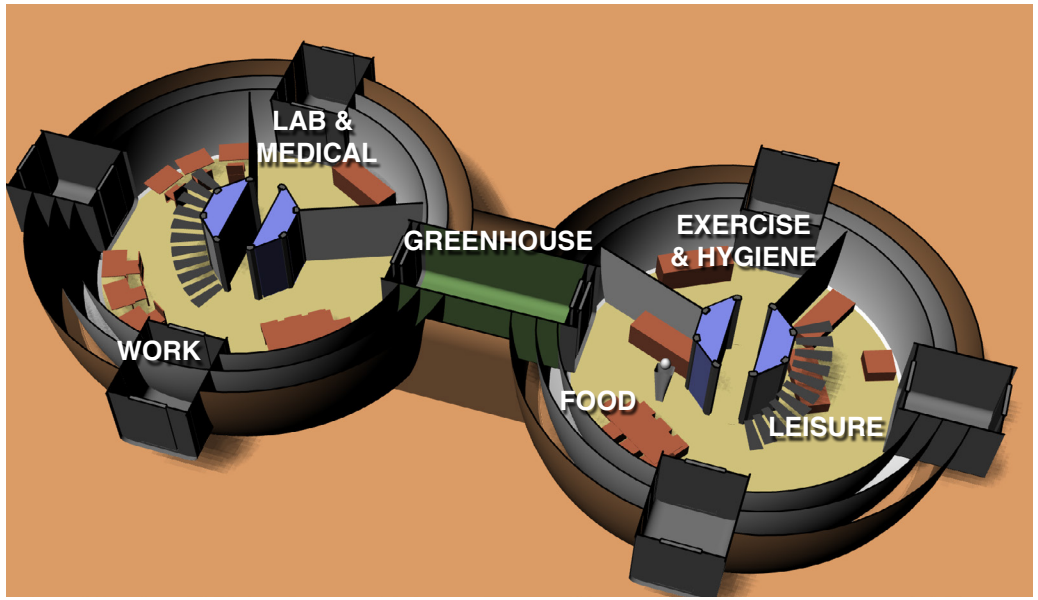
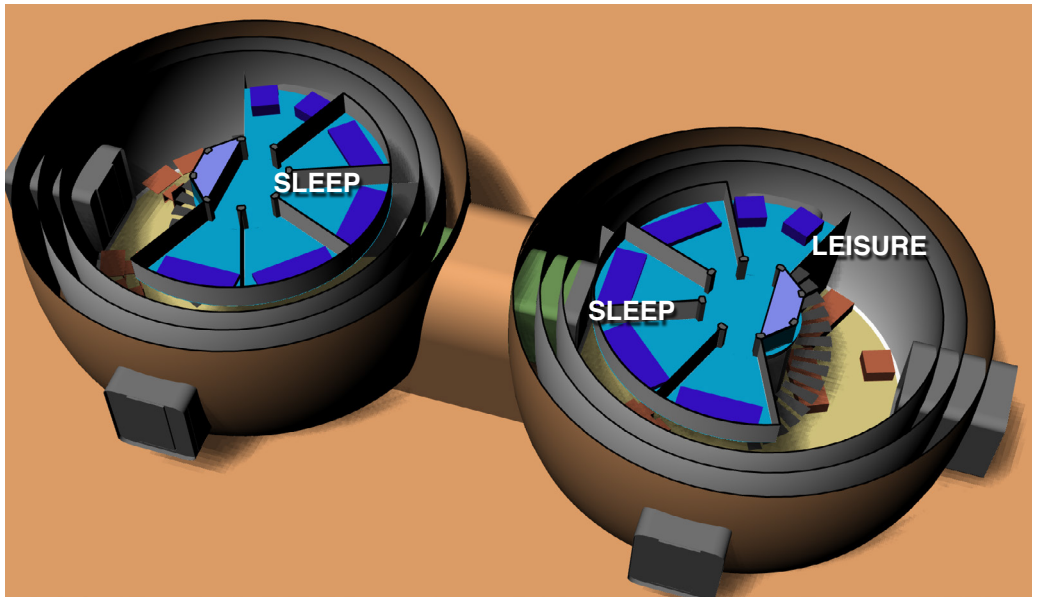
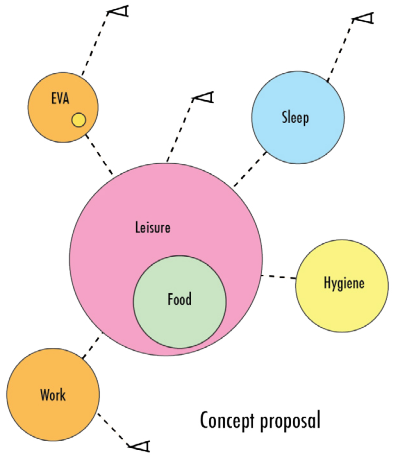
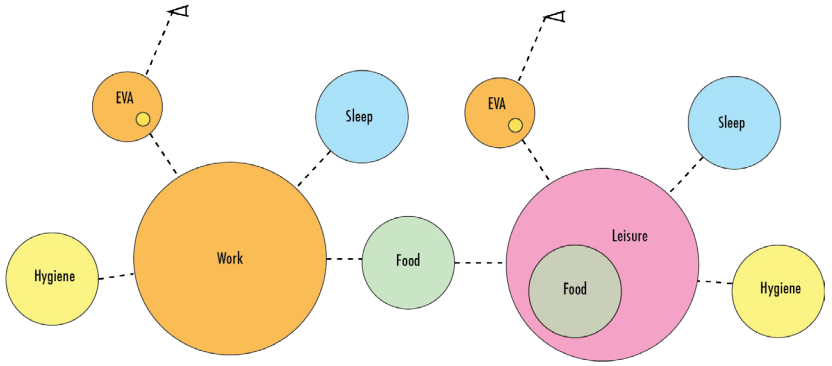


Second floor





Concept proposal

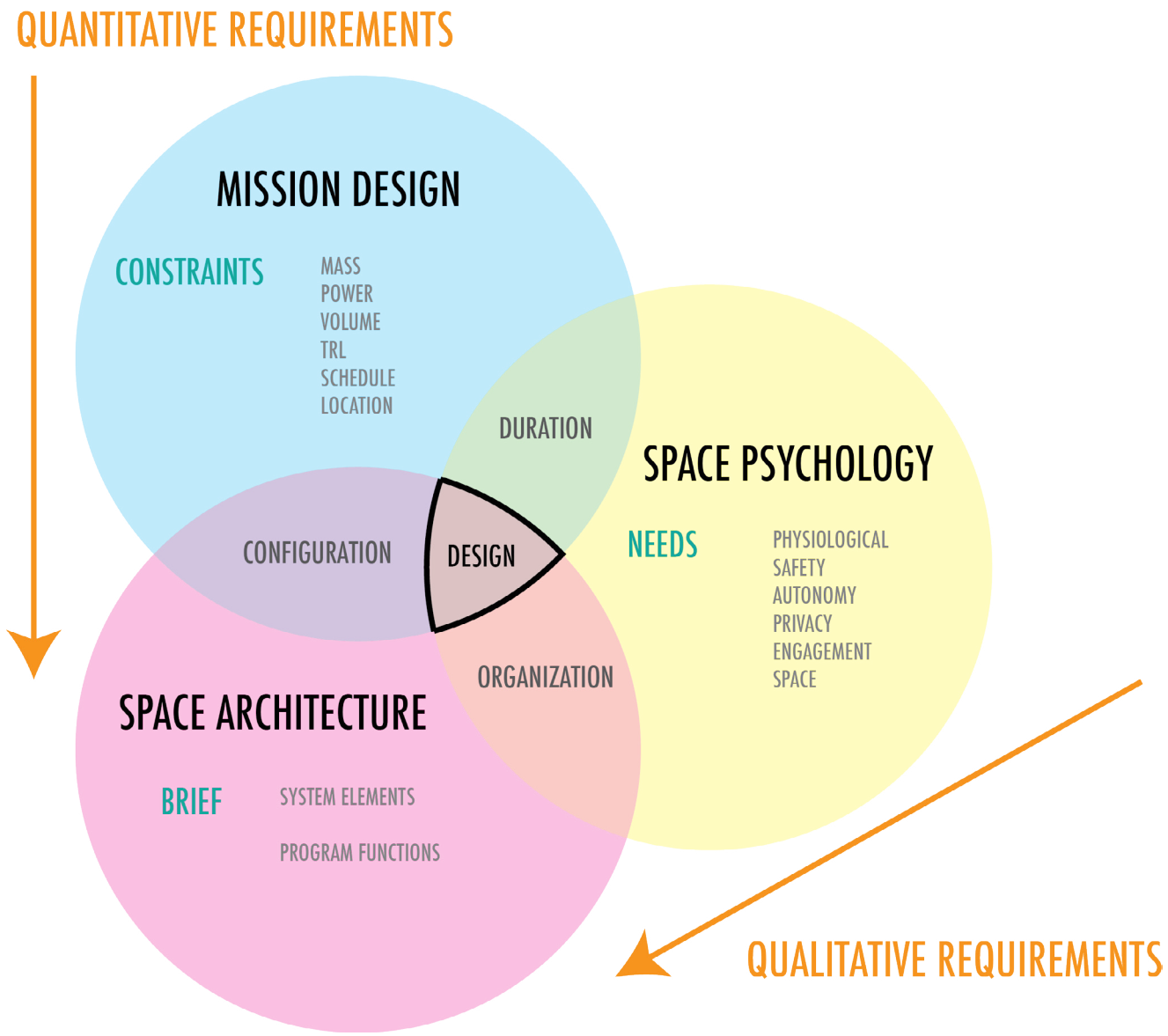


Concept design

07

CONCLUSION

SUMMARY OF FINDINGS



BASELINE PARAMETERS

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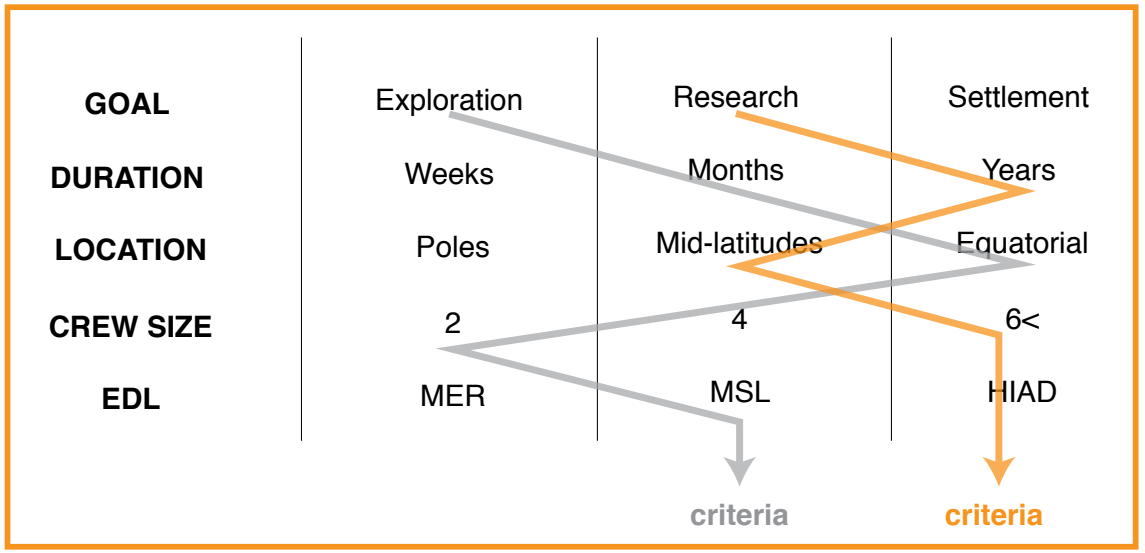

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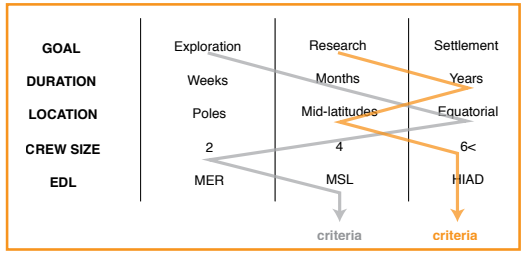
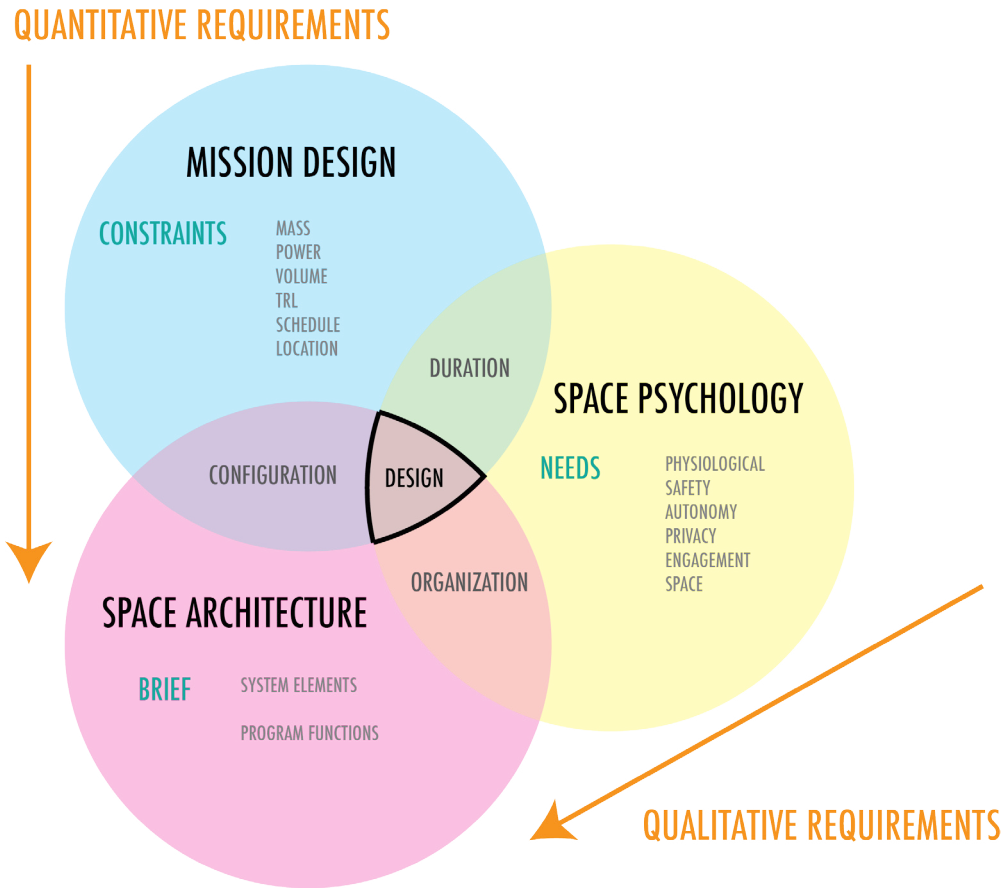




INTERDISCIPLINARY ITERATIVE PROCESS

Design Process

Establish Goals
Engineers | Mission Science | Client | Users

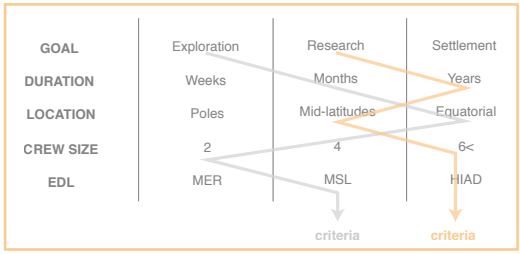
Collect & Analyse Data
Engineers | Architects | Researchers | Client | Users

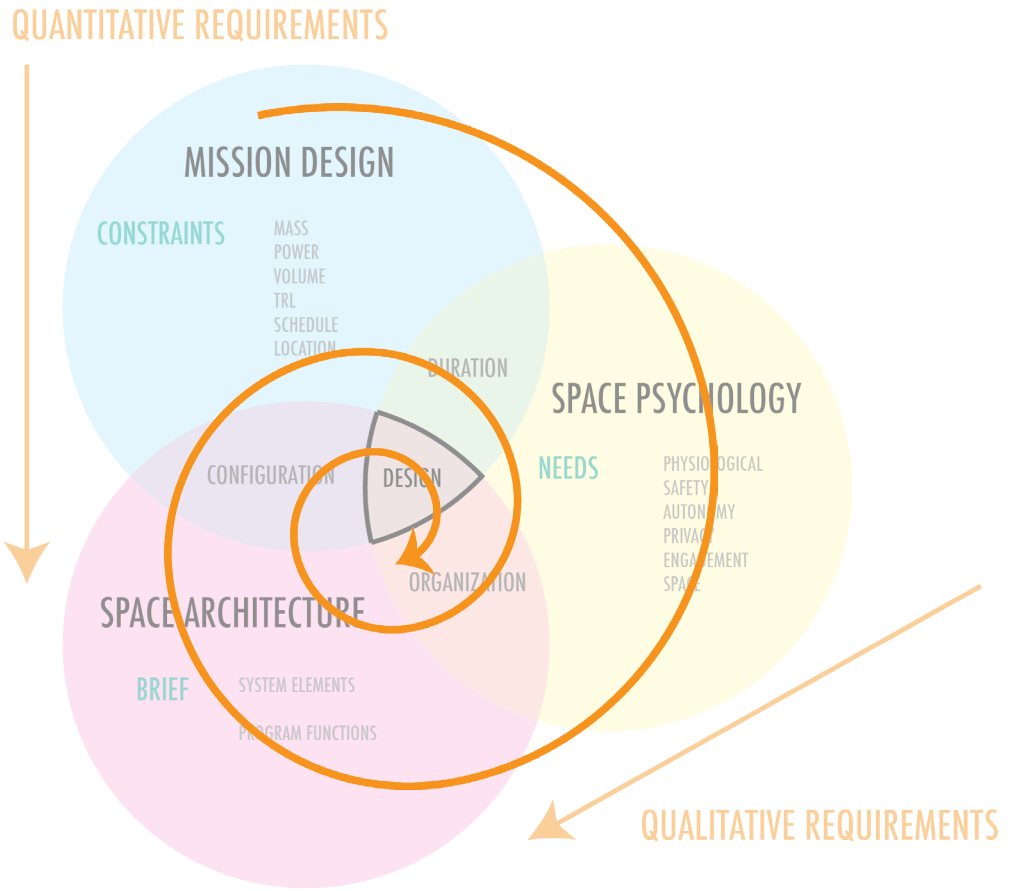
Determine Needs
Engineers | Architects | Client | Users | Mission Objectives

Test Concepts
Engineers | Architects | Arts | Life Sciences

Review Design

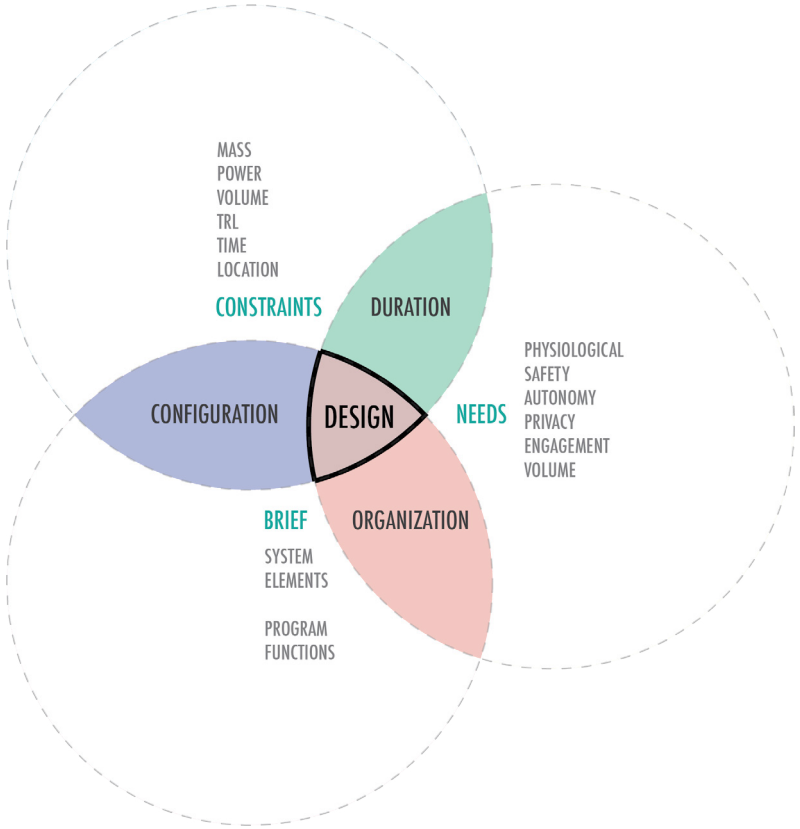
Final Design





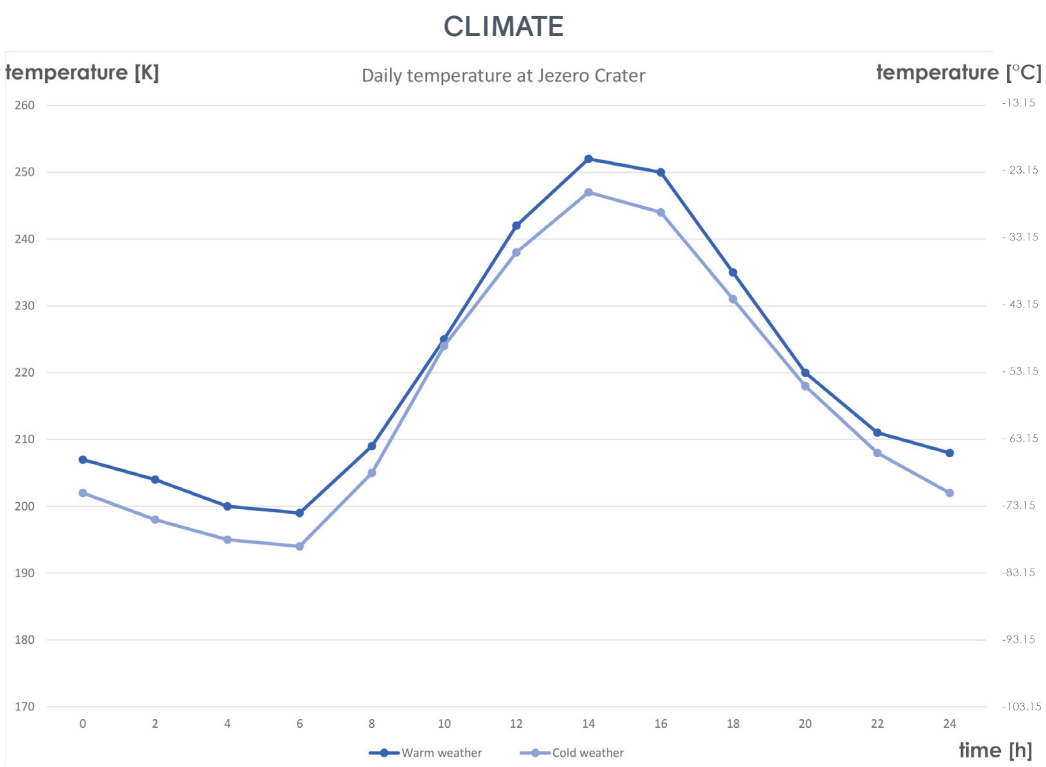
RECOMMENDATIONS

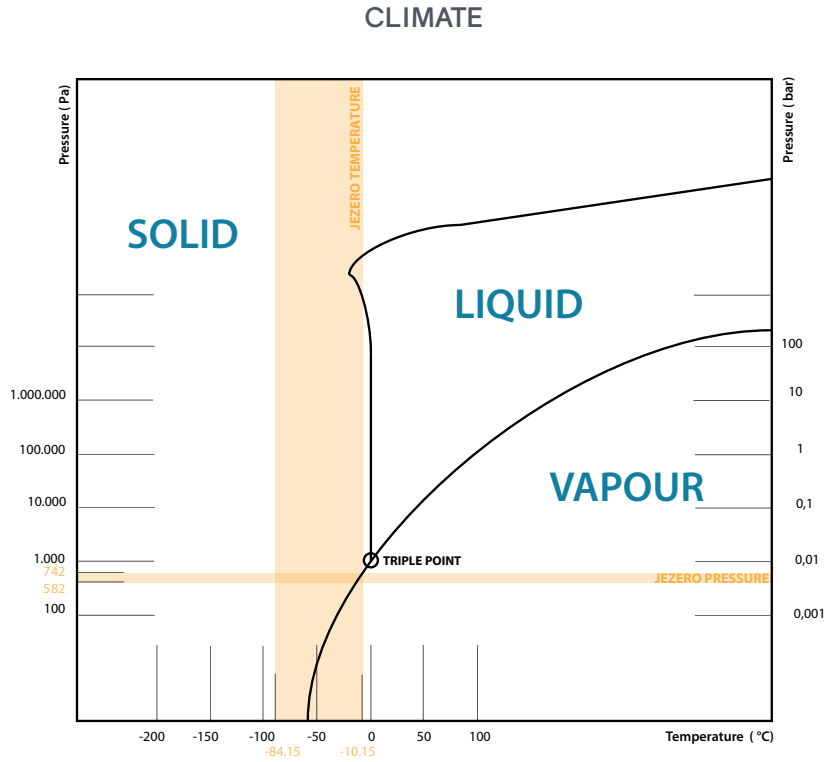
1. Framework applications
2. Radiation Shielding rule of thumb
3. Parametric optimization for overlapping functional volumes
4. Parametric optimization of volume irt mass
5. Design integration of functional systems:
   waterstorage as radiation shielding
6. Acoustical detailing



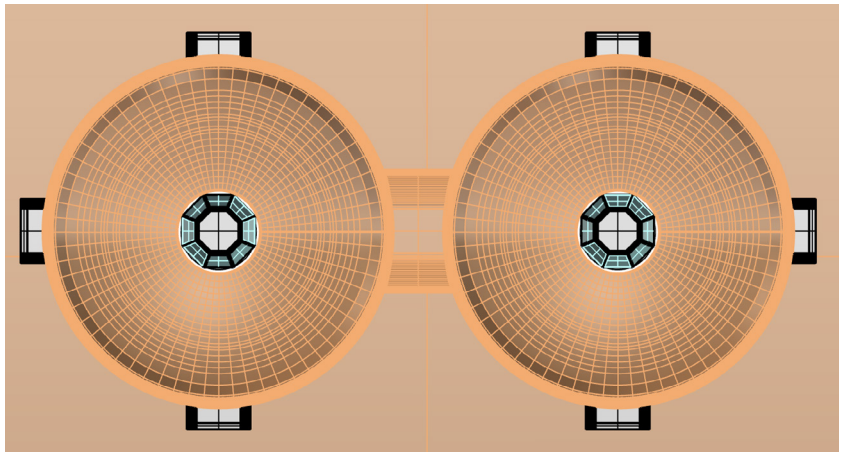
THANK YOU

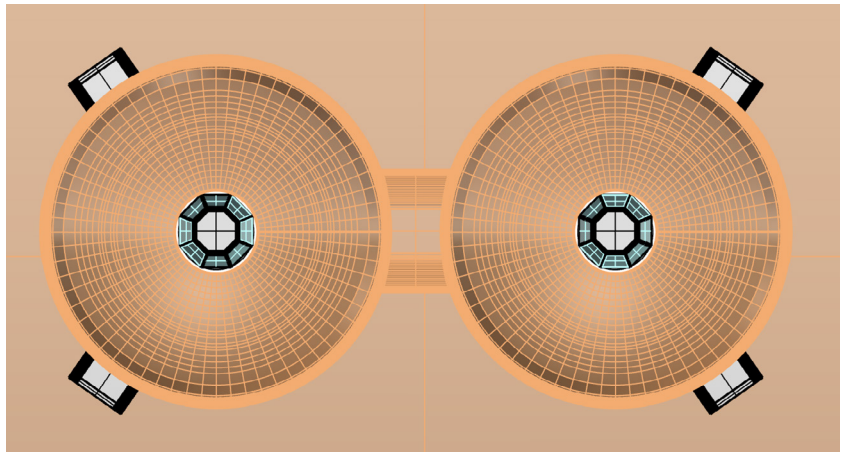
CLIMATE CONDITIONS AT JEZERO CRATER

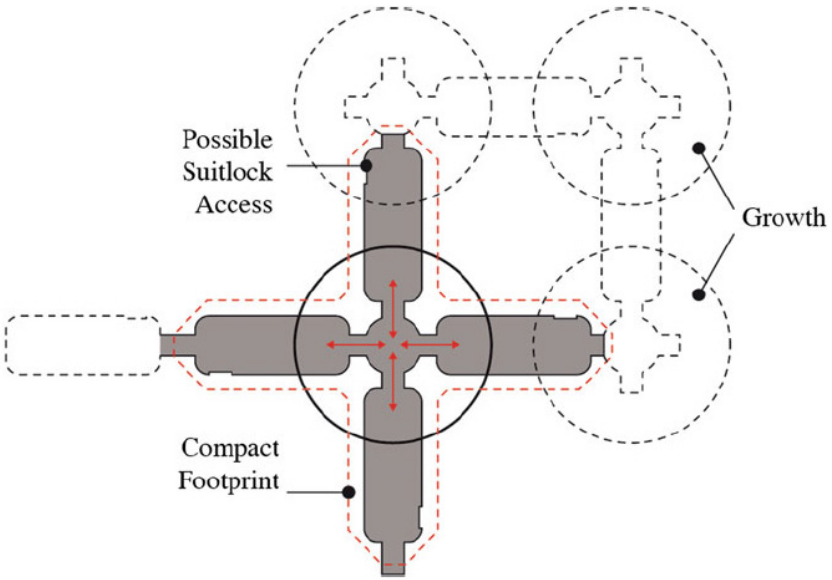


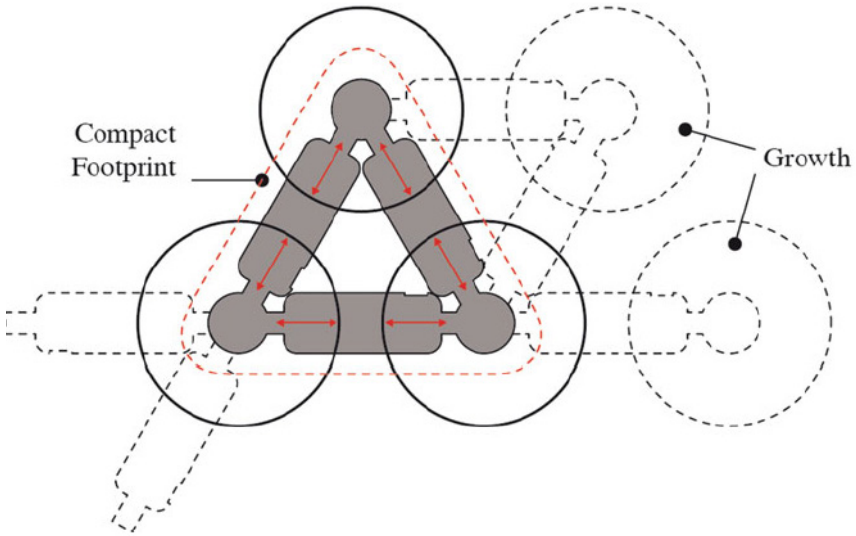


EVALUATION






Possible
Suitlock
Access
Growth
Compact
Footprint


Compact
Footprint
Growth

EVALUATION

Foldable floors drive radius, thus volume