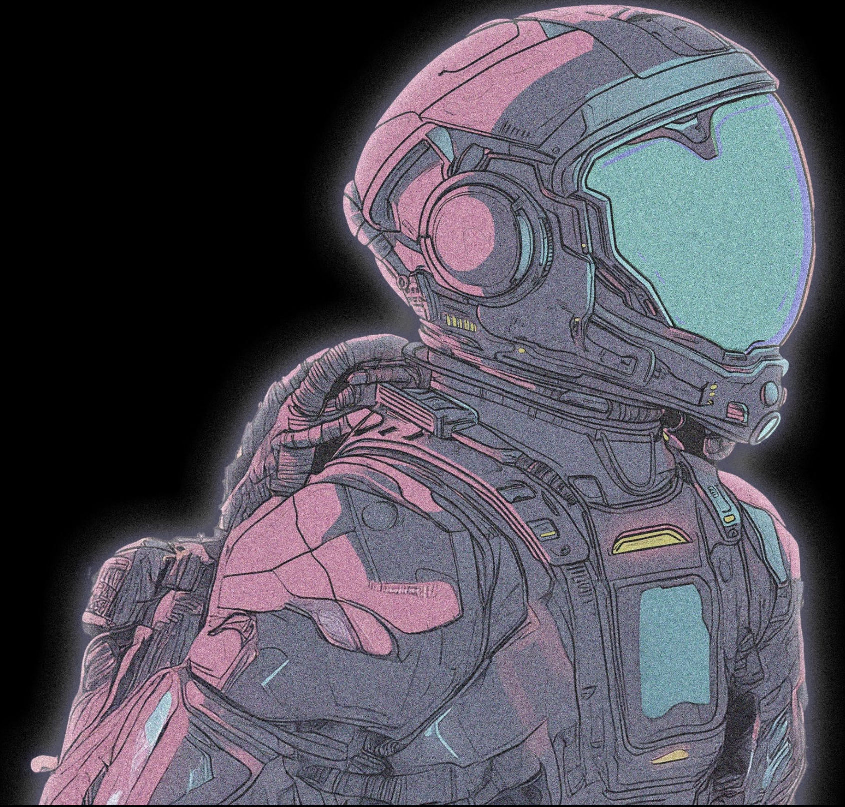
LUNAR PLAYSCAPE:

DESIGNING A CLIMBING-BASED HABITAT FOR DYNAMIC HUMAN BODY AND SPACE INTERACTION



living on the moon?

TO WORK?

TO PLAY?

TO COMMUNE?

LUNAR ARCHITECTURE & INFRASTRUCTURE

JONATHAN JONATHAN | P4 PRESENTATION
GRADUATION PROJECT 2024-2025 TU DELFT BK
TUTORS: HENRIETTE BIER, FERRY ADEMA, ARWIN HIDDING

moon exploration

IN THE PAST

tasks intensive missions

11

PERFORMED LUNAR LANDING AND RETURN TO EARTH
(NATIONAL GOAL BY PRESIDENT KENNEDY)

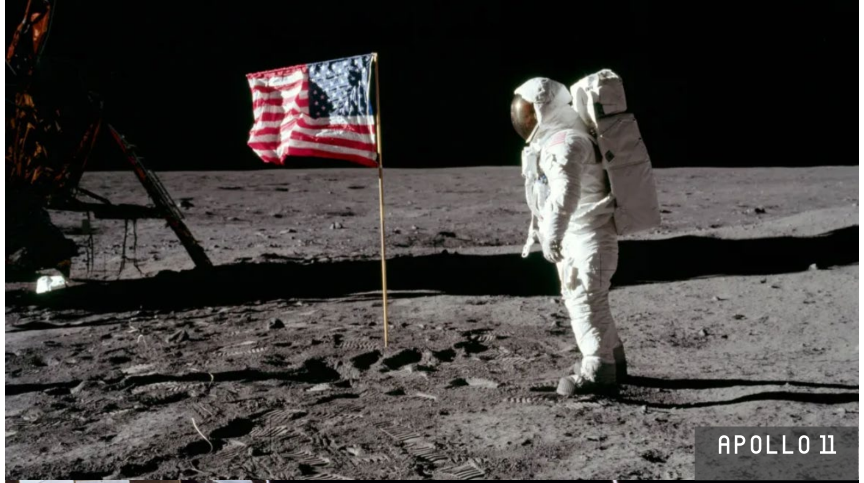
12

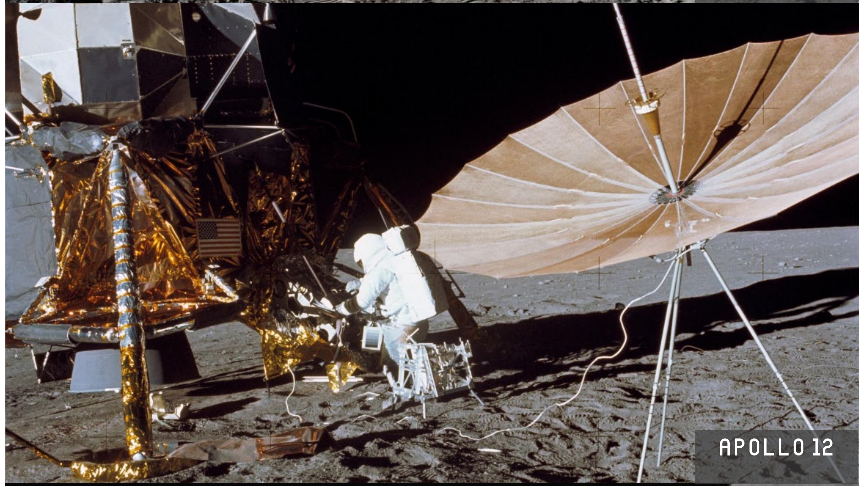
LUNAR EXPLORATION TASKS BY THE LUNAR MODULE,
DEPLOYMENT OF THE APOLLO LUNAR SURFACE EXPERIMENTS PACKAGE,

17

GEOLOGICAL SURVEYING AND SAMPLING OF MATERIALS, DEPLOYING AND ACTIVATING SURFACE EXPERIMENTS, CONDUCTING IN-FLIGHT EXPERIMENTS AND PHOTOGRAPHIC TASKS DURING LUNAR ORBIT AND TRANS-EARTH COAST,

SOURCE: NASA.GOV

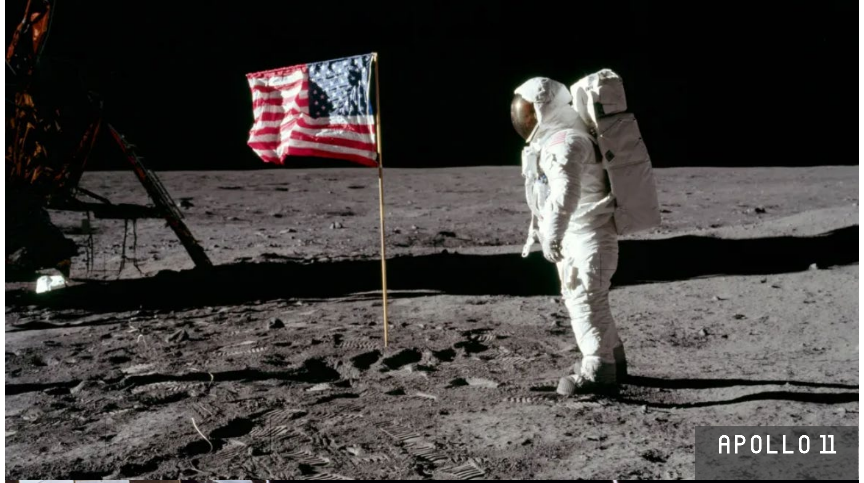

APOLLO 11


APOLLO 12

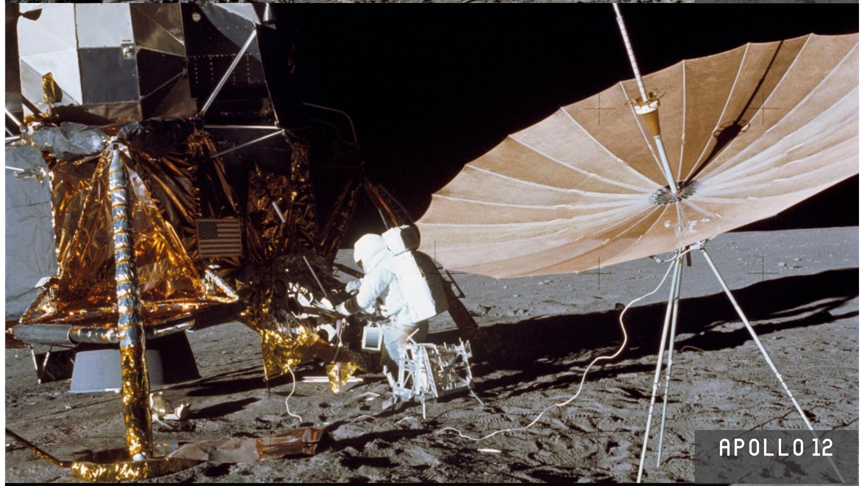

APOLLO 17

NUMEROUS SECONDARY TASKS

DEPLOYMENT OF A TELEVISION CAMERA TO TRANSMIT SIGNALS TO EARTH, DEPLOYMENT OF A SOLAR WIND, SEISMIC EXPERIMENT PACKAGE AND A LASER RANGING RETROREFLECTOR, GATHER SAMPLES OF LUNAR-SURFACE MATERIALS, PHOTOGRAPH THE LUNAR TERRAIN, DEPLOYED SCIENTIFIC EQUIPMENT, LUNAR MODULE SPACECRAFT



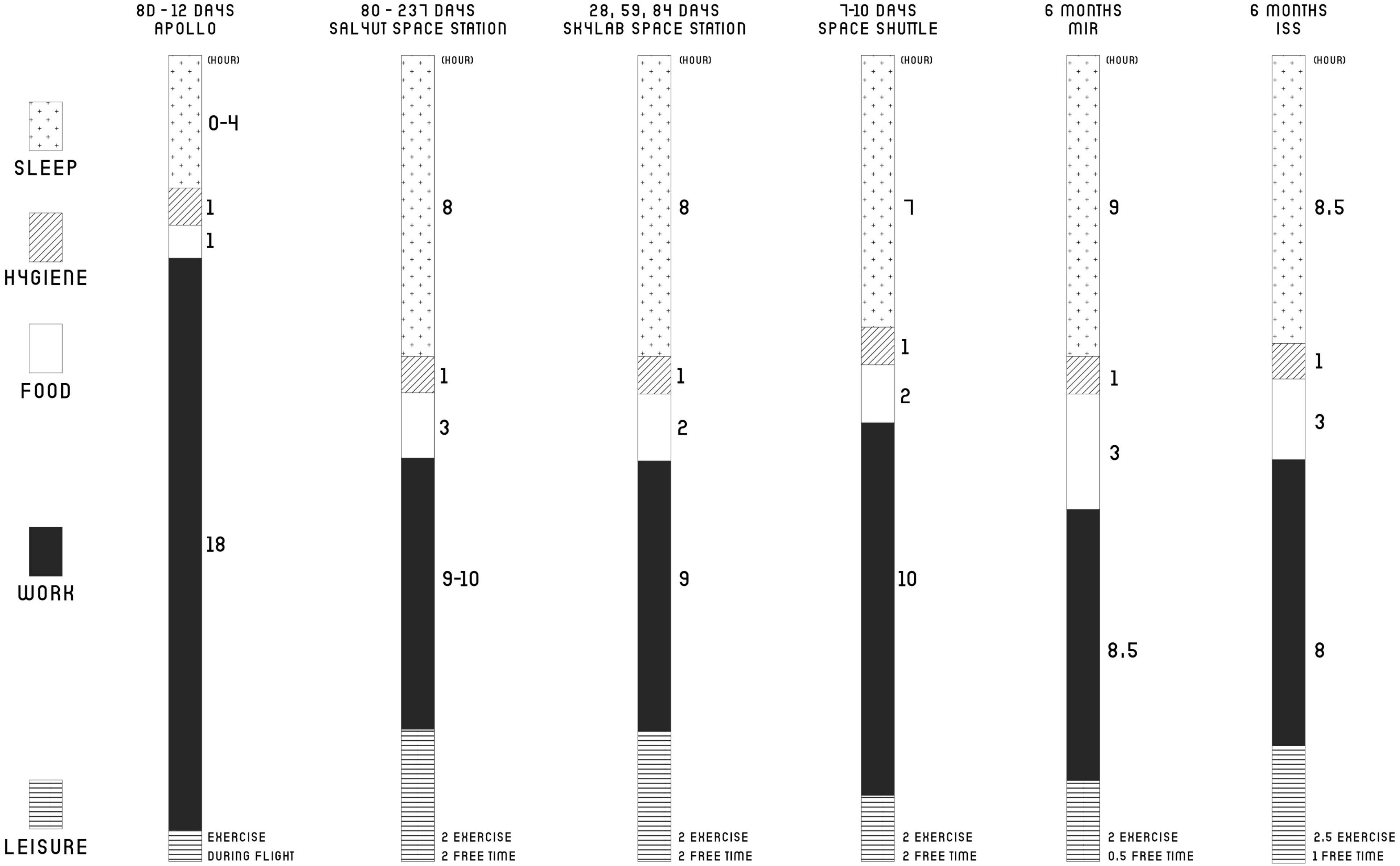
SELENOLOGICAL INSPECTION, SURVEYS AND SAMPLINGS IN LANDING AREAS, DEVELOPMENT FOT PRECISION-LANDING CAPABILITIES, FURTHER EVALUATIONS OF WORKING FOR LONG PERIOD, DEPLOYMENT AND RETRIEVAL OF OTHER SCIENTIFIC EXPERIMENTS, PHOTOGRAPHY OF CANDIDATE EXPLORATION SITES FOR FUTURE MISSIONS



DEPLOYED EXPERIMENTS SUCH AS APOLLO LUNAR SURFACE EXPERIMENTS PACKAGE, WITH A HEAT FLOW EXPERIMENT, LUNAR SEISMIC PROFILING, LUNAR SURFACE GRAVIMETER, LUNAR ATMOSPHERIC COMPOSITION EXPERIMENT, LUNAR EJECTA AND METEORITES, LUNAR SAMPLING AND LUNAR ORBITAL EXPERIMENTS

SOURCE: NASA.GOV

RESEARCH BACKGROUND | ACTIVITIES DISTRIBUTION

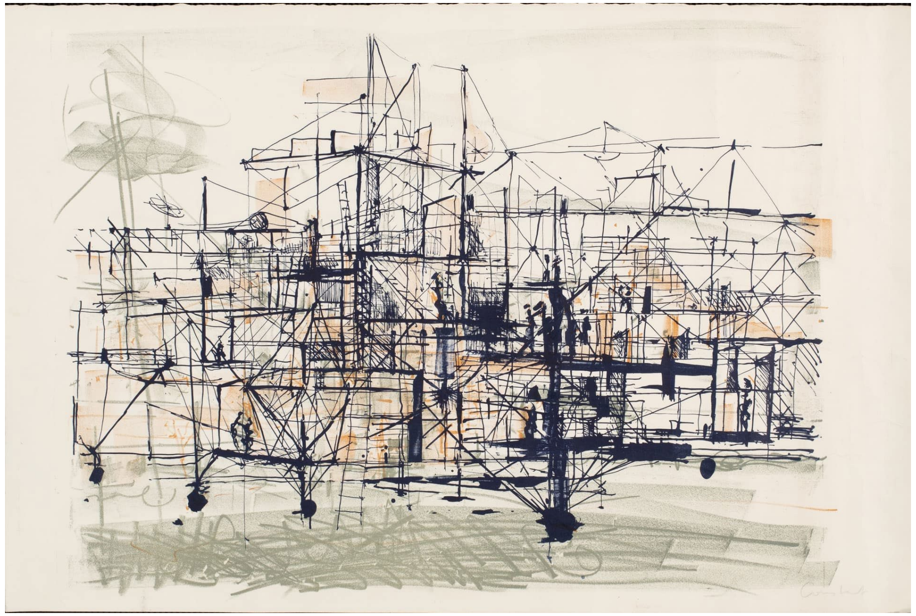


SOURCE: ARCHITECTURE FOR ASTRONAUTS (BOOK) short term missions

vs

long term habitation

human's playing nature



SOURCE: NIEUWE INSTITUUT

NEW BABYLON BY CONSTANT

CHARLES DUKE FROM APOLLO 16 SAID:

"TOWARDS THE END OF OUR STAY,

WE GOT EXCITED AND WE WERE GOING TO DO THE HIGH JUMP,

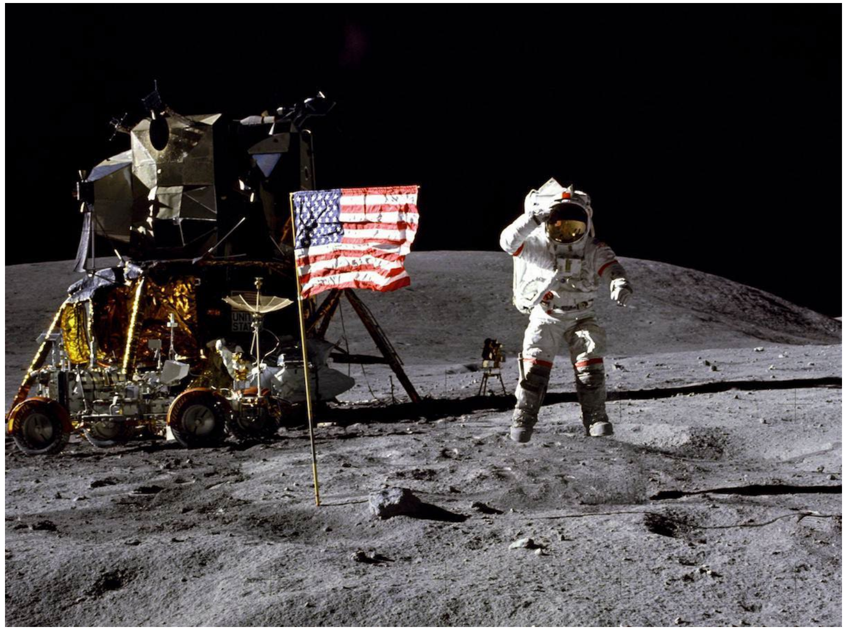
AND I JUMPED AND FELL OVER BACKWARDS.
THAT WAS A SCARY TIME,
BECAUSE IF THE BACKPACK GOT BROKEN,
I WOULD HAVE HAD IT."

BUILDING HABITATS ON THE MOON P.248

human's playing nature

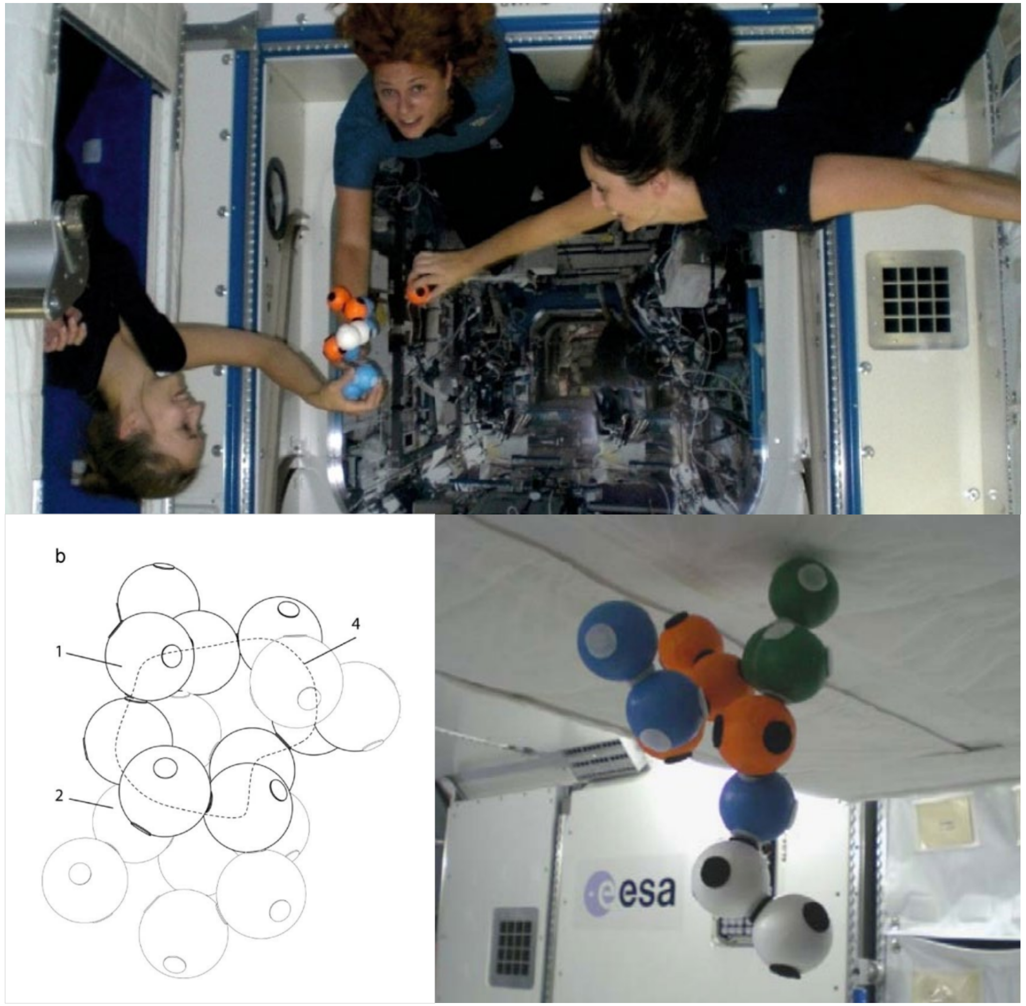
ALAN SHEPARD (AP14)
GOLF ON THE MOON

DAVID SCOTT (AP15)
HAMMER AND FEATHER



SOURCE: NASA.GOV

JOHN YOUNG (AP16)
MID-AIR SALUTE PHOTO



GAME FOR SPACE PROTOTYPE TESTED AT ISS

SOURCE: S. HAUPLIK-MEUSBURGER, ET AL., A GAME FOR SPACE, ACTA ASTRONAUTICA (2009), DOI: ''10.1016/J.ACTAASTRO.2009.07.017

current leisure situation

``SUBJECTED TO HIGH WORKLOADS UNDER A TIGHT SCHEDULE WITHIN A CONFINED ENVIRONMENT, ASTRONAUTS HAVE DRAWN ON **LEISURE ACTIVITIES IMPORTED MOSTLY FROM EARTH. POPULAR LEISURE ACTIVITIES DOCUMENTED TO-DATE HAVE CONCENTRATED ON PASSIVE PERUSAL OF MEDIA** LIKE RECORDS, AUDIO CASSETTES, NEWSPAPER, LETTERS, BOOKS, MAGAZINES, TELEVISION, AND MOVIES''

ARCHITECTURE FOR ASTRONAUTS P.281

LUNAR PLAYSCAPE → REIMAGINES THE LIFESTYLE / ACTIVITIES

physical requirement

and

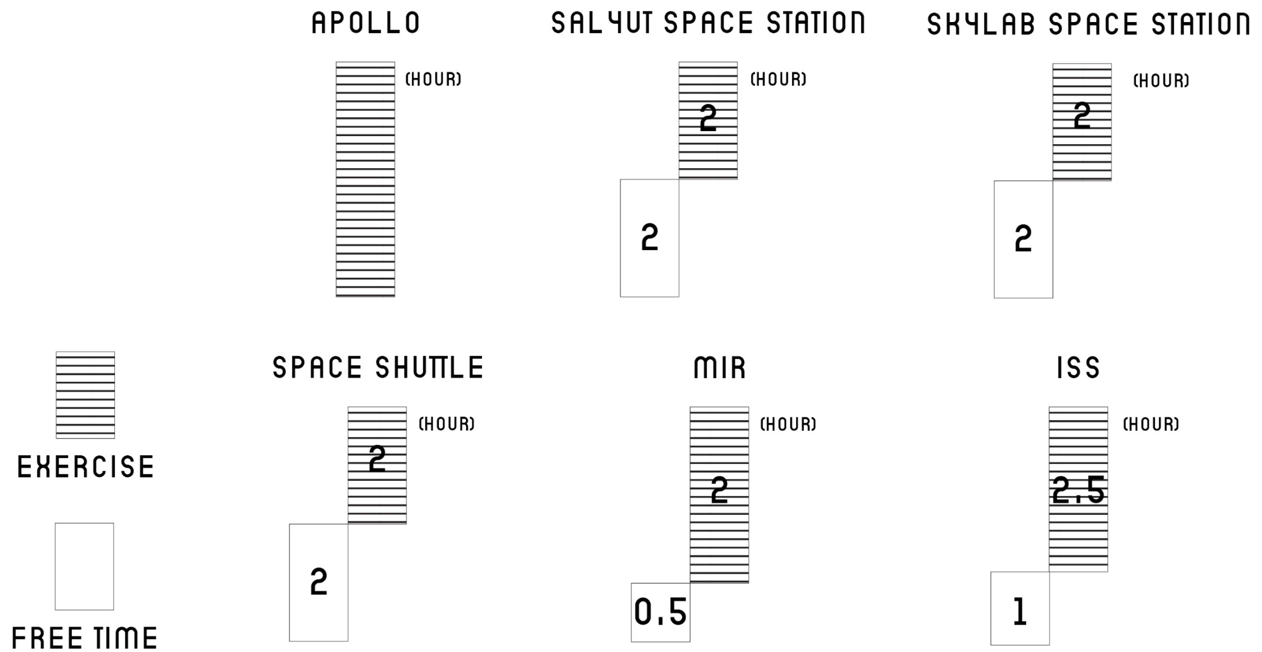
social requirement

1. physical

LONG-TERM HABITATION
IN
LOW LUNAR GRAVITY

AFFECTS

BODY STRUCTURE
MUSCLE & BONE DENSITY



PREVIOUS MISSIONS: AVE. 2-HR DAILY WORK OUT

SOURCE: ARCHITECTURE FOR ASTRONAUTS (BOOK)

NEW WAY OF EXERCISING -> DISTRIBUTING WORK OUT

HAVING BREAKFAST
GOING TO MEETING

SITTING IN LUNCH LECTURE
HAVING SOCIAL EVENING

GOING TO GYM
HEADING HOME

"...I DO GET A **SENSE OF SATISFACTION FROM WORKING OUT** ... EXERCISE IS NOT ONLY A CRITICAL PHYSICAL COMPONENT ... IT HAS **AN IMPORTANT PSYCHOLOGICAL COMPONENT** TOO."
-PEGGY WHITSON, ISS-

"I COULD REALLY RUN [IN PLACE] AT DIFFERENT SPEEDS AND FOR **LONG DURATIONS**, AND THAT'S THE WAY I DID ALL MY EXERCISE."
-GENE CERNAN, APOLLO 17-

"I HATE OUR EXERCISES ...
BORING AND MONOTONOUS, AND HEAVY WORK ..."
-VALERY RYUMIN, SALYUT-

"SOMETIMES IT IS VERY HARD TO FORCE YOURSELF TO DO. WE LIKE THE TREADMILL THE MOST, BECAUSE **WE CAN DO SUCH A VARIETY OF EXERCISES ON IT**. IN FACT, WE'VE EVEN **MADE UP SOME NEW EXERCISES OF OUR OWN.**"
-LEBEDEV, SALYUT-

ARCHITECTURE FOR ASTRONAUTS (BOOK)


TREADMILLING IN THE MIR SPACE STATION
(SAMANTHA CRISTOFORETTI, ESA)

2. social

INCREASING MOONERS POPULATION

LEADS TO

A QUERY IN COMMUNITY CREATION

SPACE STATION WARDROOM TABLE FOR SKYLAB, AMERICA'S FIRST EXPERIMENTAL SPACE STATION

SOURCE: NASA

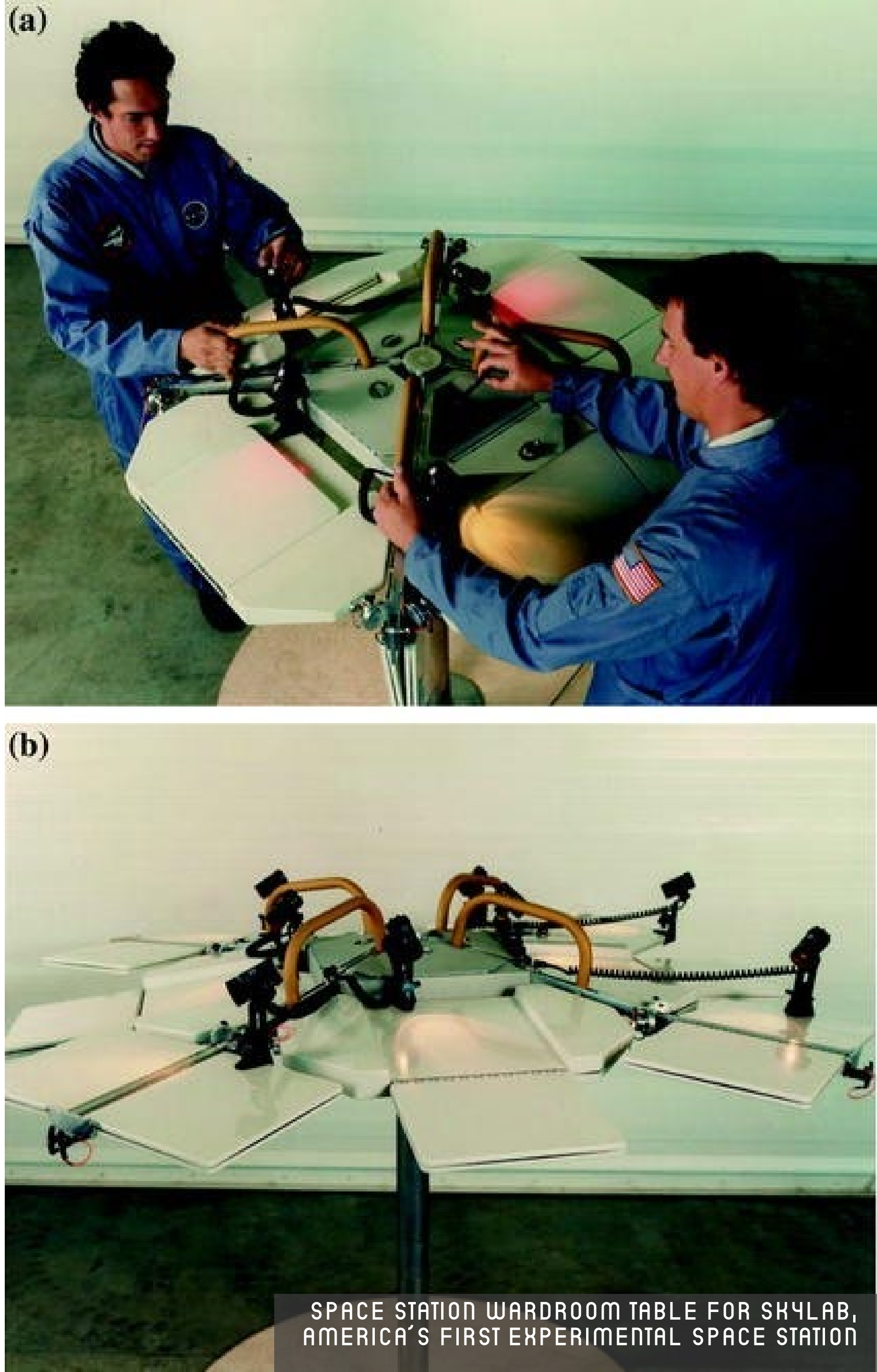
social life in previous spaceship

<u>VERY LOW IN PRIORITY</u>

"HAVING DINNER IS A SOCIAL ACTIVITY SHARED BY MANY CULTURES AND IS ONE OF THE HABITUAL SOCIAL CUSTOMS THAT PEOPLE CARRY INTO SPACE ... ON SKYLAB MISSIONS, **CREWS REFUSED TO FLOAT OVER THE TABLE** ... **THEY HAD FOR THE FIRST TIME A LARGE DEDICATED AREA FOR FOOD** PREPARATION AND DINING AND WERE EATING TOGETHER ON A SPECIALLY DESIGNED TABLE, EATING WITH KNIVES, FORKS AND SPOONS

SPACE ARCHITECTURE EDUCATION FOR ARCHITECTS AND ENGINEERS P.131

MORE WAYS OF SOCIALISING?

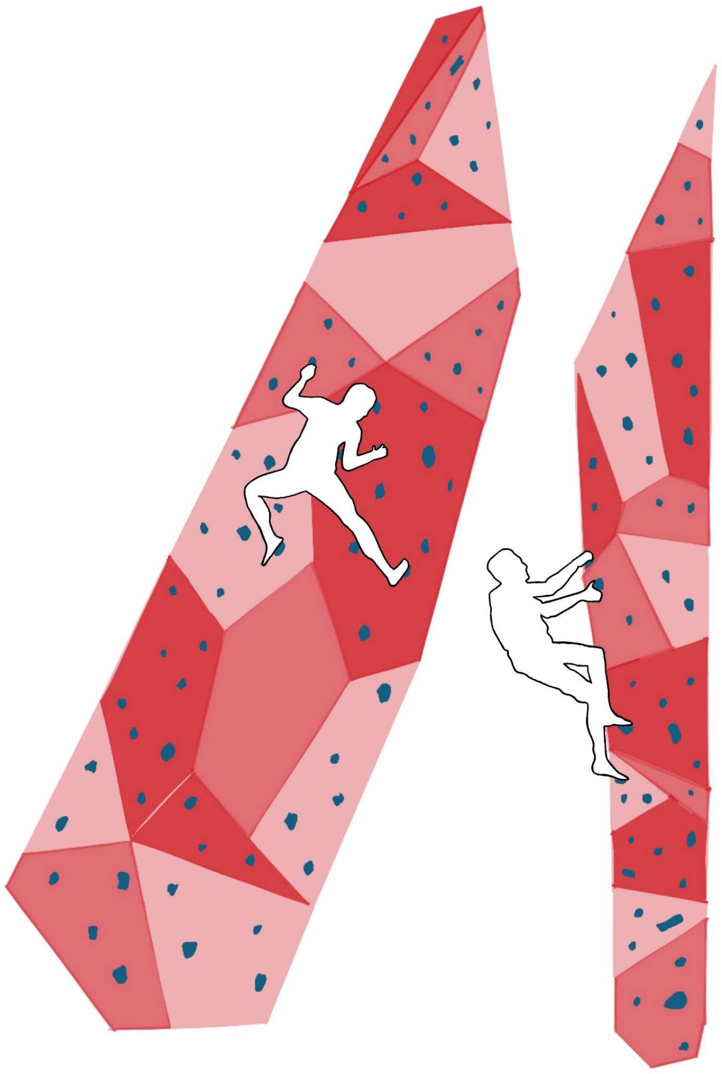


SPACE STATION WARDROOM TABLE FOR SKYLAB, AMERICA'S FIRST EXPERIMENTAL SPACE STATION

SOURCE: SPACE ARCHITECTURE EDUCATION FOR ARCHITECTS AND ENGINEERS P.77

PHYSICAL & SOCIAL WELL-BEING

playscape = incorporating muscle work & various postures with architecture



climbing as an act of new normal

TO MOVE BY CLIMBING -› IMMERSIVE DIFFUSION INTO LUNAR CONDITIONS

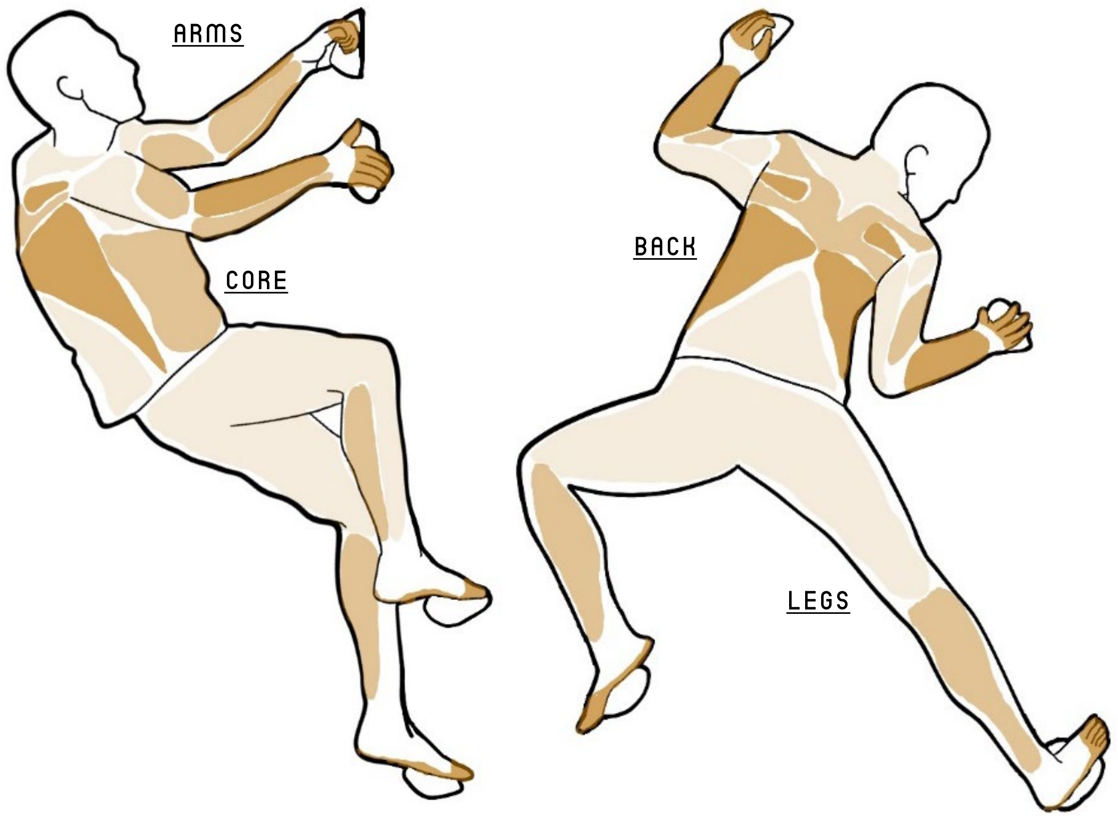
1/6 WEIGHT OF EARTH -›
LIGHTER BODY WEIGHT, HIGHER IMPACT-LESS FALL

FULL BODY MUSCLE USE

RICH ACTIVITY
DEVELOPMENT OPTIONS

TRIGGER OF ANOTHER
BODY MOVEMENTS
(GRIPPING, JUMPING, FALLING)

muscle activation



90-100% STRESSED

50-90% STRESSED

LESS THAN 50% STRESSED

SOURCE: THE WANDERING CLIMBER

EXPERIENCING CLIMBING

an effective social bonding tool

YOUTUBE.COM/WATCH?V=KWTICV9AI_Q&T=43S&AB_CHANNEL=THEMAPLEMEDIA

RESEARCH QUESTION

how is **playscape** designed under benefits of lunar environment
to foster work productivity and social interaction
during long-term lunar habitation?

DESIGN DIRECTION

climbing habitat -> to create interactive and engaging
environment, space and furniture

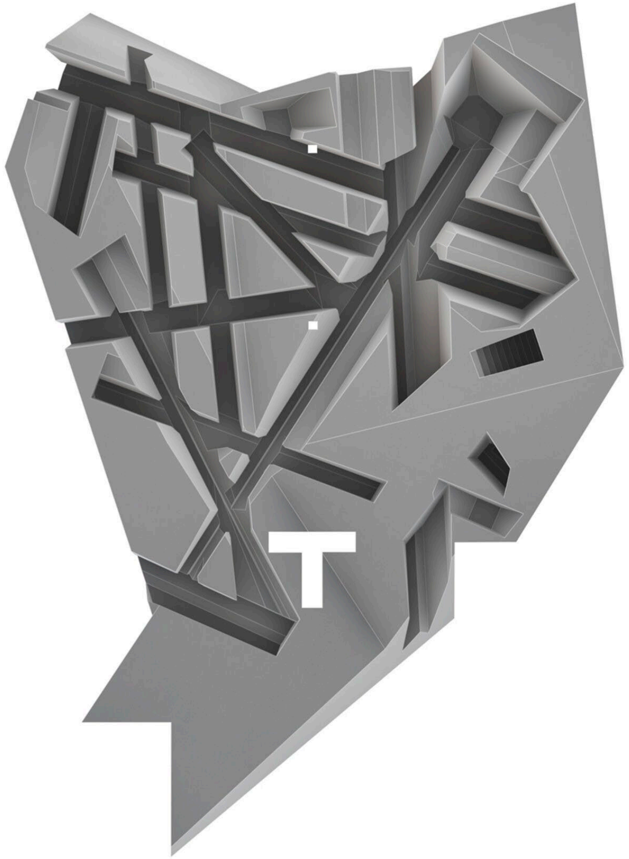
NEW RITUAL

being on the moon is the perfect time to **re-feel our body** by engaging with new gravity & new architecture around us

human body postures & interactions in between

UNCONVENTIONAL VERTICAL SURFACES AS A COUNTERACT OF SEDENTARY WORKSTYLE

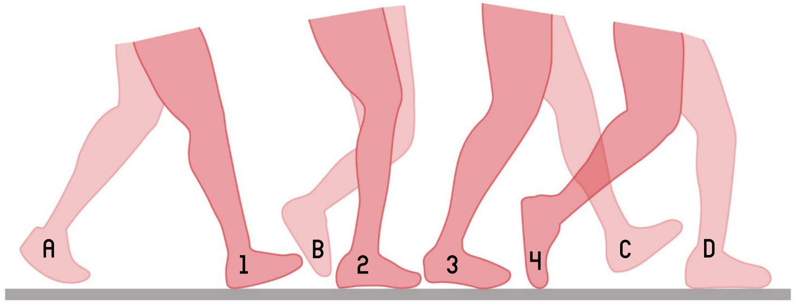
THE END OF SITTING BY RAAAF



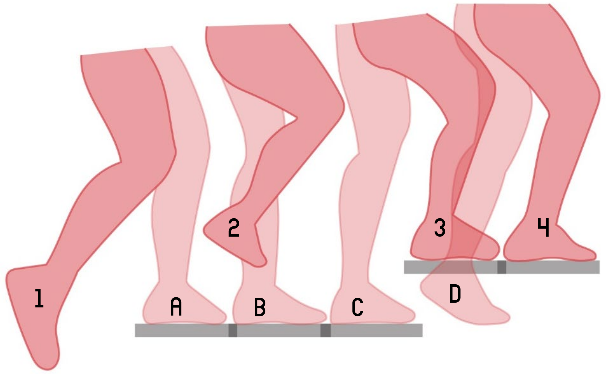
SOURCE: RAAAF.NL

human body postures & interactions in between

CLIMBING AS A COUNTERACT OF REPETITIVE AND STATIC MOVEMENTS ON EARTH

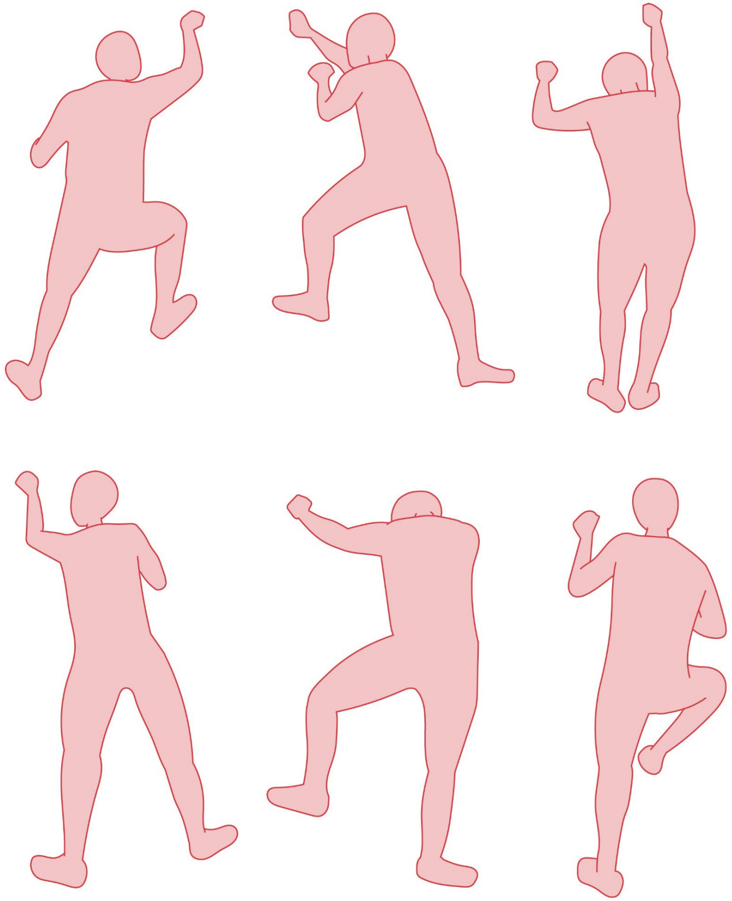


WALKING = LINEAR MOTION ADAPTED TO FLAT & STABLE TERRAIN



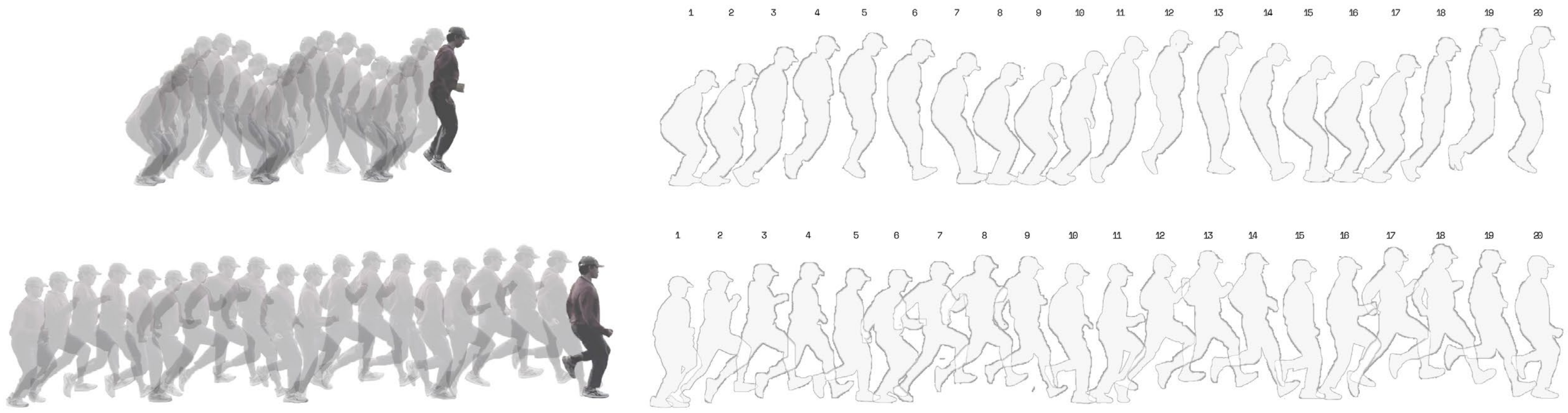
UNIFORM DIMENSIONS OF STAIR RUNS AND RISES RESULT IN CONSTANT MOTION

VS

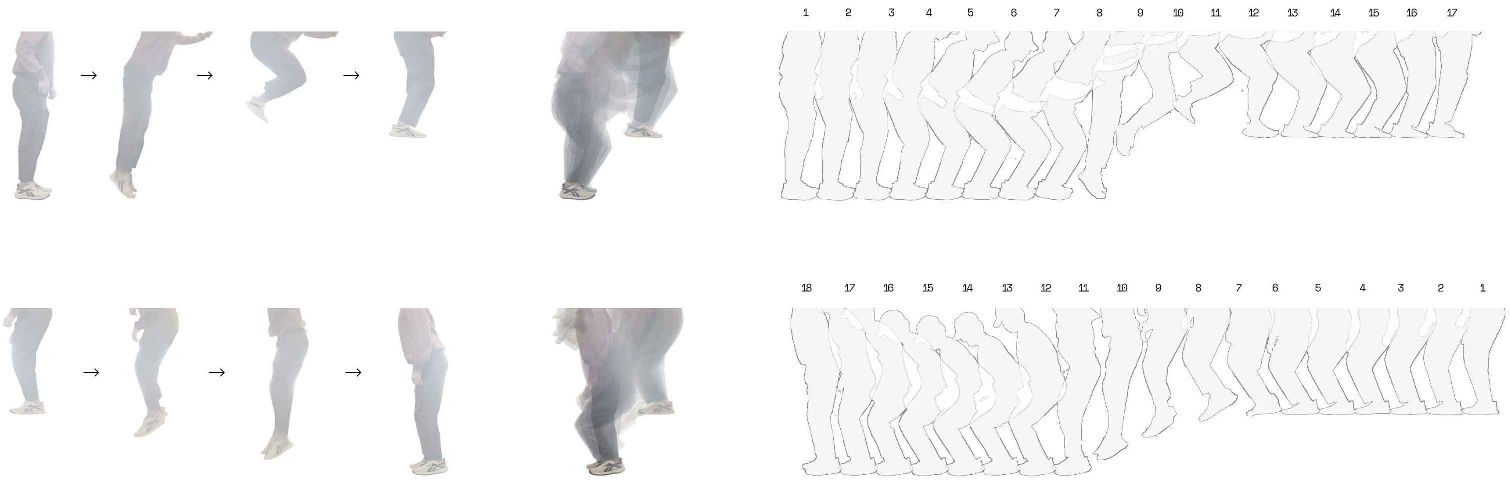


CLIMBING MOTIONS

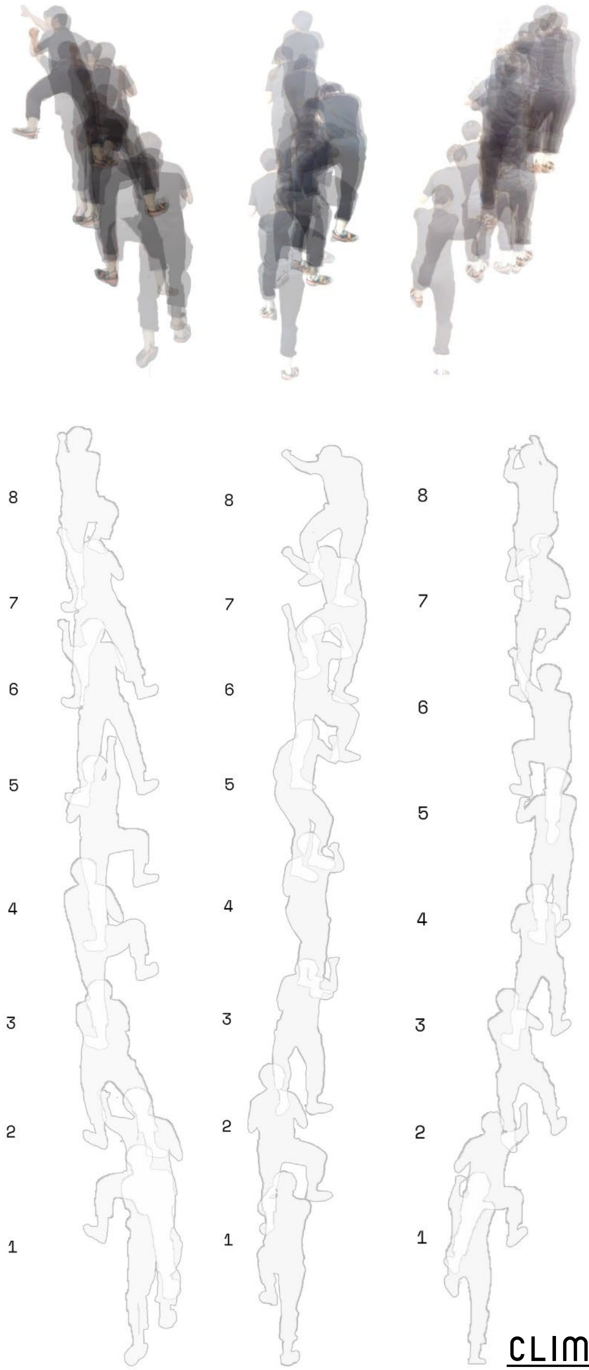
human body movements mapping



HOPPING & GALLOPING

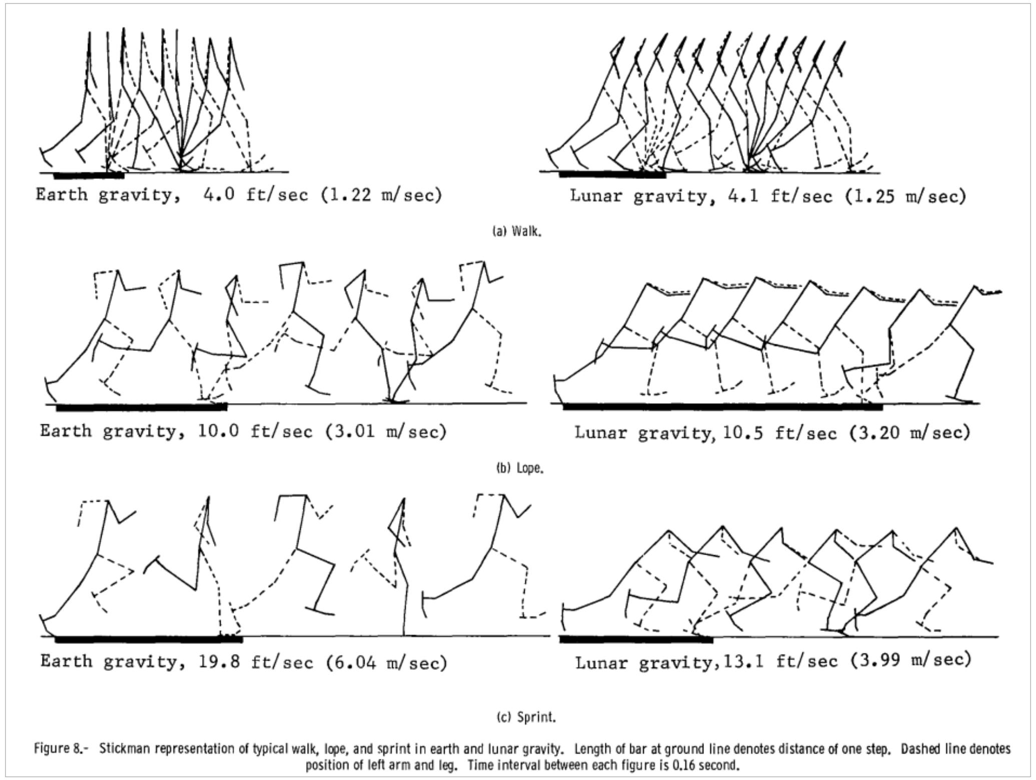


HIGH JUMP (UP & DOWN 500MM)



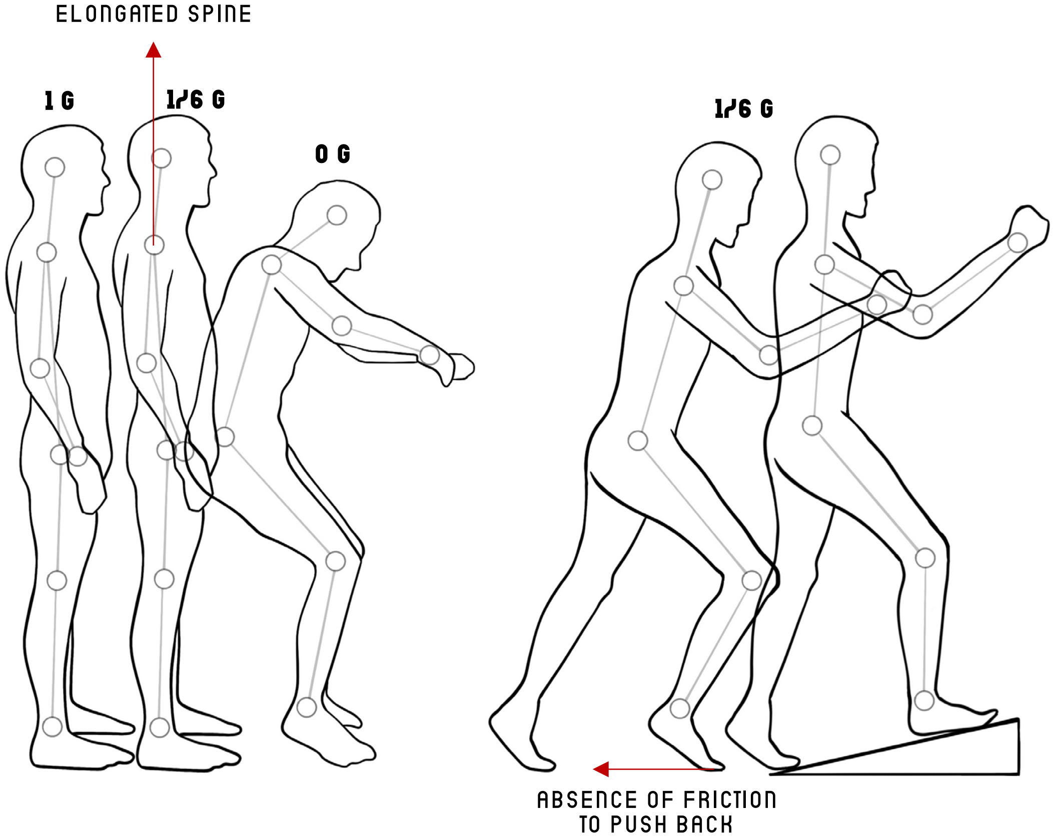
CLIMBING

body movement against gravity



SOURCE: NASA

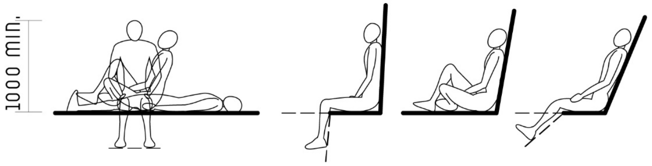
COMPARATIVE MEASUREMENTS OF WALKING AND RUNNING GAITS (1966)



NEUTRAL POSITION & START OF WALKING

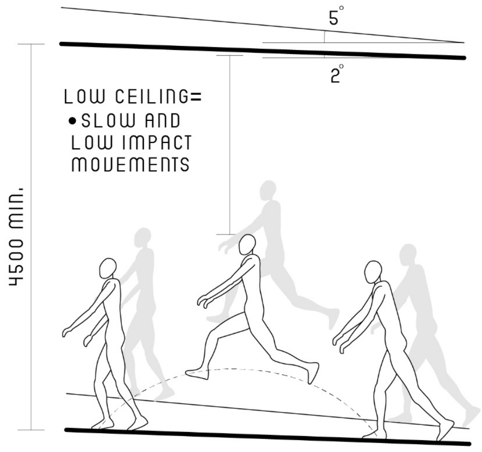
parameters derived from lunar physics

ALL DIMENSIONS
IN MILIMETRES

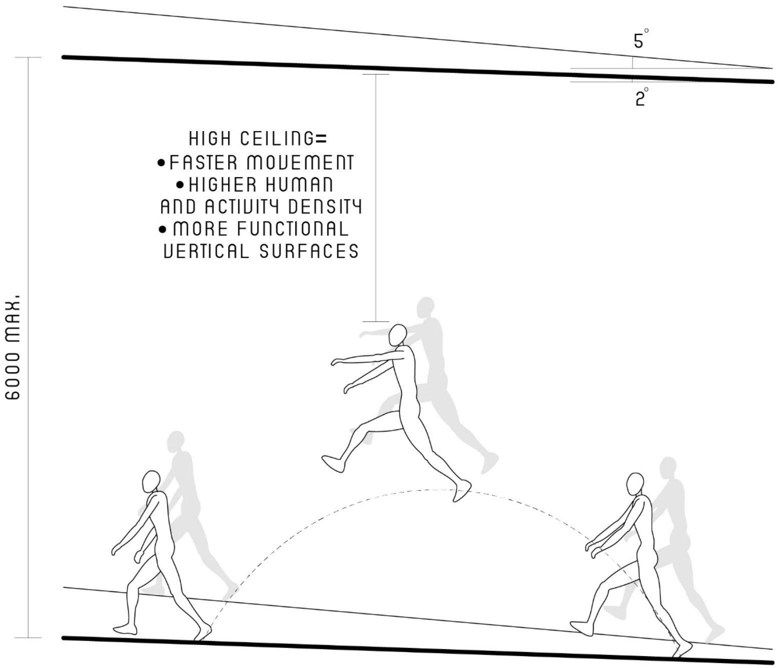


LAYING AND FLAT-SEATED LEANING (RESTING POSITION)

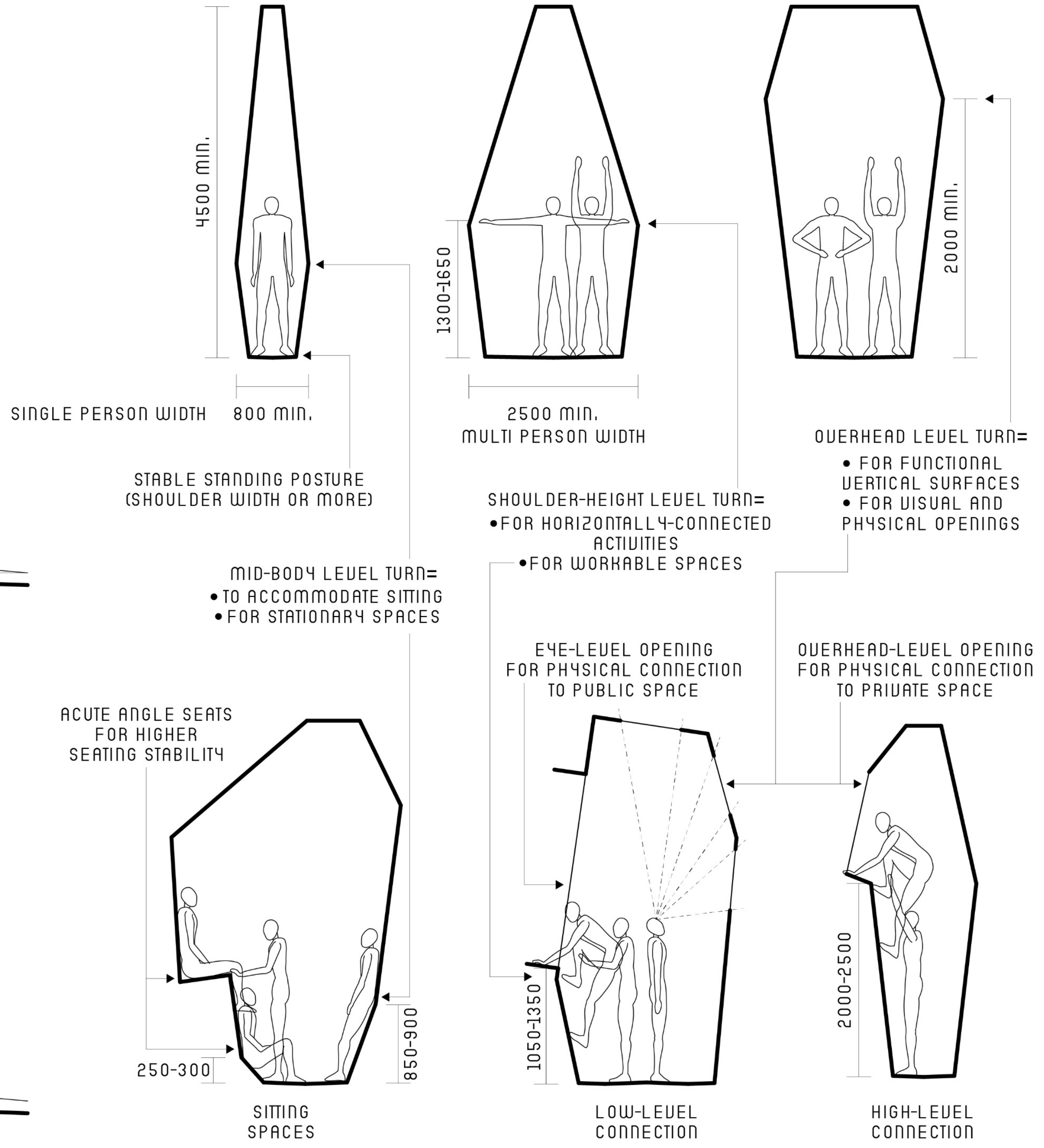
INCLINATION OF HORIZONTAL MOVEMENT (2°-5°)
TO STRAIGHTEN BODY AND
TO INCREASE SURFACE FRICTION



PERSONAL CLEARANCE SPACE



PUBLIC CLEARANCE SPACE



parameters derived from lunar physics

GRAVITY (M/S2)

EARTH	MOON
9.8	1.6

FALL FROM 1M

0.45 SEC
V= 4.4M/S

1.1 SEC
V= 1.8M/S

↓

V= 1.8M/S
0.17M

FALL FROM 2M

0.64 SEC
V= 6.26M/S

1.6 SEC
V= 2.5M/S

↓

V= 2.5M/S
0.32M

FALL FROM 3M

0.78 SEC
V= 7.7M/S

1.9 SEC
V= 3.1M/S

↓

V= 3.1M/S
0.49M

FALL FROM 10M

1.43 SEC
V= 14M/S

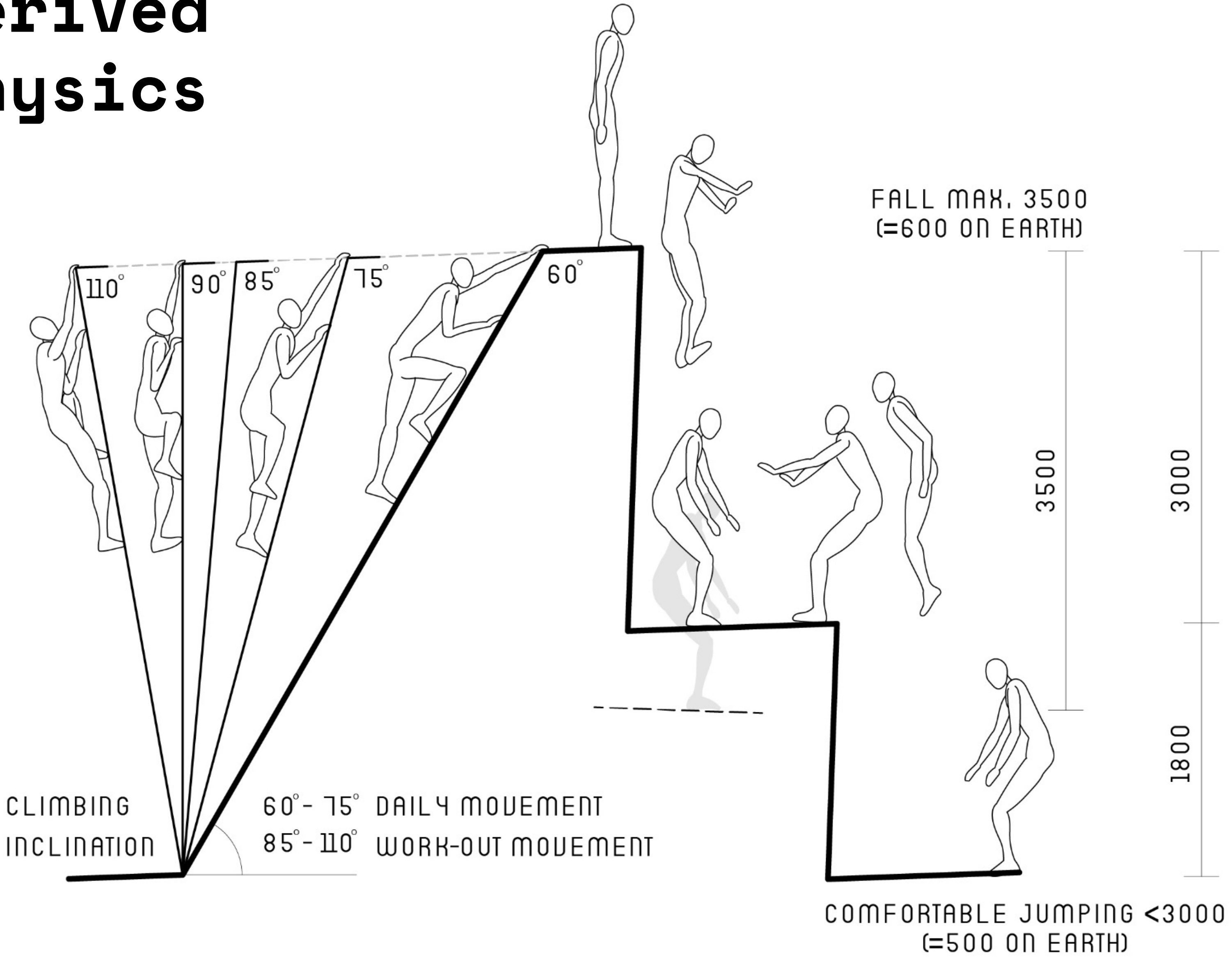
3.54 SEC
V= 5.6M/S

↓

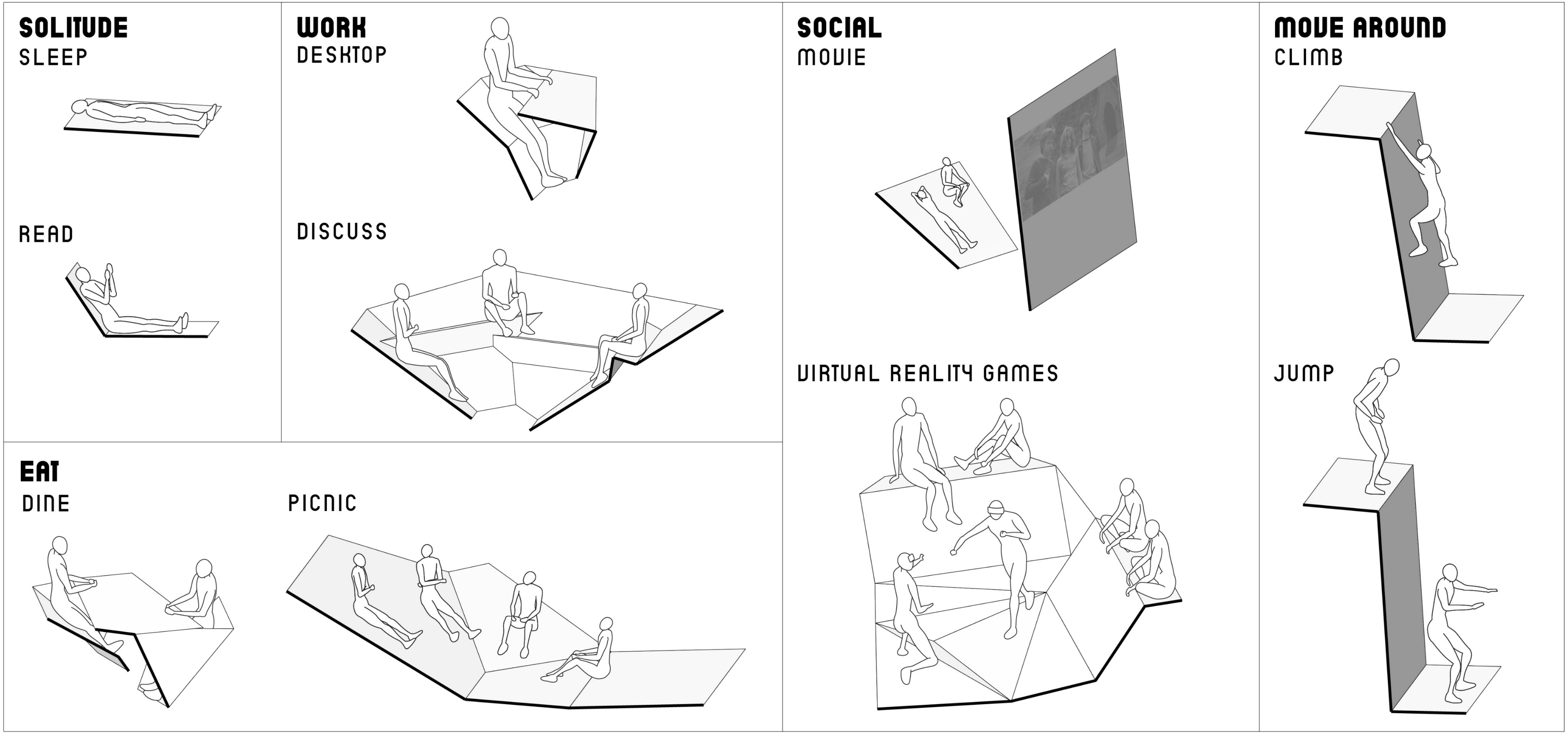
V= 5.6M/S
1.6M

JUMP FROM GROUND

0.5 M ⟶ 2.7 - 3 M



(assumptive) fundamental postures to activities



program requirements

(MIN. 80M3 PER PERSON)

1. PUBLIC OPEN SPACES

ATRIUM/ PLAYGROUND
VERTICAL GARDEN/ FOOD GALLERY
KITCHEN & DINING
SEMI-OUTDOOR SPACE

2. CIRCULATION

CLIMBING WALLS FOR ENCOURAGED MAIN CIRCULATION

PROGRAM	MIN. VOLUME PER PERSON (M3)	%	MIN. HEIGHT (M)	MAX. CAPACITY	CONNECTION ORIENTATION
PRIVATE QUARTERS (BED)	6	4 %	1.5	1 (EACH)	HORIZONTAL
PRIVATE QUARTERS (STUDY)	25	17 %	4.5	3 (EACH)	VERTICAL
PRIVATE QUARTERS (HYGIENE)	4	3 %	3	1 (EACH)	-
KITCHEN & DINING	15	10 %	4.5	3	HORIZONTAL
GYM	10	7 %	4.5	3	HORIZONTAL
WORK FACILITIES	20	14 %	6	6	VERTICAL
MINIMUM HABITABLE	80				
PLAYGROUND	30	21 %	10	>6	VERTICAL
FOOD GALLERY	20	14 %	10	>6	VERTICAL
CLINIC	4	3 %	4.5	3	HORIZONTAL
STORAGE	5	3 %	3	-	HORIZONTAL
SERVICE	5	3 %	3	-	-
TOTAL	144	100 %			

3. SPECIFIC WORKING SPACES

RESEARCH LAB
DESK STATIONS
CONTROL CENTRE
CLINIC
GYM

4. PERSONAL SOLITUDE SPACES

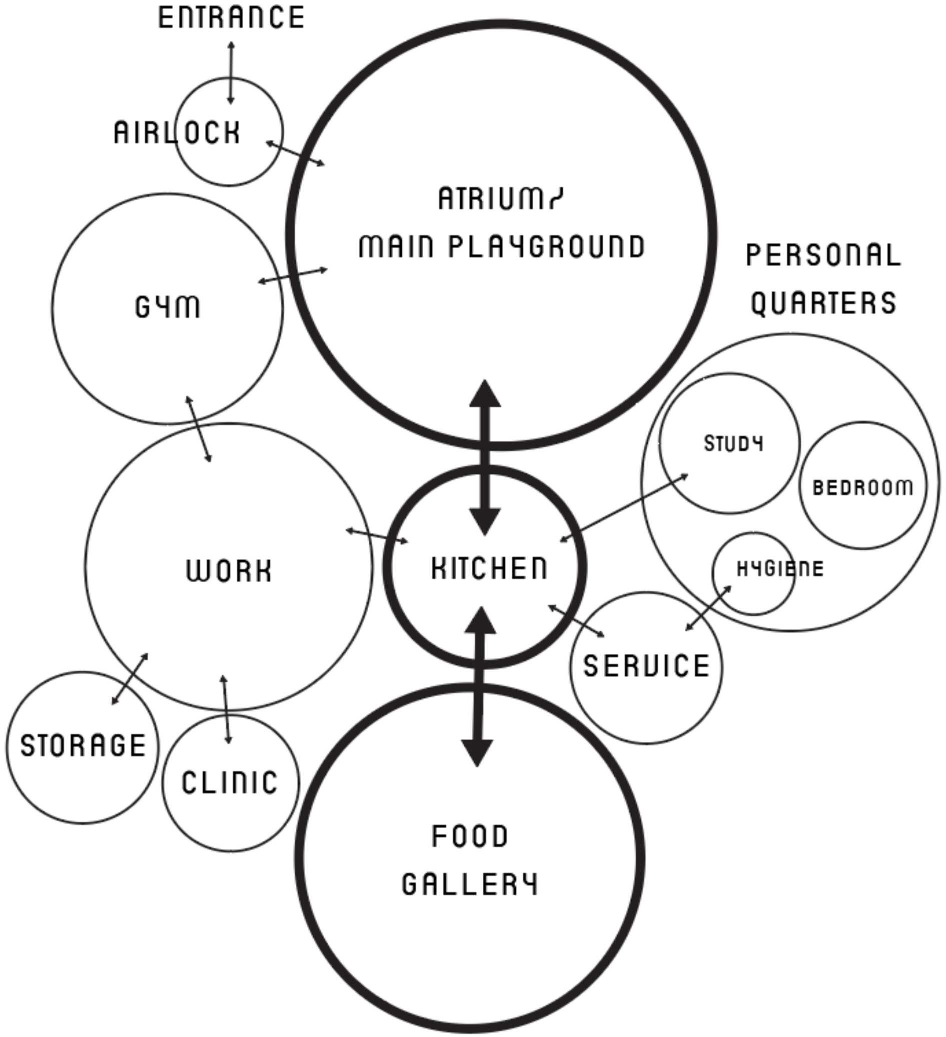
BEDROOM
STUDY
HYGIENE

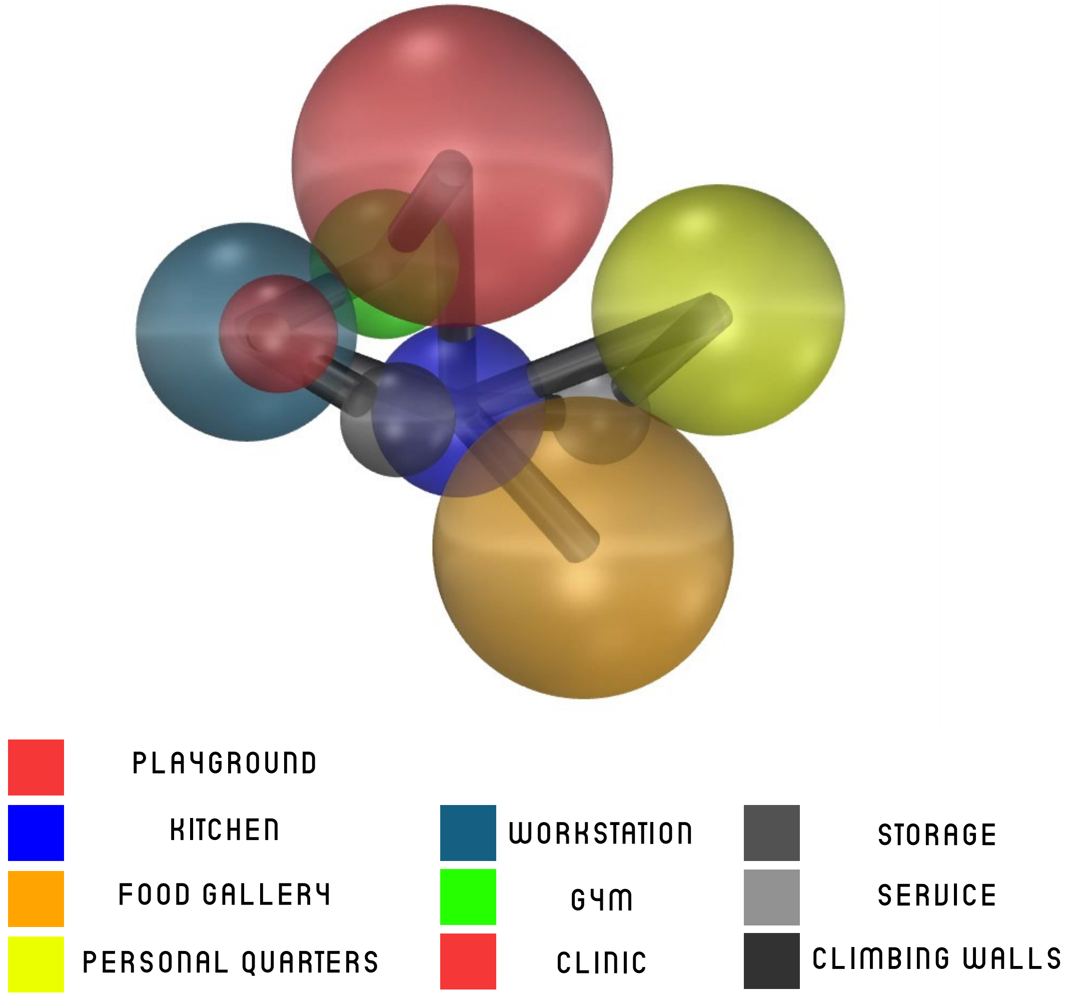
5. SERVICE SPACES

LIFE SUPPORT STORAGE
AIRLOCK CHAMBERS
DONNING & DOFFING AREA
STORAGE

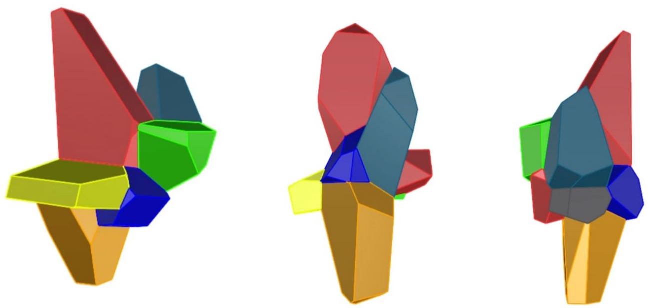
DERIVED FROM: SPACE ARCHITECTURE EDUCATION FOR ENGINEERS AND ARCHITECTS (BOOK)

previous iterations
lessons learnt





previous iterations
lessons learnt



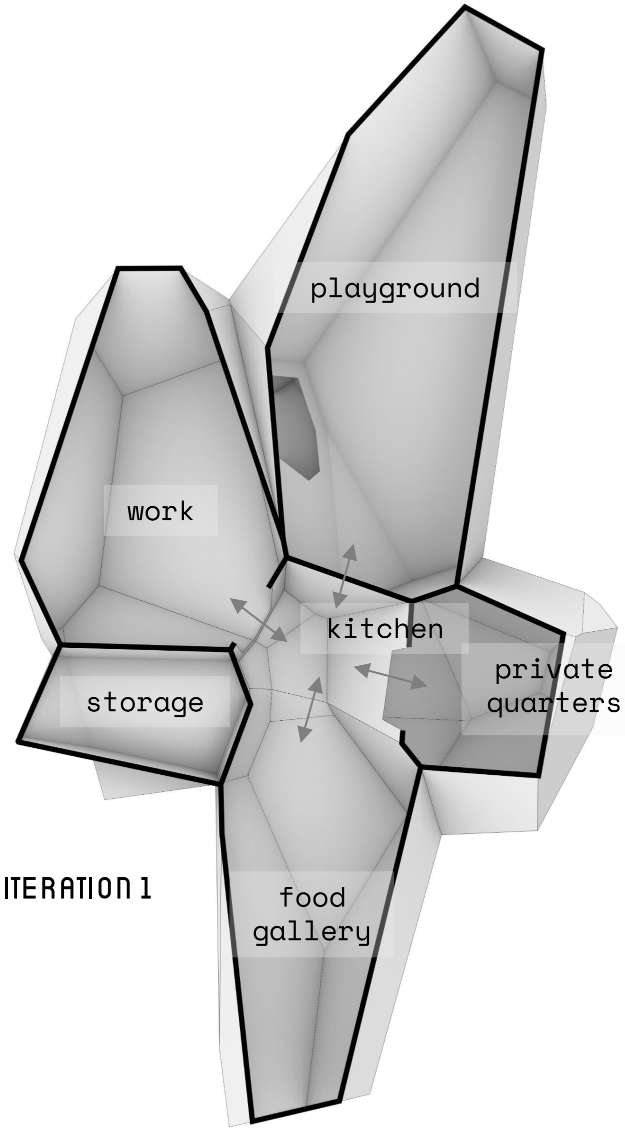
TAKEAWAYS

CONTROL NARROWNESS OF ATRIUM TO MAINTAIN HUMANELY PLEASANT SPACES

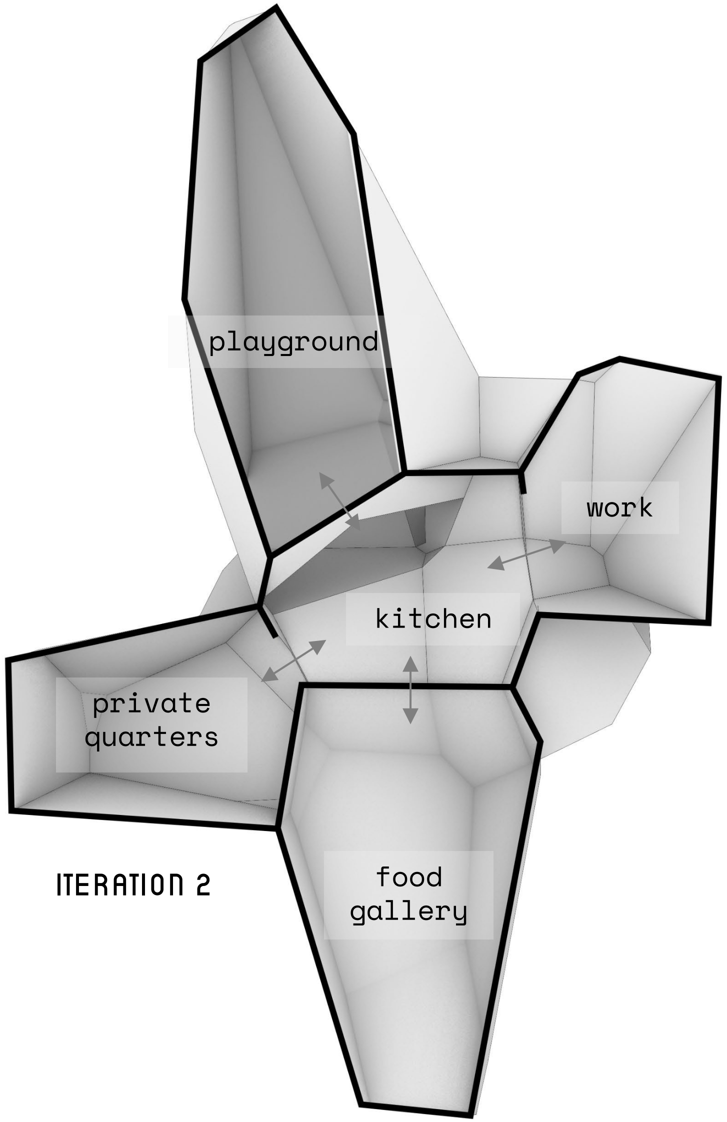
MORE DIAGONAL RELATIONSHIPS INSTEAD OF STRICT VERTICAL CONNECTED SPACES

INTRODUCE SPACES HIERARCHY

EXTERIOR NATURE SHALL BE INCLUDED

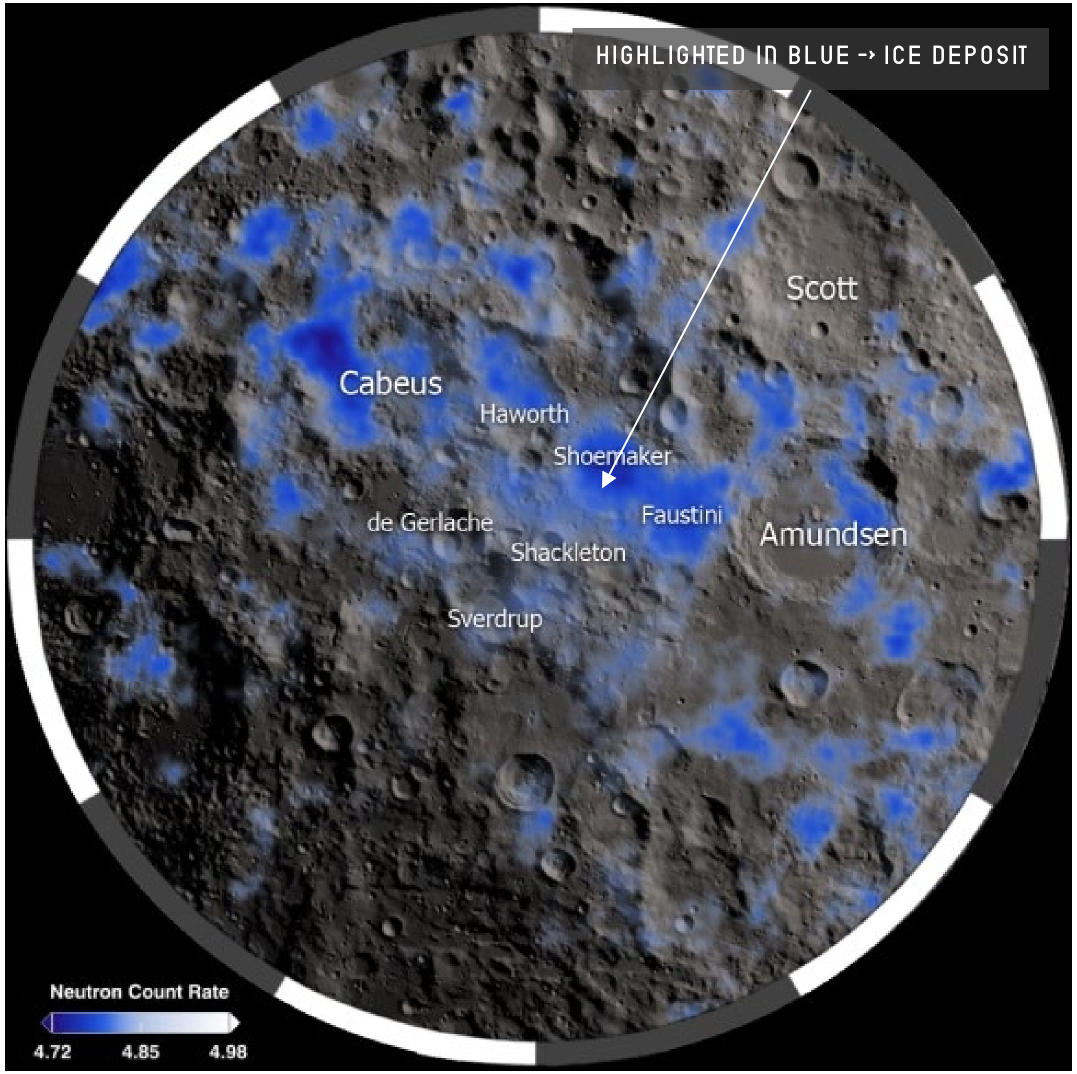


ITERATION 1

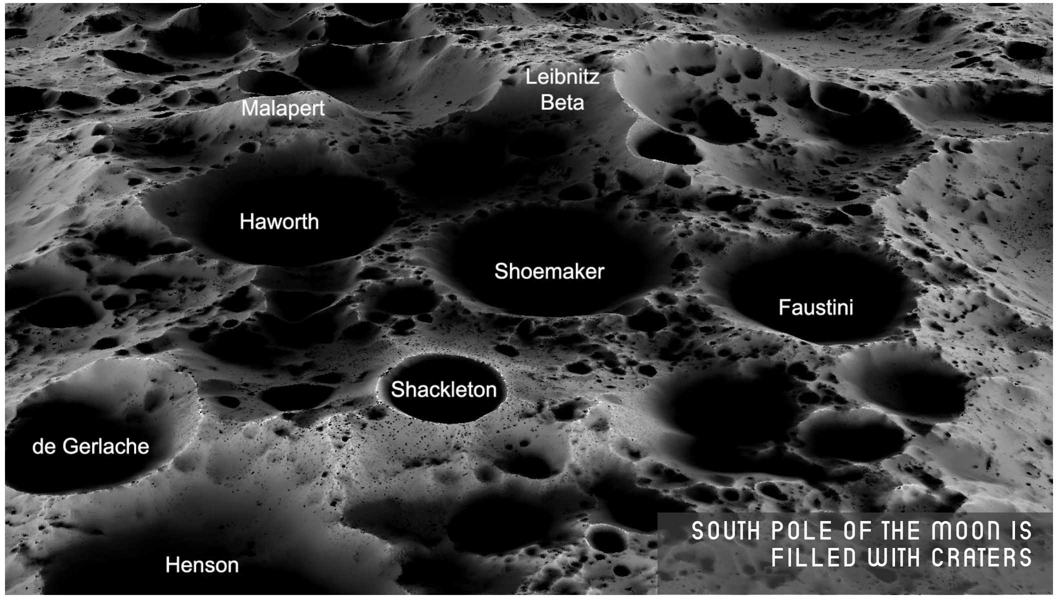


ITERATION 2

site



SOURCE: AMERICASPACE.COM



SOURCE: LPI.USRA.EDU

SOUTH POLE OF MOON

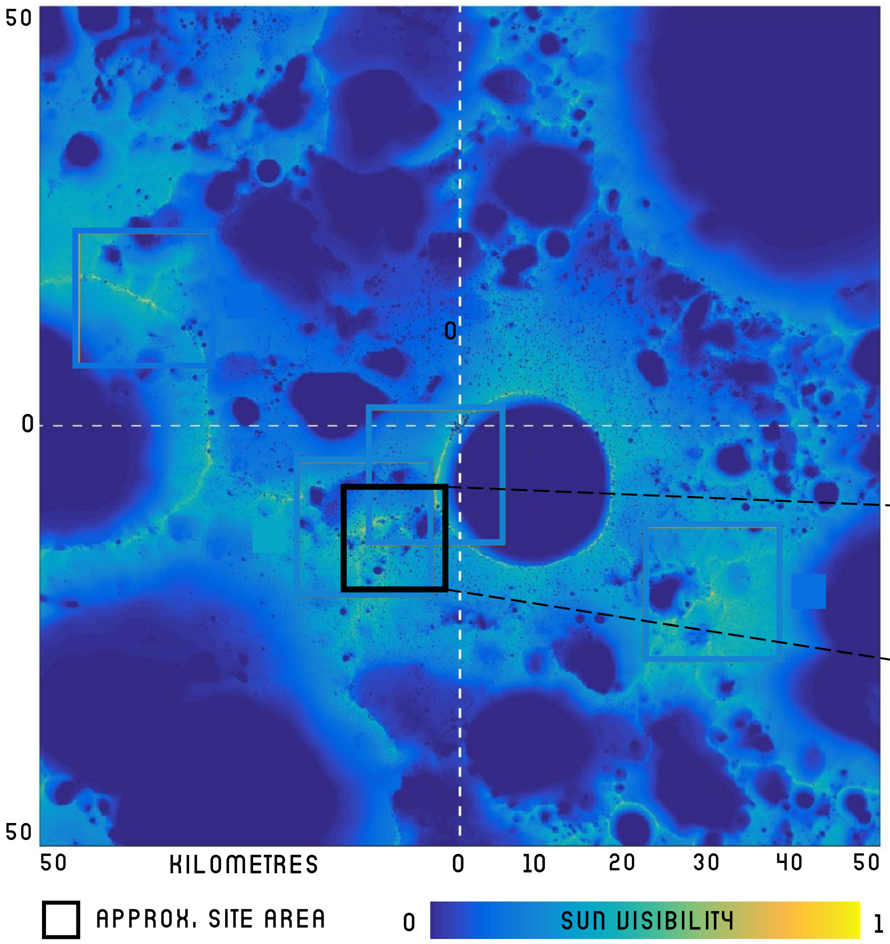
RESOURCES

WATER (ICE) → CRATER BASE

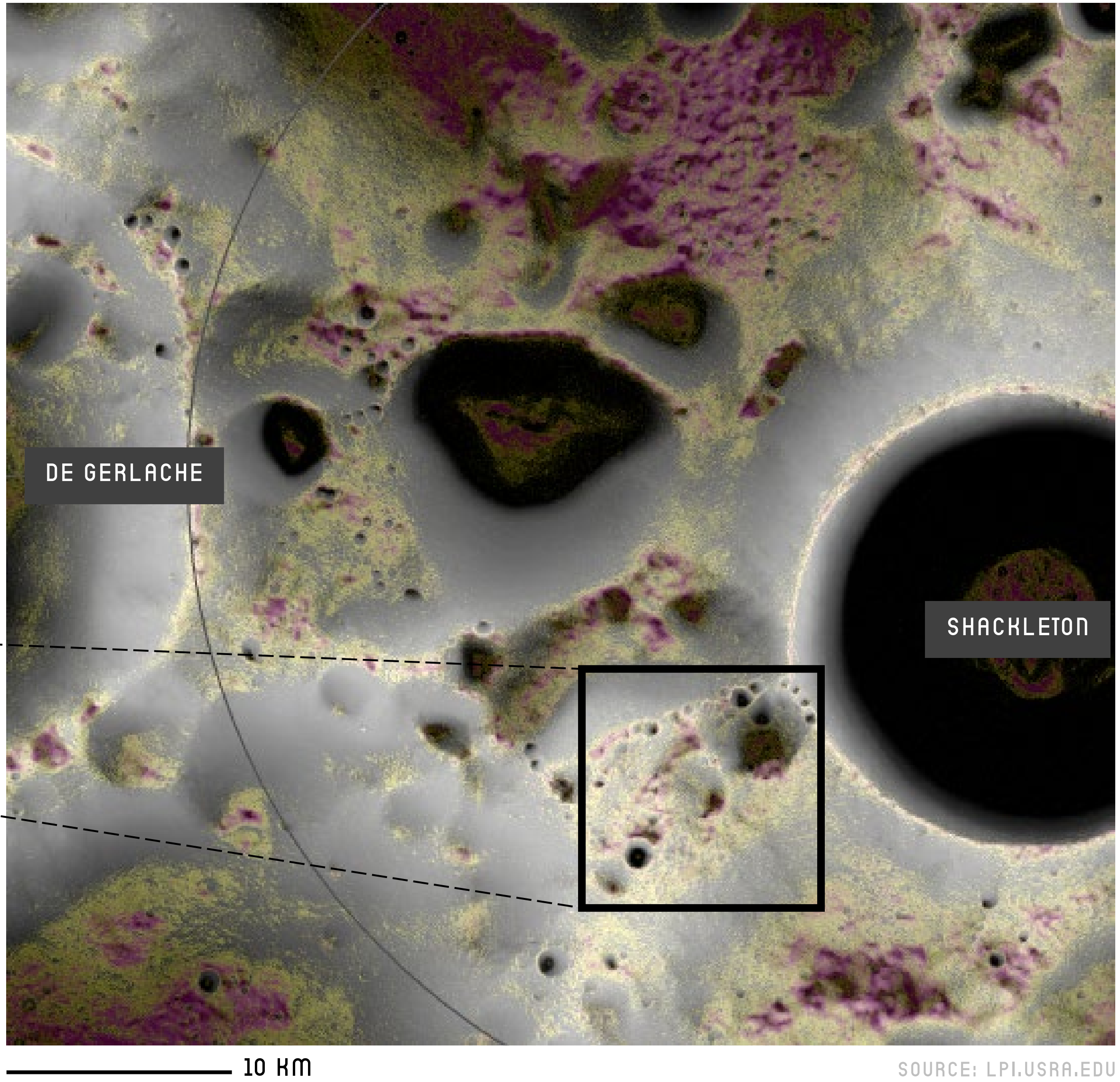
SUN POWER → CRATER RIM

site

SOUTHWEST AREA OF SHACKLETON CRATER



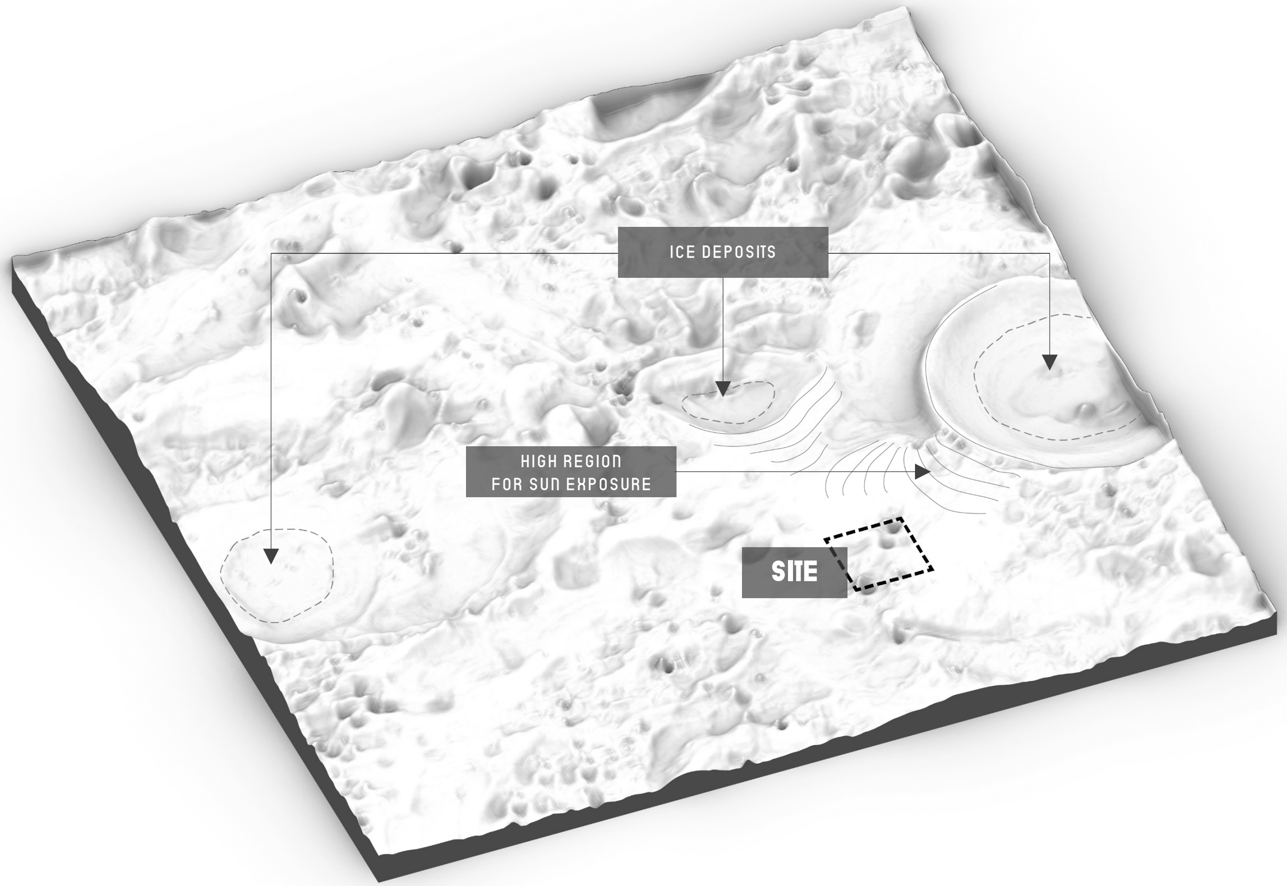
SOURCE: NCCS.NASA.GOV

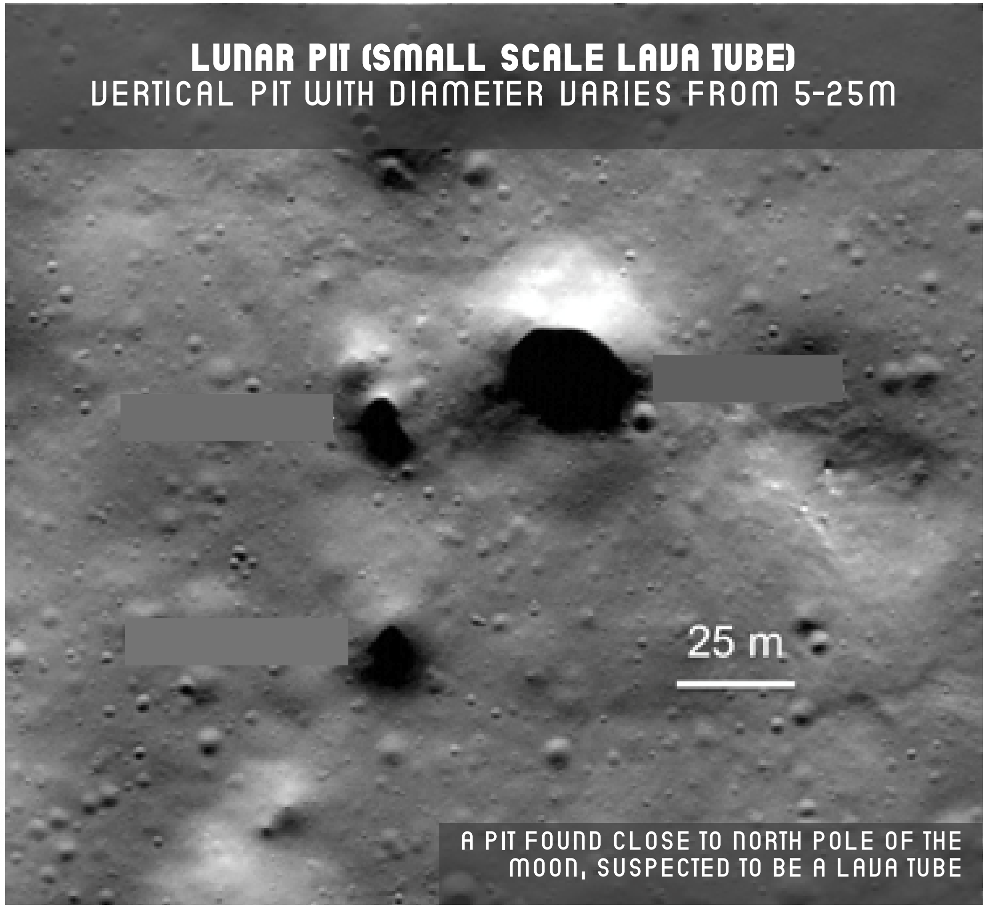


SOURCE: LPI.USRA.EDU

site

(zoom in to 1:1000)





SOURCE: SETI INSTITUTE

PROTECTION FROM

RADIATION (200x > EARTH SURFACE)

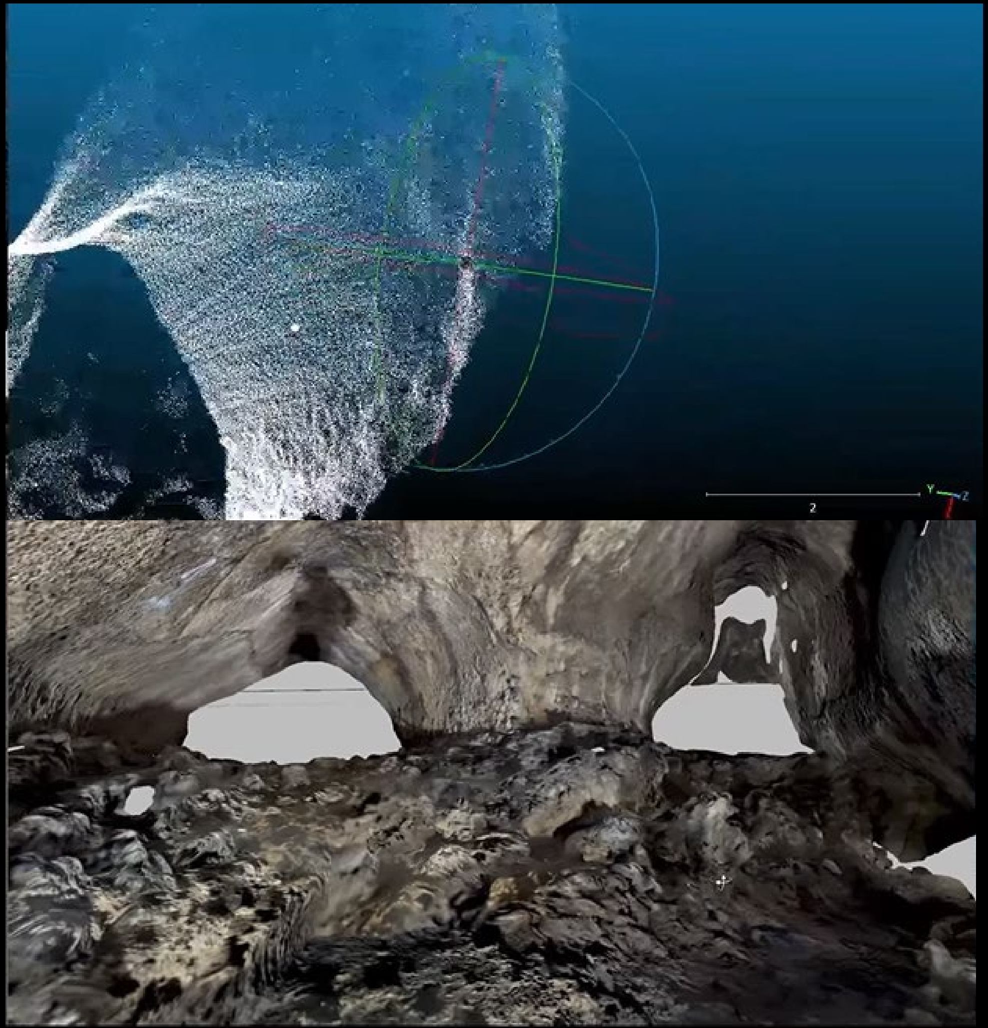
TEMPERATURE FLUCTUATIONS (-133 TO 121°C)

METEORITE SHOWER

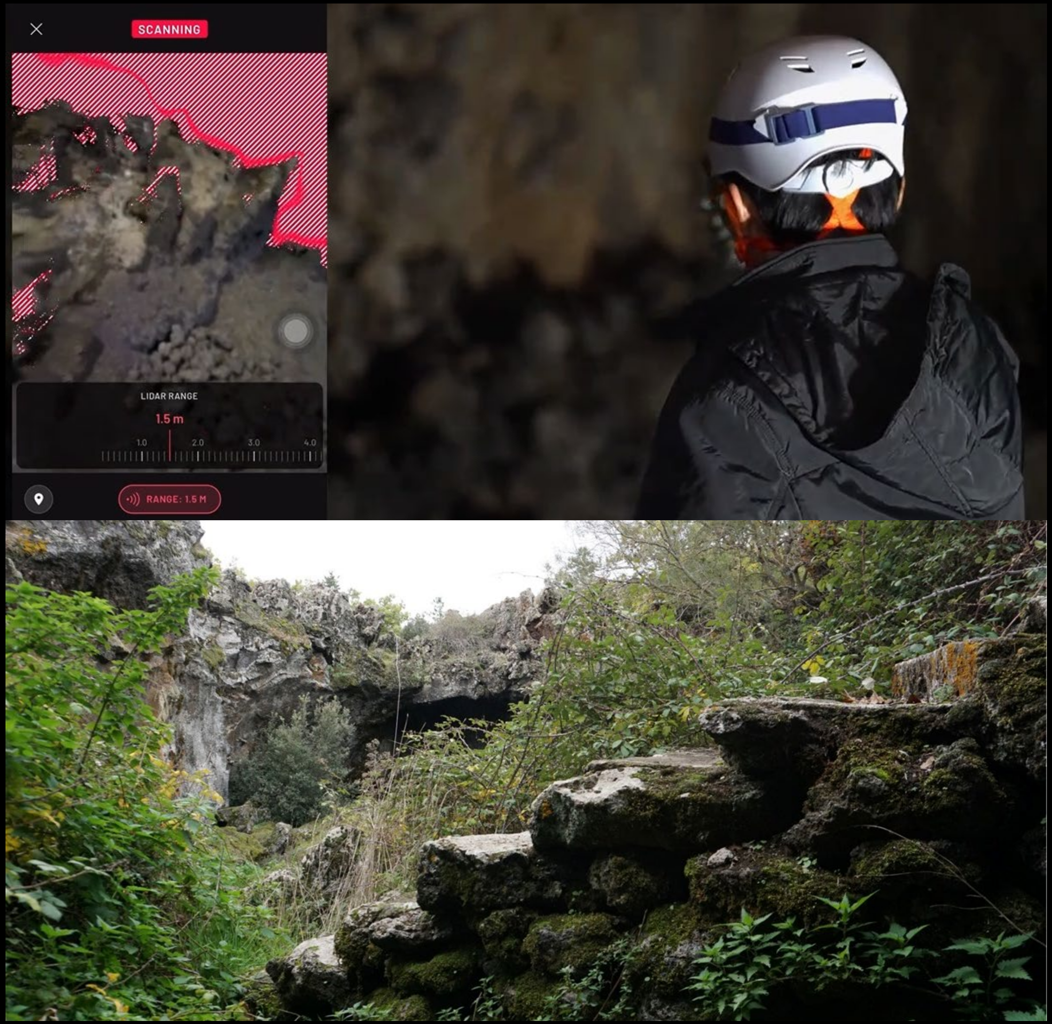
lava tube mission

CHALLENGING LAVA TUBE TERRAIN → EYES & BRAIN → BODY DIMENSIONS → SPATIAL COORDINATION

lava tube mission

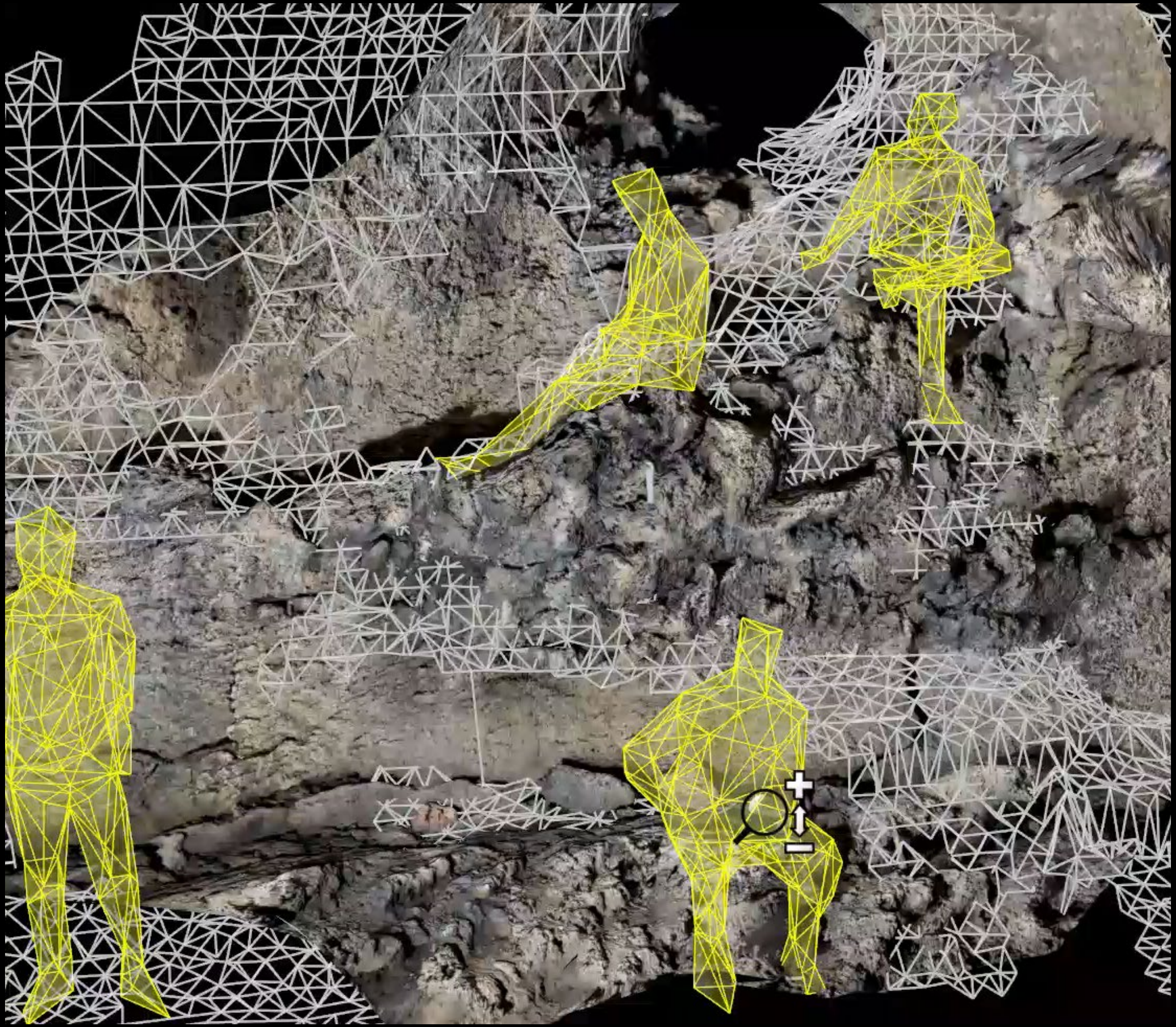


URBAN & ARCHITECTURAL SCALES



FURNITURE & MATERIAL SCALES

body dimensions to architectural scales



WALL TECTONICS & TEXTURES (VERTICAL AND DIAGONAL) INTRODUCE EXTENSION OF FUNCTIONAL SPACES

project timeline

PAST MISSIONS | **NOW** | **ANTICIPATED FUTURE IMPLEMENTATION** | **DISTANT FUTURE**

APOLLO,
PAST SPACE STATIONS

SPACE STATIONS
(ISS, TIANGONG)

PHASE 1

- DEPLOYING EQUIPMENT

-SHELTER TO HOUSE IMPORTANT EQUIPMENT FOR FUTURE LONG-TERM EXPLORATION

- SIMPLE STRUCTURE BUILT ENTIRELY ON EARTH AND THEN DEPLOYED BY ROBOTS OR HUMANS

- IF HUMANS´ PRESENCE IS NEEDED, IT WILL BE A SHORT (A FEW DAYS) MISSION

PHASE 2

- PREPARATION OF LUNAR PERMANENT BASE

- STRUCTURE TO HOST MEDIUM LENGTH (SEVERAL MONTHS) MISSION FOR LESS THAN 10 INHABITANTS

- INFLATABLES AND MODULAR TO BE CONNECTED TO PHASE 3, WITH ALL BASIC NEEDS: SHIELDING & OXYGEN

- START OF ISRU REGOLITH UTILISATION WITH HUMAN-ROBOT INTERACTION

PHASE 3

- PERMANENT HABITATION WITH BETTER RADIATION SHIELD TO HOUSE MORE PEOPLE

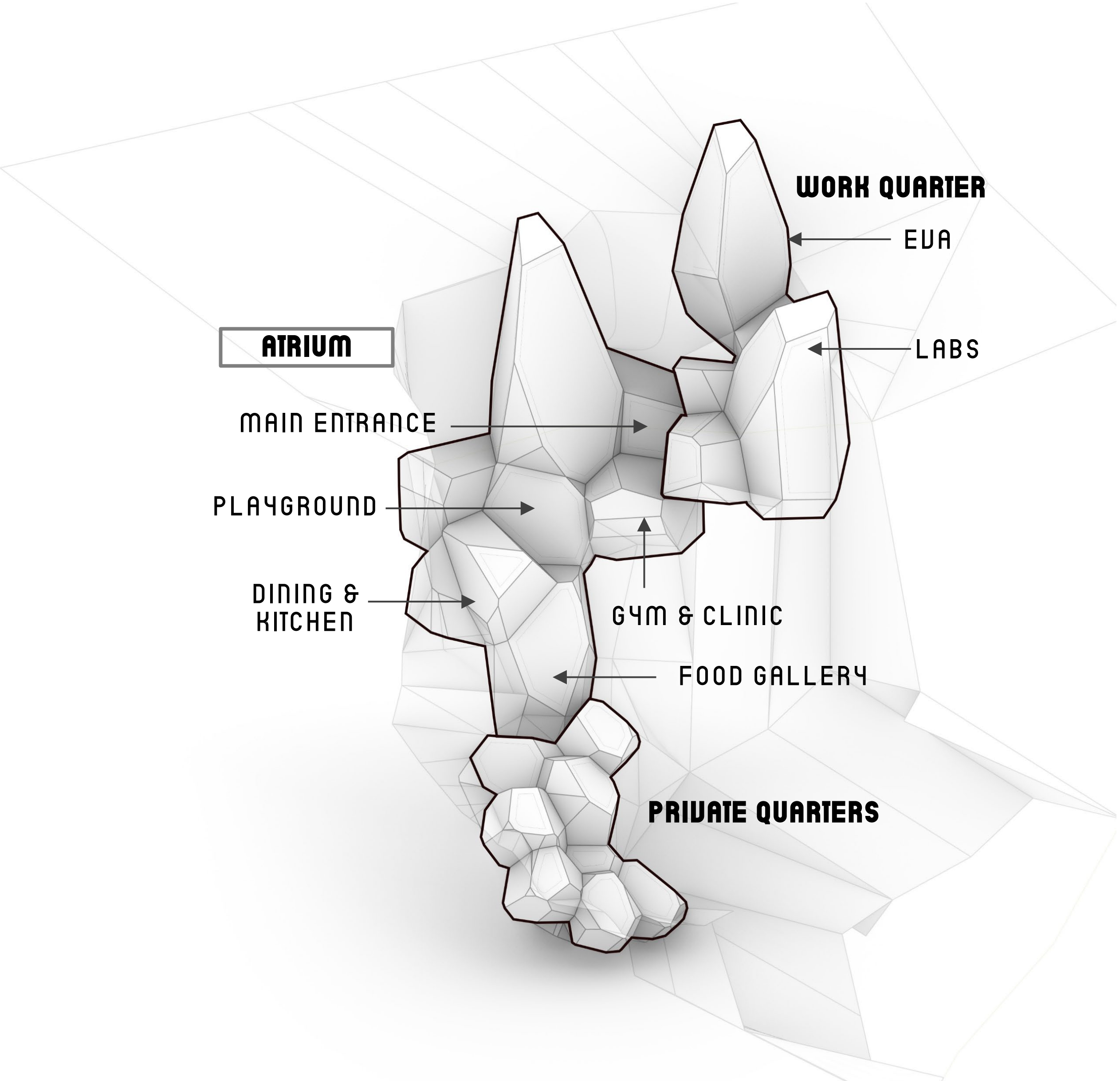
- CONSTRUCTION IN WELL ANALYSED SITE, I.E. LAVA TUBE

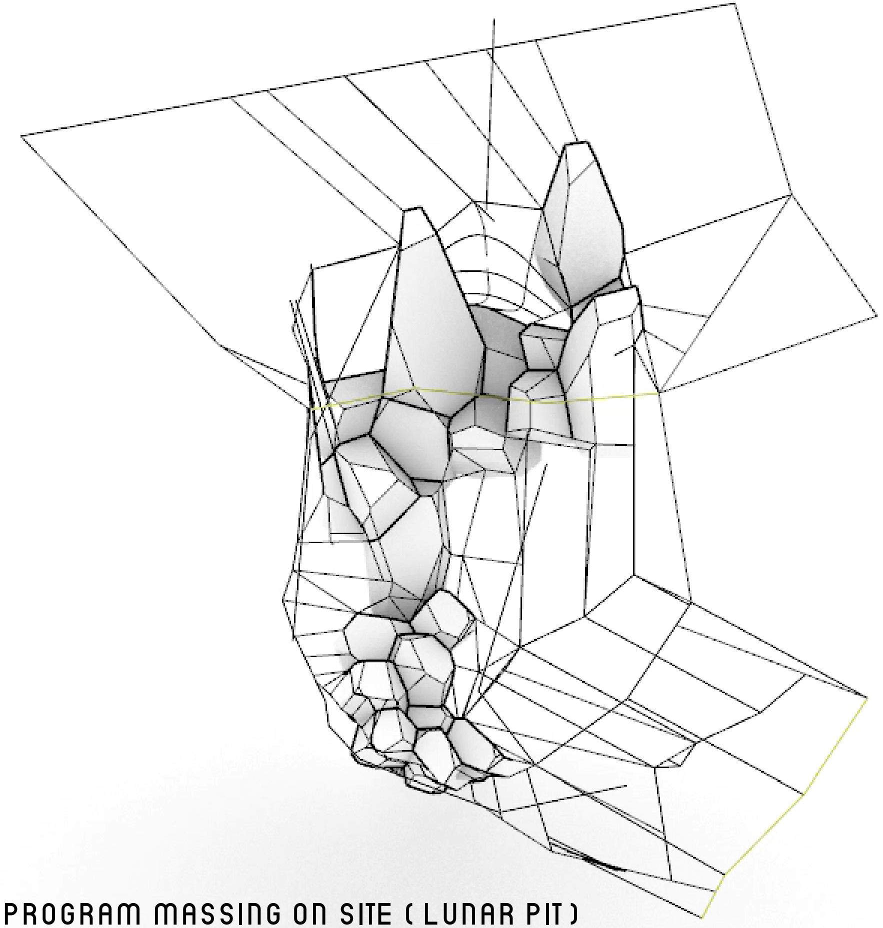
- CONSTRUCTION WITH DEVELOPED ISRU TECHNOLOGY FROM THE PREVIOUS PHASES

climbing habitat
constructed within stages

SOURCE: LUNAR SETTLEMENTS (BOOK) BY HAYM BENAROYA (2010)

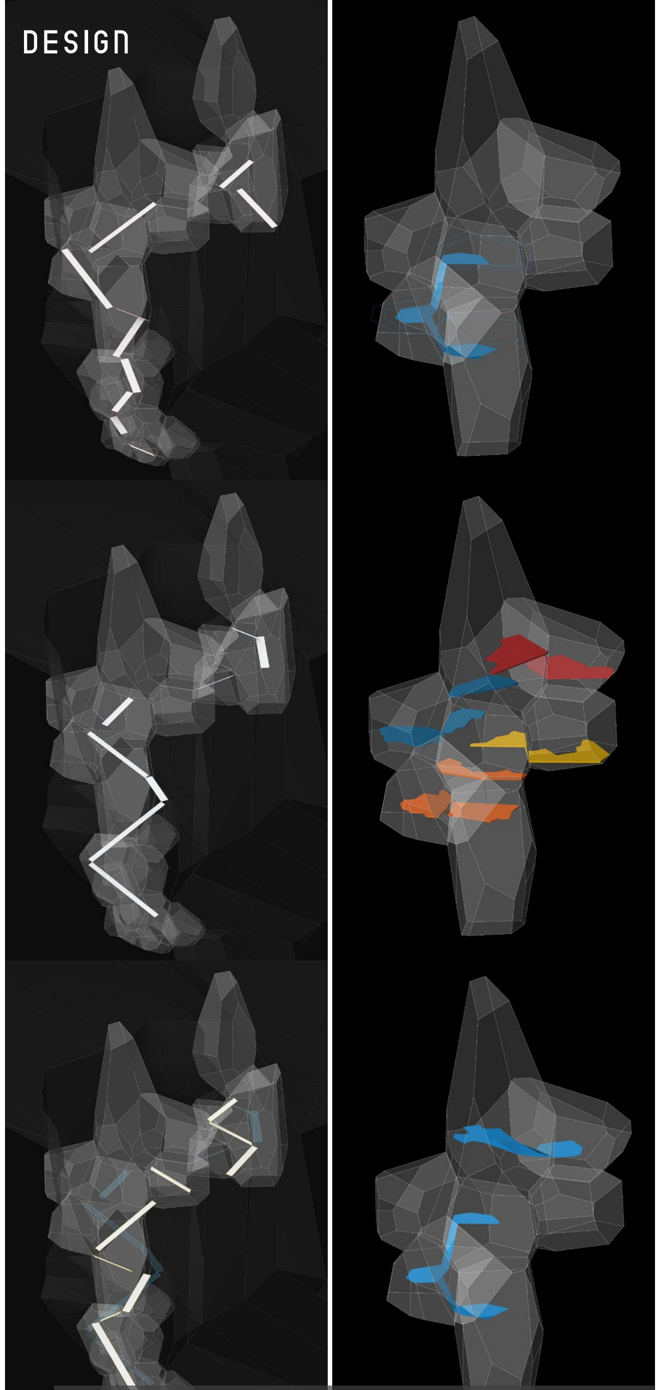
site plan/ site isometric





PROGRAM MASSING ON SITE (LUNAR PIT)

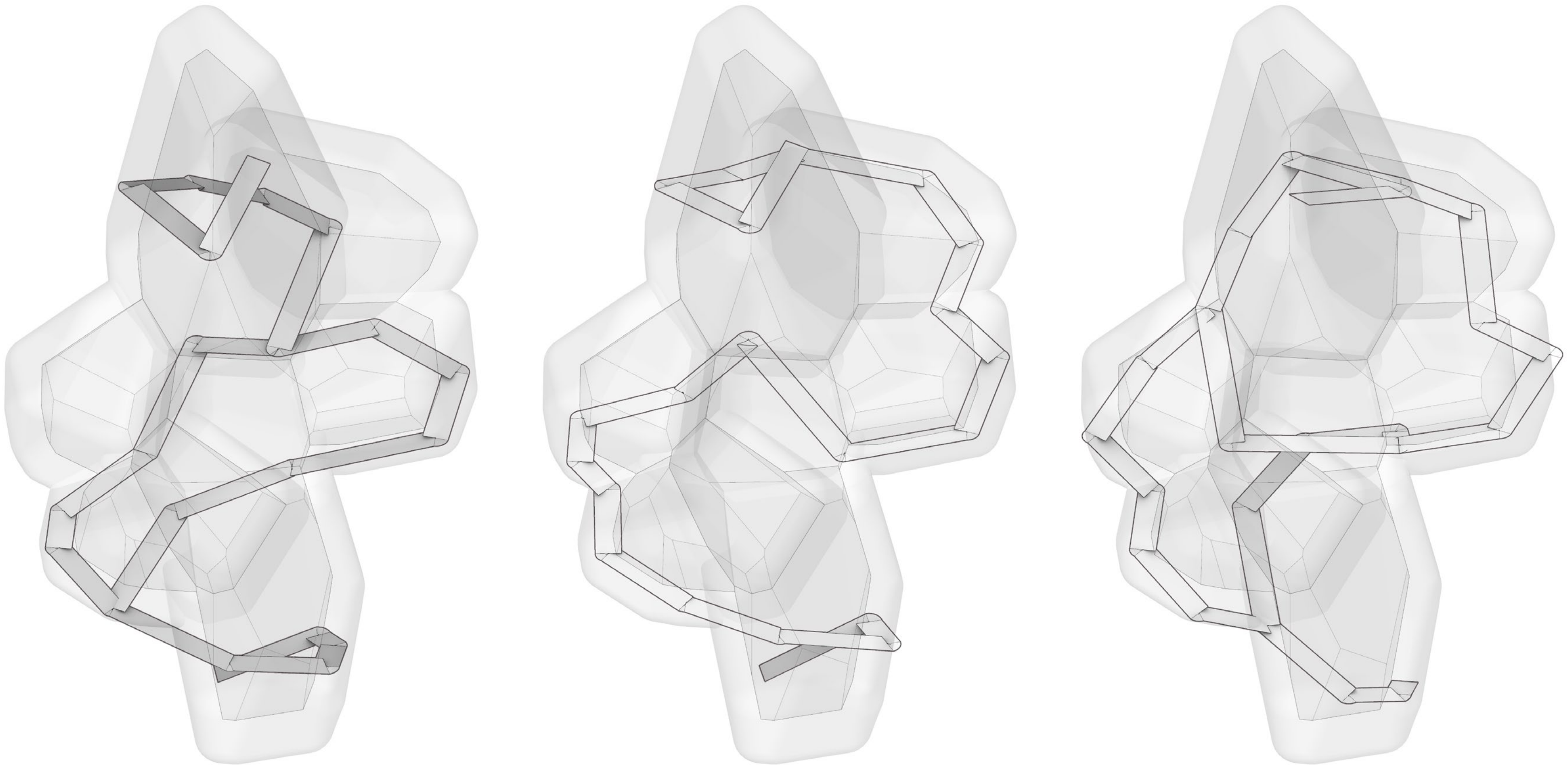
DESIGN



PROCESS STUDY OF RAMPS AND PLATFORMS

form finding

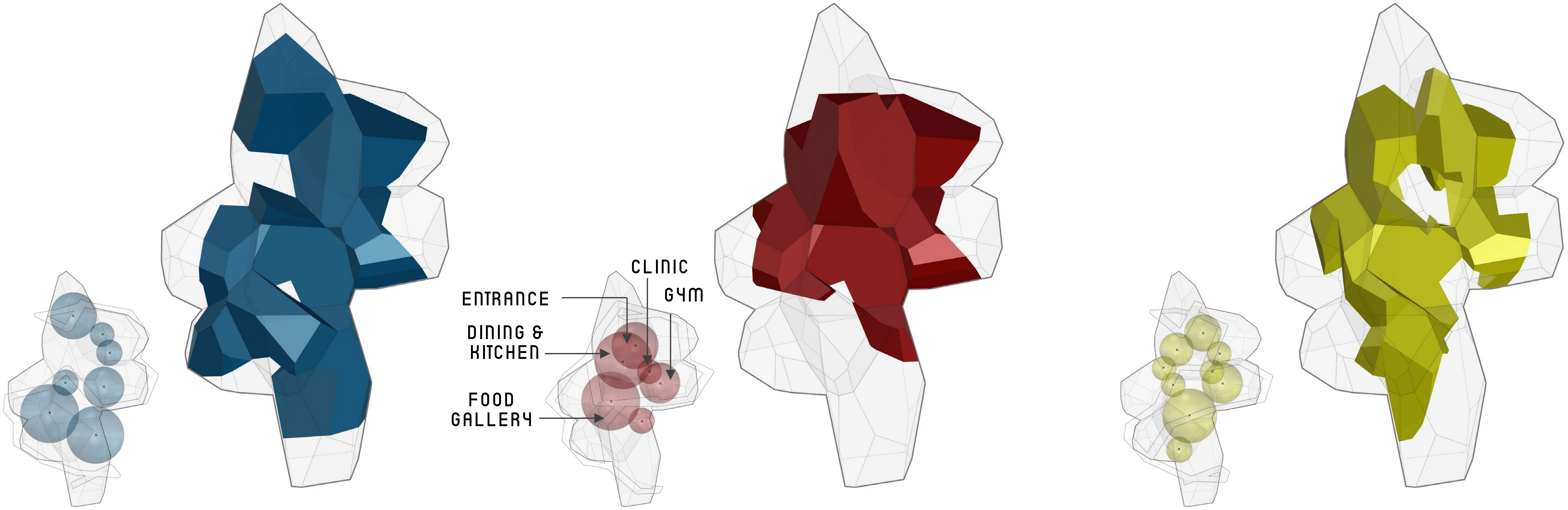
thick walls and circulation



GRADUAL ANGLED PATH GOES THROUGH THICK WALLS

form finding

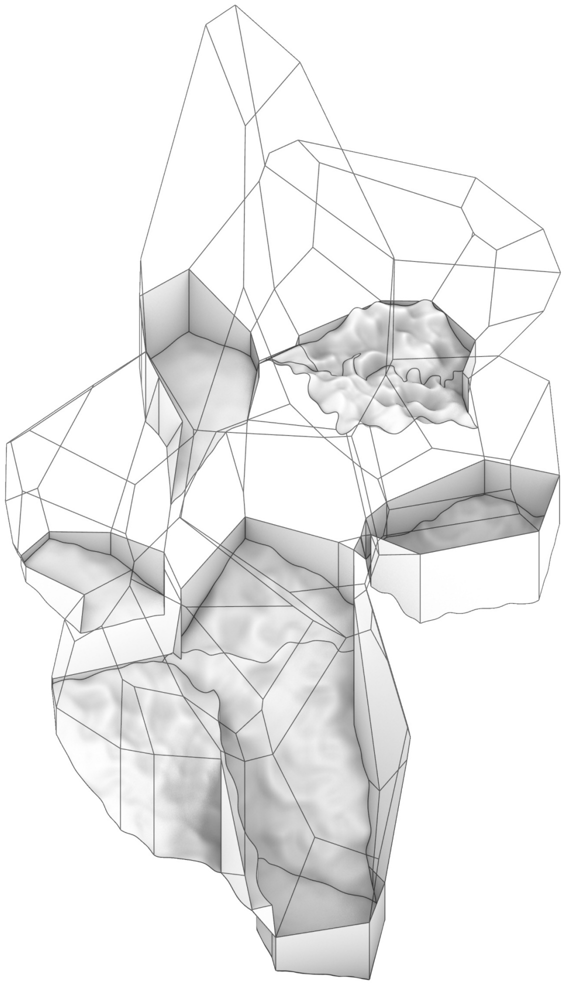
programmatic function



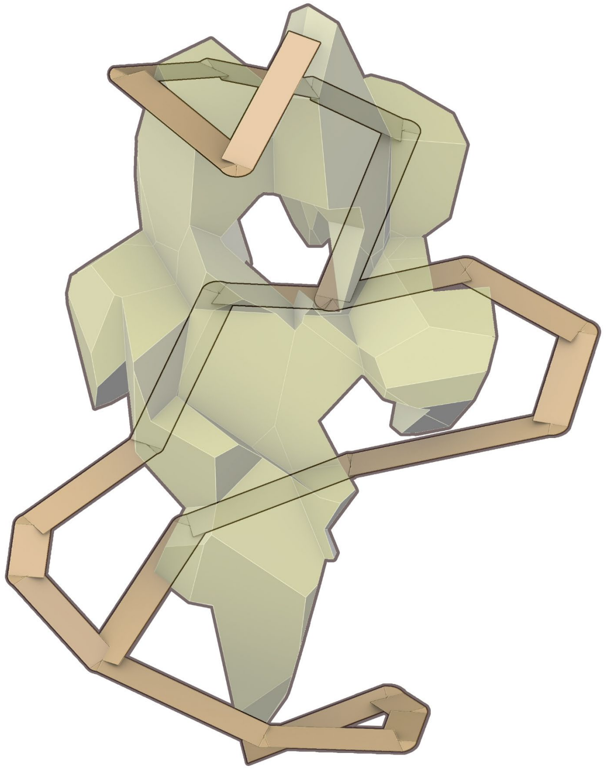
PROGRAM PLACEMENT TESTED ALONG CIRCULATION
POINTS GENERATED FROM SPHERES -> CONVERTED INTO VORONOI-BASED SPACES

form finding

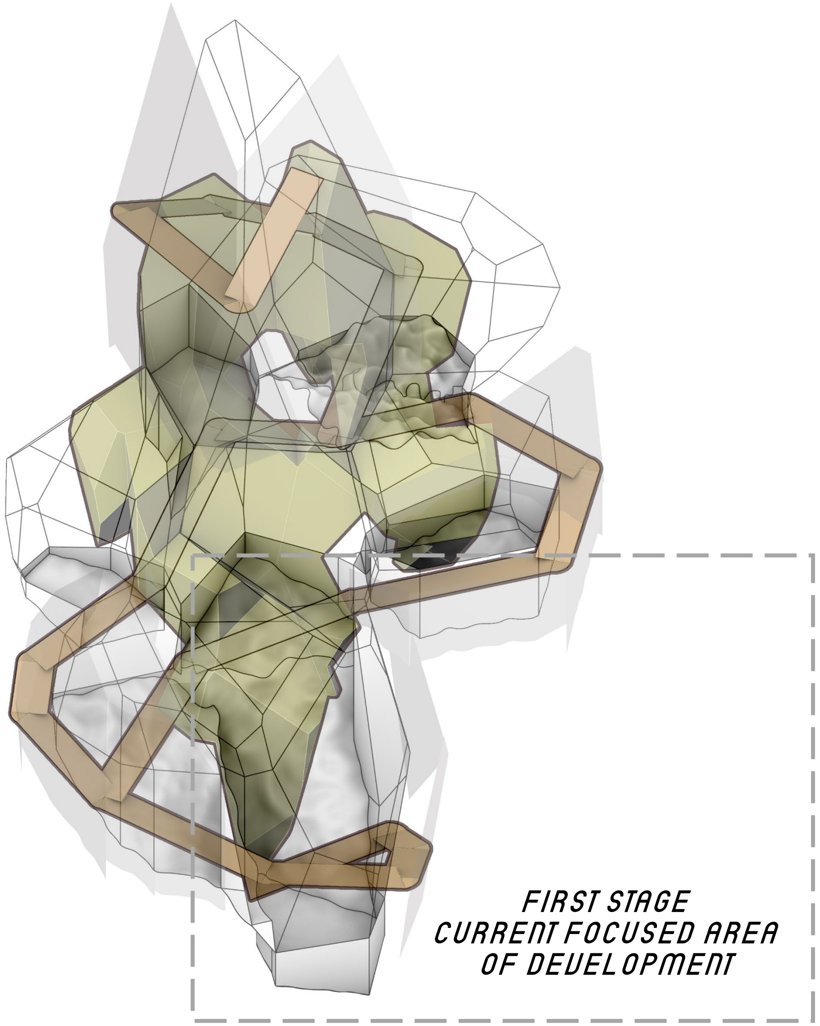
man-made to nature



NATURAL TERRAIN



BUILT ELEMENTS



INTERTWINED

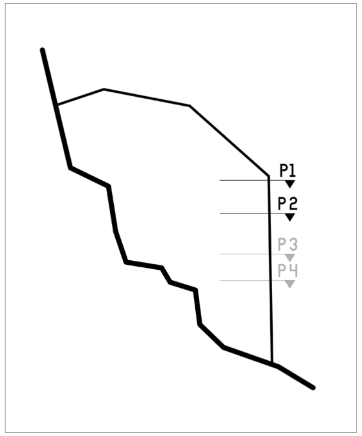
ARCHITECTURAL ELEMENTS - EXISTING TERRAIN -> SURFACES ANGLES AND RESOLUTION

plans

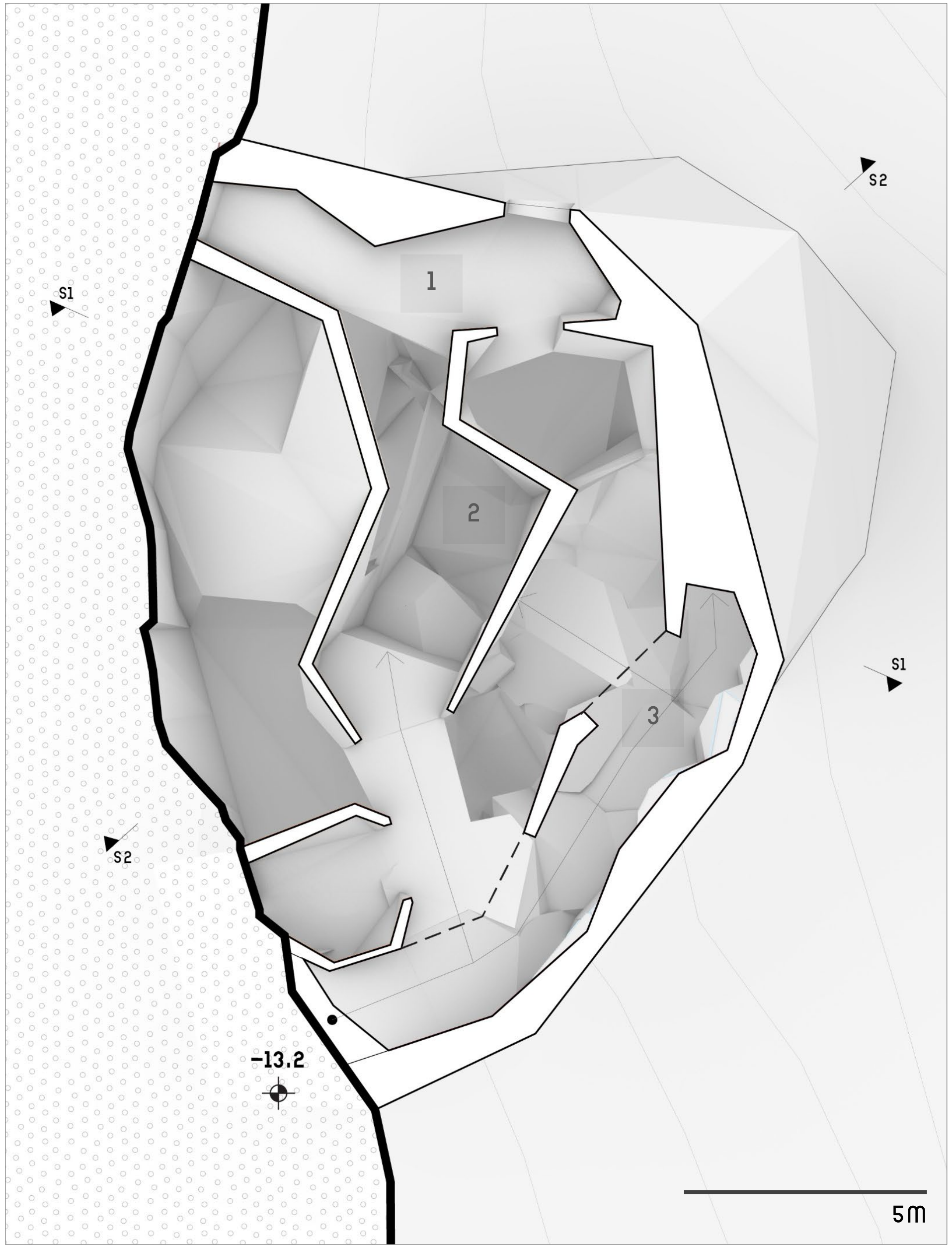
(zoom in to 1:100)

ARCHITECTURAL ELEMENTS - VIEWS, BODY ENGAGEMENT

1	WORK ZONE
2	EAT ZONE
3	INTERNAL RAMPWAY



PLAN 1



PLAN 2

DESIGN

plans

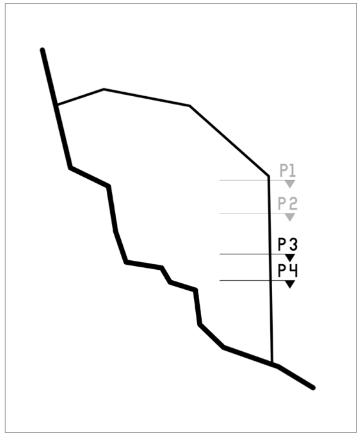
ARCHITECTURAL ELEMENTS -

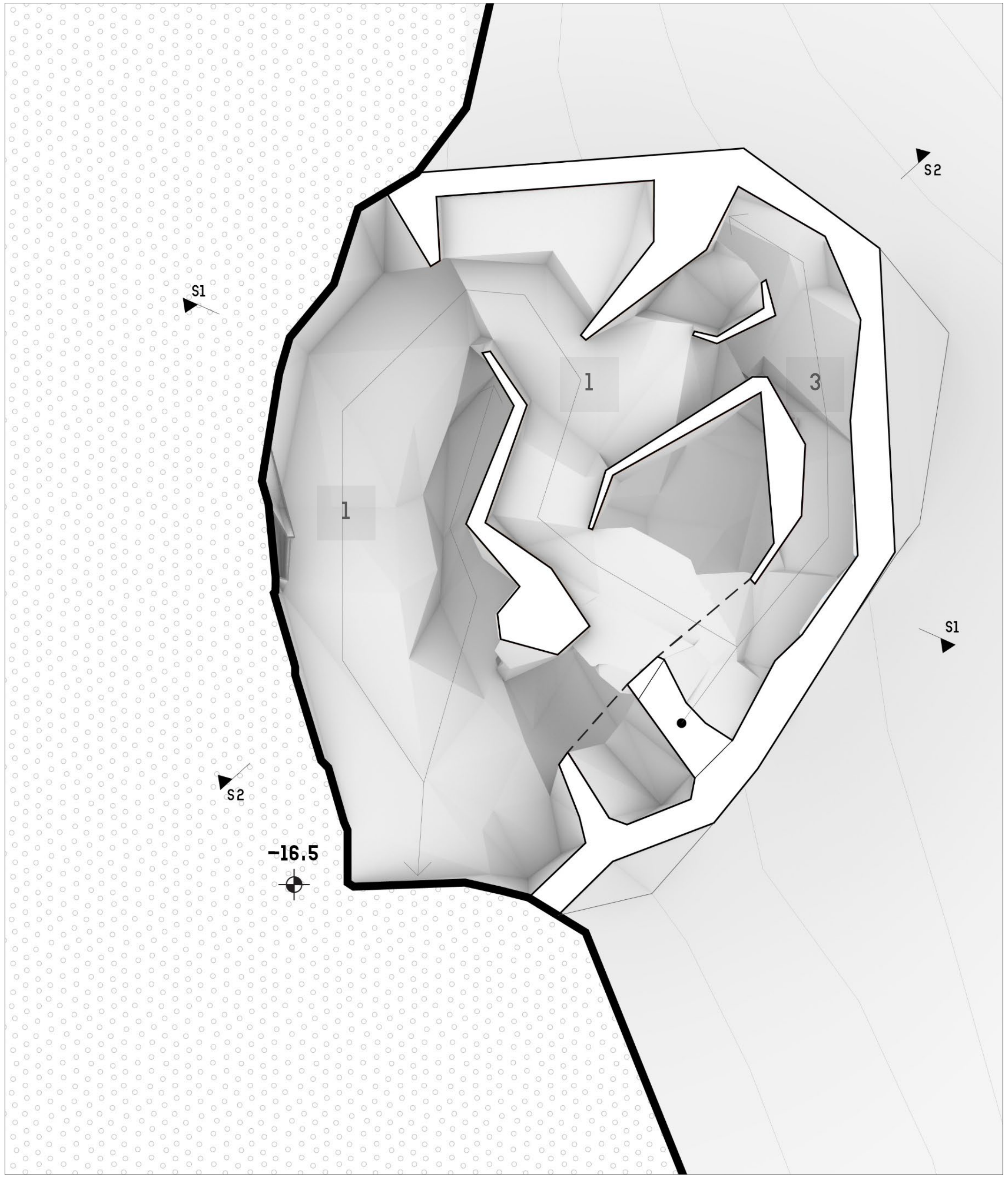
VIEWS, BODY ENGAGEMENT

1 EAT ZONE

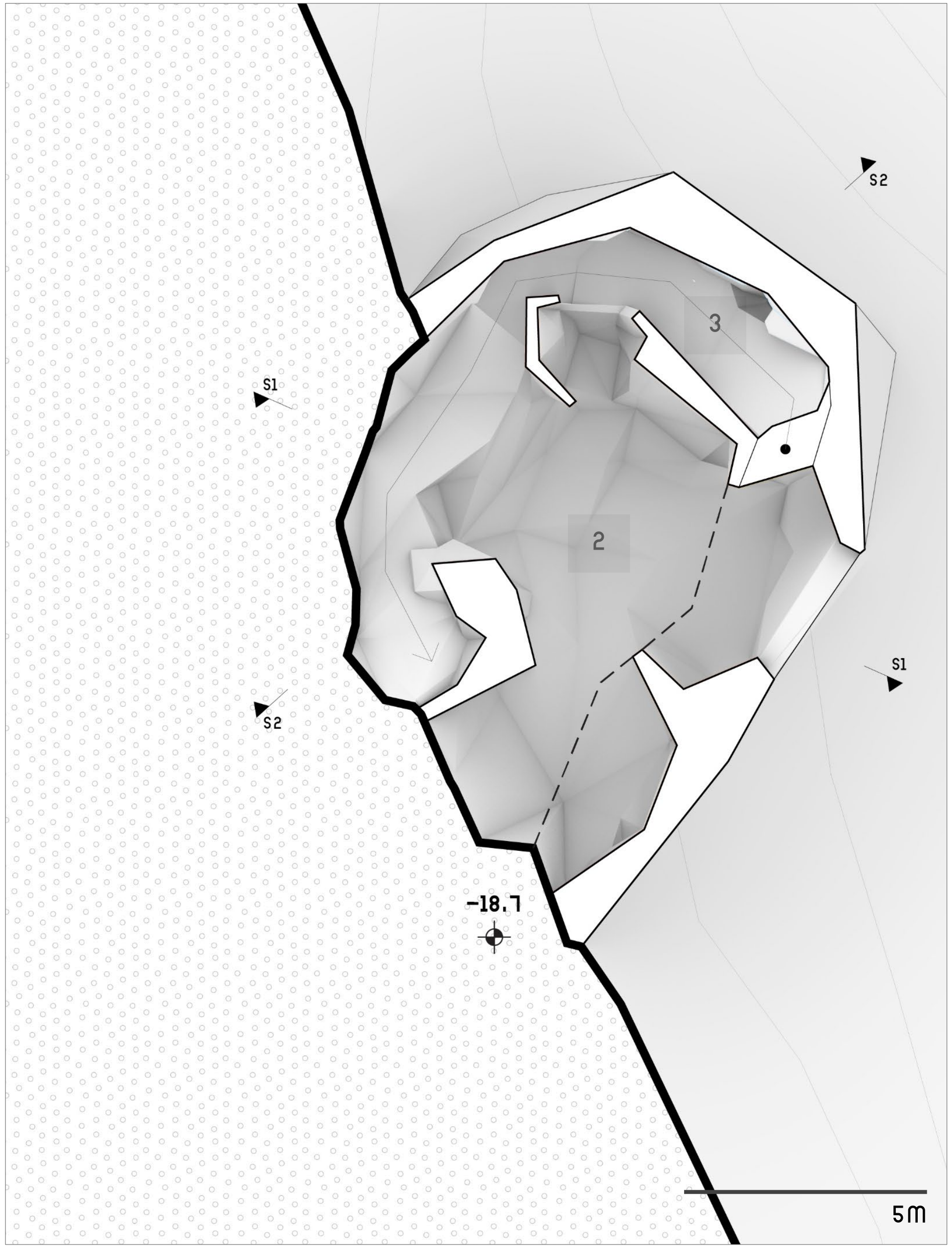
2 SOCIALISE ZONE

3 INTERNAL RAMPWAY





PLAN 3



PLAN 4

DESIGN

sections

ARCHITECTURAL ELEMENTS - VIEWS, BODY ENGAGEMENT

1	WORK ZONE
2	EAT ZONE
3	SOCIALISE ZONE
4	INTERNAL RAMPWAY

SECTION 1

5m

DESIGN

sections

ARCHITECTURAL ELEMENTS –

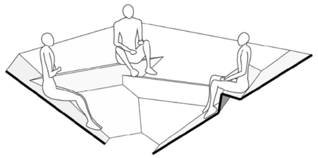
VIEWS, BODY ENGAGEMENT

1	WORK ZONE
2	EAT ZONE
3	SOCIALISE ZONE
4	INTERNAL RAMPWAY

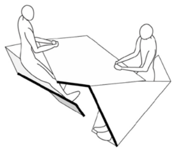
activities to furniture integration

(zoom in to 1:50)

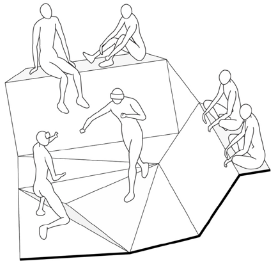
HUMAN BASIC ACTIVITIES AT THE MAIN ATRIUM



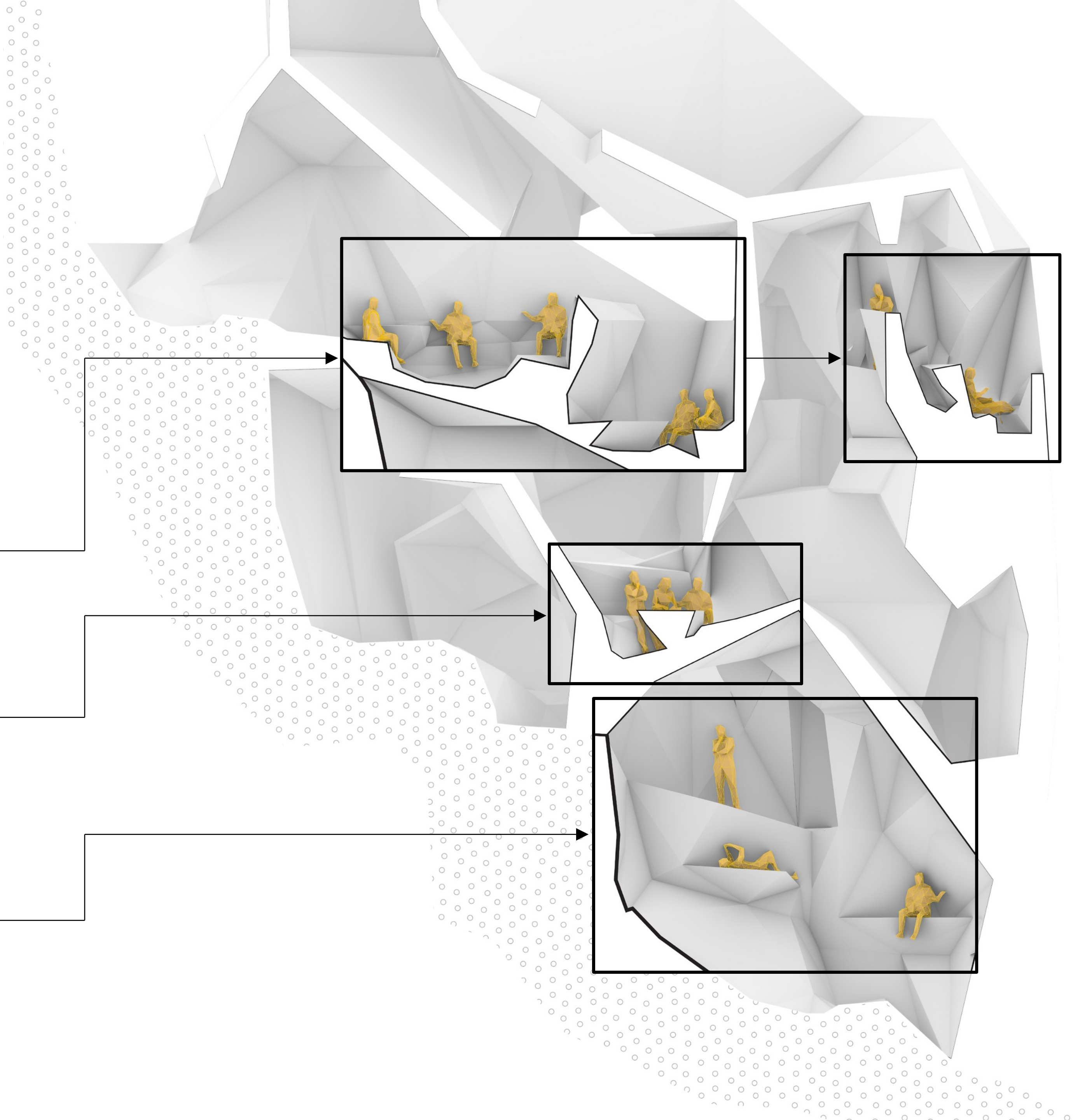
WORK



EAT

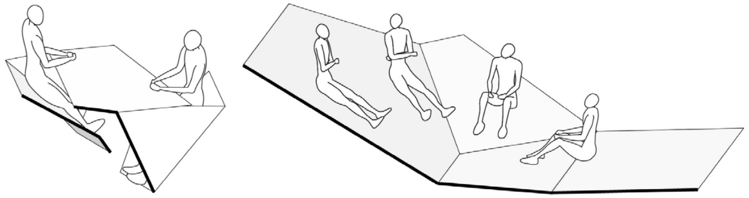


SOCIALISE



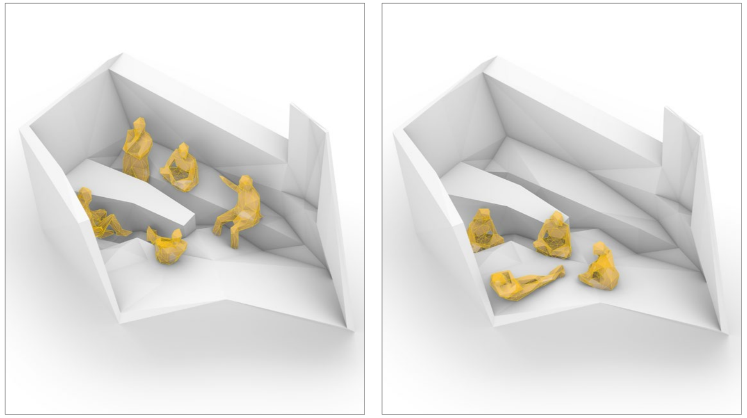
activities to furniture integration

EAT

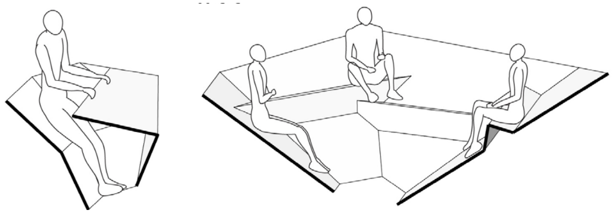


DINE

PICNIC

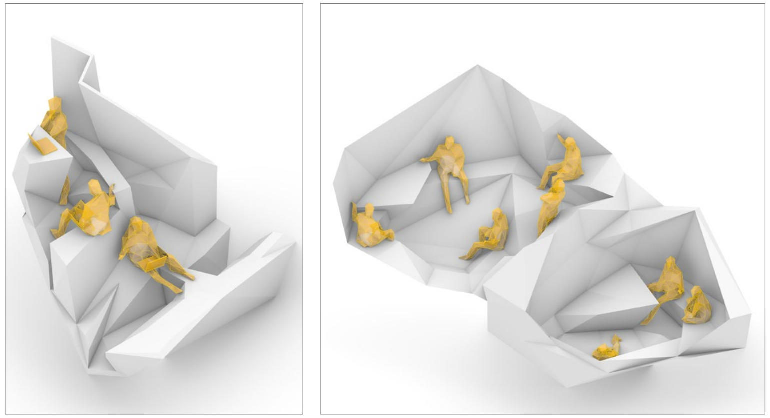


WORK

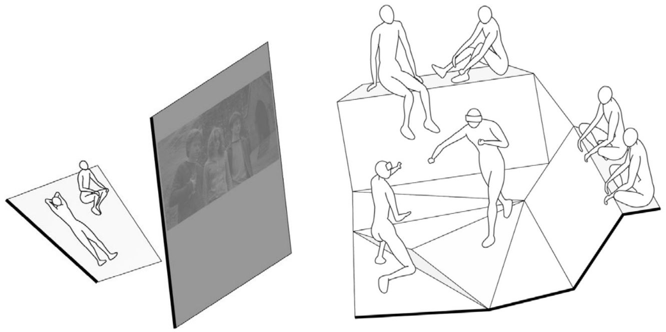


DESKTOP

DISCUSS

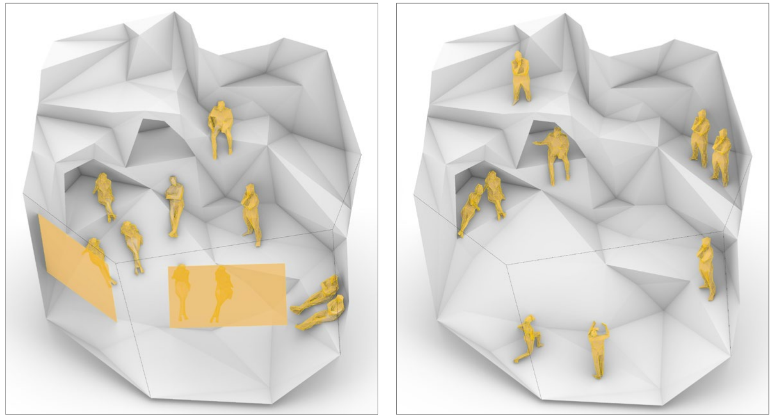


SOCIALISE



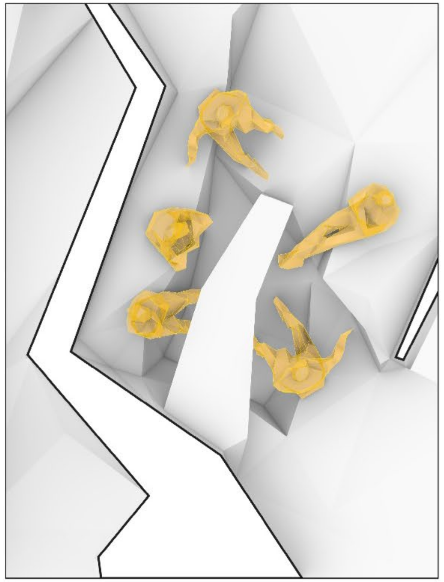
MOVIE

VIRTUAL REALITY

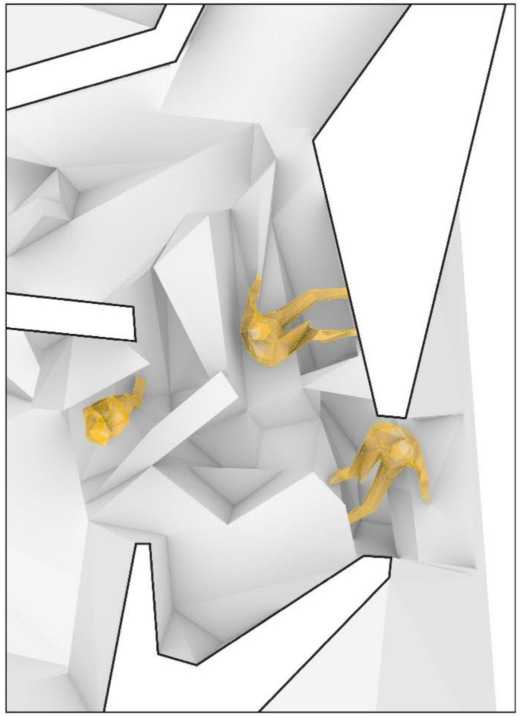


body to furniture design

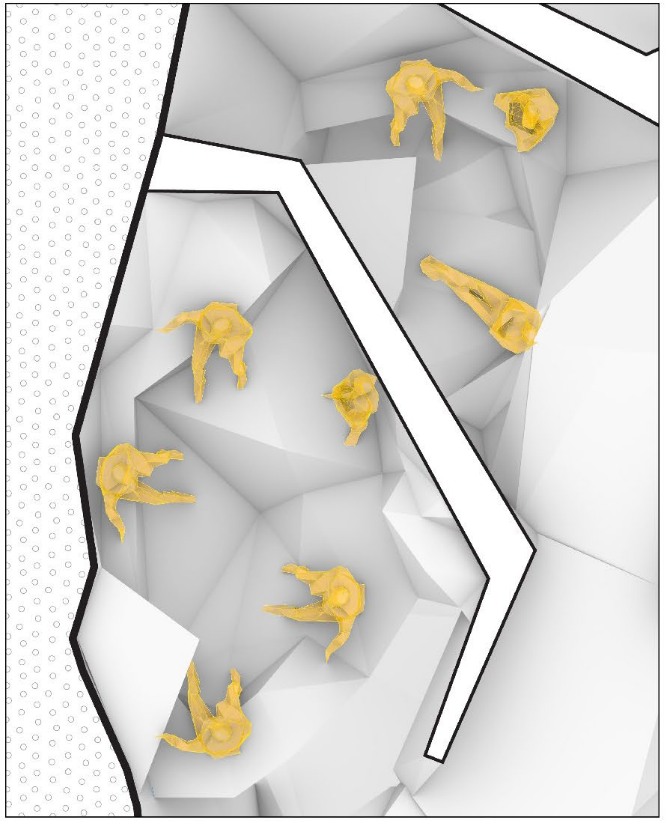
EAT



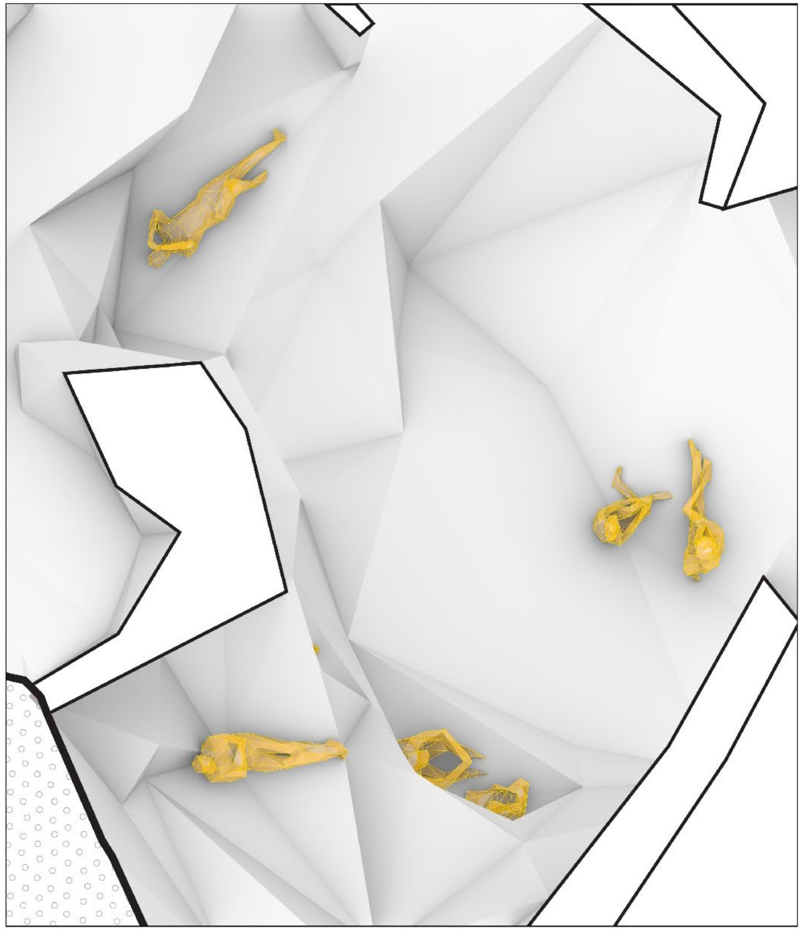
WORK (DESKTOP)



WORK (DISCUSSION)

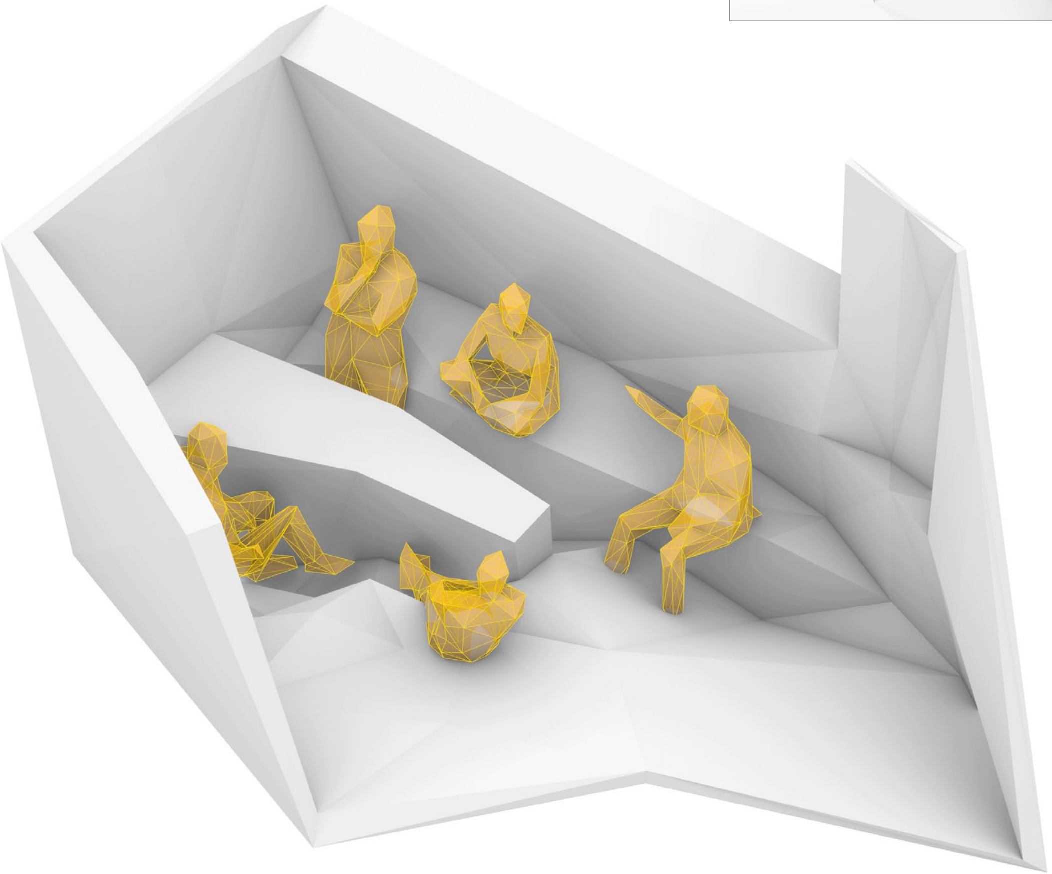


SOCIALISE

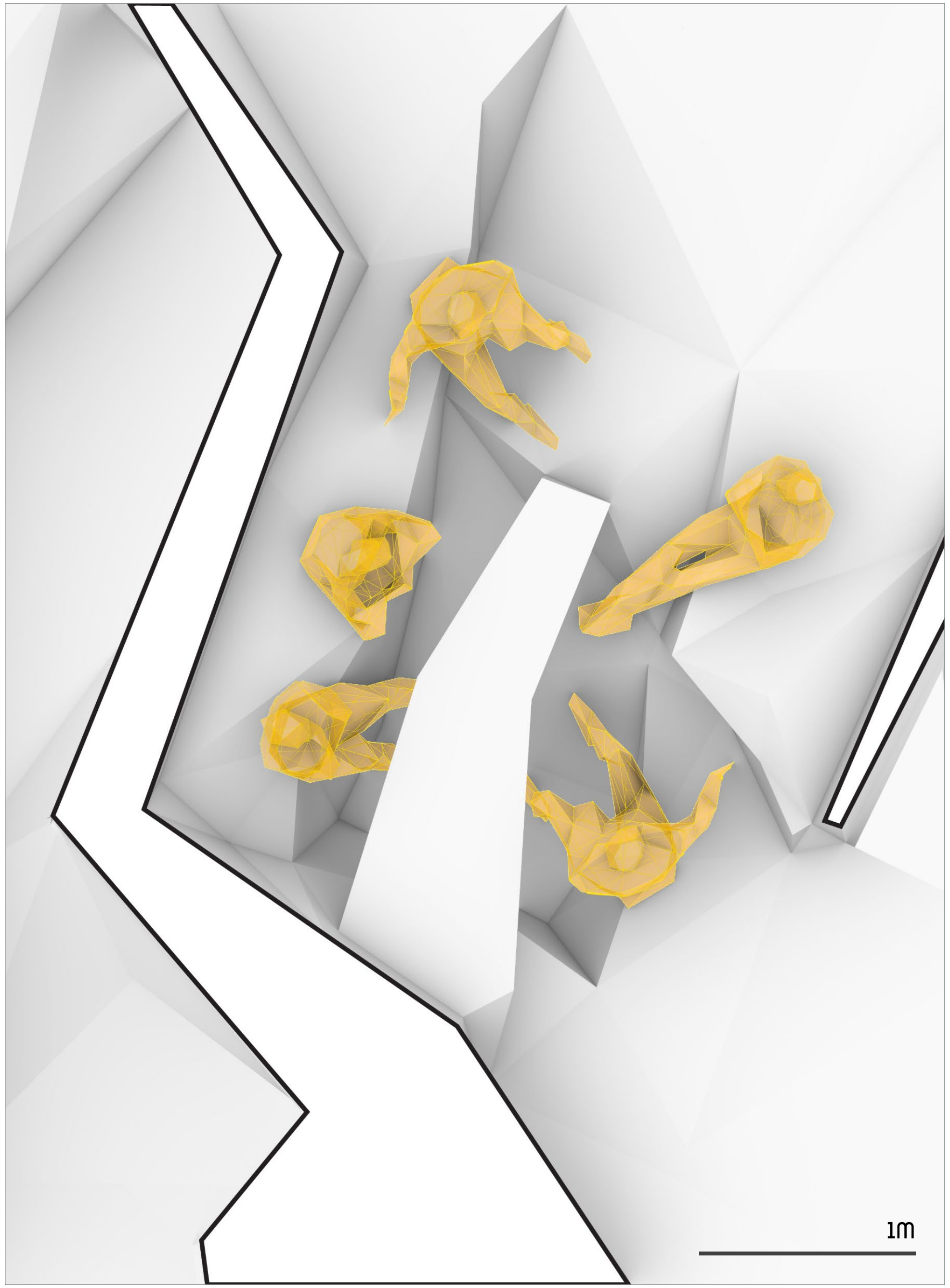


2m

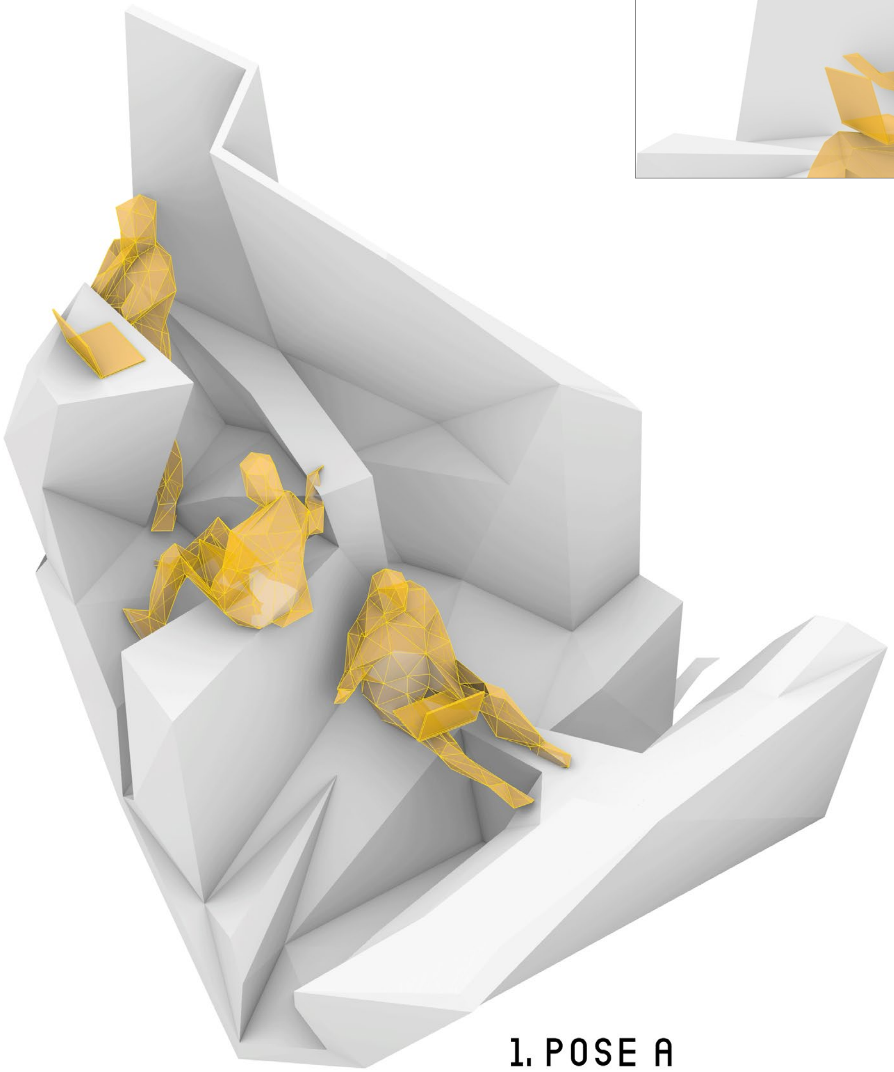
eat



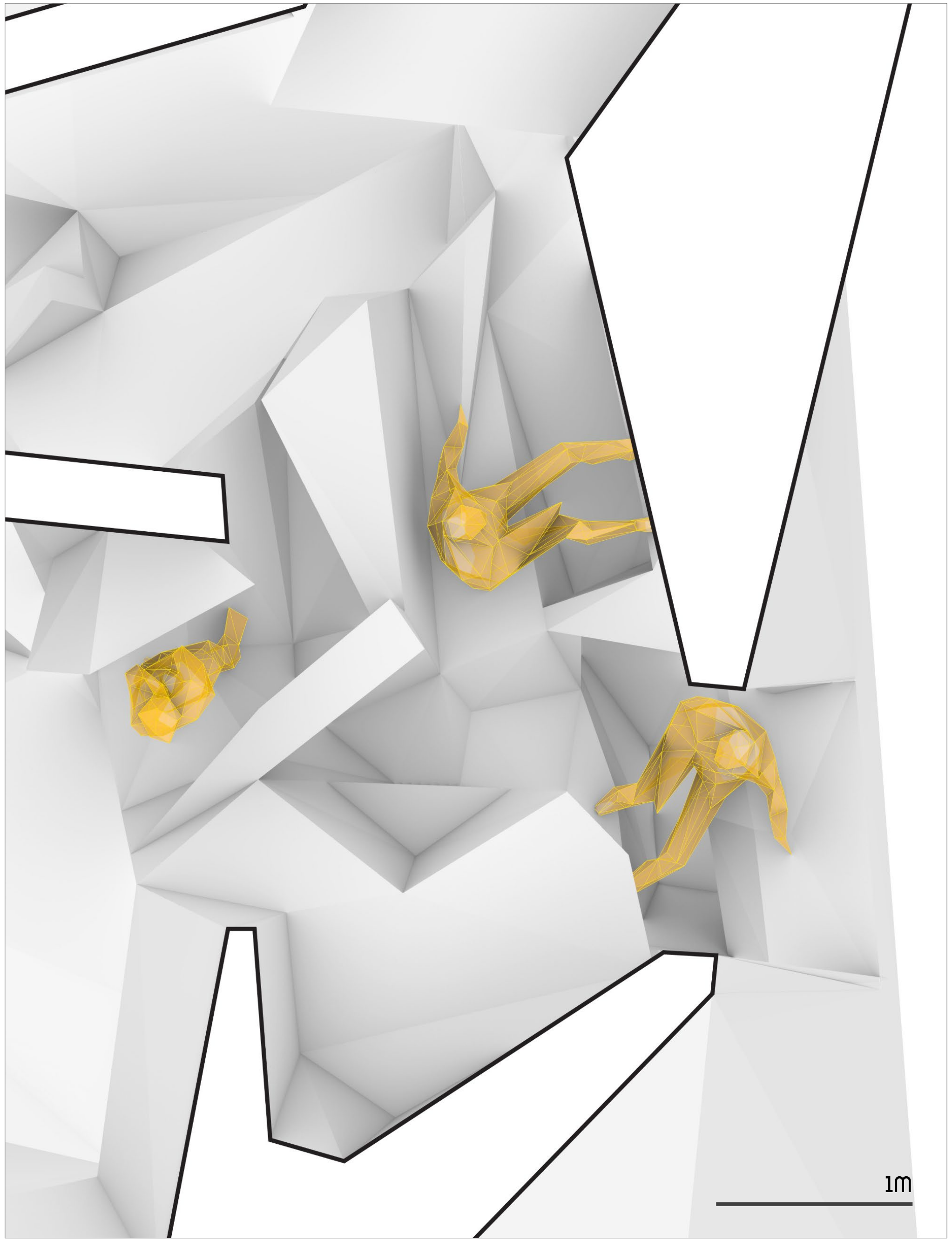
1. SHARED-TABLE



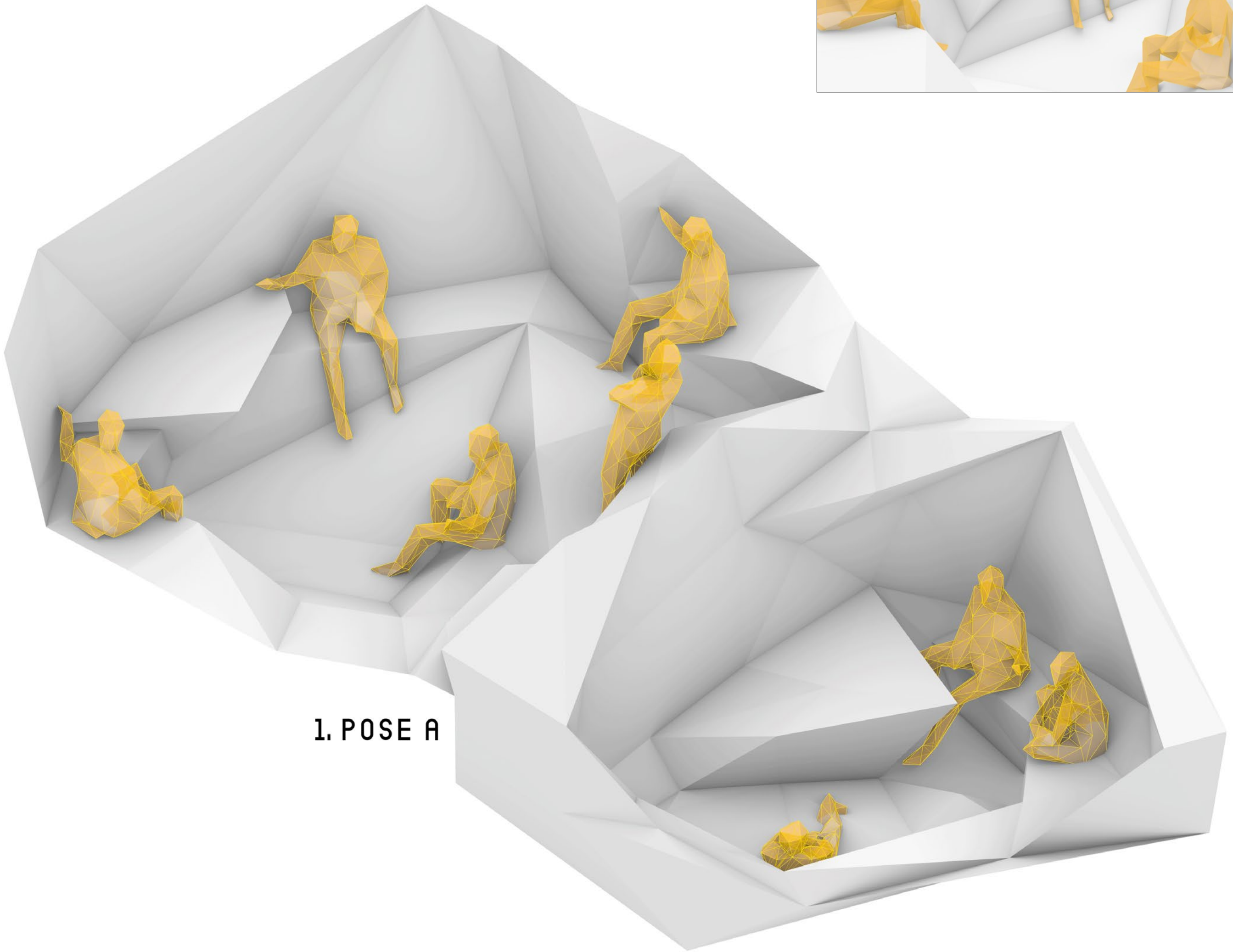
work (desktop)



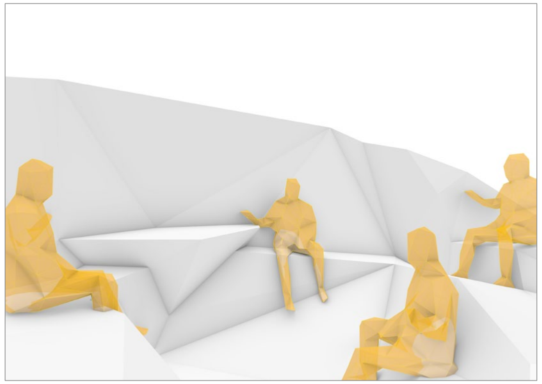
1. POSE A

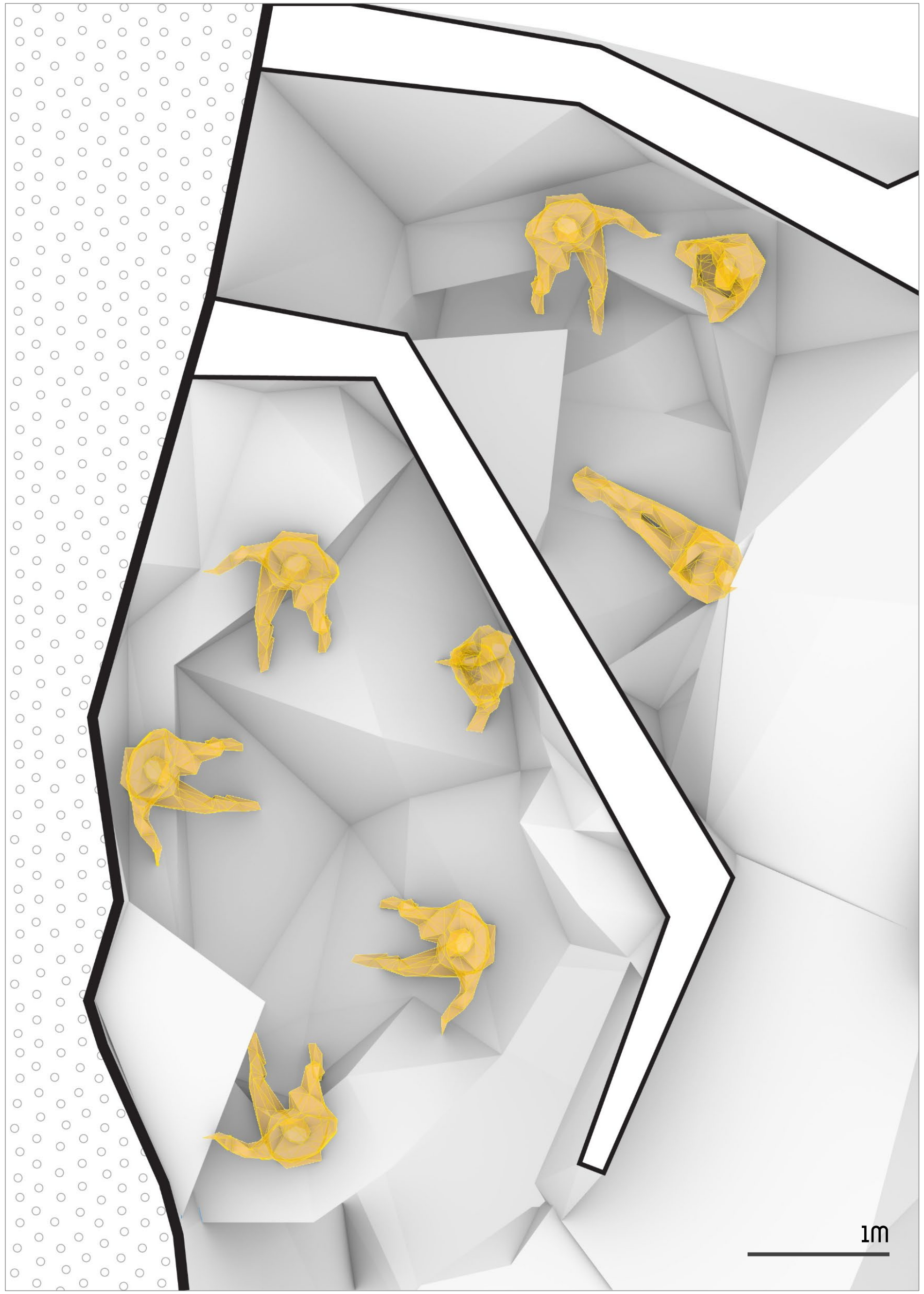


work (discussion)

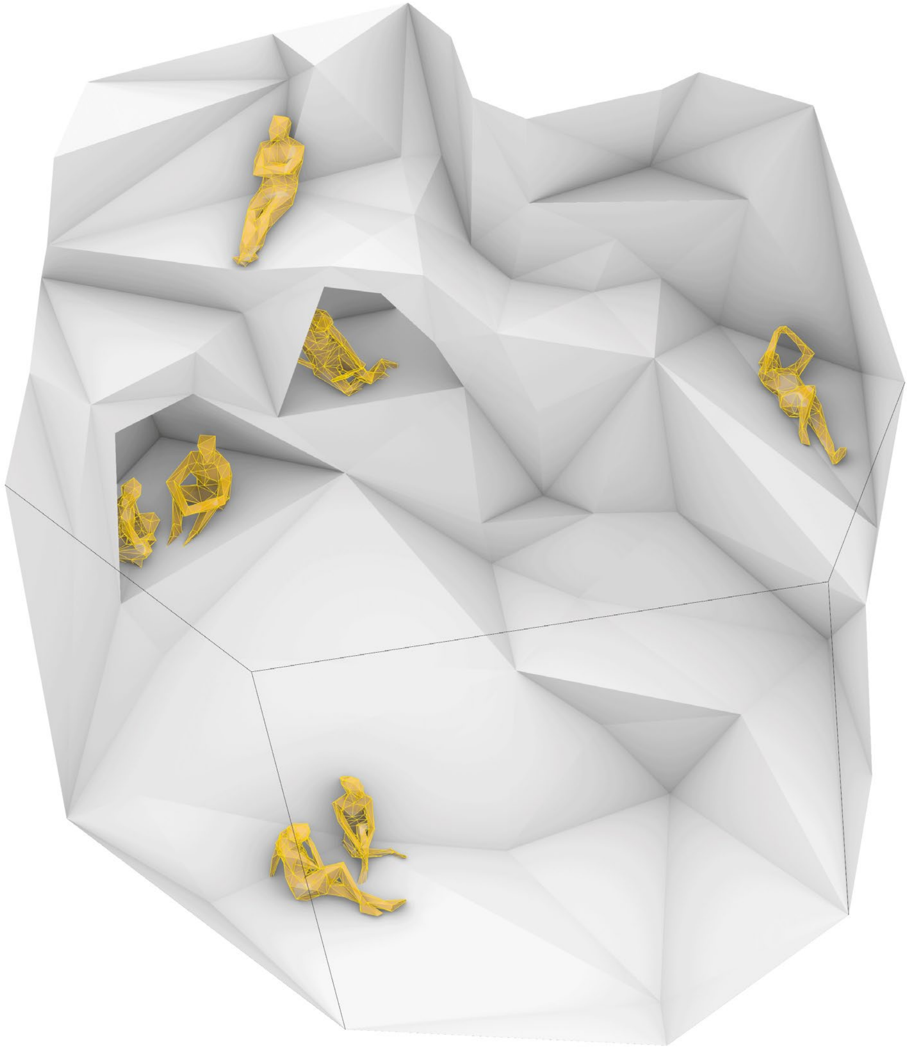


1. POSE A

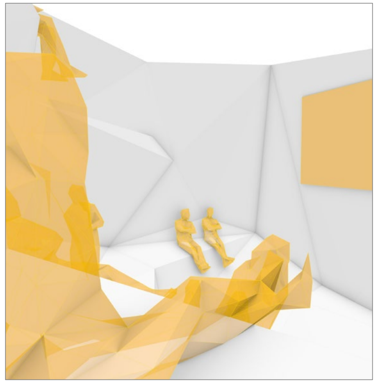




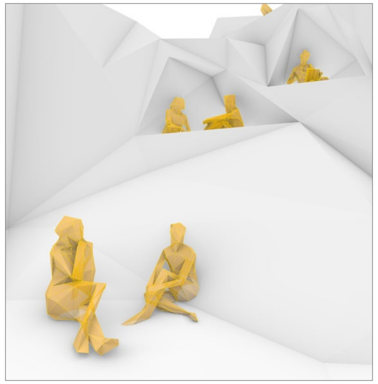
socialise



1. SINGLE/SMALL GROUP

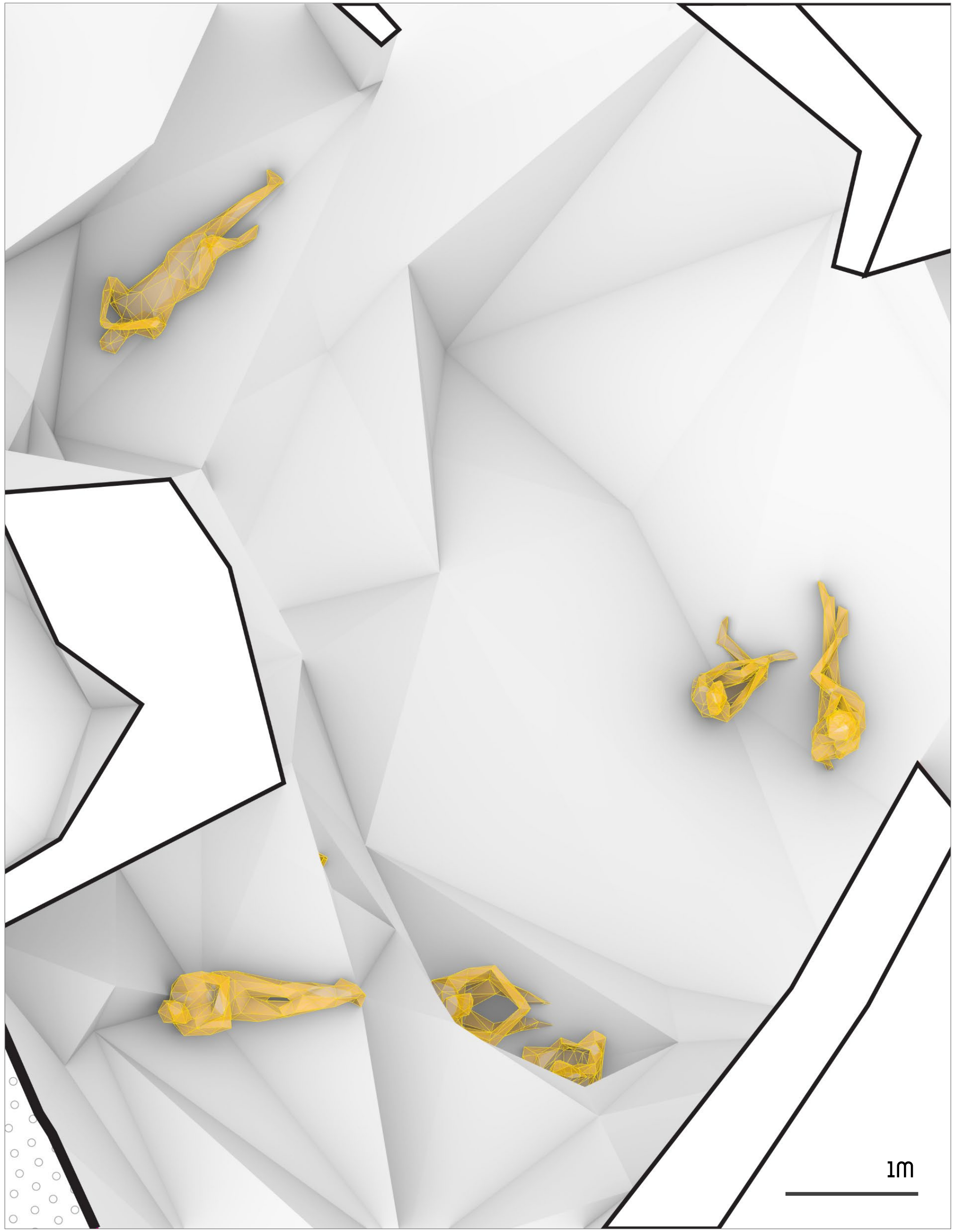


MOVIE

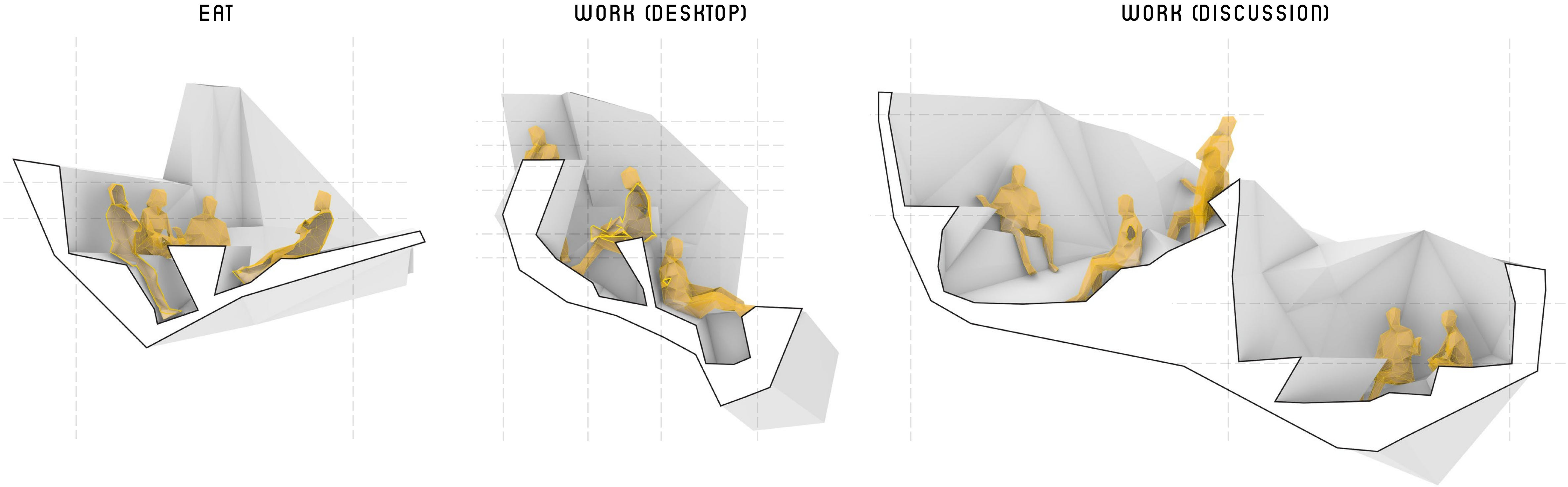


SMALL GROUP

VR GAMES



furniture design: zoning and levels



RESOLUTION/ SPECIFICITY OF SURFACES — STABLE SURFACES I.E. FOR FOOD/ LAPTOP

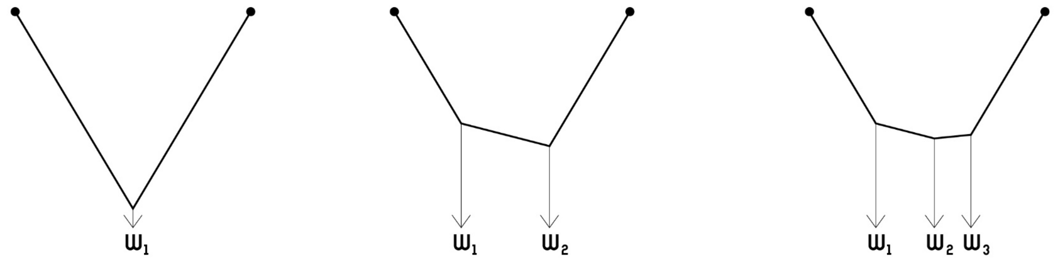
SPATIAL ZONING — PRIVACY LEVELS
SPECIFIC PREDETERMINED FUNCTION **VS** FLEXIBILITY FOR FURTHER DEVELOPMENT

SPACE <--> BODY — SIZE, LEVEL DIFFERENCE, DEGREE OF OPENNESS

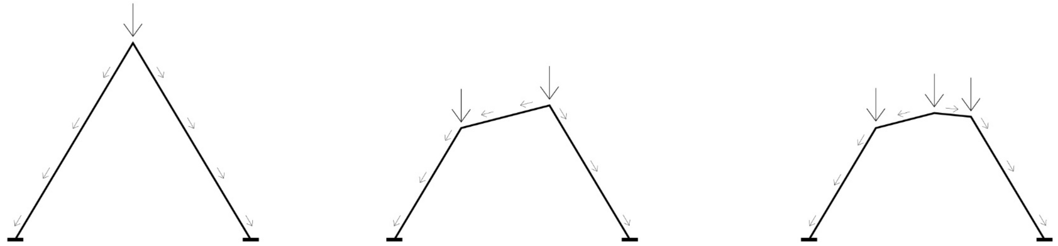
OVERVIEW OF

construction & materialisation

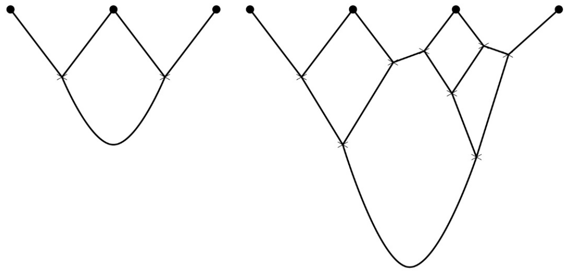
(inverted) catenary structure relationship



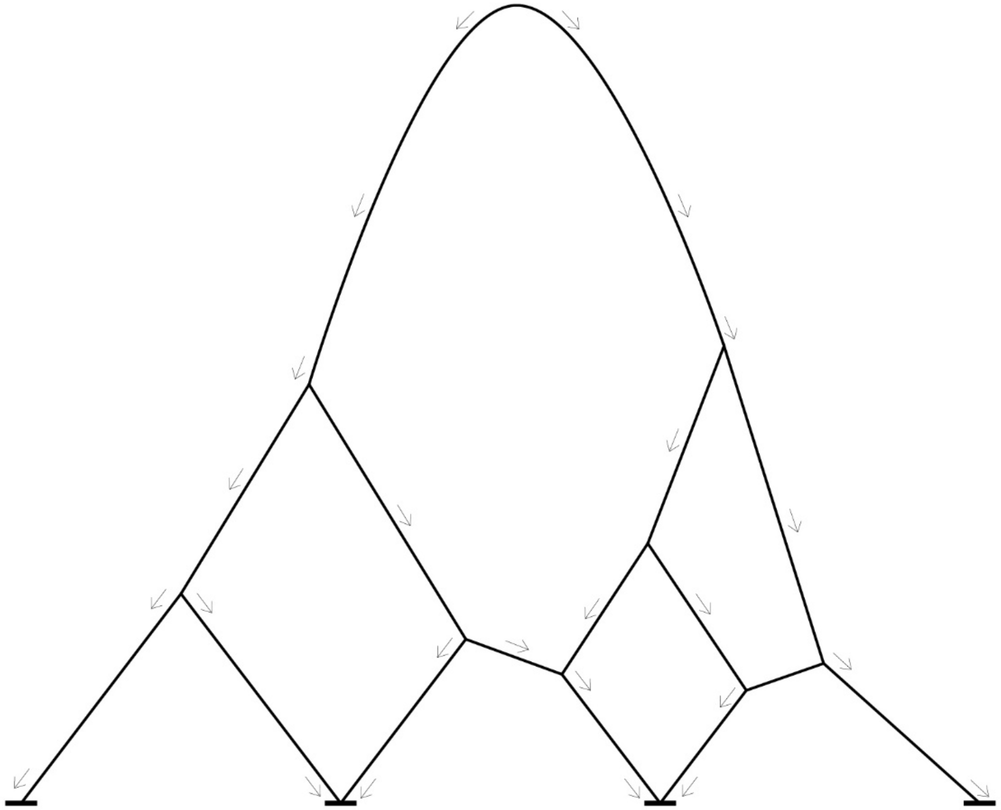
HANGING CHAINS (CATENARIES)



INVERTED CATENARIES = VORONOI THRUST LINES



NESTED CATENARIES

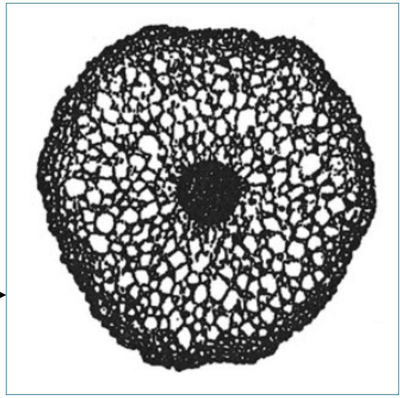


INVERTED NESTED CATENARIES

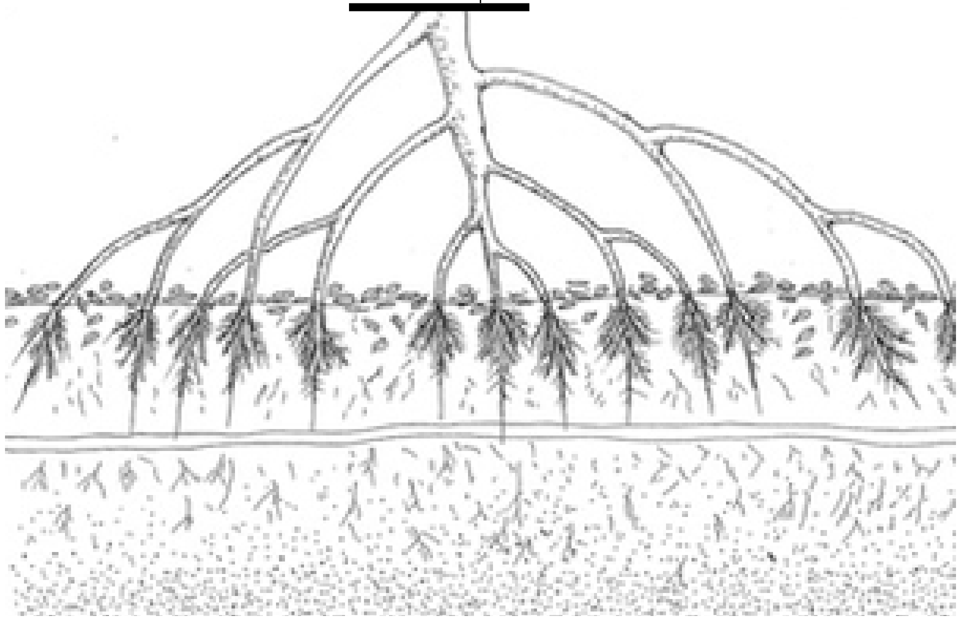
inverted nested catenaries in nature

MANGROVE TREE ROOTS

SOURCE: JOURNAL OF PLANT RESEARCH (2004), PLANTSNAP



MICRO-STRUCTURE THAT RESEMBLES VORONOI

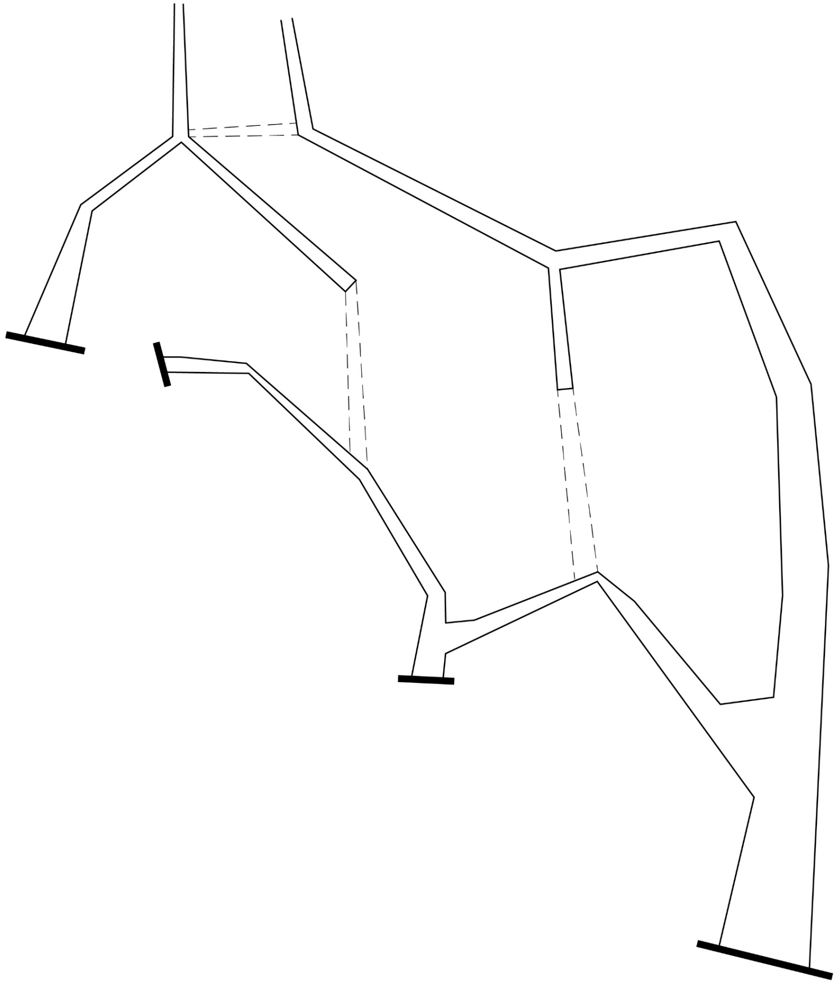


STILT-ROOT = STRUCTURE THAT GROWS AND EXPANDS OVER TIME

SOURCE: PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES (2016)

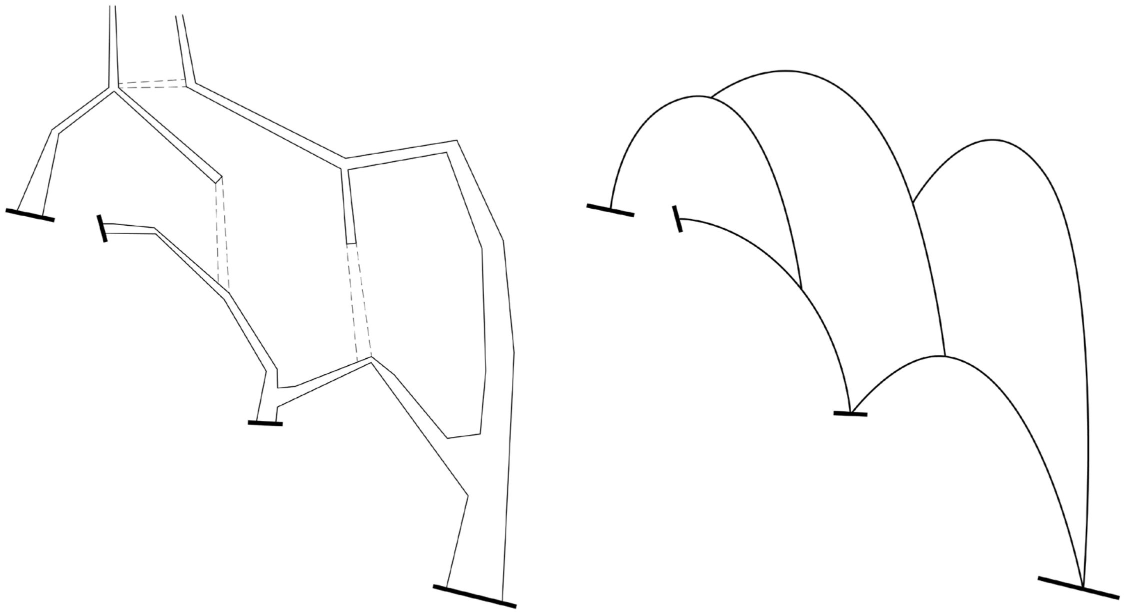
overall structural logic

BUILDING SECTION CUT

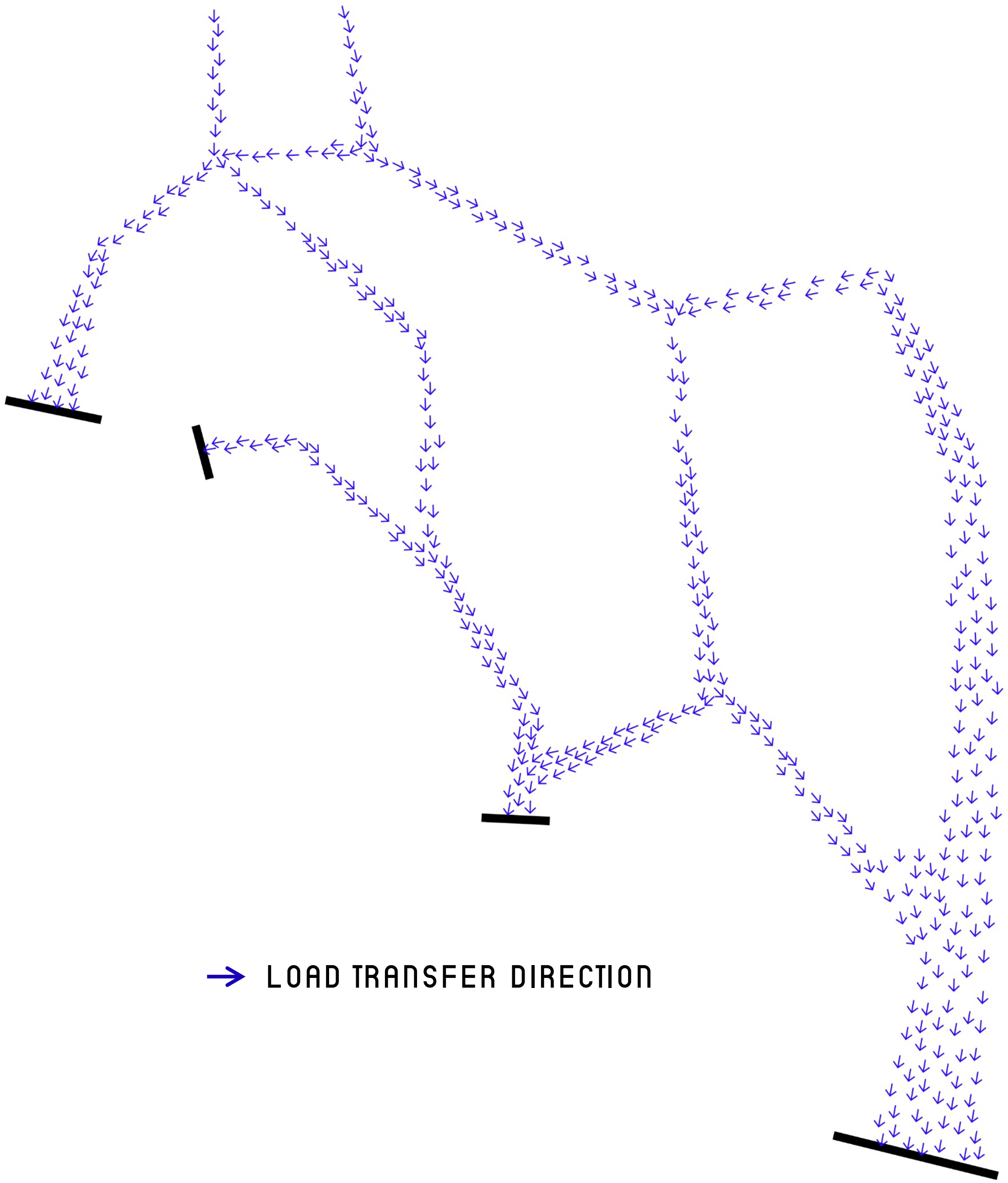


CONCEPTUALISED STRUCTURAL MEMBERS

overall structural logic

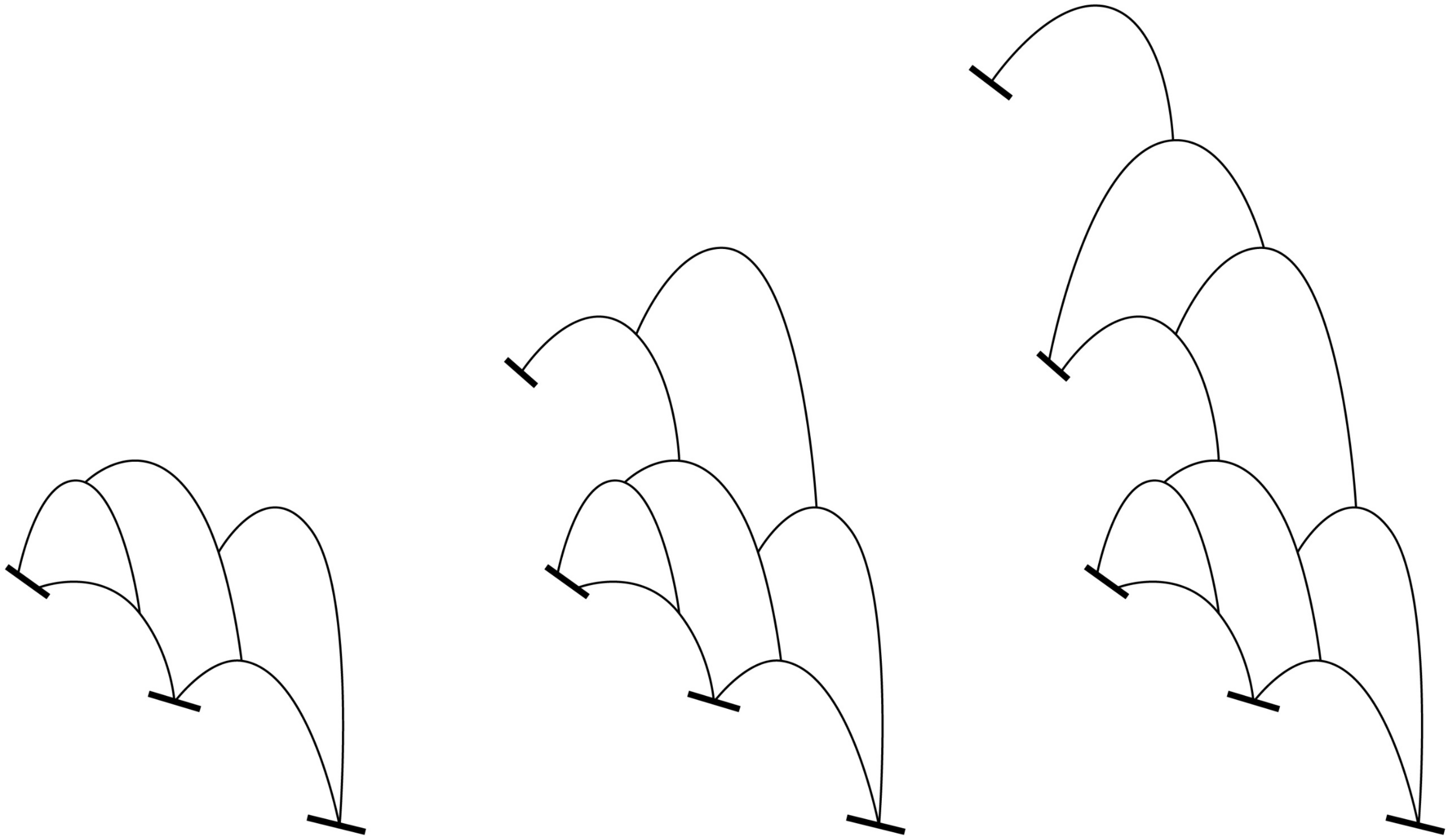


INVERTED NESTED CATENARIES TRANSLATION



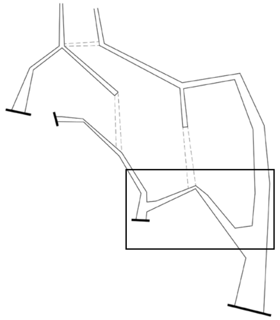
LOAD TRANSFER DIRECTION

habitat expansion overtime

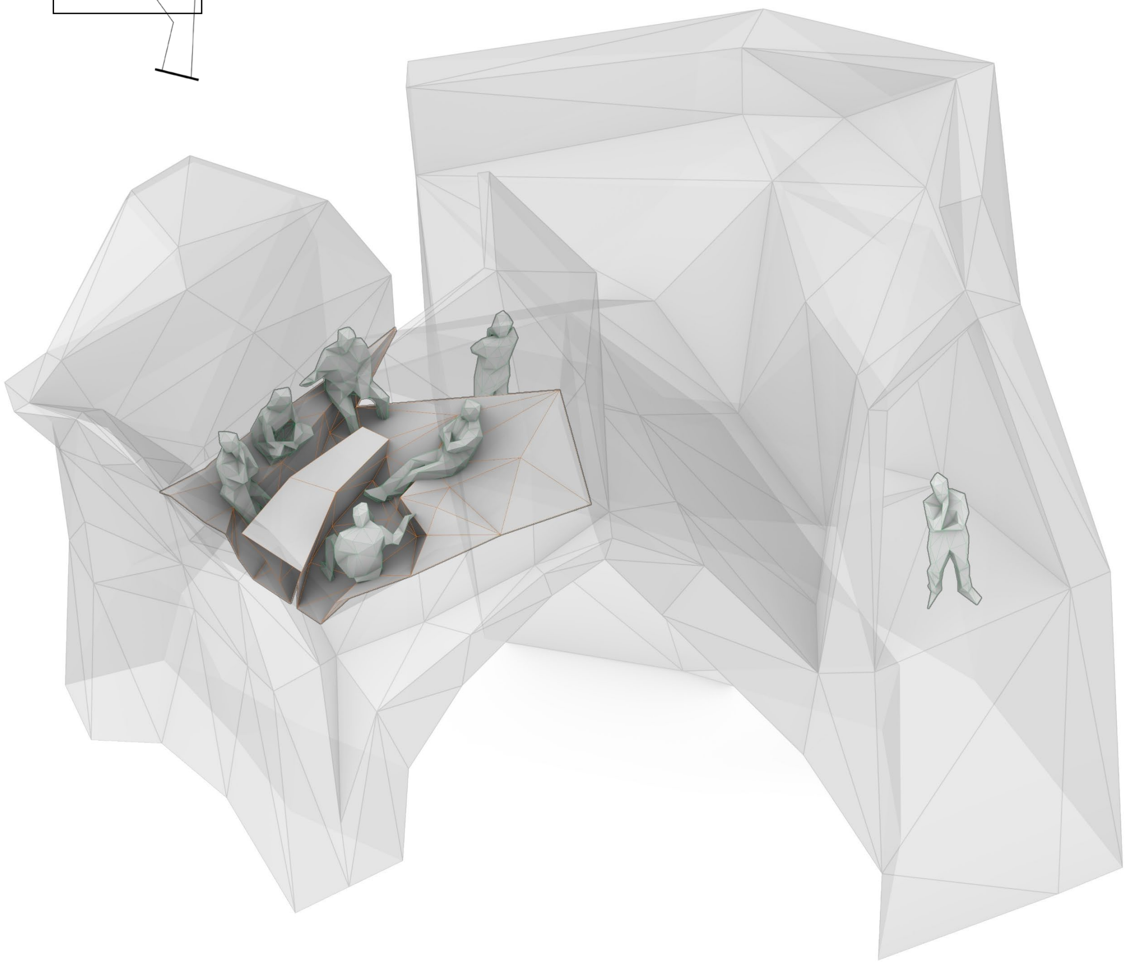


CURRENT STAGE → FUTURE STAGE

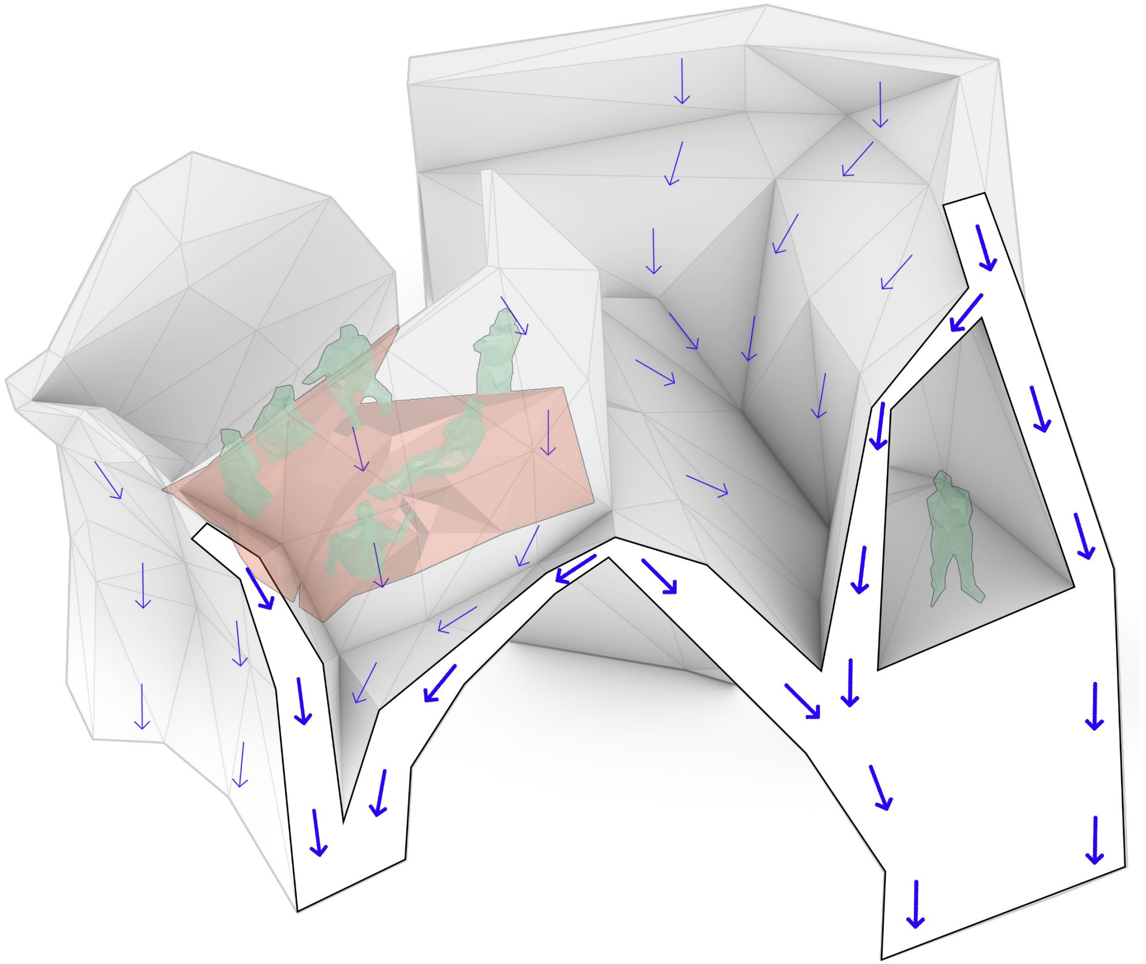
NESTED CATENARIES STRUCTURE IS EXPANDABLE OVERTIME



structural fragment



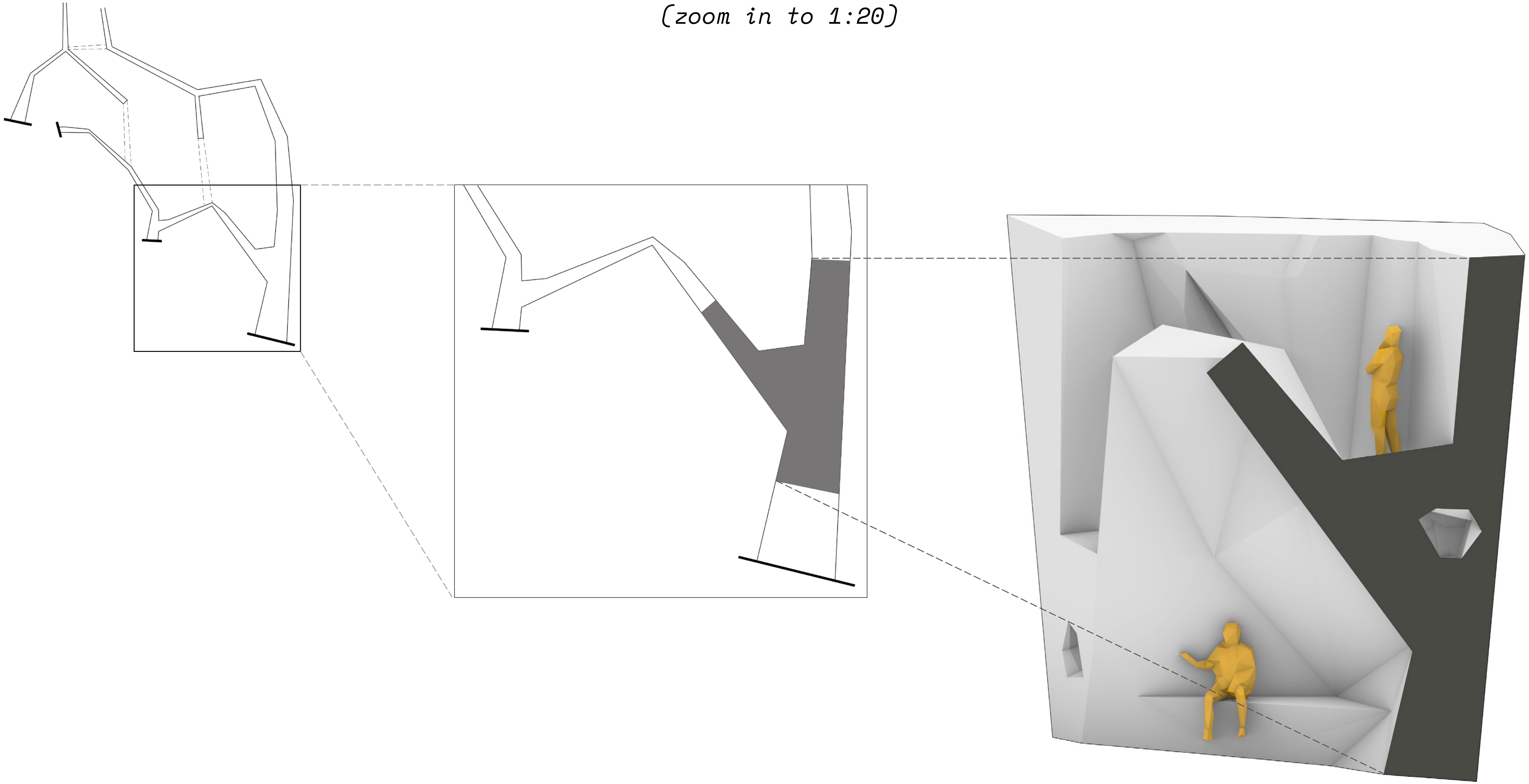
LOAD BEARING MEMBERS SUPPORTING DINING AREA & INTERNAL RAMP



COMPRESSION LOAD TRANSFER DIRECTION

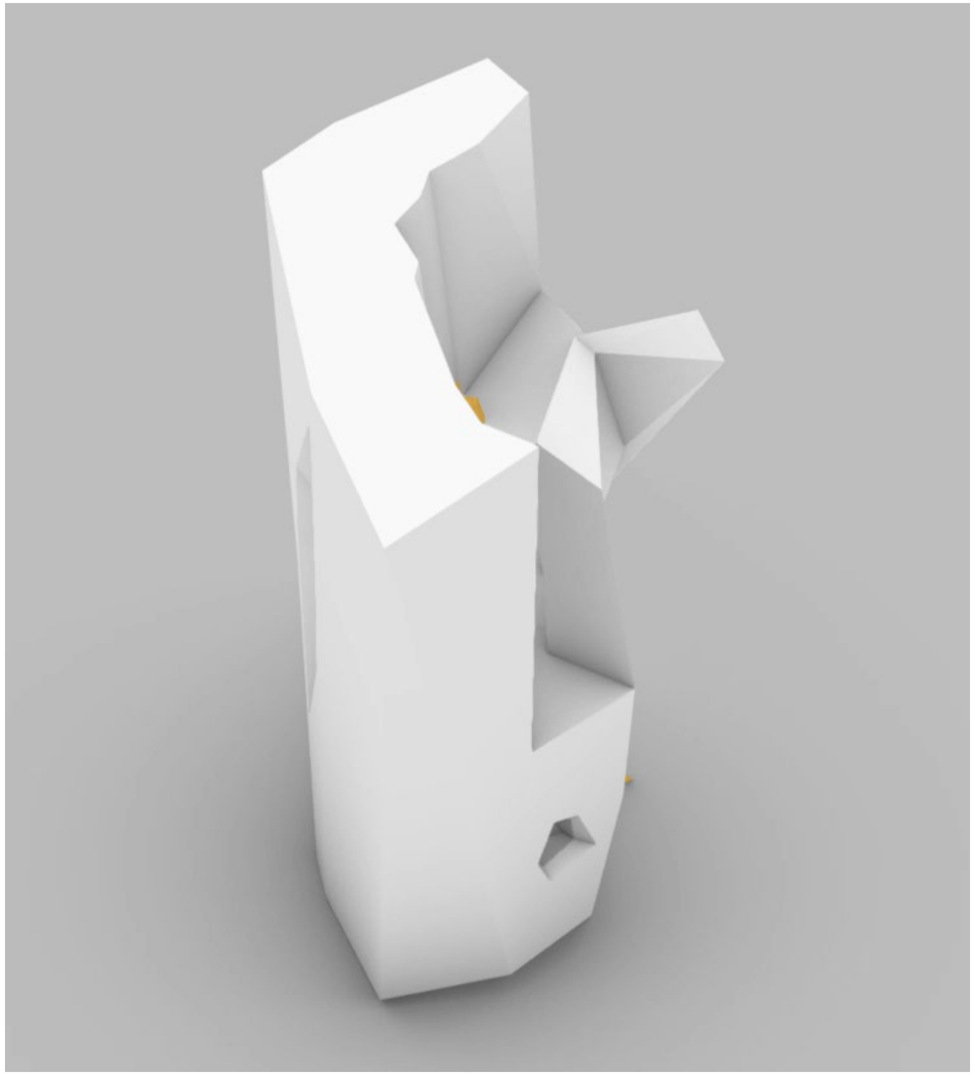
wall fragment for assembly

(zoom in to 1:20)

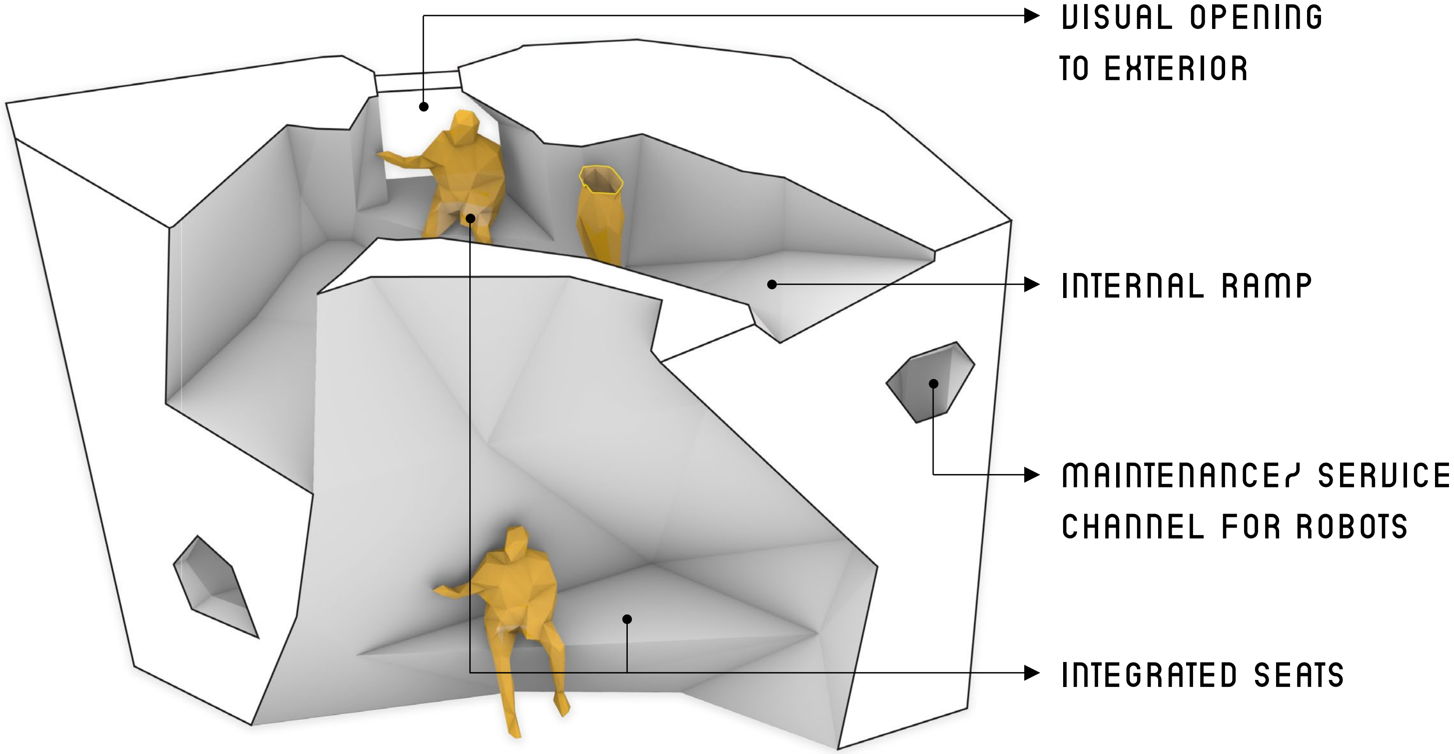


SELECTED WALL FRAGMENT

wall fragment for assembly



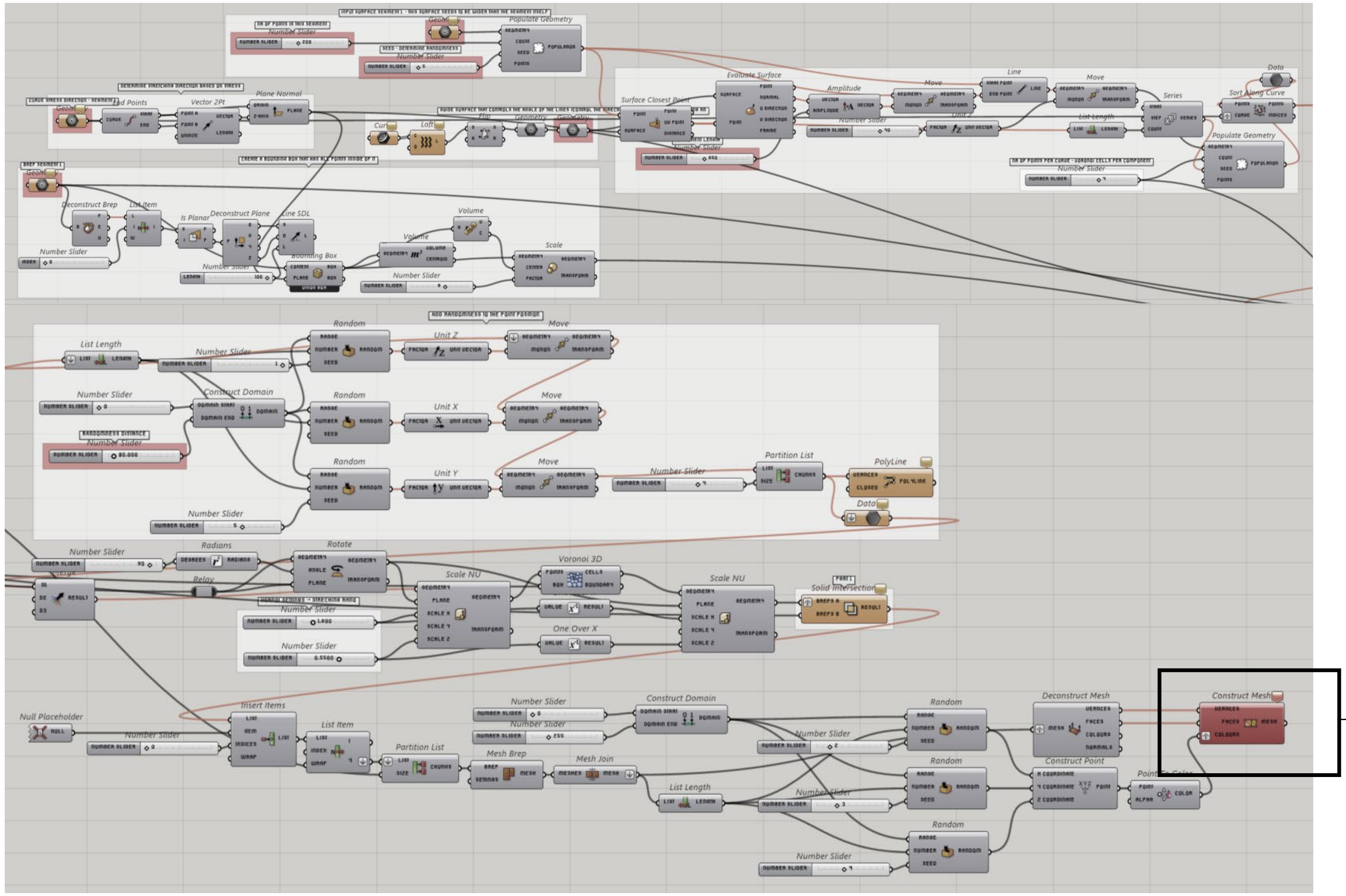
WALL FRAGMENT OVERVIEW



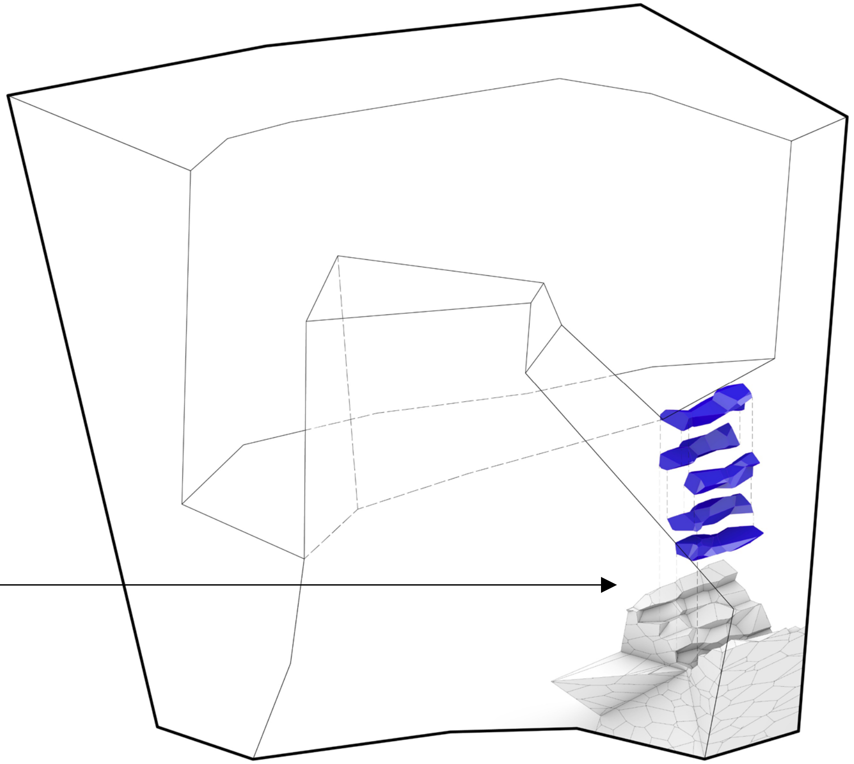
INTEGRATED FUNCTIONS

components design generation

(zoom in to 1:5)

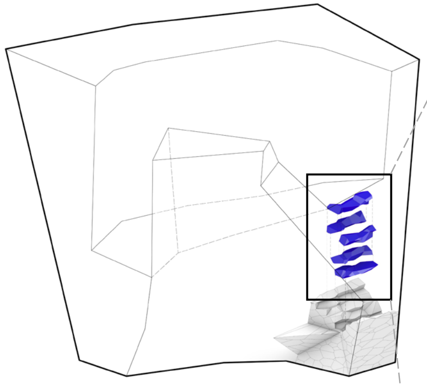


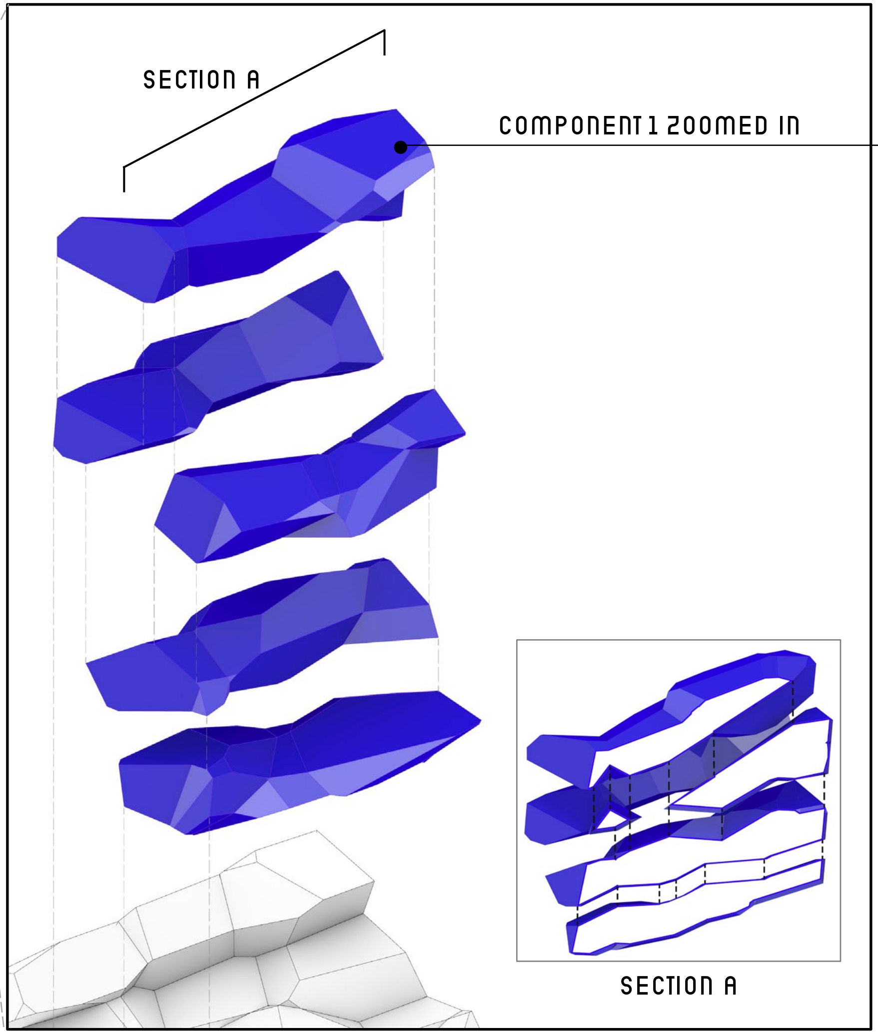
COMPUTATIONAL SCRIPT TO GENERATE COMPONENTS



COMPONENTS RESULTS

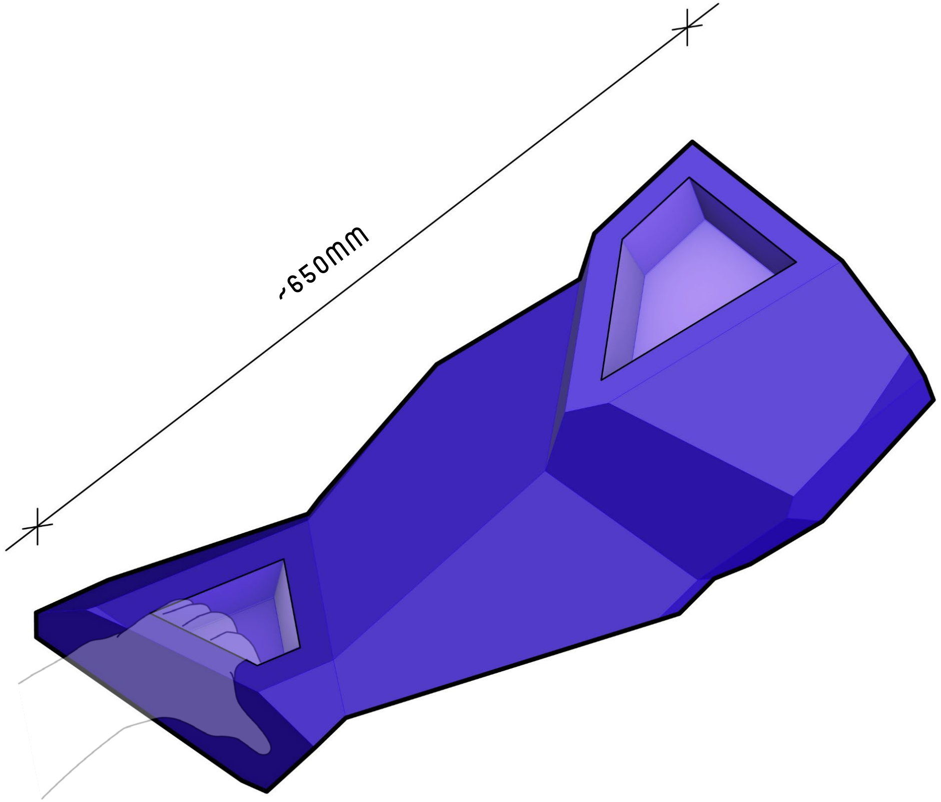
component integration details





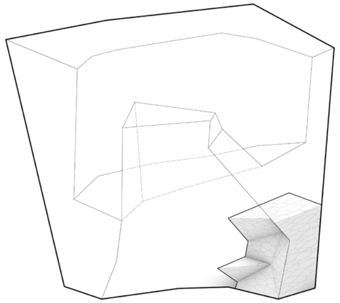
COMPONENTS ARE STACKED & 3D INTERLOCKED GEOMETRICALLY

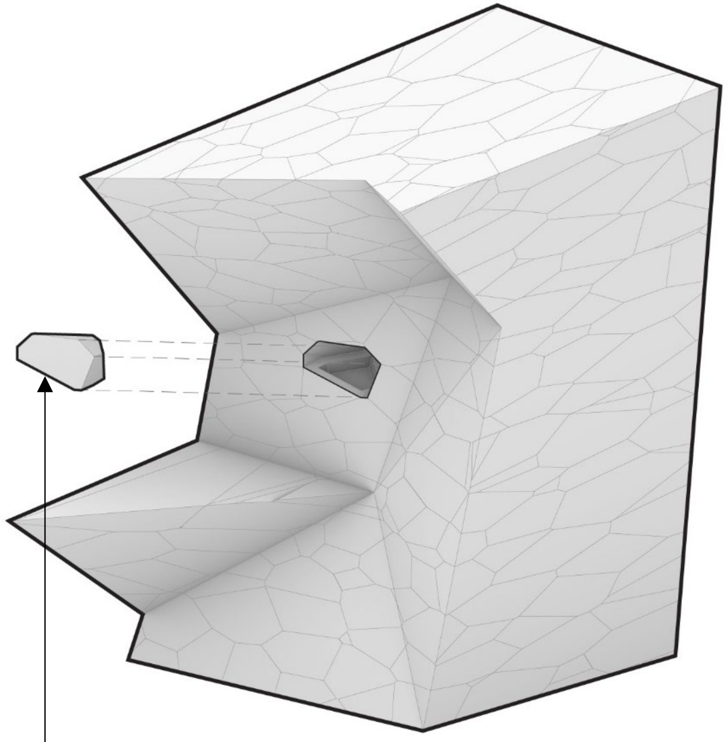
SOURCE: FANG CHE CHENG ET AL.(2016)



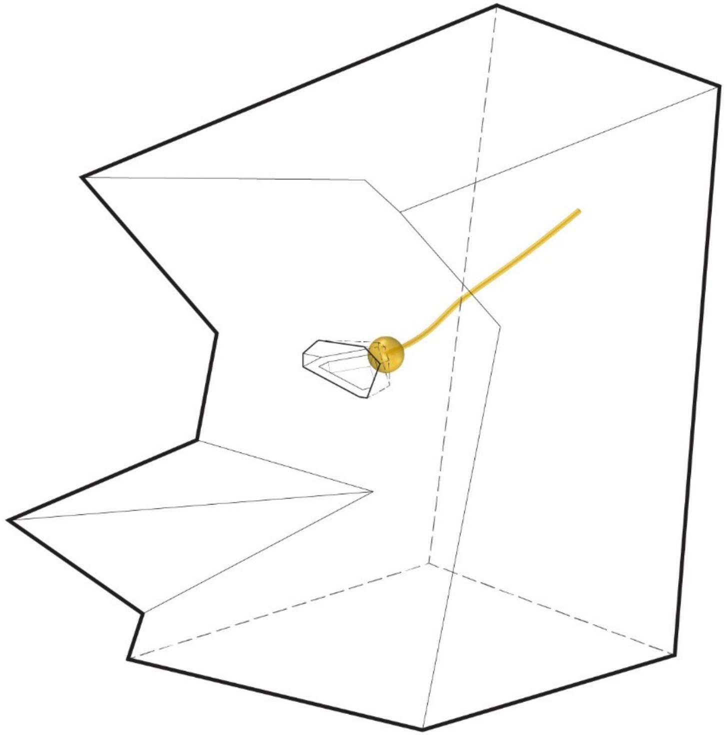
HOLE FOR GRABBING THE COMPONENTS

component integration details

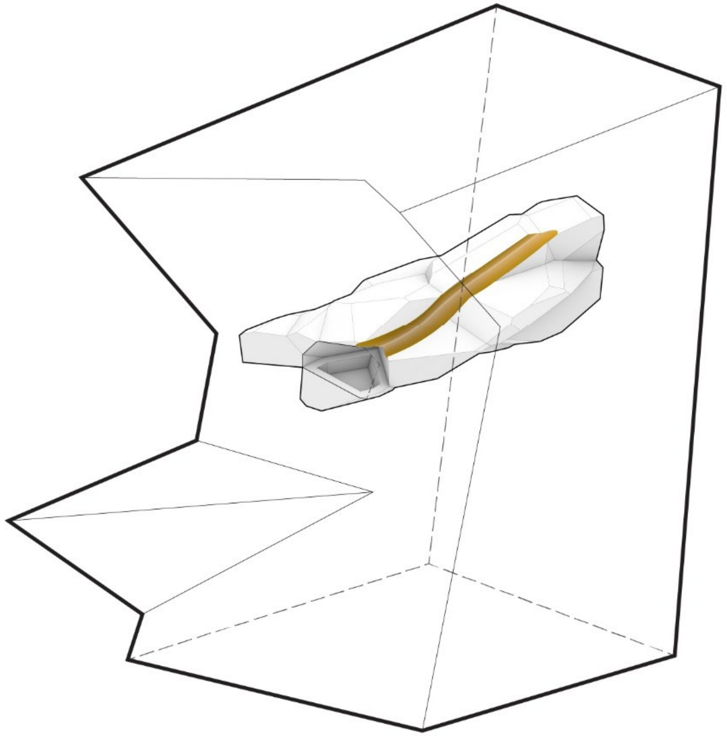




REMOVING SUB-COMPONENT
TO CREATE ACCESSIBLE HOLES

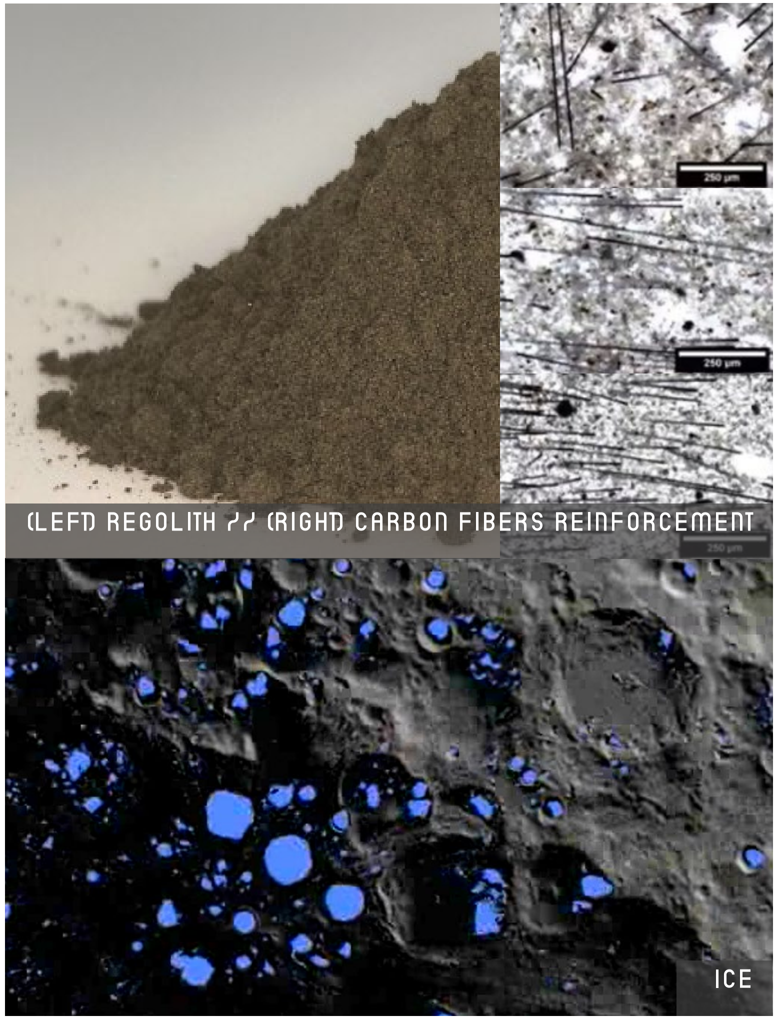


HOLES = CLIMBING HOLDERS AND
LIGHTING FIXTURES



INTEGRATE PIPE & CABLE CHANNEL
IN THE DESIGN AND PRINTING PROCESS

In Situ Resource Utilisation (ISRU)


(LEFT) REGOLITH // (RIGHT) CARBON FIBERS REINFORCEMENT

ICE

SOURCE: ESA, MATTHIAS RUTZEN (U AUGSBURG)

REGOLITH :

- **STRUCTURAL BLOCKS** (HIGH COMPRESSION STRENGTH), 3D PRINTED WITH
- **CARBON FIBERS** AS STRUCTURAL REINFORCEMENT MATERIAL (TENSILE STRENGTH IMPROVEMENT) SOURCE: DIRK VOLKMER (2016), RUTZEN ET AL. (2021)

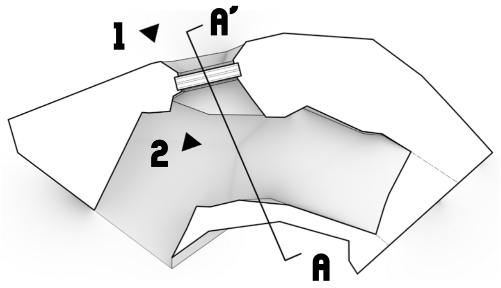
EXTRACTED FROM REGOLITH :

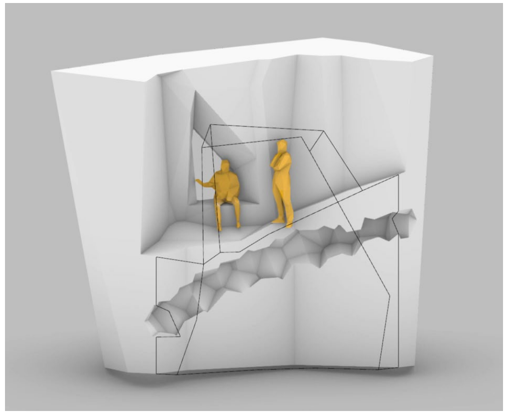
- 40-45% **OXYGEN** FOR COMBUSTION & LIFE SUPPORT
- 42-48% **SILICON** PRODUCTS: **GLASS FIBRE, AEROGELS** FOR SEAL MATERIALS, FOR INSULATION LAYER (NASA)
- **METAL ALLOYS (ALUMINIUM)** FOR FRAME

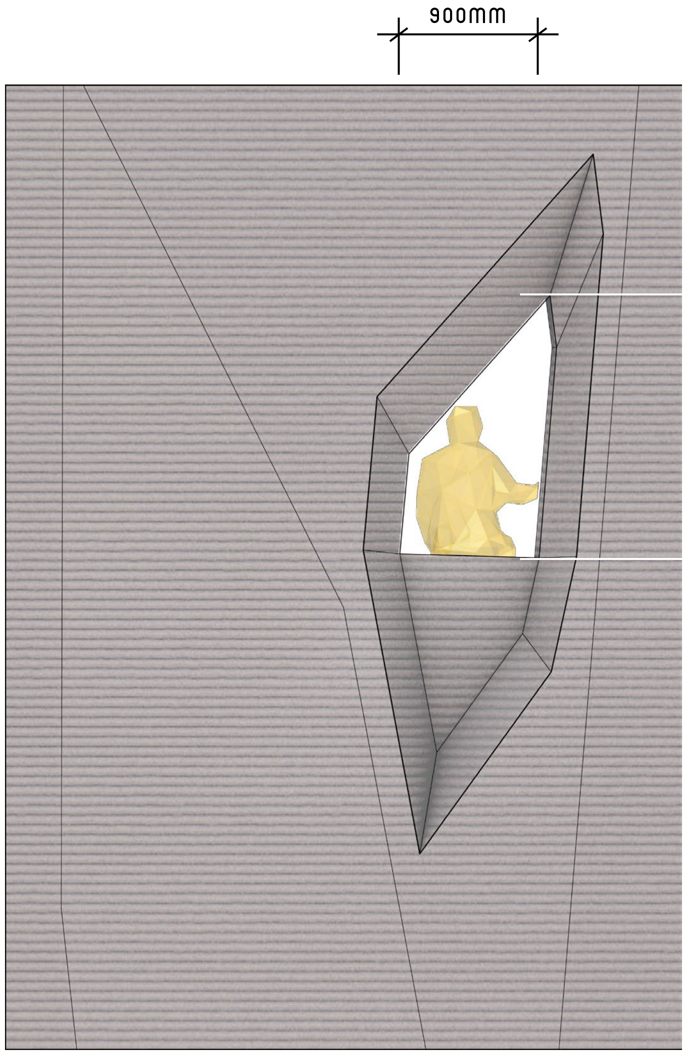
ICE :

- LIFE SUPPORT MATERIALS (**WATER, OXYGEN, HYDROGEN**) SOURCE: ESA, NASA

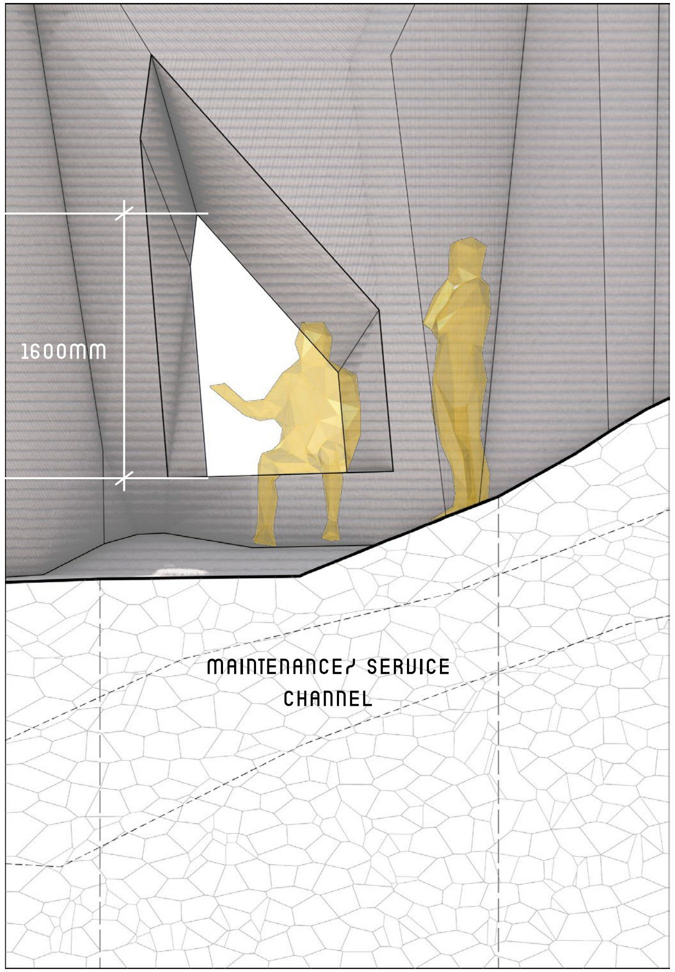
wall fragment



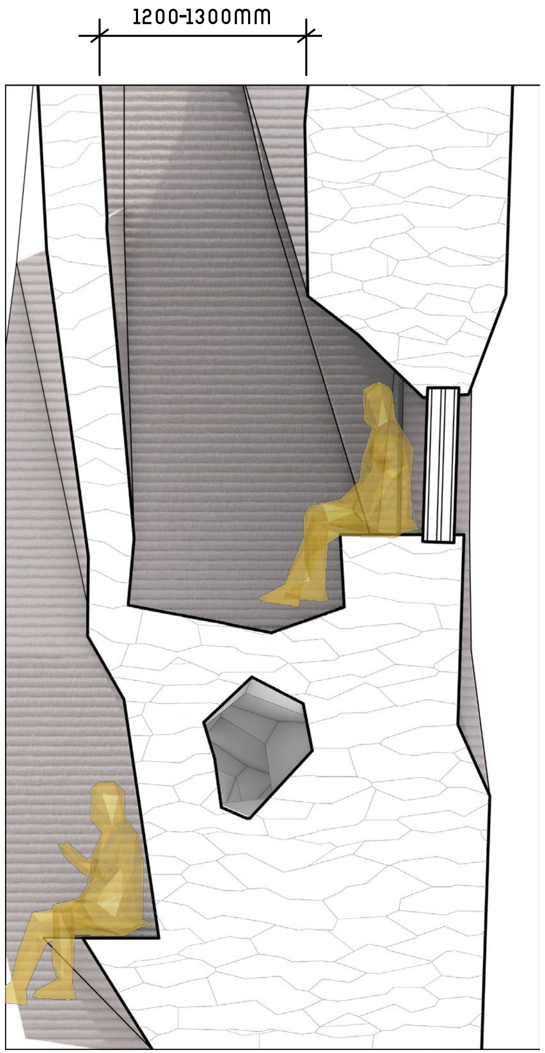




1. EXTERIOR FACADE

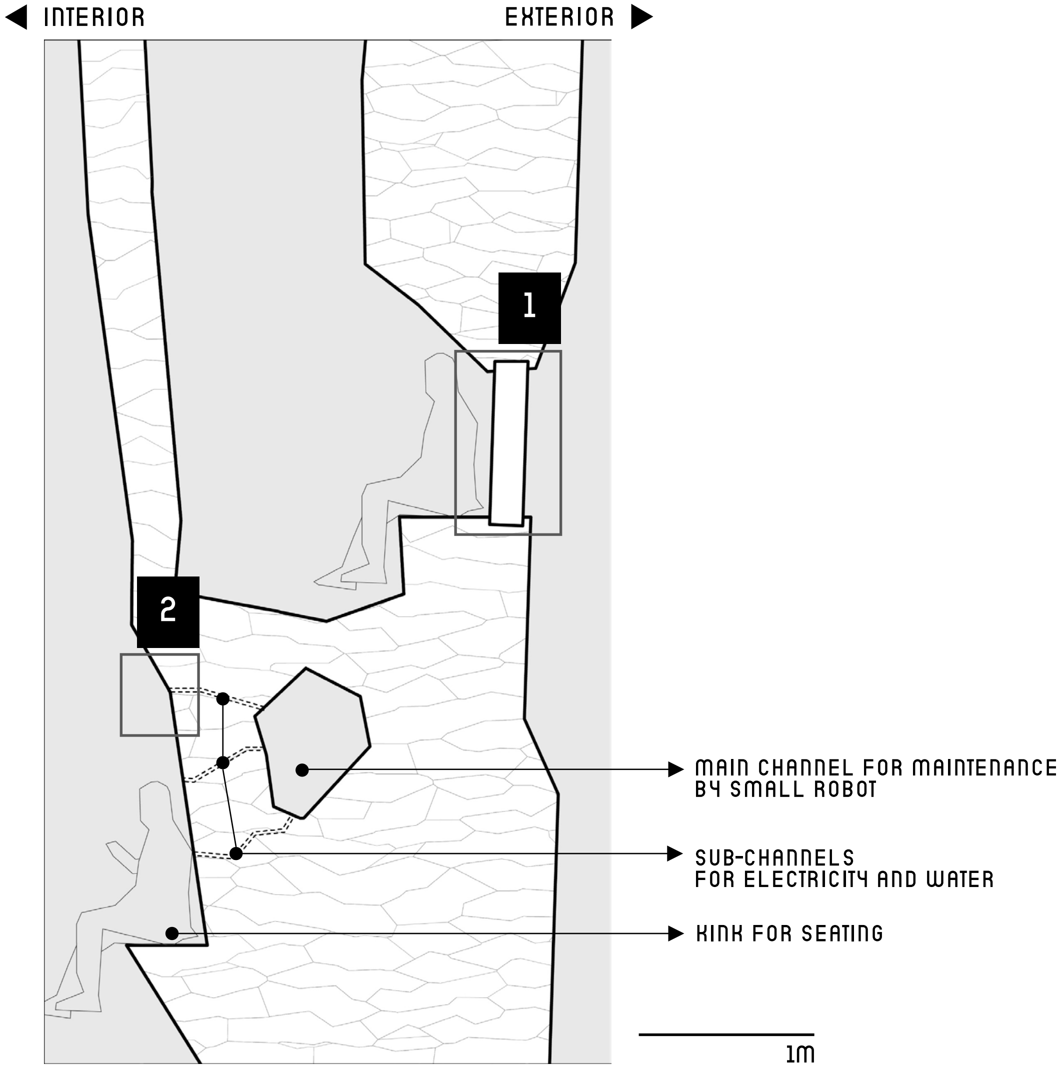


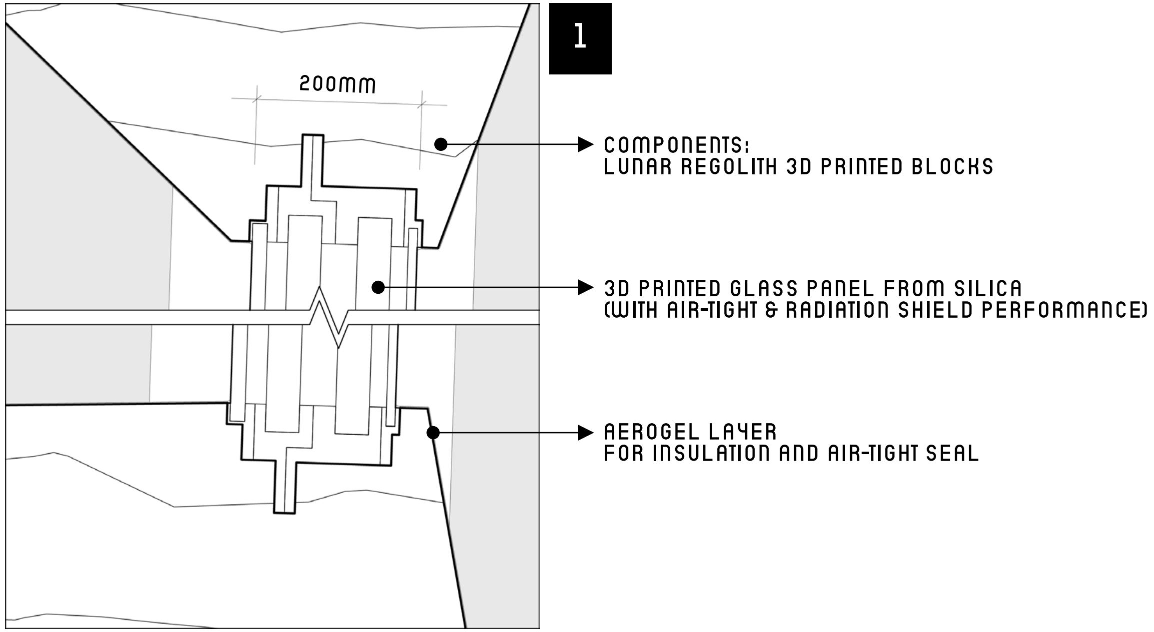
2. INTERIOR FACADE

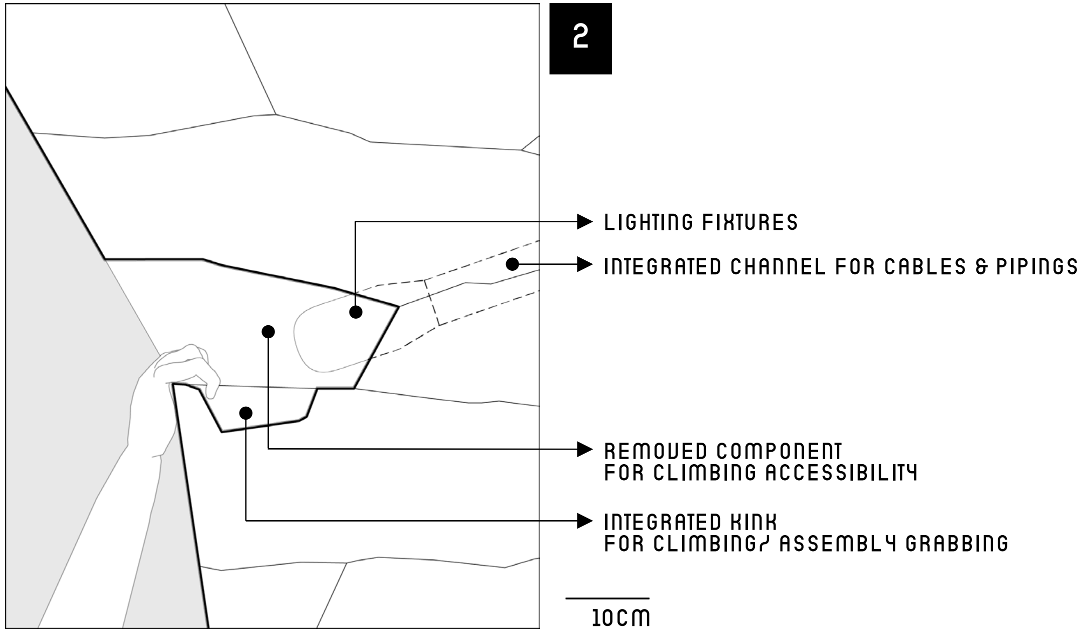


SECTION A-A'

fragment details

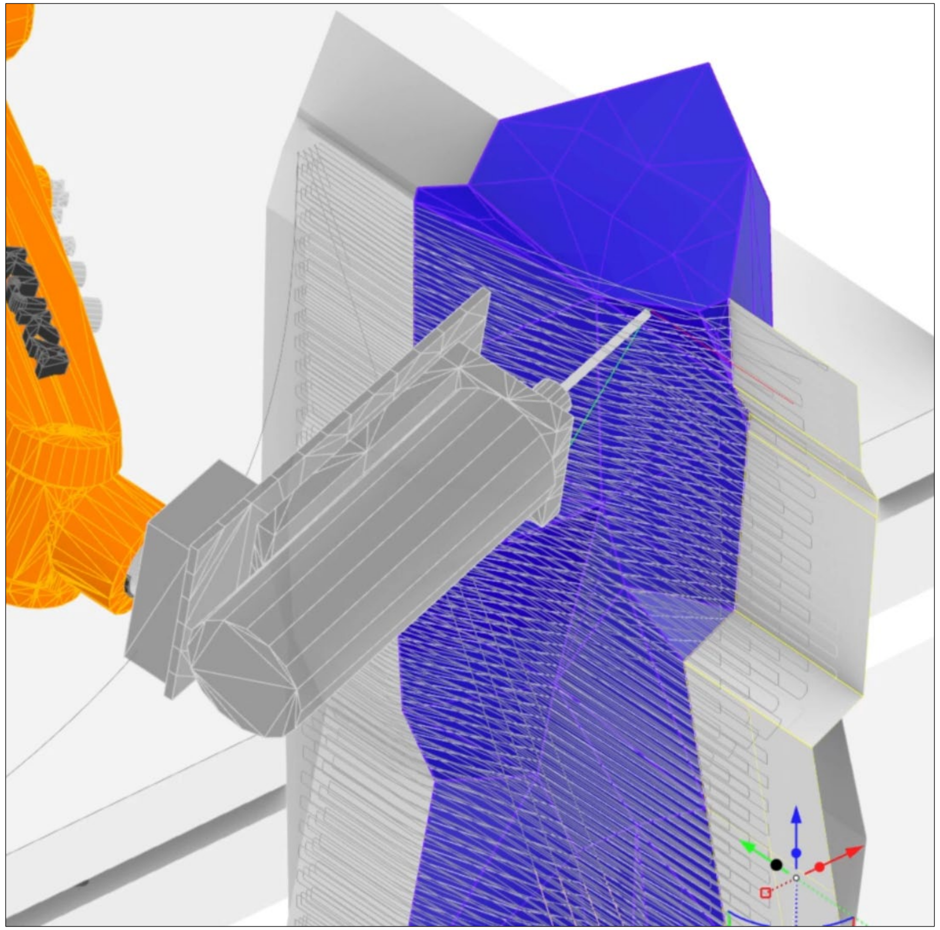






fabrication: mock-up

(zoom in to 1:1)



1:1 FABRICATION MOCK-UP (EPS FOAM)

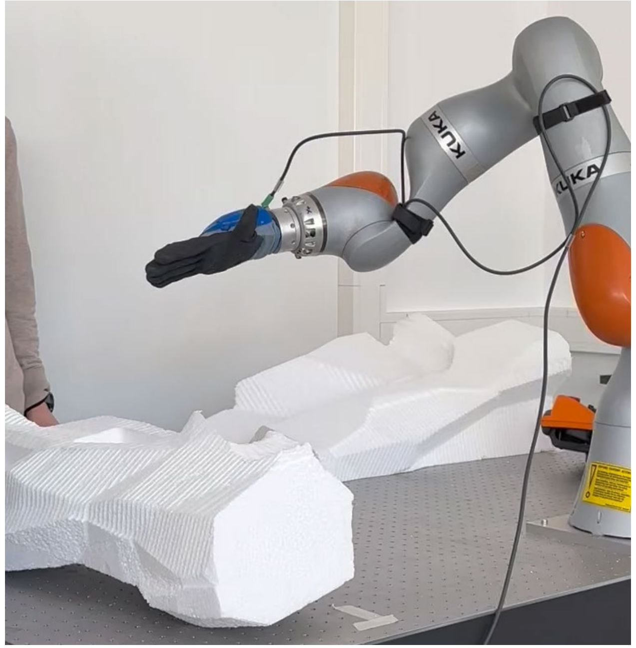
fabrication: 3D printing technology

ADDITIVE PROCESS AND RESULT
(CONCRETE 3D PRINTING AT VERTICO, EINDHOVEN)

COMPARATIVE LESSON FROM WORKSHOP: TOOLPATH DESIGN PROCESS ON THE COMPUTATIONAL TOOL

assembly mock-up: Human-Robot Interaction (HRI)

ROBOTIC PROCESS SUPPORTED BY COMPUTER VISION (CV)

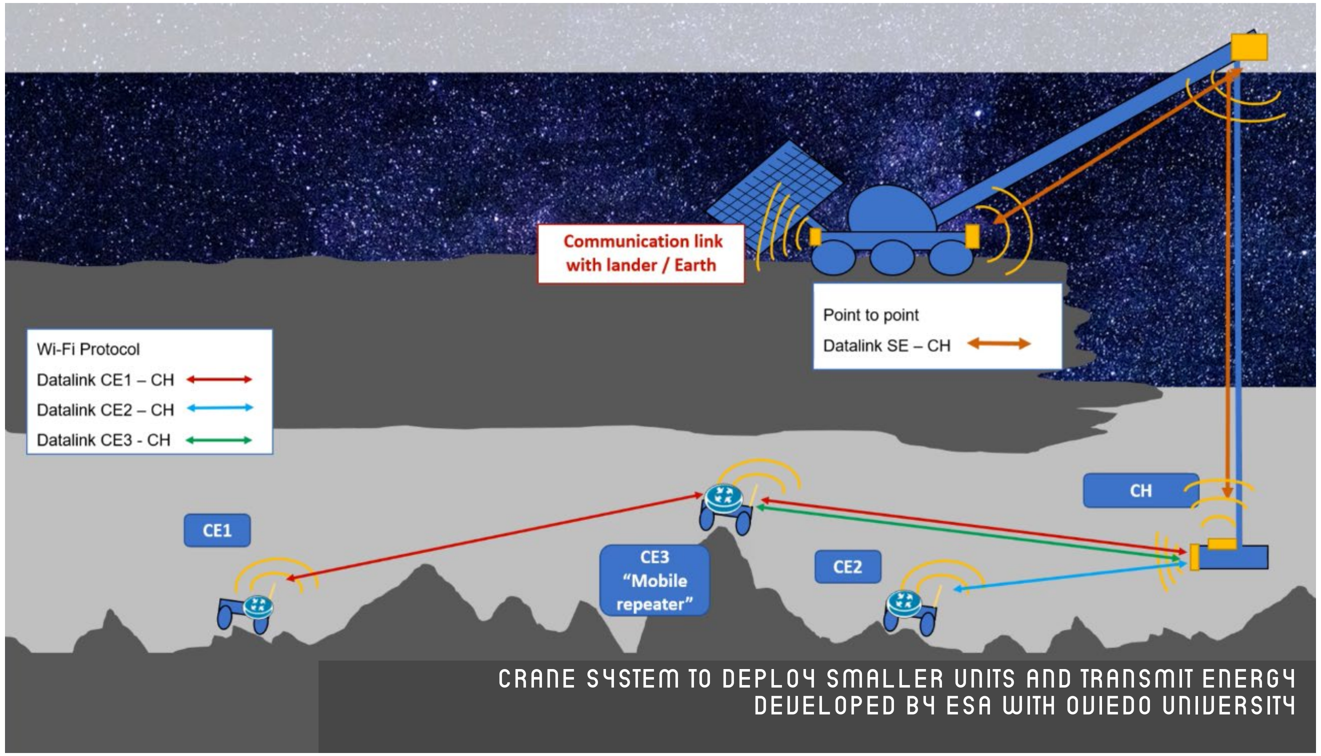


1. APPROACHING COMPONENT

1. APPROACHING COMPONENT
2. PICKING COMPONENT (ASSISTED)
3. TRANSPORTING COMPONENT TO DESIGNATED POINT

1. APPROACHING COMPONENT
2. GRABBING COMPONENT (ASSISTED)
3. TRANSPORTING COMPONENT TO DESIGNATED POINT
4. ADJUSTING COMPONENT
5. PLACING COMPONENT (ASSISTED)

robotic crane and climbing robots



CRANE SYSTEM TO DEPLOY SMALLER UNITS AND TRANSMIT ENERGY
DEVELOPED BY ESA WITH OVIEDO UNIVERSITY

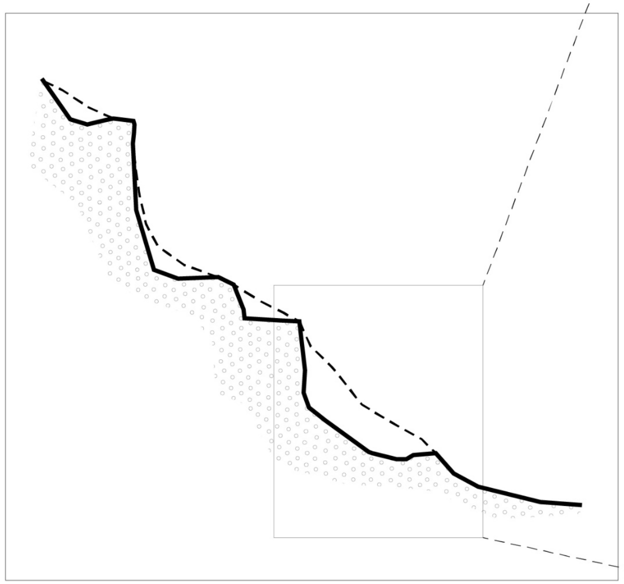
SOURCE: ESA.INT

LEMUR BY NASA
TESTED IN DEATH VALLEY, CALIFORNIA

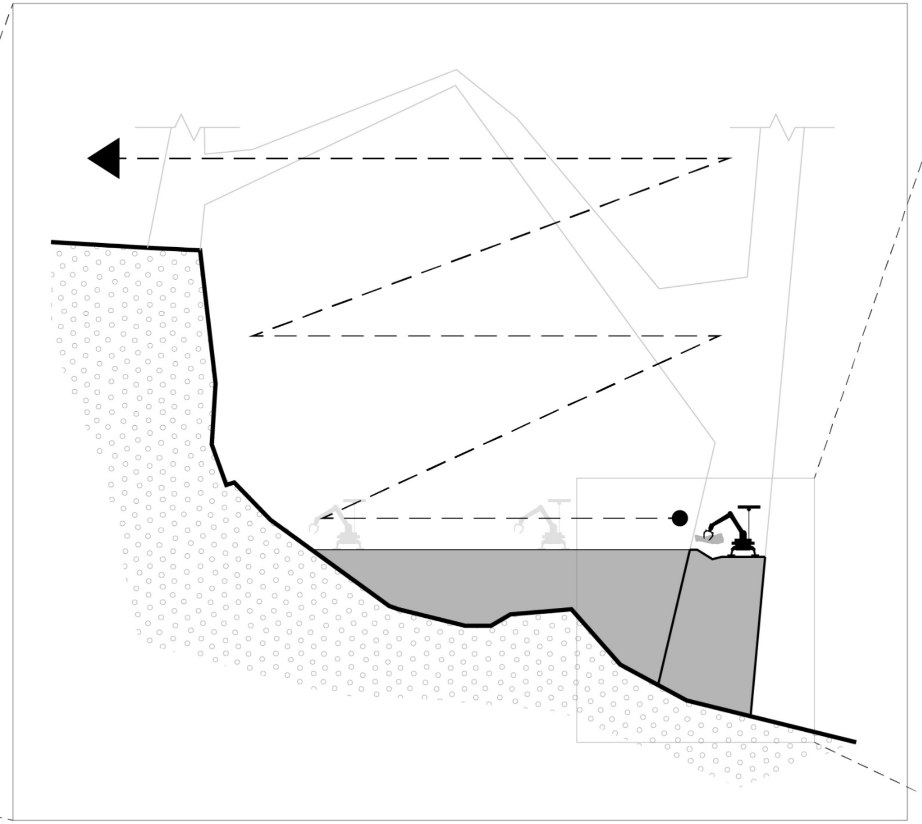
SOURCE: NASA.GOV

PROPOSED SYSTEMS FOR EXPLORING LUNAR UNDERGROUND PITS

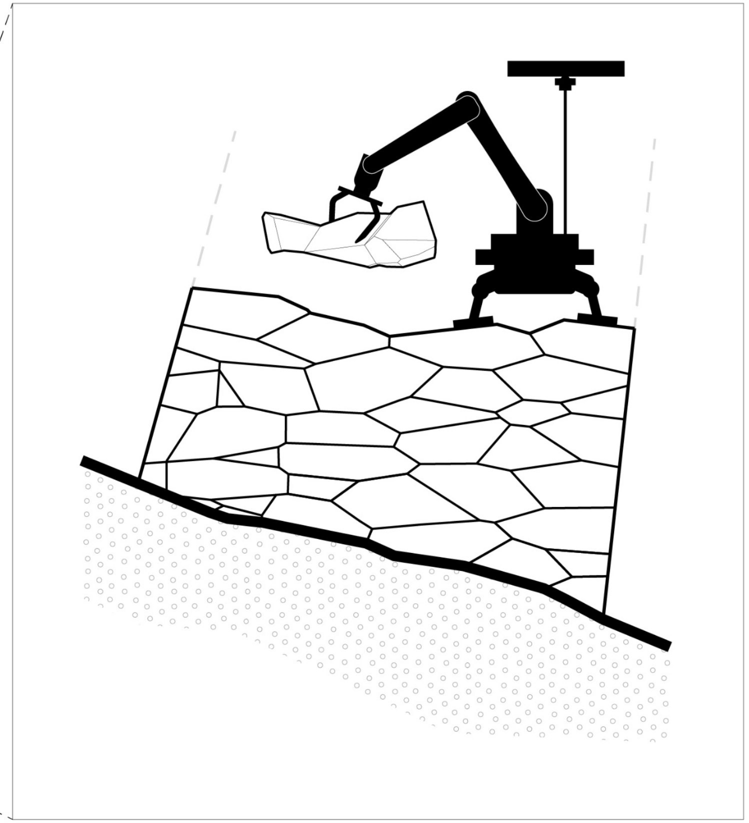
assembly during construction



MINOR ADJUSTMENT TO CREATE
ACCESSIBLE SITE TERRAIN PROFILE



COMPONENTS ASSEMBLY BY SWARM ROBOTS
LAYER BY LAYER



STACKED COMPONENTS CREATE WALKABLE TOPOGRAPHY
FOR THE ROBOTS DURING ASSEMBLY PROCESS

energy & resources collection/ distribution

SUN EXPOSURE | **ICE** | **REGOLITH** — (MAIN RESOURCES)

SOLAR RADIATION IN ORBIT & PV CELLS ON LUNAR SURFACE

IN-SITU COLLECTION USING ROVERS

(COLLECTION METHODS)

ENERGY

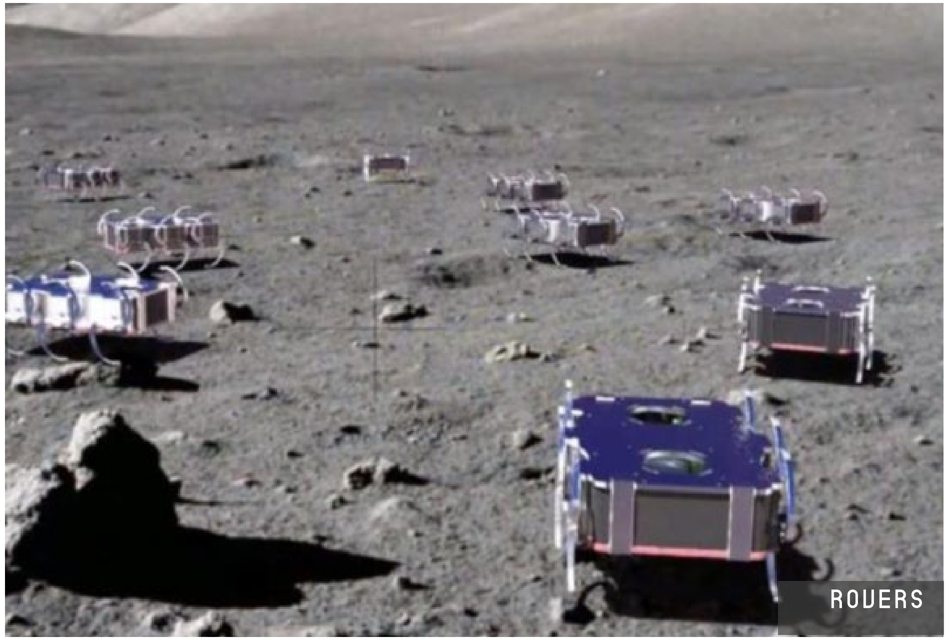
CENTRAL SMART GRID SYSTEM

TREATMENT	HEAT EXCHANGE SYSTEM HYDROGEN WATER OXYGEN CARBON SILICONE (PRODUCTS)
STORAGE	
DISTRIBUTION	

3D PRINT

BUILDING MATERIALS & FURNITURE

HABITATS

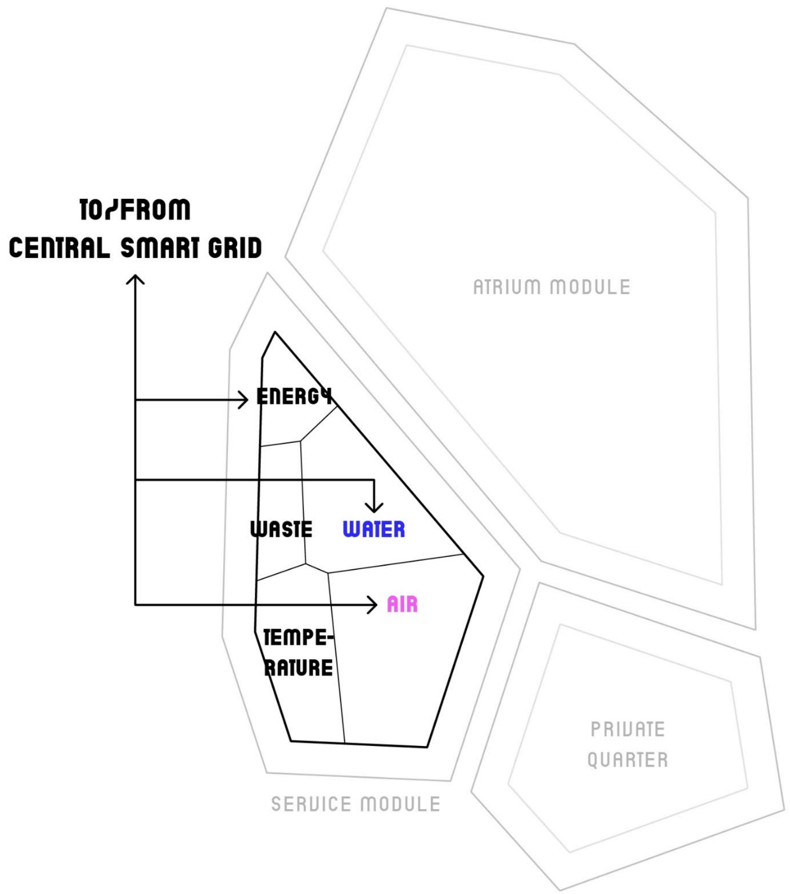


SOURCE: ADAPTIVE ON- AND OFF-EARTH ENVIRONMENT (BOOK)

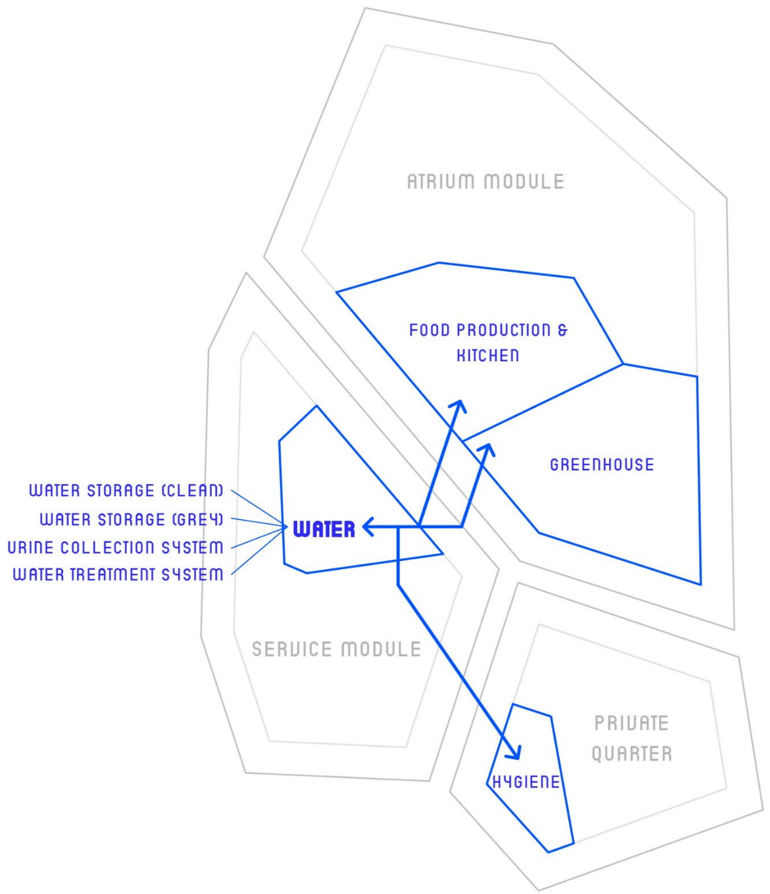
SOURCE: YOUTUBE.COM/WATCH?V=DUGJFA44ECE

building service/ life support systems

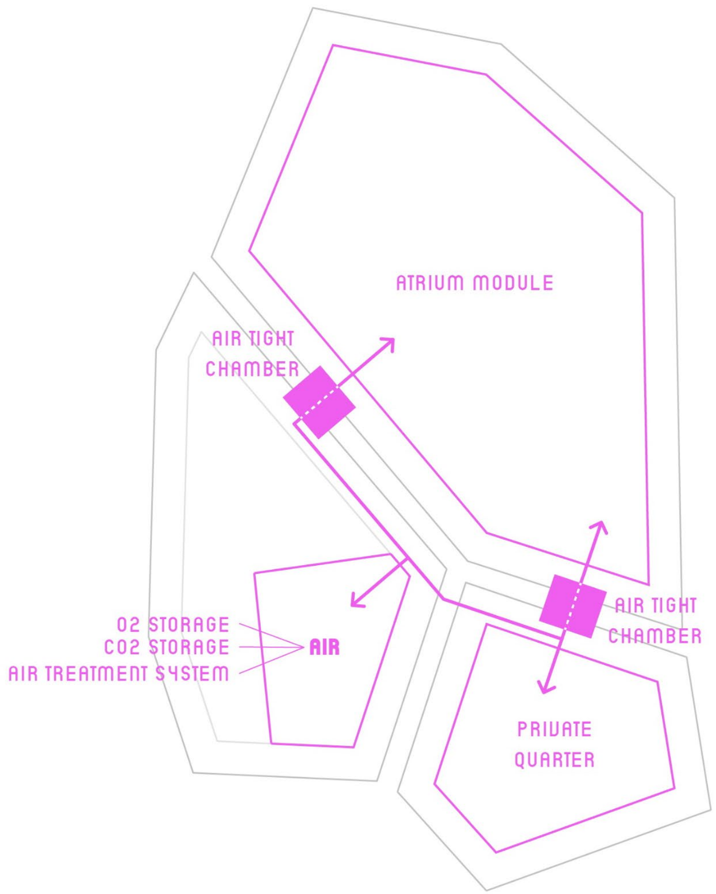
OVERALL SYSTEM



WATER REGULATION SYSTEM



AIR REGULATION SYSTEM



climate control strategy

(MACRO)

A. HEAT EXCHANGE SYSTEM FOR HEATING & COOLING

USE OF THERMAL MASS OF LUNAR REGOLITH
(CAPACITY TO STORE AND RELEASE ENERGY
DURING DAYLIGHT & NIGHT)

B. SITE & BUILDING ENVELOPE

LAVA TUBE, THICK REGOLITH WALLS
AEROGEL INSULATION LAYER

C. FURNITURE-INTEGRATED SYSTEM

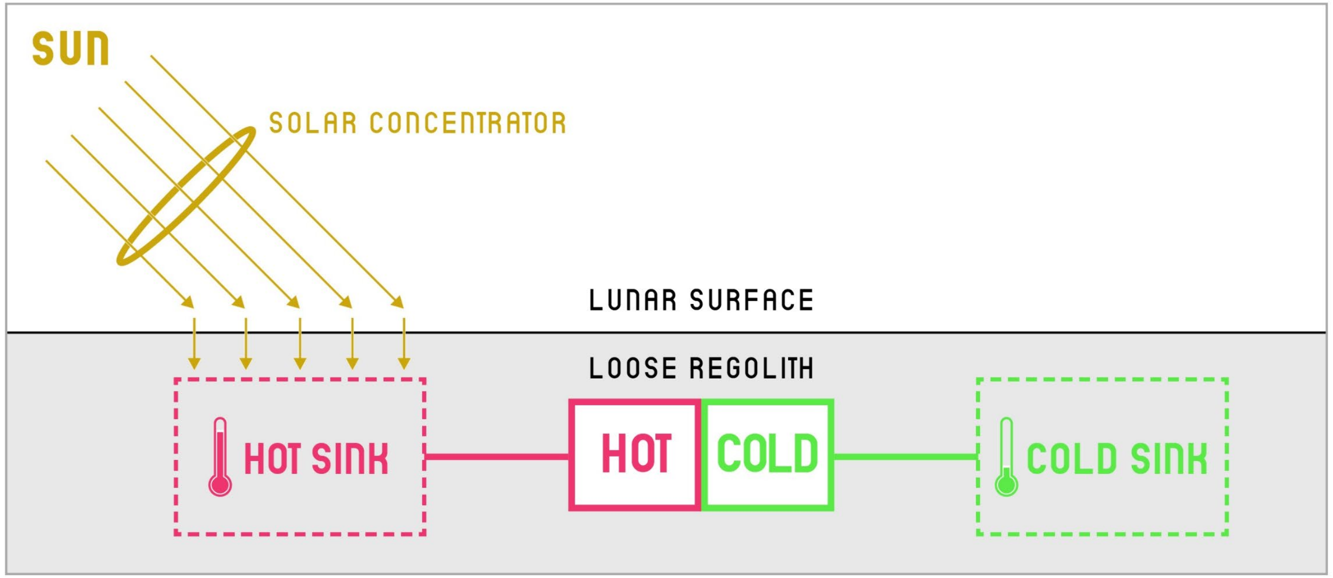
ADJUSTABLE POWER FOR SMALL ENVIRONMENT

(MICRO)

D. CLOTHING-INTEGRATED FEATURES & WEARABLE SENSORS

ANTI-BACTERIAL PROPERTIES
HEAT TRANSFER & SWEAT MANAGEMENT

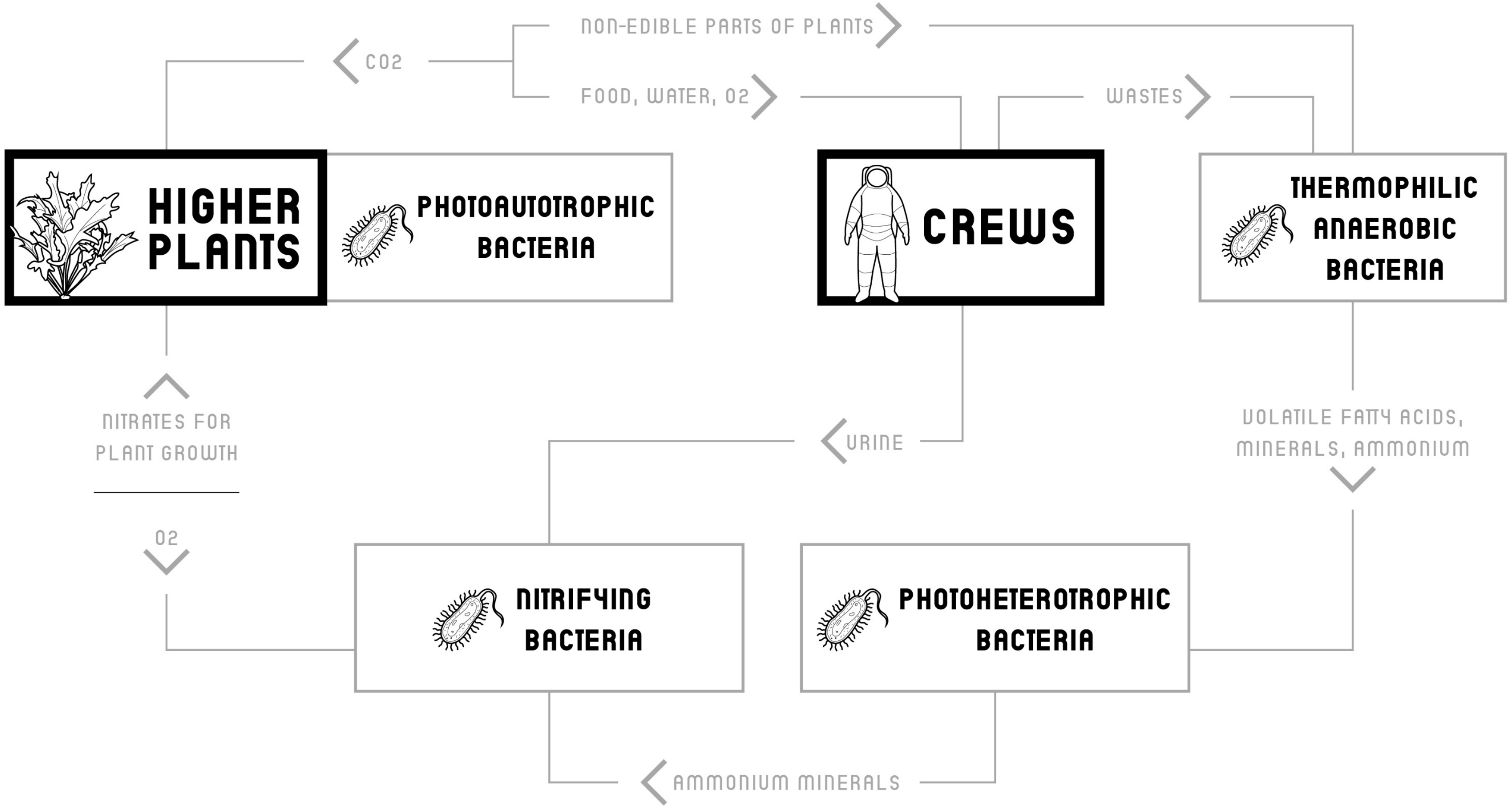
SOURCE: NASA



SOURCE: ESA

closed-loop life support system

The Micro-Ecological Life Support System Alternative (MELiSSA)



SOURCE: MELISSA FOUNDATION, ESA

final phase (P4-P5)

MINOR IMPROVEMENT & PRODUCTION

DRAWINGS/ GRAPHICAL REPRESENTATION
RENDERINGS (ILLUSTRATE MORE PLAYFULNESS)
ADDITIONAL SCALED MODELS

societal relevance

<u>KNOWLEDGE TRANSFER LOOP TO ON/OFF-EARTH ARCHITECTURE</u>

CIRCULAR DESIGN AND LIFESTYLE:
- EXEMPLARY TOWARDS OFTEN THEORETICAL CIRCULAR DESIGN ON EARTH
- IN-SITU RESOURCE UTILISATION & AUTOMATED CONSTRUCTION
- CLOSED LOOP LIFE CYCLE LEARNT FROM MELISSA

ERGONOMICS & HUMAN BODIES:
- RETHINKING SITTING POSITION TO RAISE AWARENESS ON BODIES
- MOVEMENT/POSTURE-BASED ARCHITECTURE INSTEAD OF FUNCTION-BASED ARCHITECTURE

Q & A