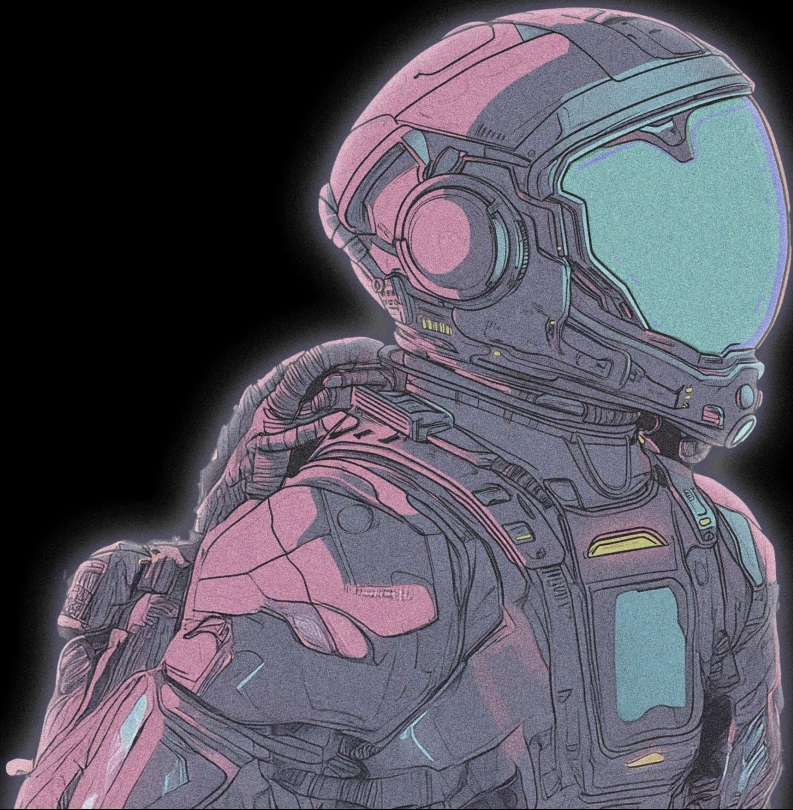


LUNAR PLAYSCAPE:

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 | P5 PRESENTATION

GRADUATION PROJECT 2024-2025 TU DELFT BK

TUTORS: HENRIETTE BIER, FERRY ADEMA, ARWIN HIDDING

moon exploration

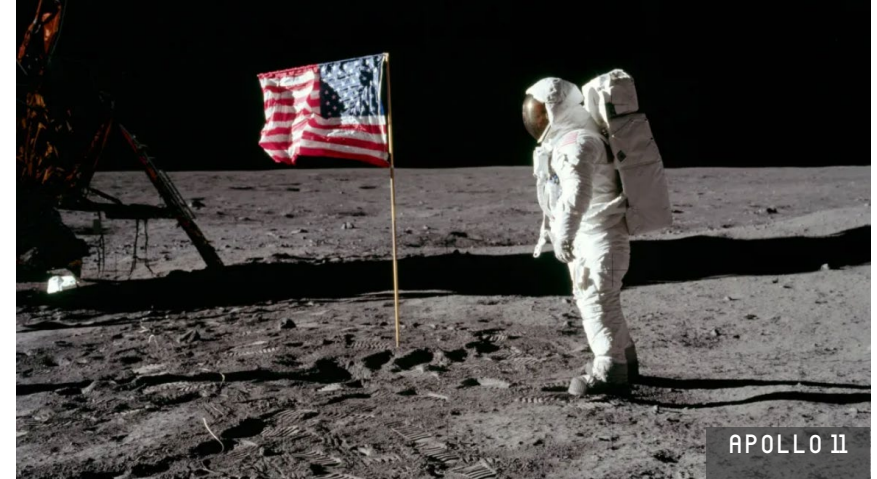
IN THE PAST



tasks intensive missions

11

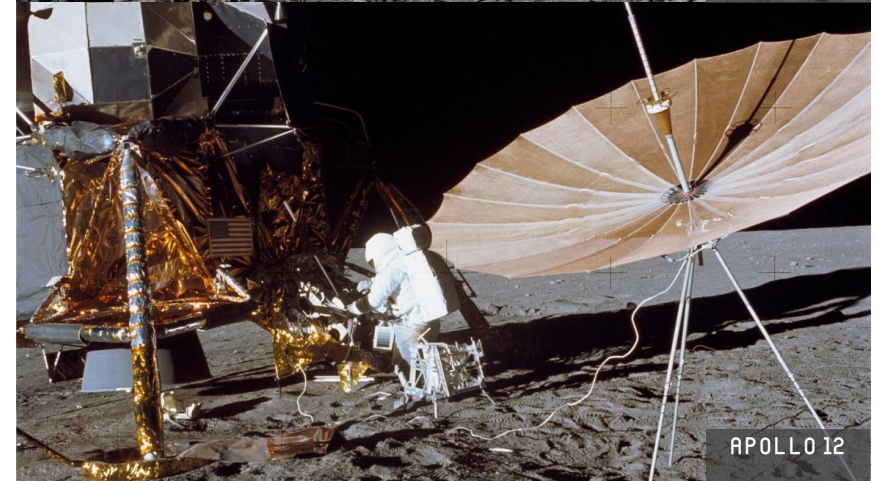
PERFORMED LUNAR LANDING AND RETURN TO EARTH
(NATIONAL GOAL BY PRESIDENT KENNEDY)



APOLLO 11

12

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



APOLLO 12

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,



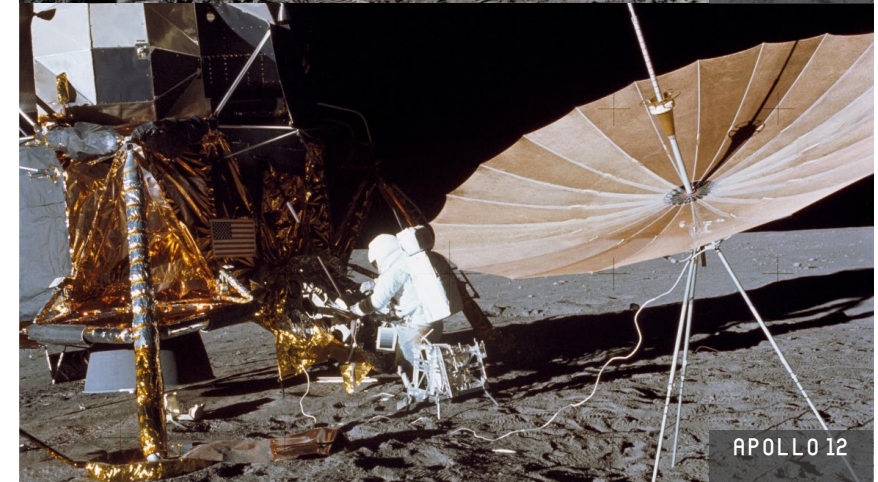
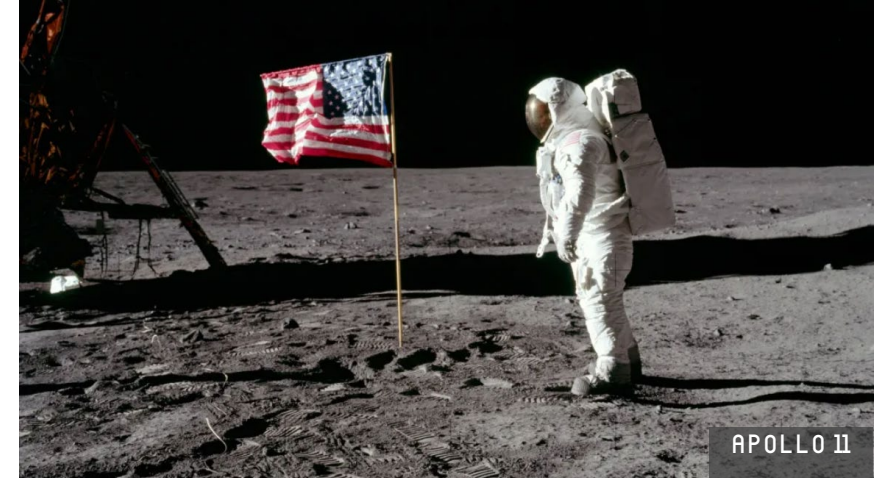
APOLLO 17

NUMEROUS SECONDARY TASKS

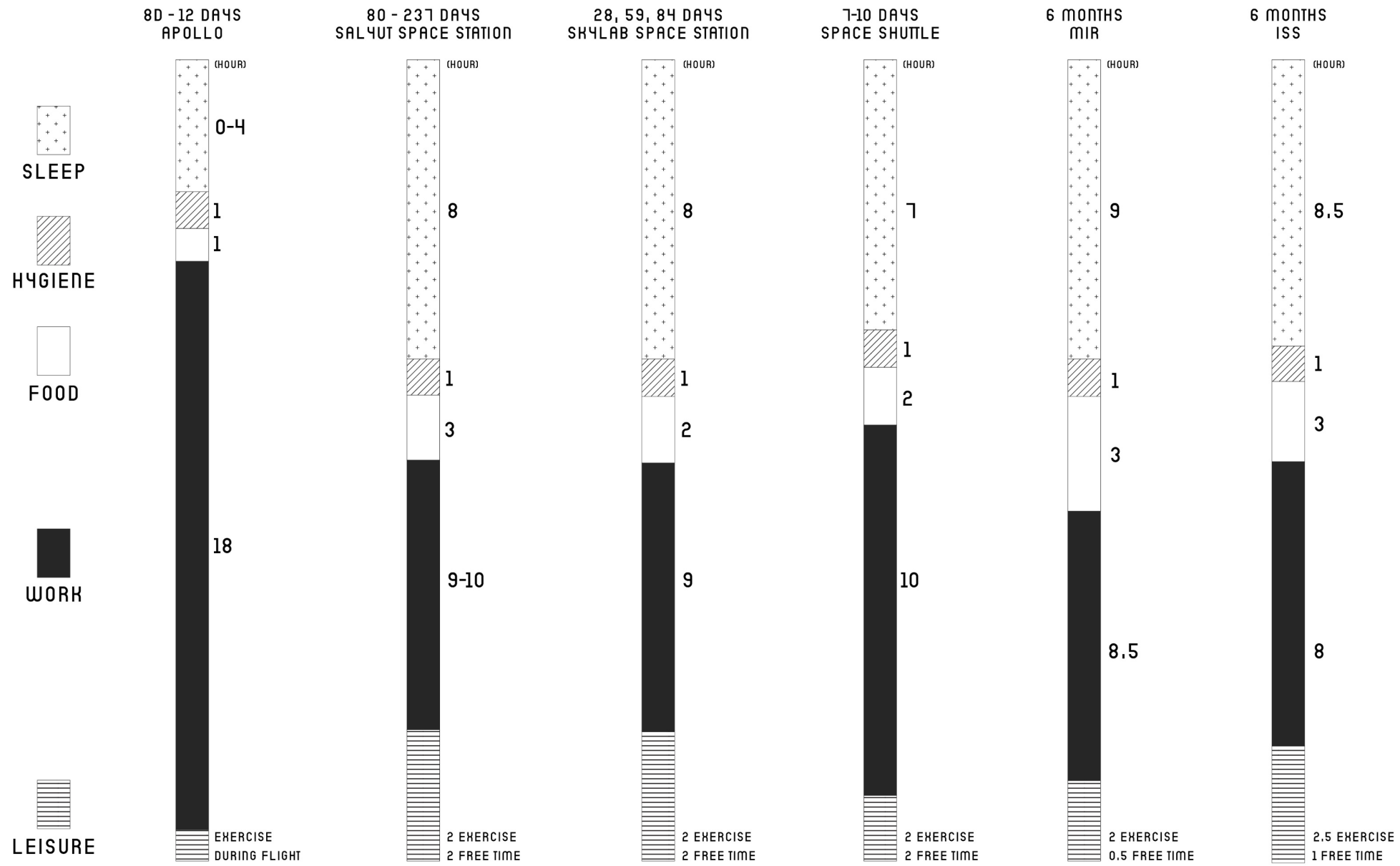
DEPLOYMENT OF A TELEVISION CAMERA TO TRANSMIT SIGNALS TO EARTH, DEPLOYMENT OF A SOLAR WIND, SEISMIC EXPERIMENT PACKAGE AND A LASER RANGING RETROREFLECTOR, GATHER SAMPLES OF LUNAR-SURFACE MATERIALS, PHOTOGRAPH THE LUNAR TERRAIN, DEPLOYED SCIENTIFIC EQUIPMENT, LUNAR MODULE SPACECRAFT

SELENOLOGICAL INSPECTION, SURVEYS AND SAMPLINGS IN LANDING AREAS, DEVELOPMENT FOR 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



RESEARCH BACKGROUND | ACTIVITIES DISTRIBUTION

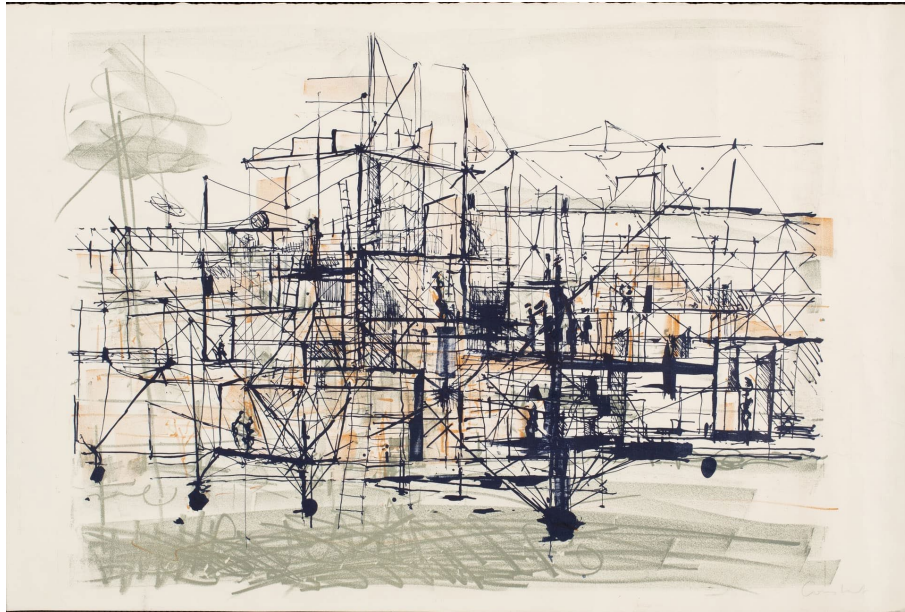


short term missions

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

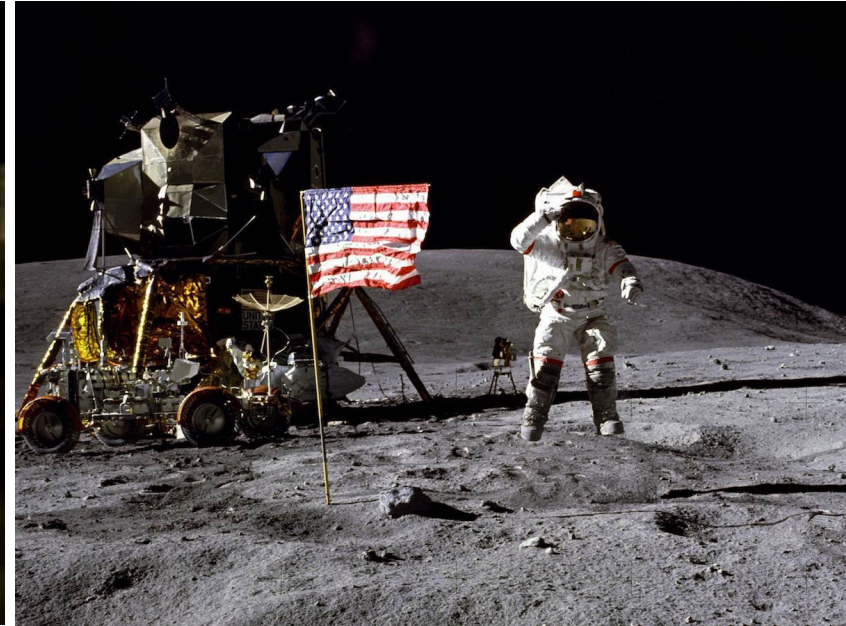
human's playing nature



ALAN SHEPARD (AP14)
GOLF ON THE MOON

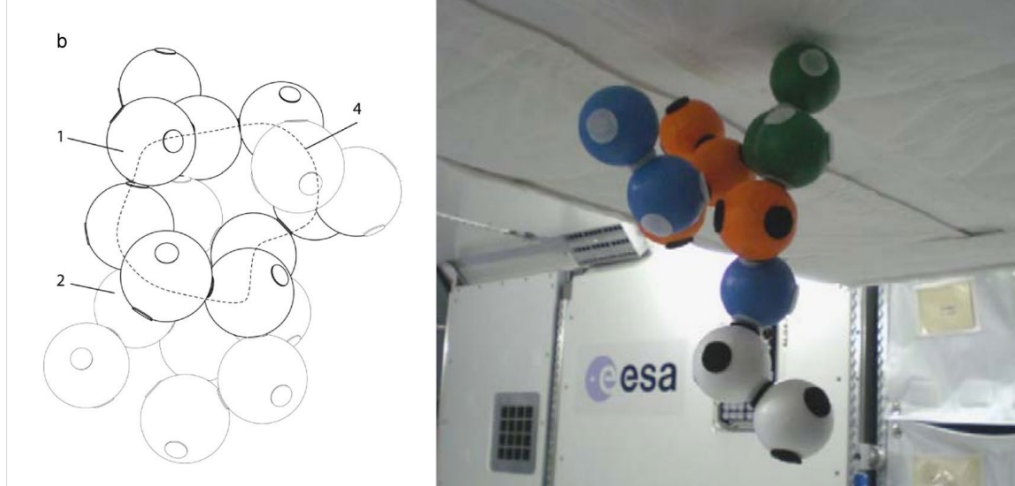


DAVID SCOTT (AP15)
HAMMER AND FEATHER



JOHN YOUNG (AP16)
MID-AIR SALUTE PHOTO

SOURCE: NASA.GOV



GAME FOR SPACE PROTOTYPE TESTED AT ISS

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

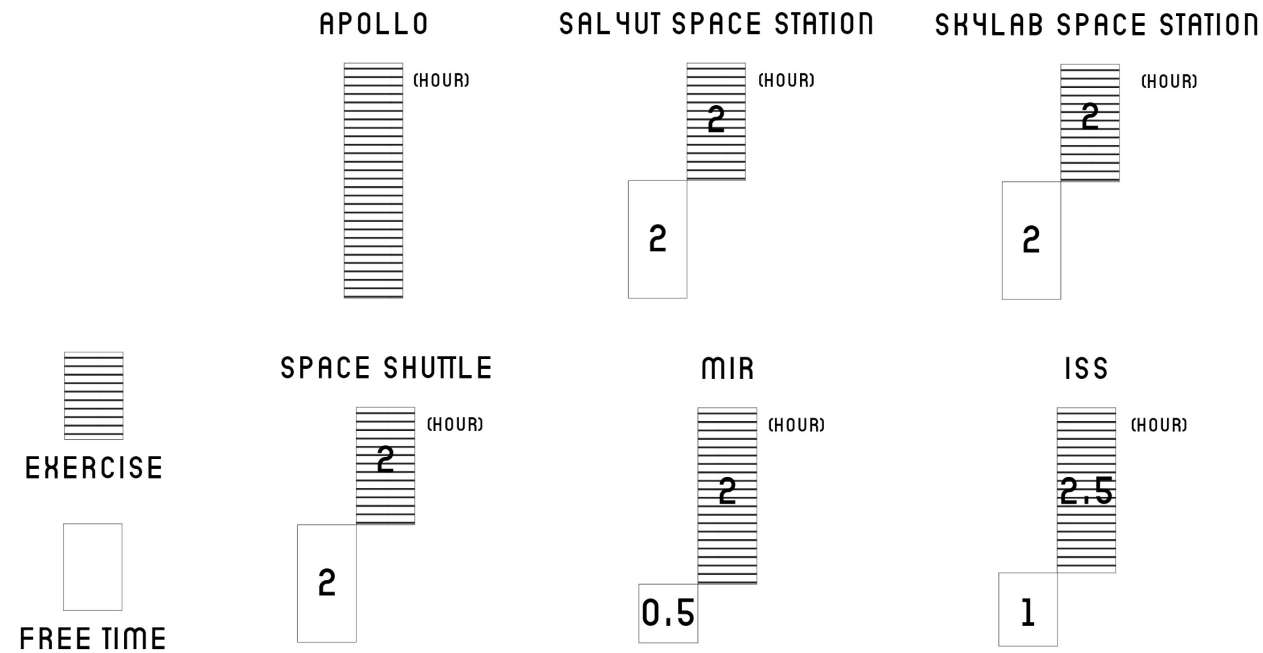
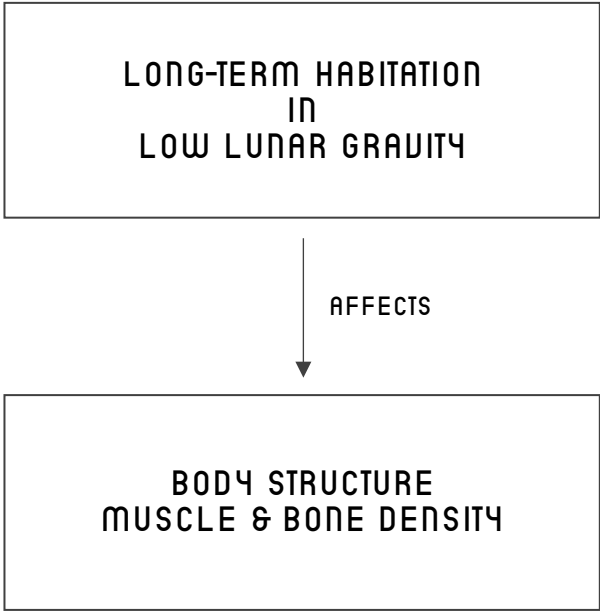
LUNAR PLAYSCAPE —————> REIMAGINES THE LIFESTYLE & ACTIVITIES

physical requirement

and

social requirement

1. physical



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



A QUERY IN
COMMUNITY CREATION



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

SOURCE: NASA

social life in previous spaceship

VERY LOW IN PRIORITY

“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?

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



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

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

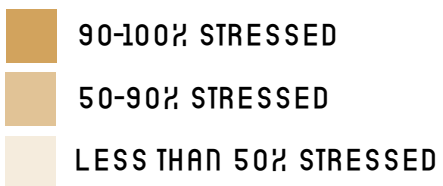
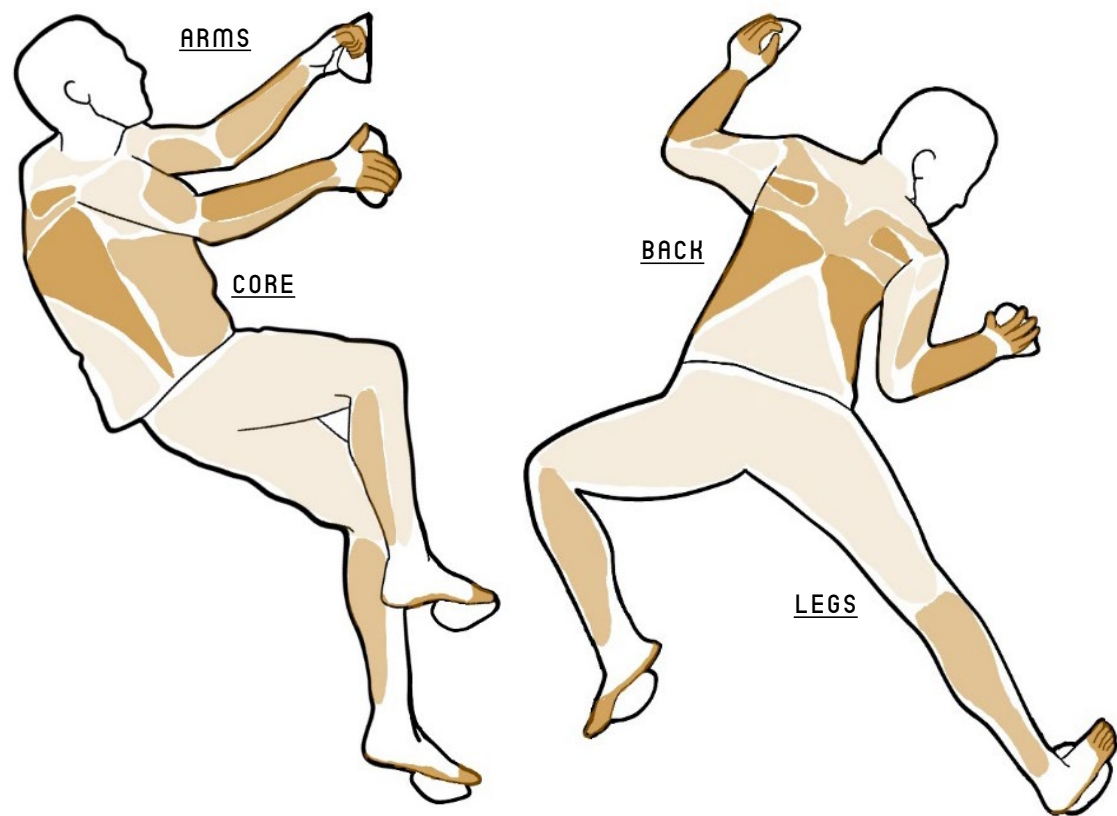
1/6 WEIGHT OF EARTH ->
LIGHTER BODY WEIGHT, HIGHER IMPACT-LESS FALL

FULL BODY MUSCLE USE

RICH ACTIVITY
DEVELOPMENT OPTIONS

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

muscle activation



SOURCE: THE WANDERING CLIMBER



EXPERIENCING CLIMBING

an effective social bonding tool



RESEARCH QUESTION

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

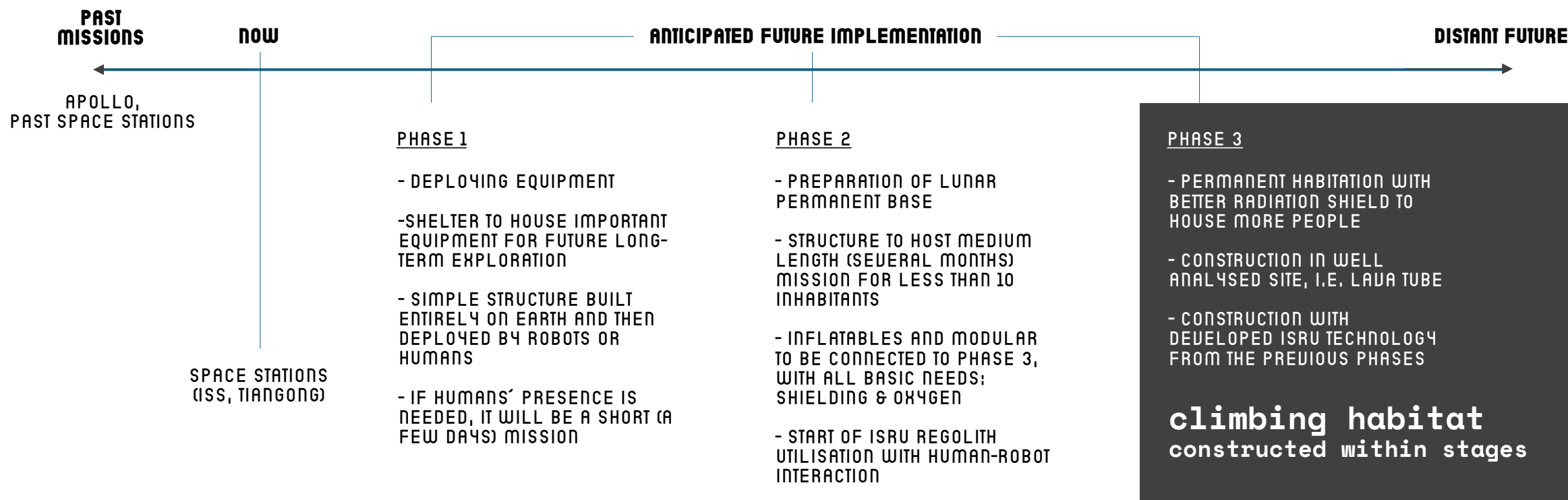
DESIGN DIRECTION

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

project timeline

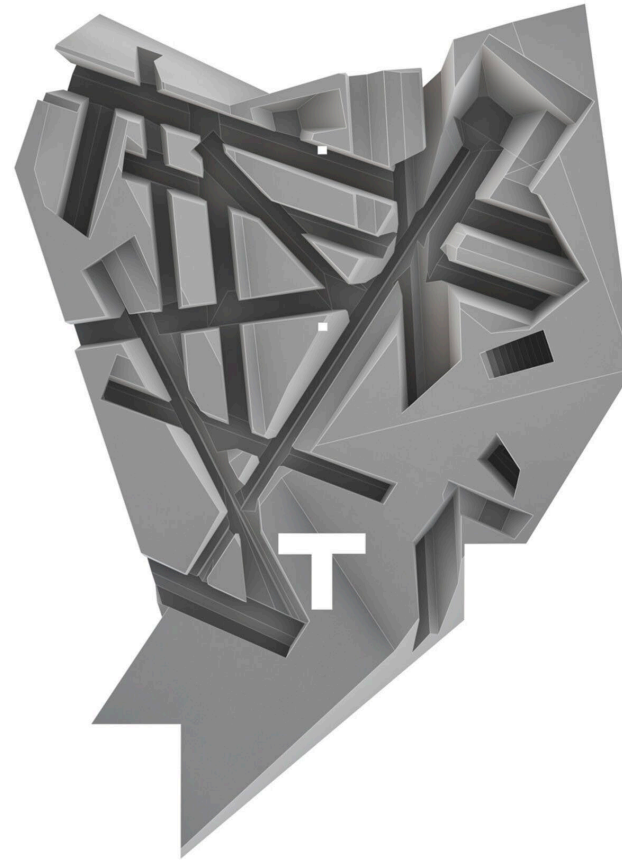


human body postures & interactions in between

UNCONVENTIONAL VERTICAL SURFACES AS A COUNTERACT OF SEDENTARY WORKSTYLE

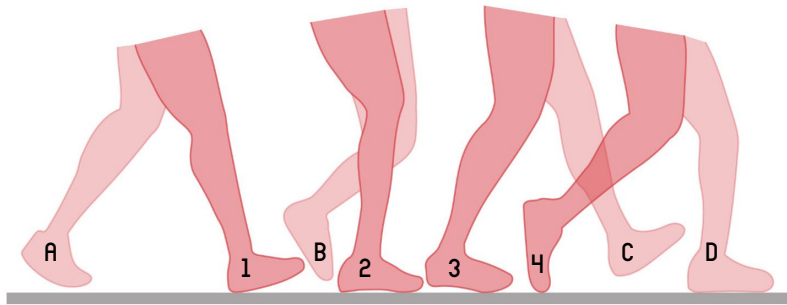


THE END OF SITTING BY RAAAF

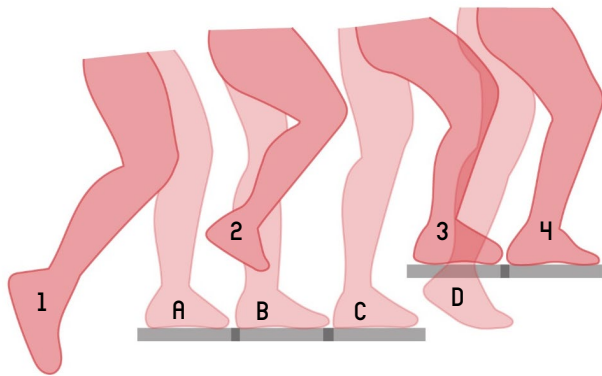


human body postures & interactions in between

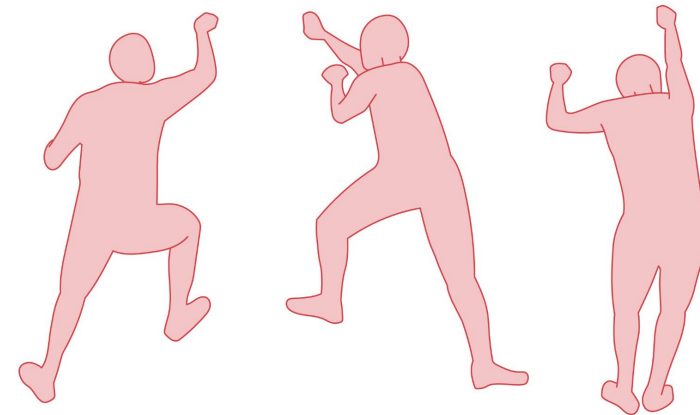
CLIMBING AS A COUNTERACT OF REPETITIVE AND STATIC MOVEMENTS ON EARTH



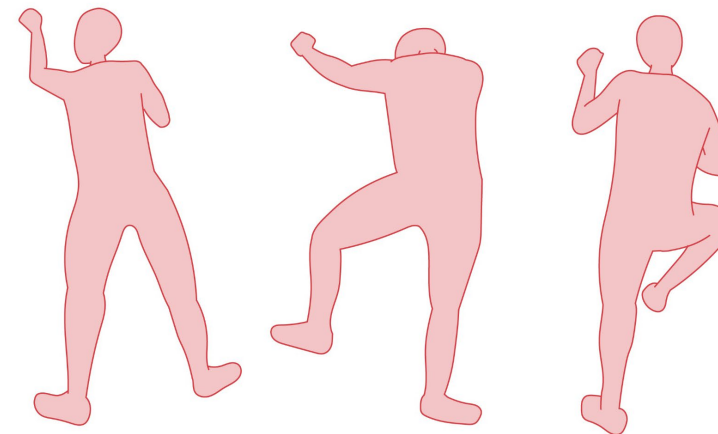
WALKING = LINEAR MOTION ADAPTED TO
FLAT & STABLE TERRAIN



UNIFORM DIMENSIONS OF STAIR RUNS AND RISES
RESULT IN CONSTANT MOTION

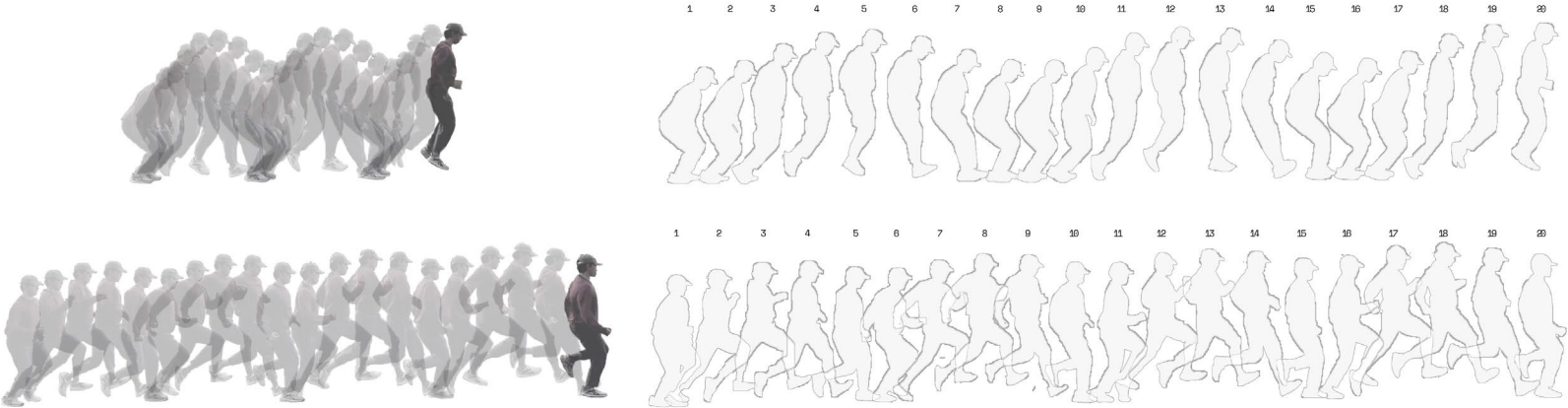


VS

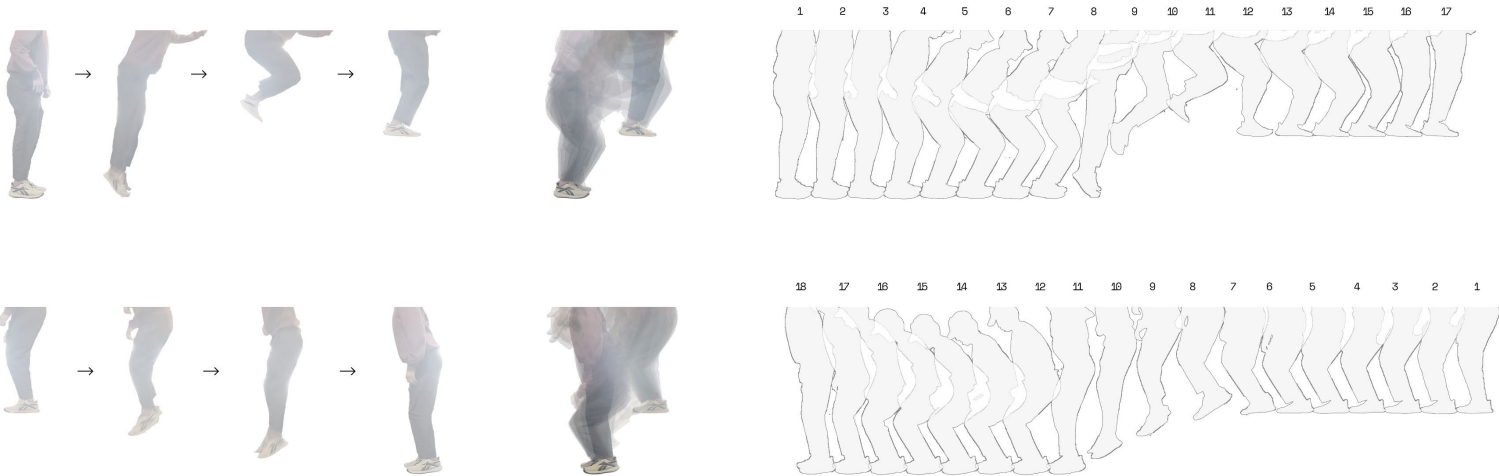


CLIMBING MOTIONS

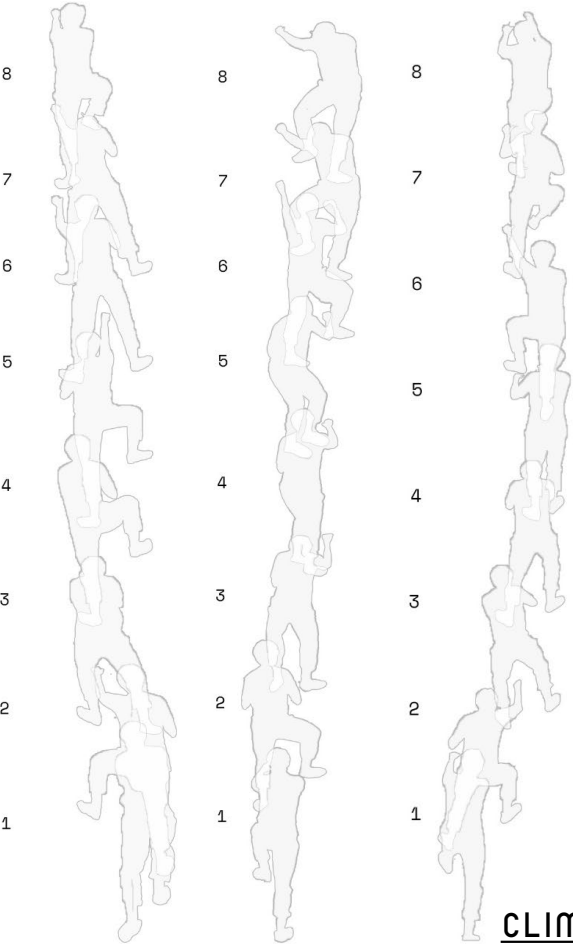
human body movements mapping



HOPPING & GALLOPING

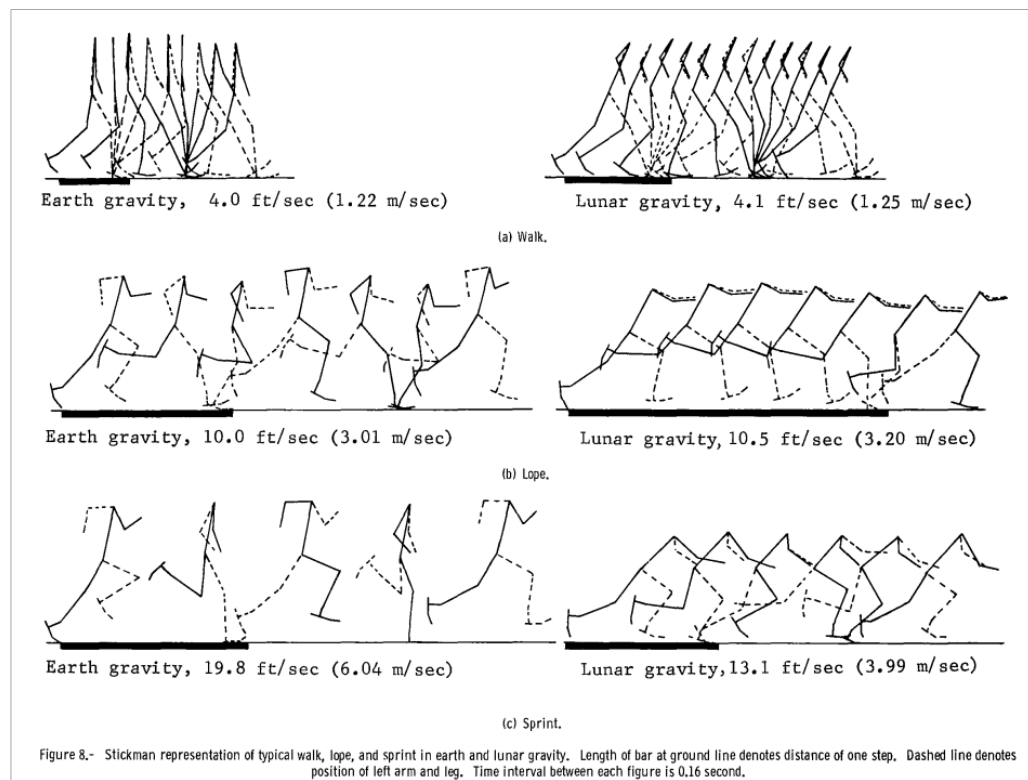


HIGH JUMP (UP & DOWN 500mm)



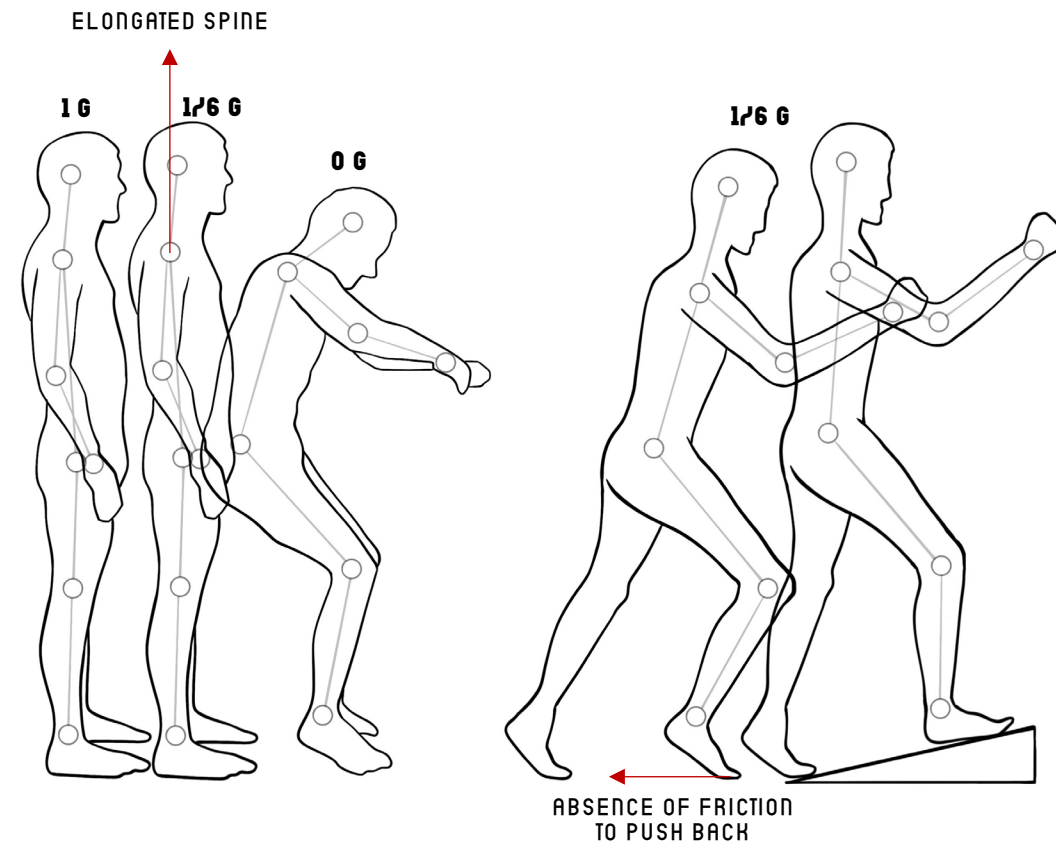
CLIMBING

body movement against gravity



SOURCE: NASA

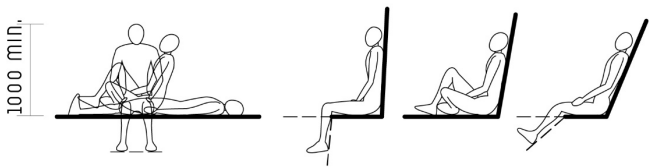
COMPARATIVE MEASUREMENTS OF
WALKING AND RUNNING GAITS (1966)



NEUTRAL POSITION & START OF WALKING

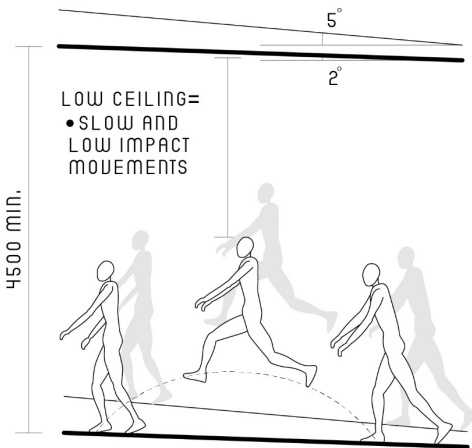
parameters derived from lunar physics

ALL DIMENSIONS
IN MILLIMETRES

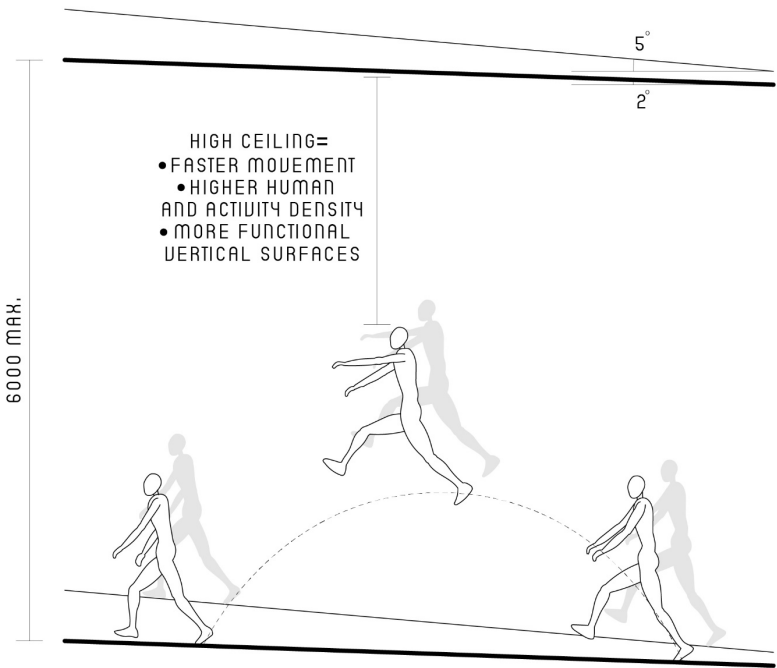


LAYING AND FLAT-SEATED LEANING (RESTING POSITION)

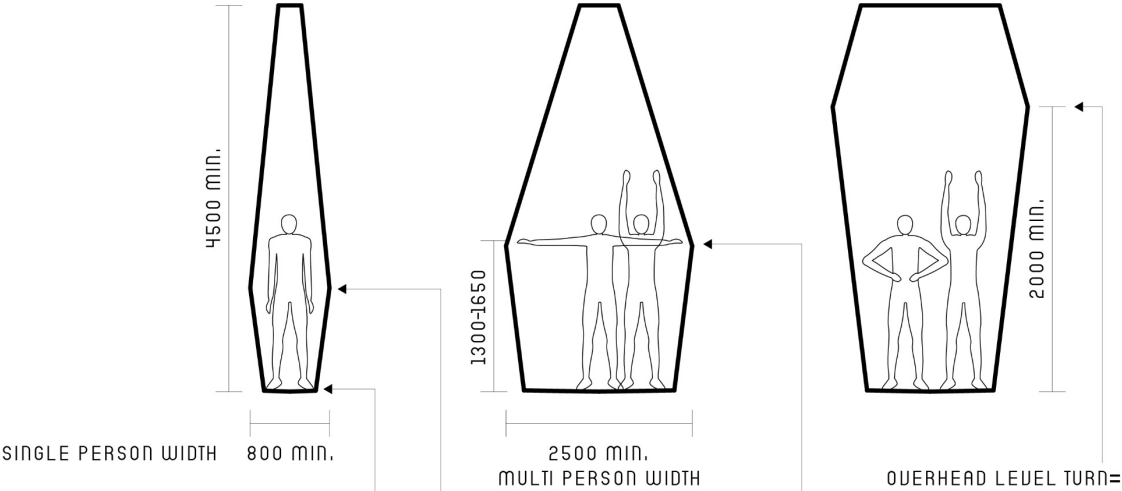
INCLINATION OF HORIZONTAL MOVEMENT (2°-5°)
TO STRAIGHTEN BODY AND
TO INCREASE SURFACE FRICTION



PERSONAL CLEARANCE SPACE



PUBLIC CLEARANCE SPACE



SINGLE PERSON WIDTH 800 MIN.

STABLE STANDING POSTURE
(SHOULDER WIDTH OR MORE)

2500 MIN.
MULTI PERSON WIDTH

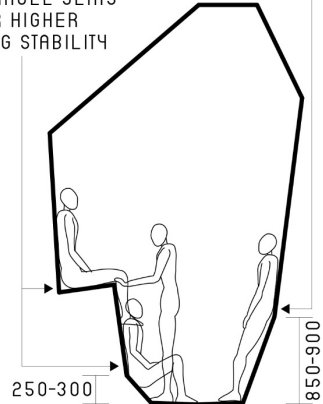
OVERHEAD LEVEL TURN=

- FOR FUNCTIONAL VERTICAL SURFACES
- FOR VISUAL AND PHYSICAL OPENINGS

SHOULDER-HEIGHT LEVEL TURN=
• FOR HORIZONTALLY-CONNECTED ACTIVITIES
• FOR WORKABLE SPACES

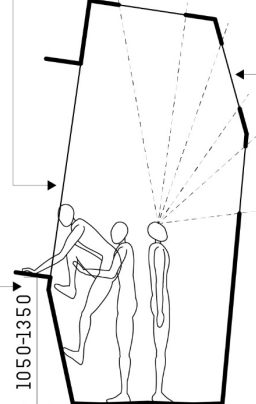
MID-BODY LEVEL TURN=
• TO ACCOMMODATE SITTING
• FOR STATIONARY SPACES

ACUTE ANGLE SEATS
FOR HIGHER SEATING STABILITY



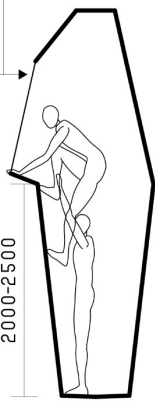
SITTING SPACES

EYE-LEVEL OPENING
FOR PHYSICAL CONNECTION
TO PUBLIC SPACE



LOW-LEVEL CONNECTION

OVERHEAD-LEVEL OPENING
FOR PHYSICAL CONNECTION
TO PRIVATE SPACE



HIGH-LEVEL CONNECTION

parameters derived from lunar physics

GRAVITY (m/s²)

EARTH	MOON
9.8	1.6

FALL FROM 1m

0.45 SEC	1.1 SEC
$U = 4.4 \text{ m/s}$	$U = 1.8 \text{ m/s}$
↓	
$U = 1.8 \text{ m/s}$	
0.17m	

FALL FROM 2m

0.64 SEC	1.6 SEC
$U = 6.26 \text{ m/s}$	$U = 2.5 \text{ m/s}$
↓	
$U = 2.5 \text{ m/s}$	
0.32m	

FALL FROM 3m

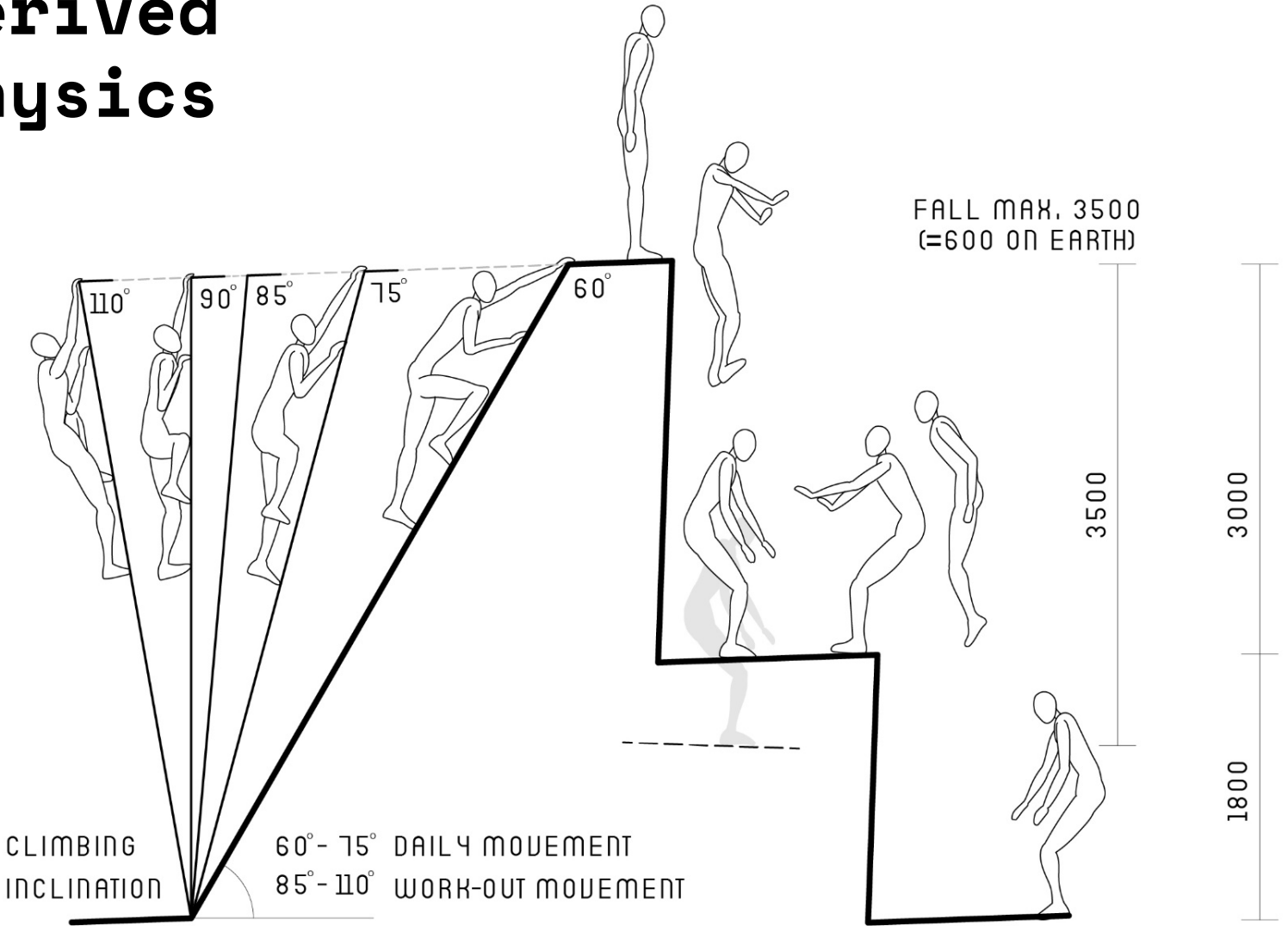
0.78 SEC	1.9 SEC
$U = 7.7 \text{ m/s}$	$U = 3.1 \text{ m/s}$
↓	
$U = 3.1 \text{ m/s}$	
0.49m	

FALL FROM 10m

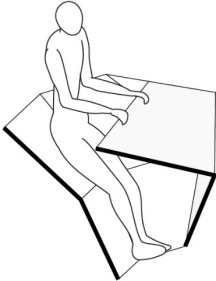
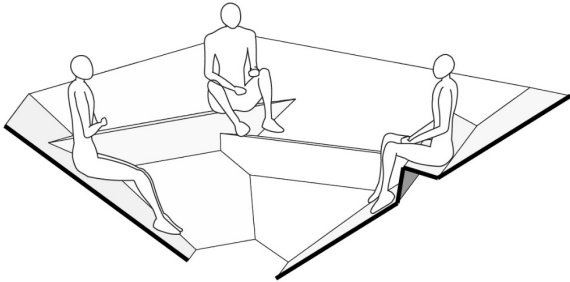
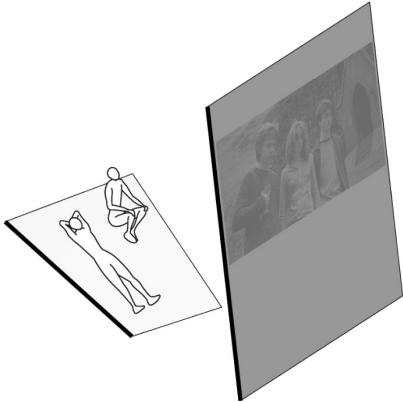
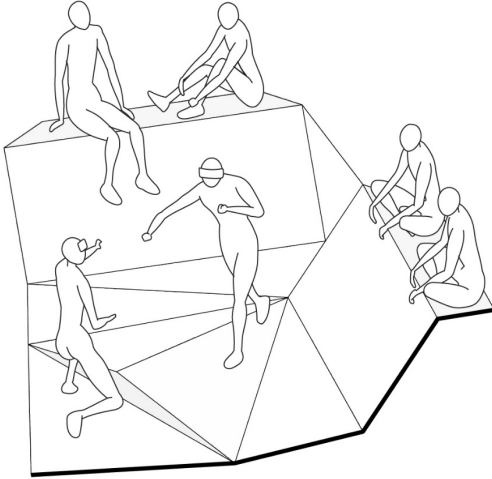
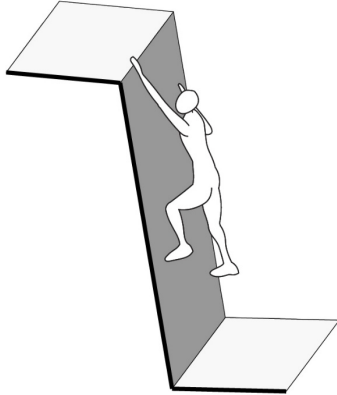
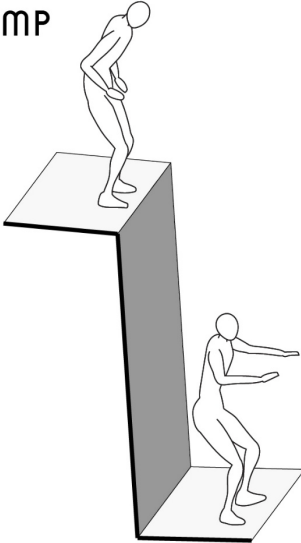
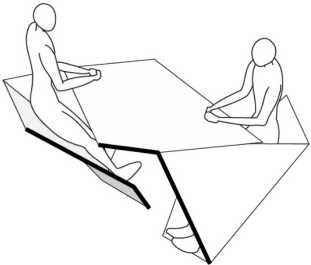
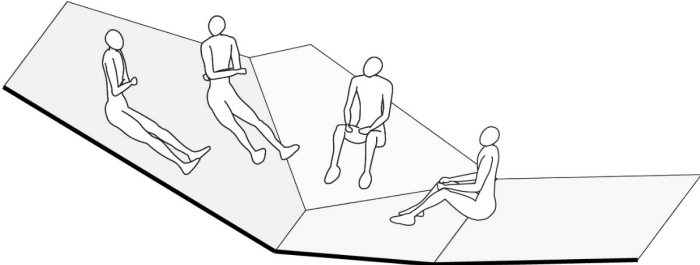
1.43 SEC	3.54 SEC
$U = 14 \text{ m/s}$	$U = 5.6 \text{ m/s}$
↓	
$U = 5.6 \text{ m/s}$	
1.6m	

JUMP FROM GROUND

0.5 m → 2.7 - 3 m



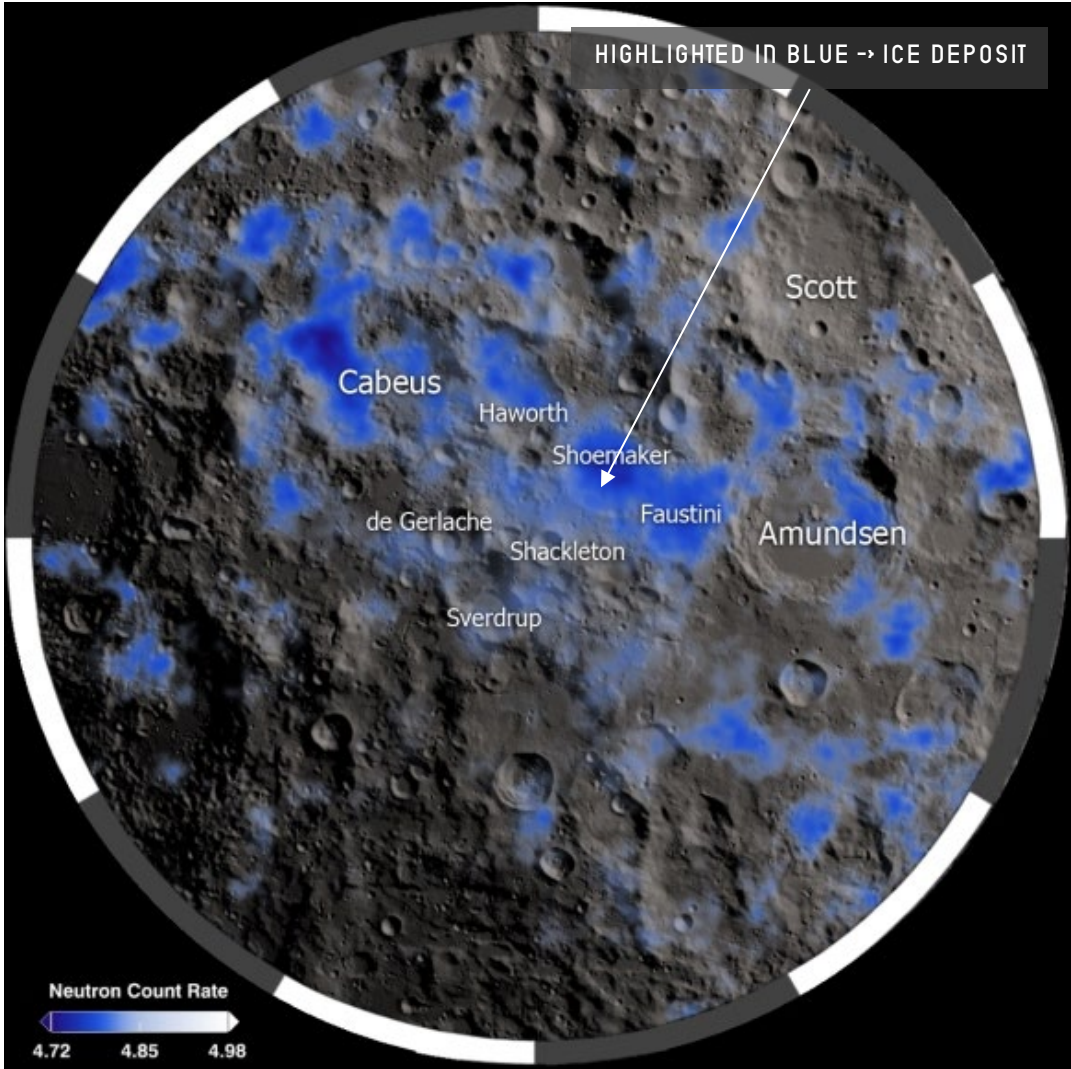
(assumptive) fundamental postures to activities

SOLITUDE SLEEP 	WORK DESKTOP  DISCUSS 	SOCIALISE MOVIE  VIRTUAL REALITY GAMES 	MOVE AROUND CLIMB  JUMP 
EAT DINE 	PICNIC 		

designing lunar habitat



site



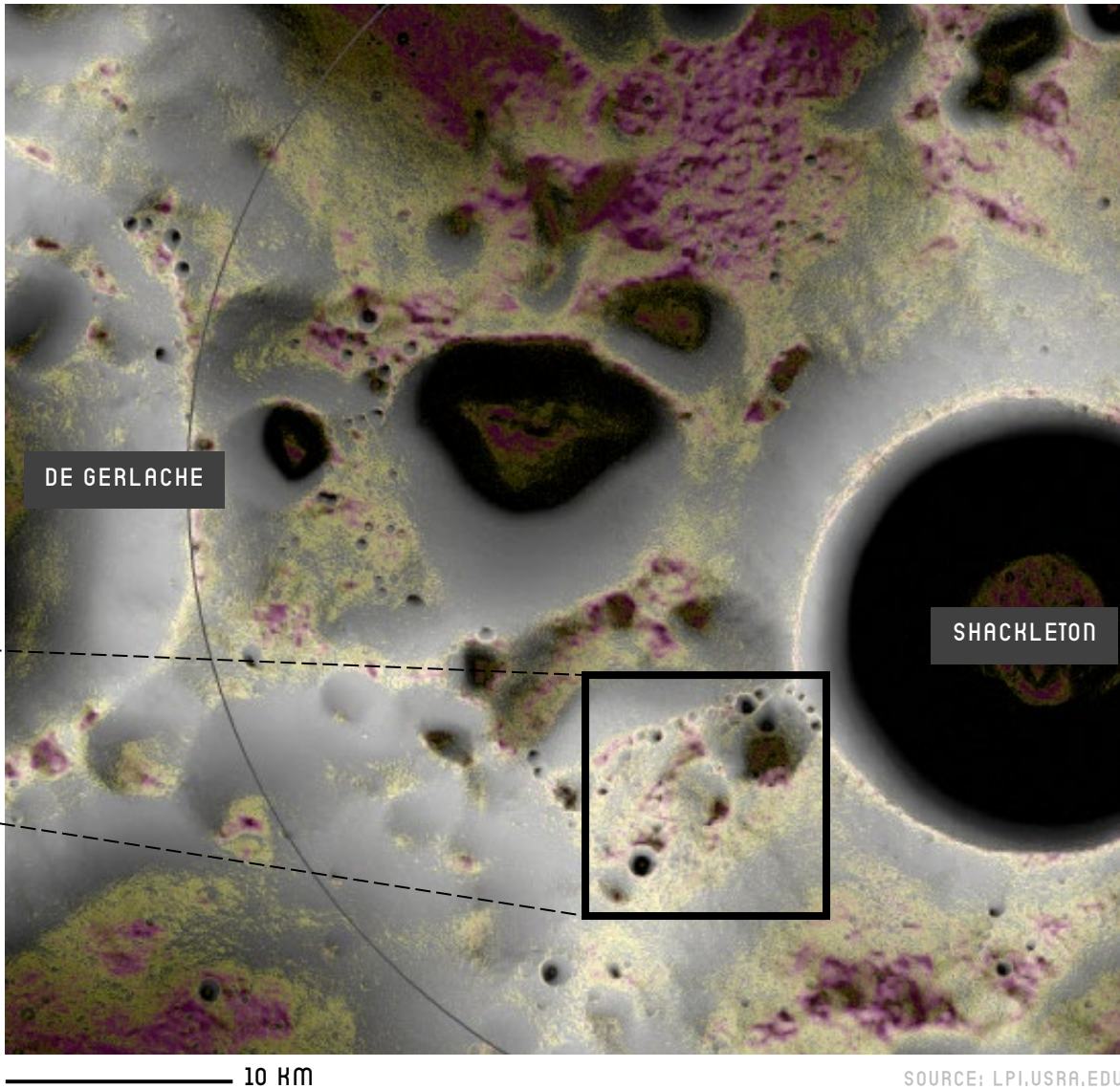
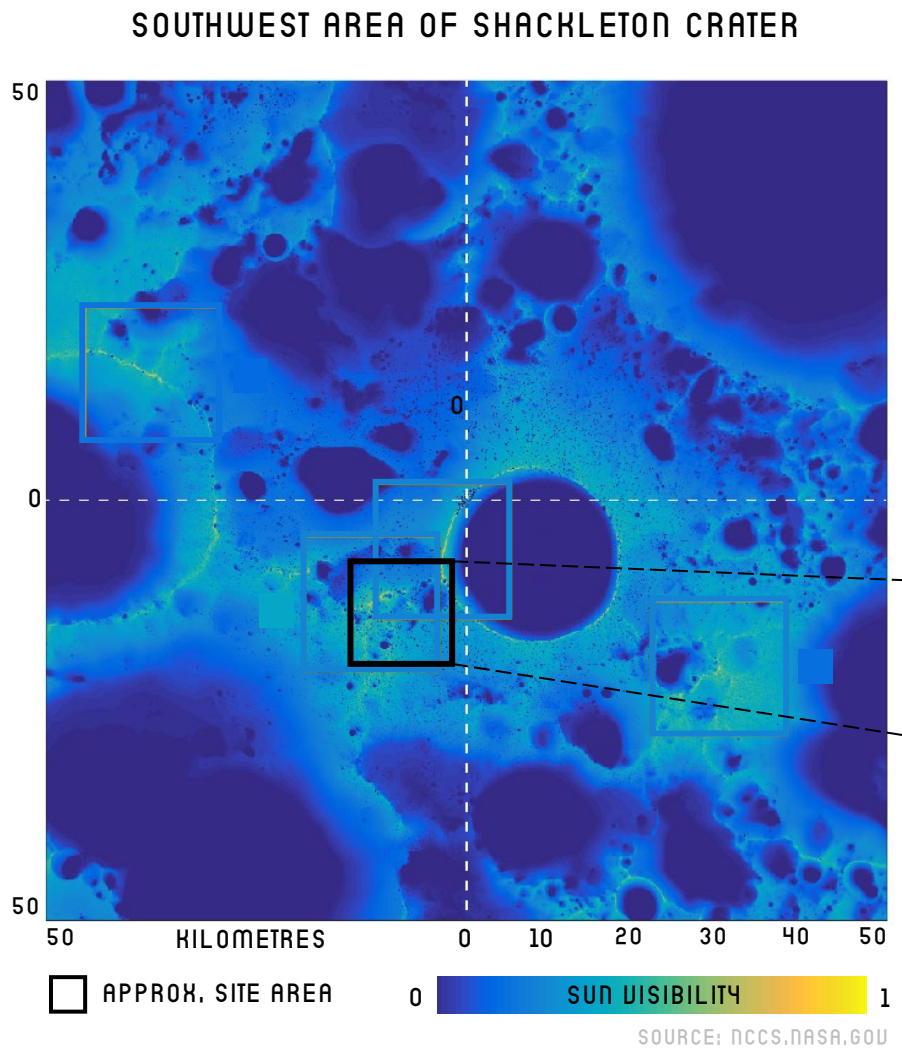
SOURCE: AMERICASPACE.COM



SOURCE: LPI.USRA.EDU

SOUTH POLE OF MOON
RESOURCES
WATER (ICE) -> CRATER BASE
SUN POWER -> CRATER RIM

site



site

(zoom in to 1:1000)



PROTECTION FROM

RADIATION (200x > EARTH SURFACE)
TEMPERATURE FLUCTUATIONS (-133 TO 121°C)
METEORITE SHOWER

program requirements

(min. 80m3 PER PERSON)

1. PUBLIC OPEN SPACES		2. CIRCULATION	
atrium/ playground	kitchen & dining	climbing walls for encouraged main circulation	
vertical garden/ food gallery	semi-outdoor space		

- 3. SPECIFIC WORKING SPACES**
- RESEARCH LAB
 - DESK STATIONS
 - CONTROL CENTRE
 - CLINIC
 - Gym

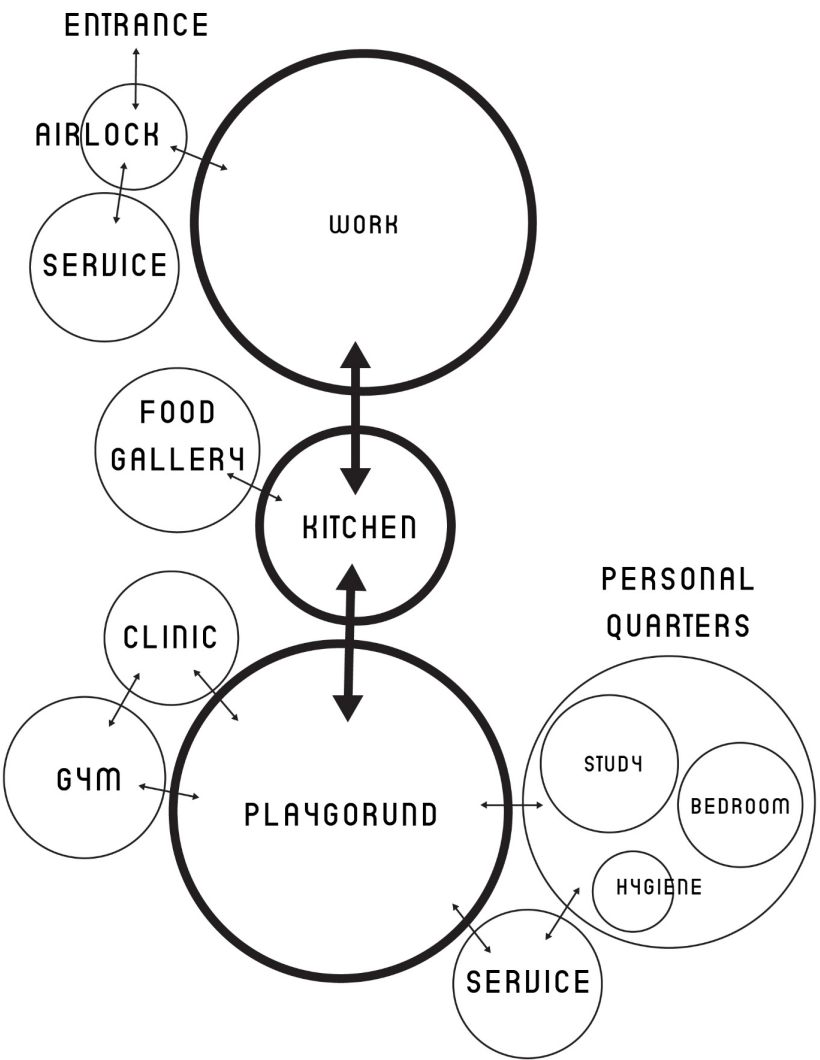
PROGRAM	MIN. VOLUME PER PERSON (m3)	%	MIN. HEIGHT (m)	MAX. CAPACITY	CONNECTION ORIENTATION
PRIVATE QUARTERS (BED)	6	4 %	1.5	1 (EACH)	HORIZONTAL
PRIVATE QUARTERS (STUDY)	25	17 %	4.5	3 (EACH)	VERTICAL
PRIVATE QUARTERS (HYGIENE)	4	3 %	3	1 (EACH)	-
KITCHEN & DINING	15	10 %	4.5	3	HORIZONTAL
Gym	10	7 %	4.5	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 %			

- 4. PERSONAL SOLITUDE SPACES**
- BEDROOM
 - STUDY
 - HYGIENE

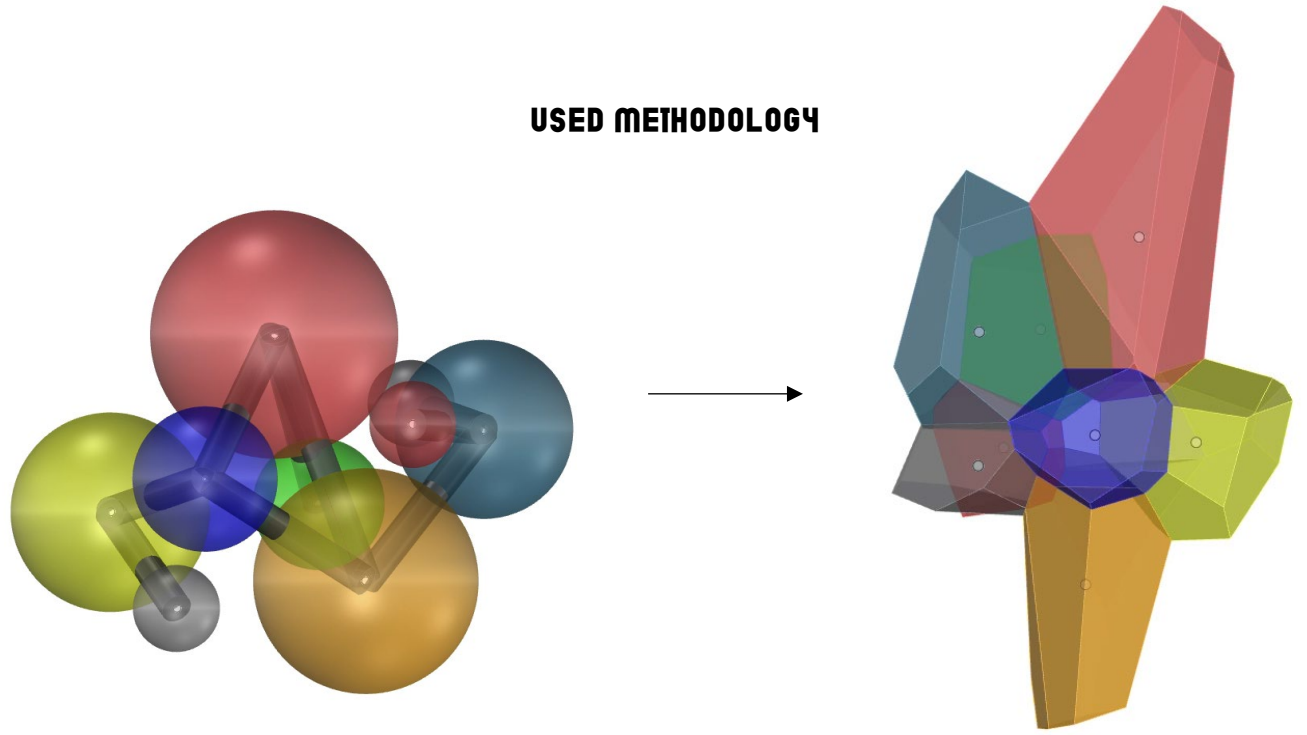
- 5. SERVICE SPACES**
- LIFE SUPPORT STORAGE
 - AIRLOCK CHAMBERS
 - DONNING & DOFFING AREA
 - STORAGE

program spatial distribution

2D program adjacencies to 3D connectivity



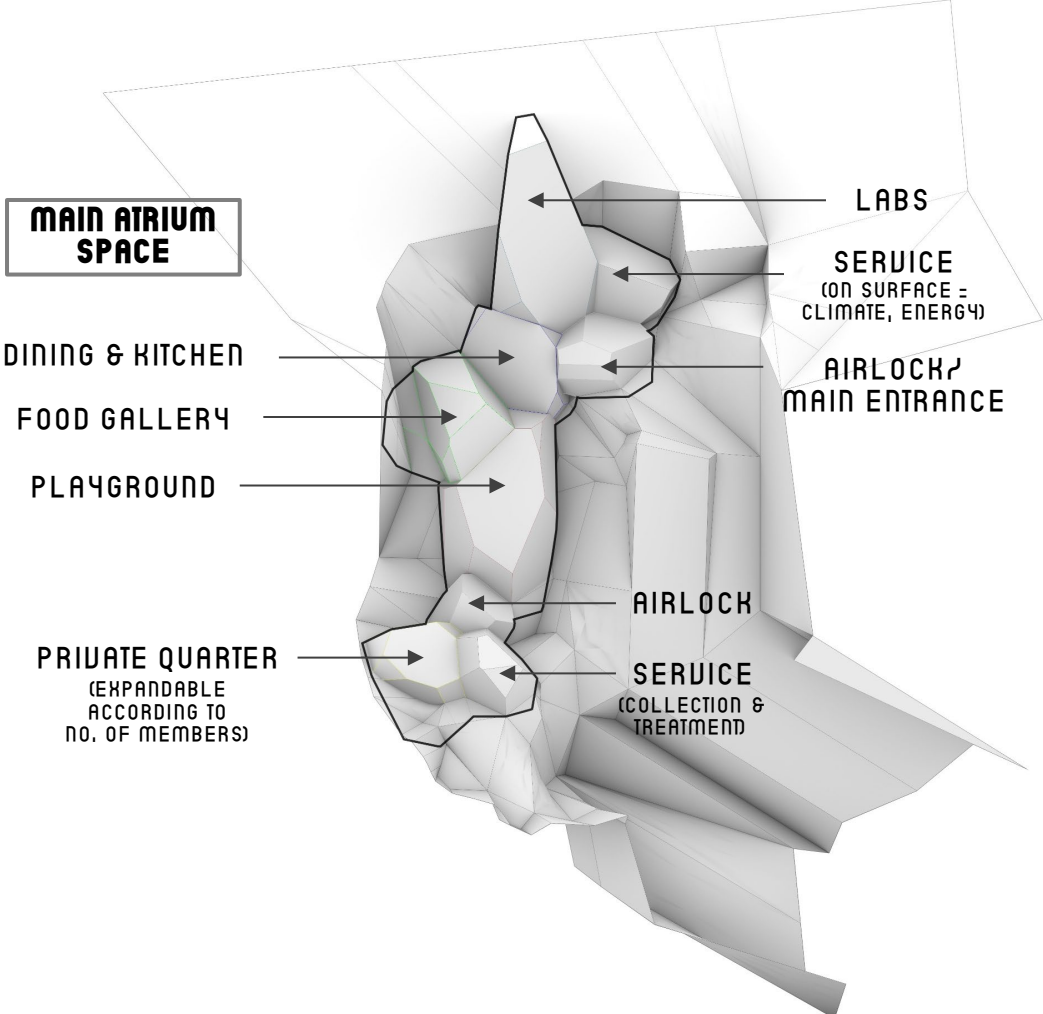
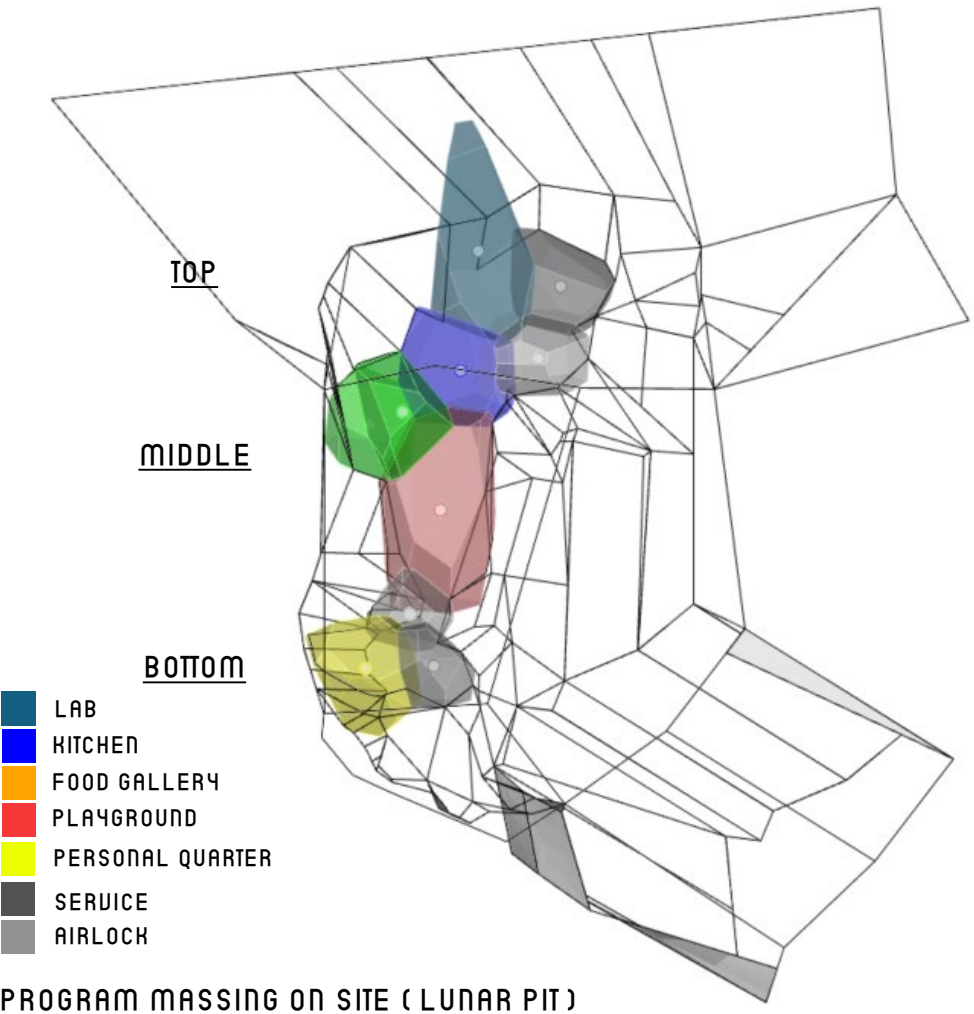
USED METHODOLOGY



- | | | | | | |
|-------------|--------------|-------------|------------------|-------------|---------|
| <div></div> | PLAYGROUND | <div></div> | PERSONAL QUARTER | <div></div> | CLINIC |
| <div></div> | KITCHEN | <div></div> | WORKSTATION | <div></div> | SERVICE |
| <div></div> | FOOD GALLERY | <div></div> | GYM | <div></div> | AIRLOCK |

program massing

3D program adjacencies on site



lava tube mission



**CHALLENGING
LAVA TUBE TERRAIN**



**EYES &
BRAIN**



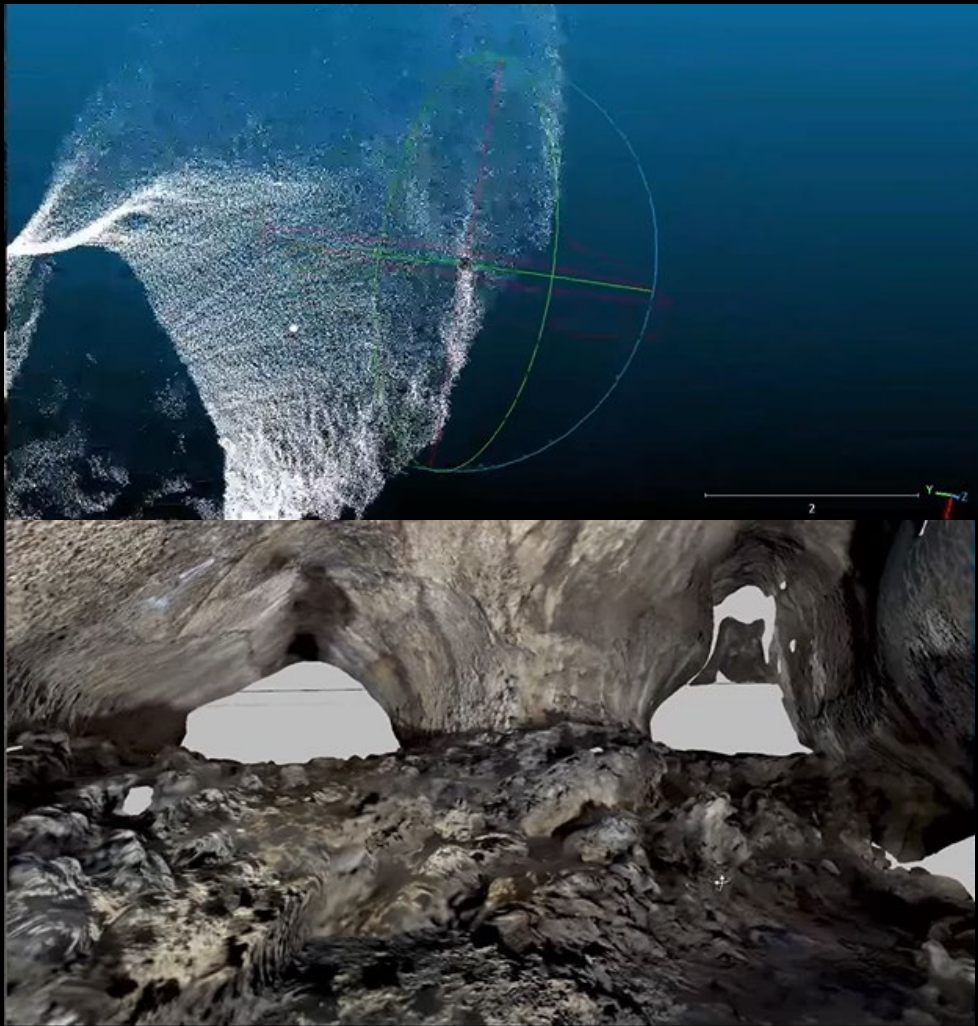
**BODY
DIMENSIONS**



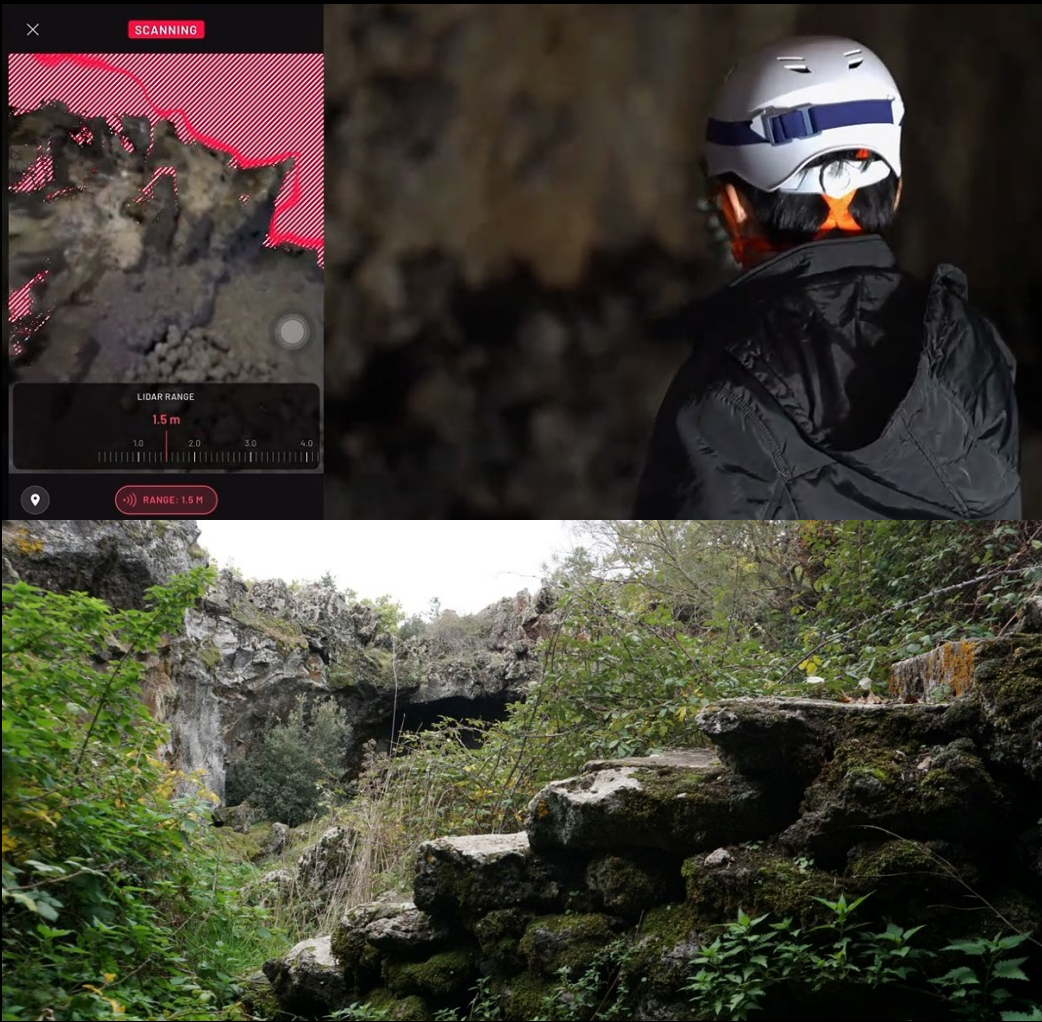
**SPATIAL
COORDINATION**



lava tube mission

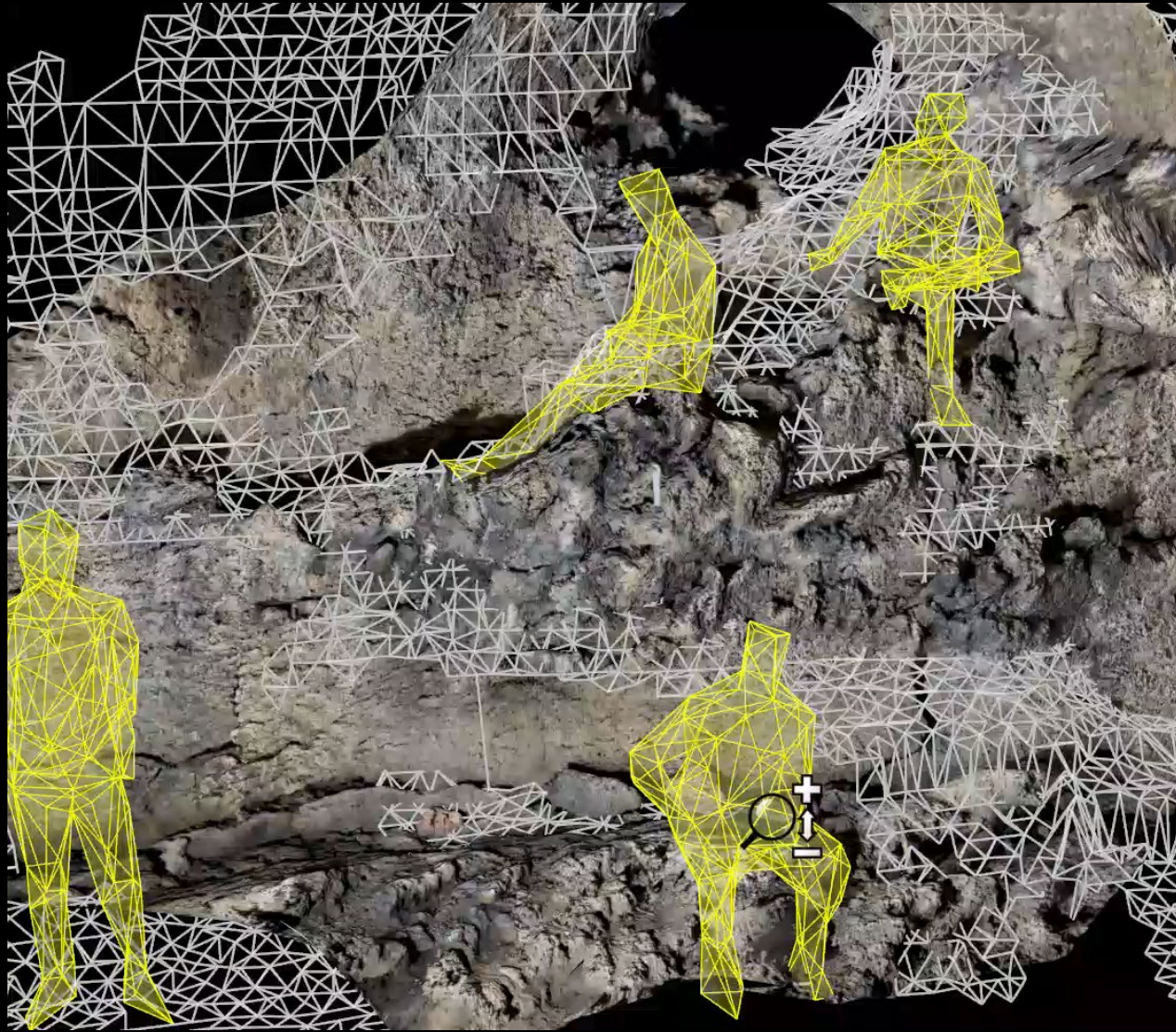


URBAN & ARCHITECTURAL SCALES



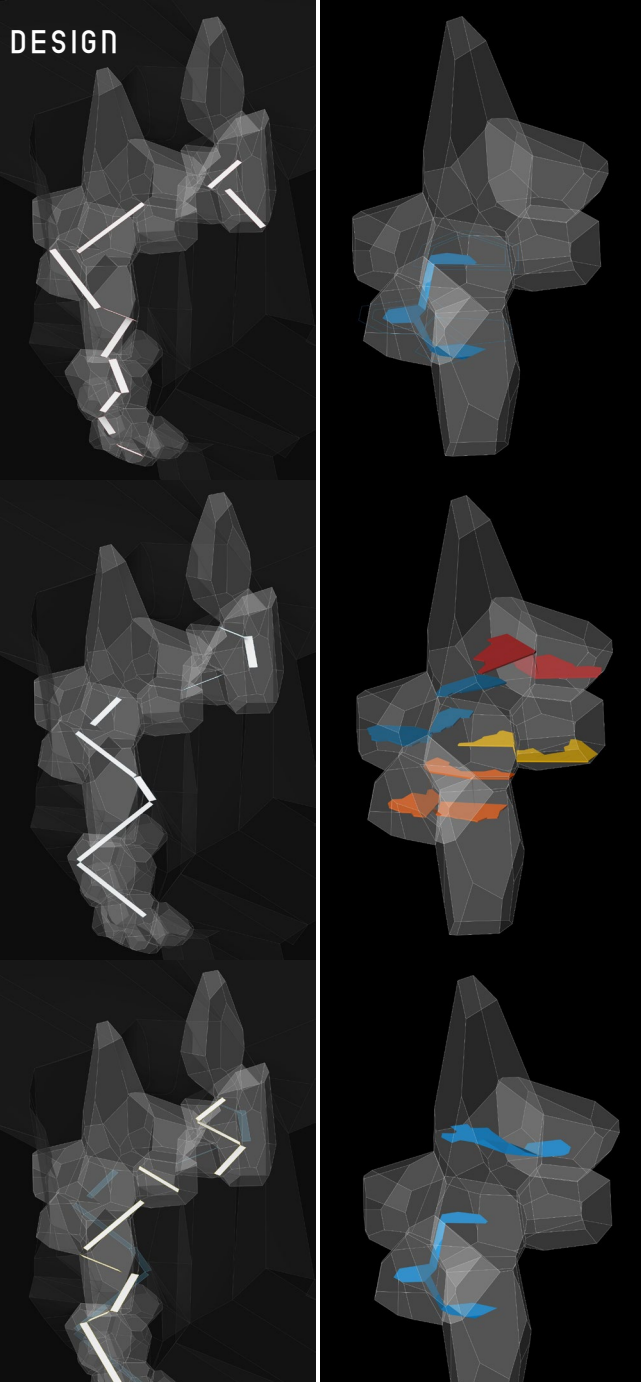
FURNITURE & MATERIAL SCALES

body dimensions to architectural scales



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

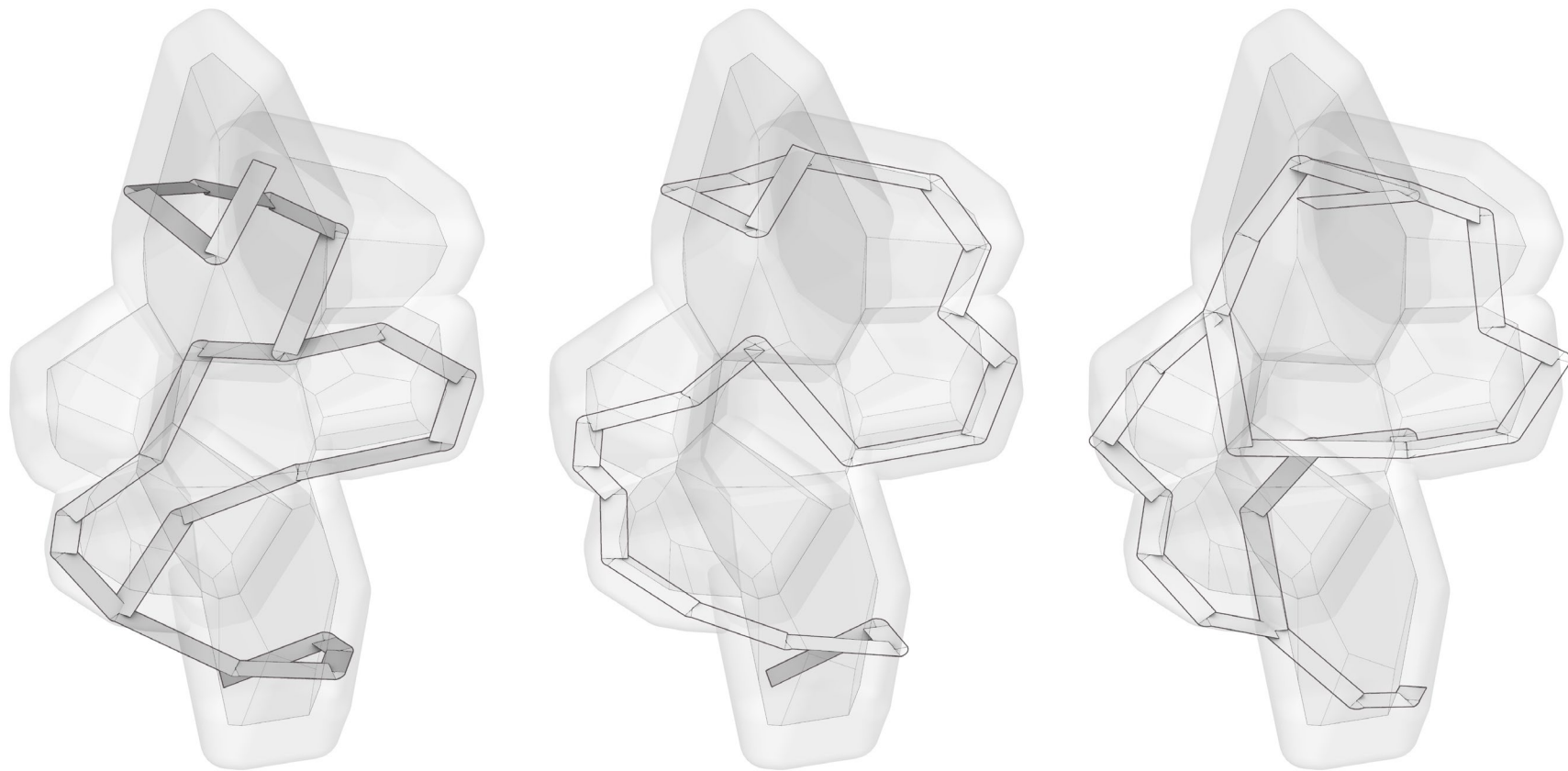
DESIGN



PROCESS STUDY OF RAMPS AND PLATFORMS

form finding

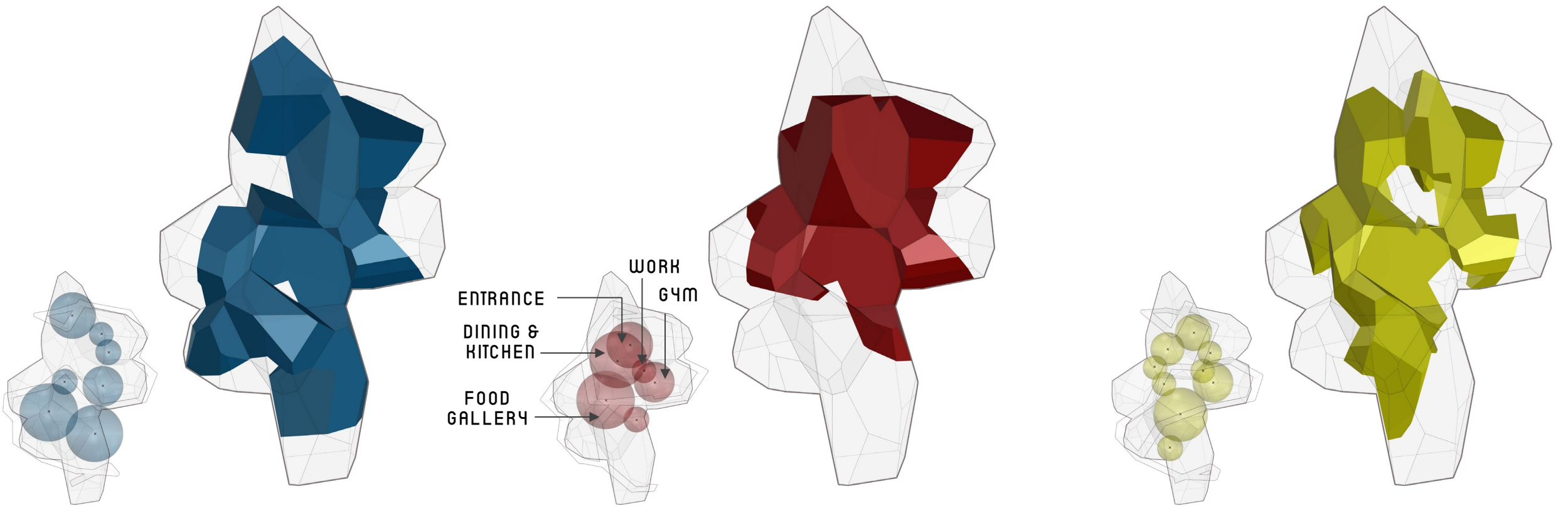
thick walls and circulation



GRADUAL ANGLED PATH GOES THROUGH THICK WALLS

form finding

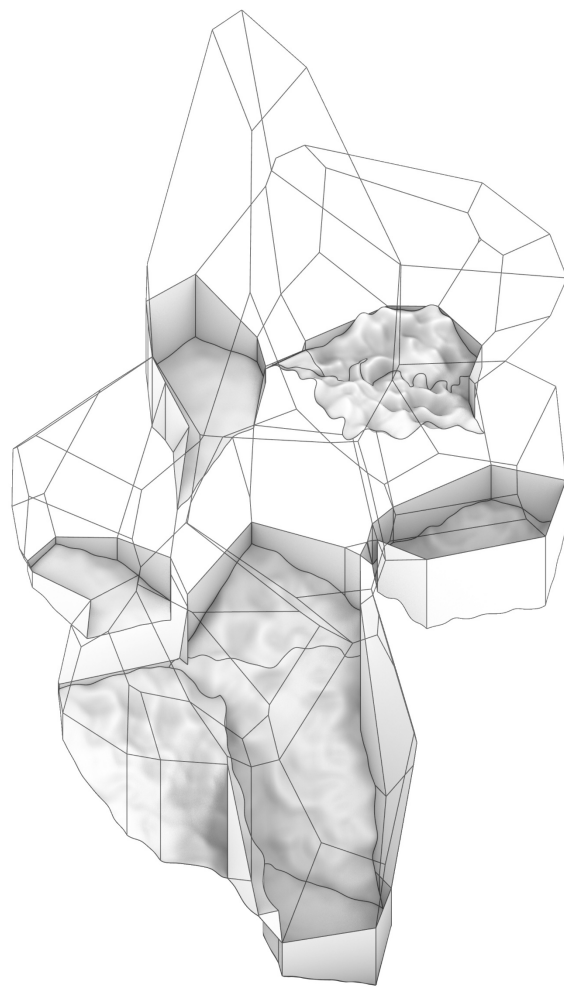
programmatic function



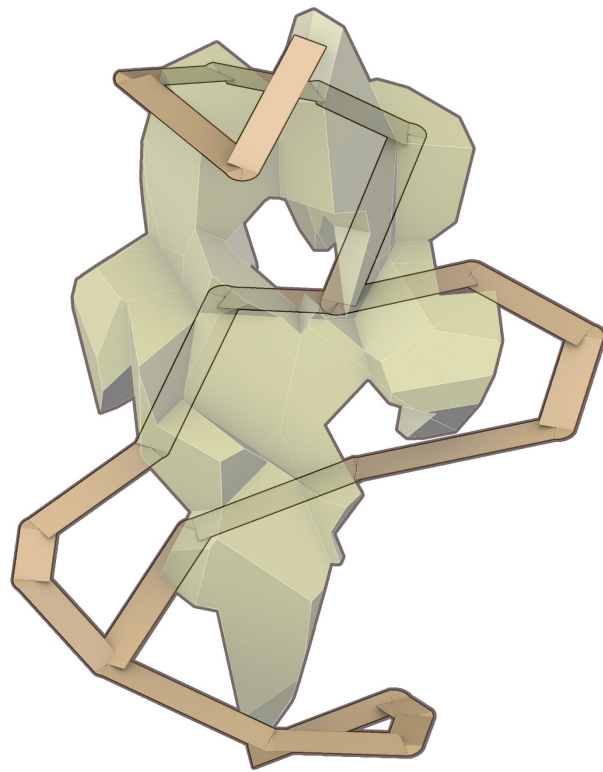
PROGRAM PLACEMENT TESTED ALONG CIRCULATION
POINTS GENERATED FROM SPHERES -> CONVERTED INTO VORONOI-BASED SPACES

form finding

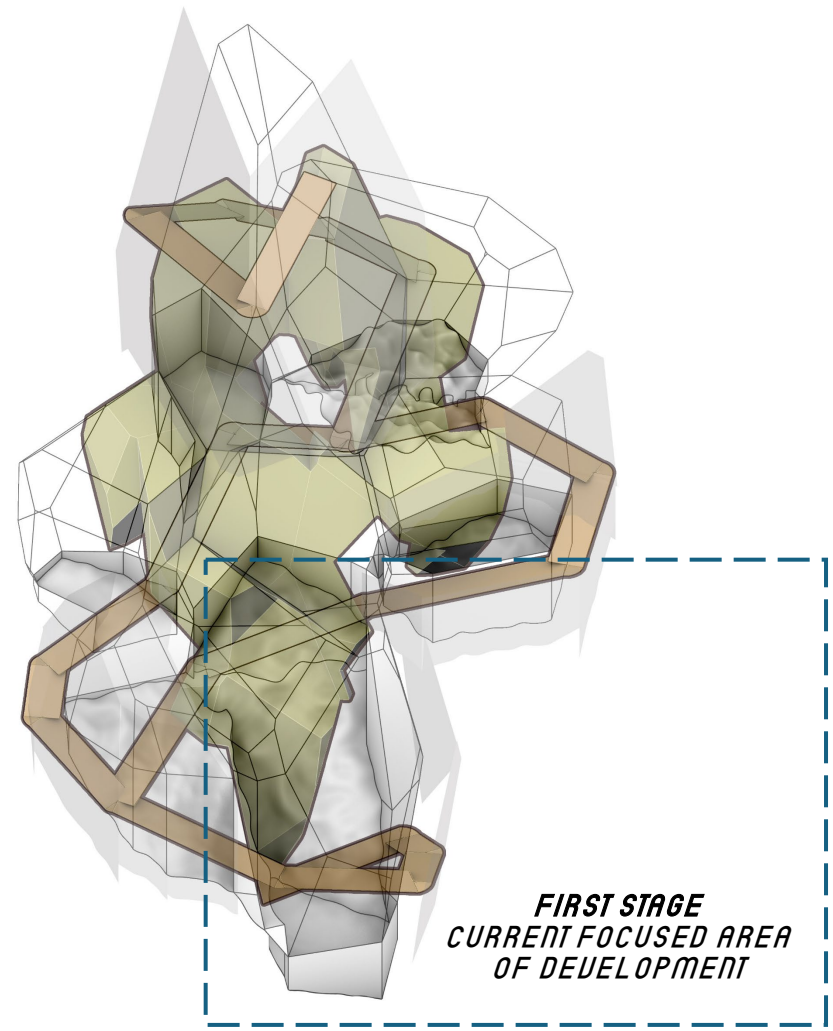
man-made to nature



NATURAL TERRAIN



BUILT ELEMENTS



INTERTWINED

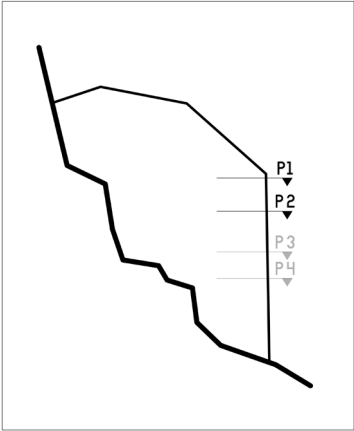
ARCHITECTURAL ELEMENTS + EXISTING TERRAIN -> SURFACES ANGLES AND RESOLUTION

plans

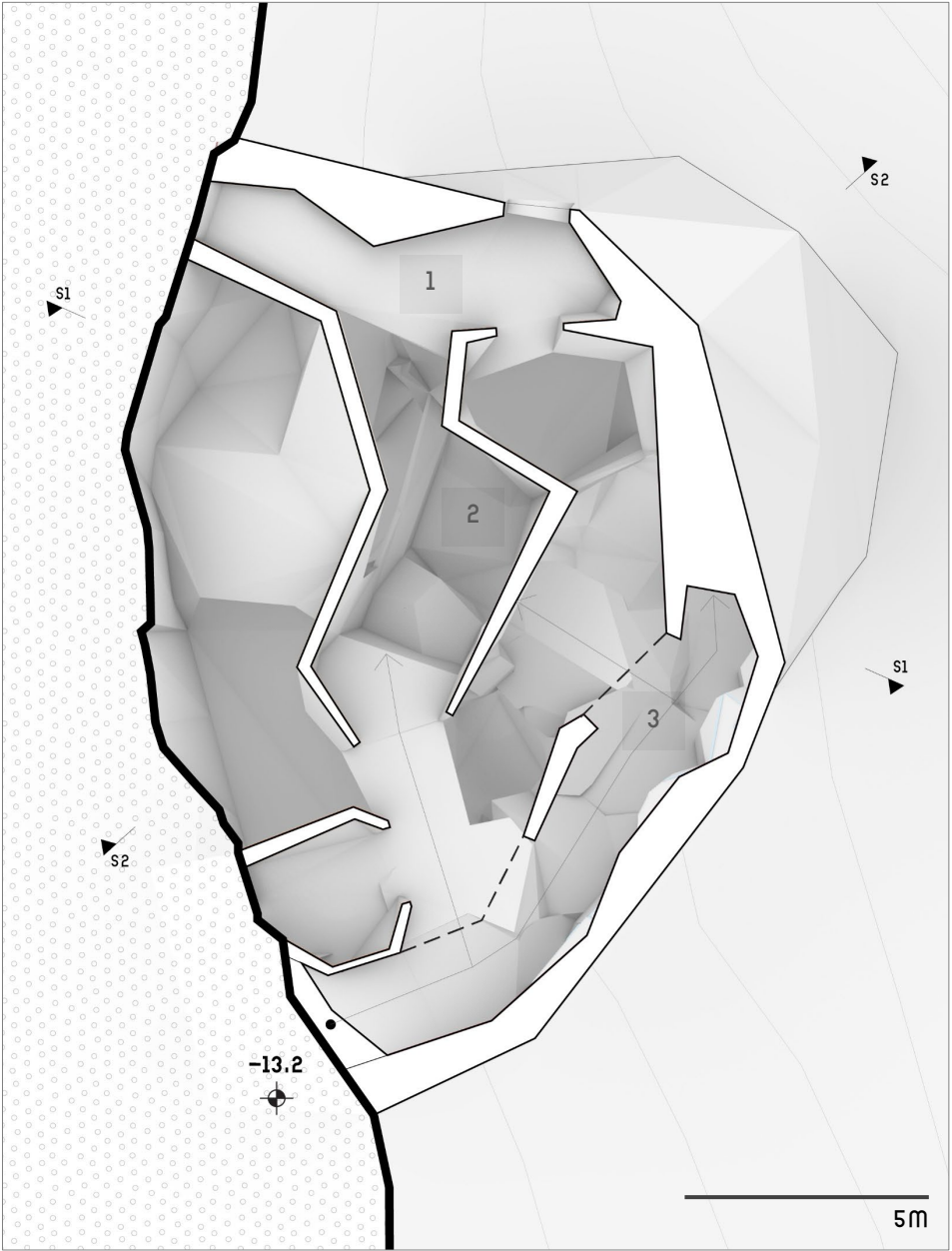
(zoom in to 1:100)

ARCHITECTURAL ELEMENTS -
VIEWS, BODY ENGAGEMENT

- 1 WORK ZONE
- 2 EAT ZONE
- 3 INTERNAL RAMPWAY



PLAN 1 (-10.5m)

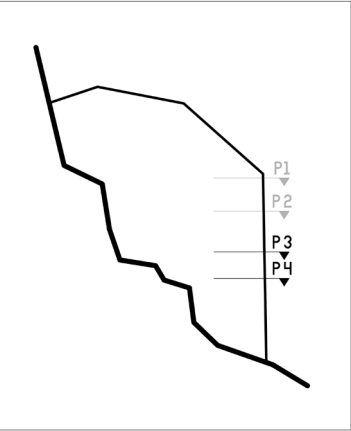


PLAN 2 (-13.2m)

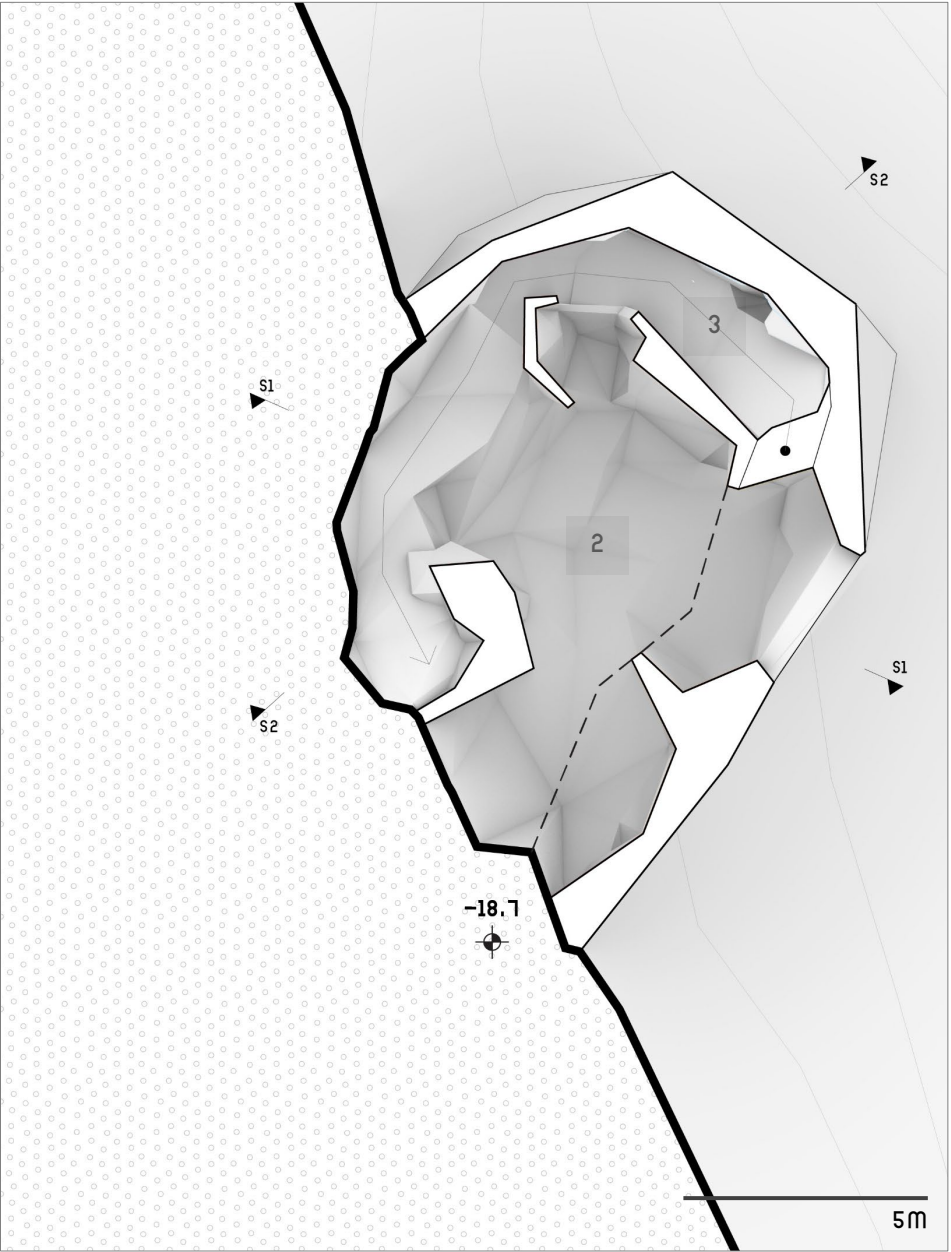
plans

ARCHITECTURAL ELEMENTS -
VIEWS, BODY ENGAGEMENT

- 1 EAT ZONE
- 2 SOCIALISE ZONE
- 3 INTERNAL RAMPWAY



PLAN 3 (~ -16.5m)



PLAN 4 (~ -18.7m)

sections

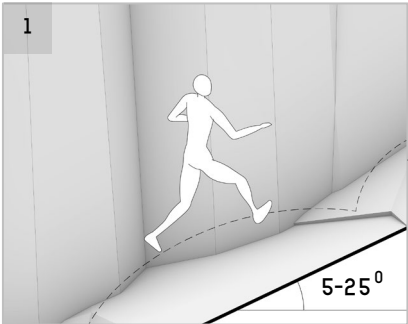
ARCHITECTURAL ELEMENTS -
VIEWS, BODY ENGAGEMENT

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

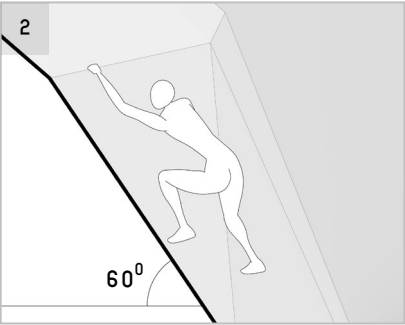


motion and movements

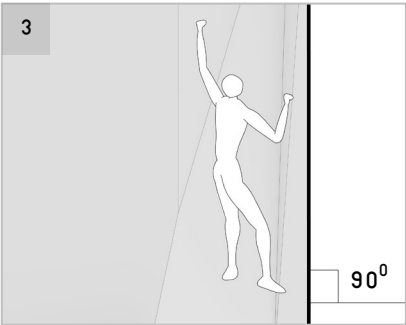
BODY ENGAGEMENT THROUGH THE ARCHITECTURAL ELEMENTS



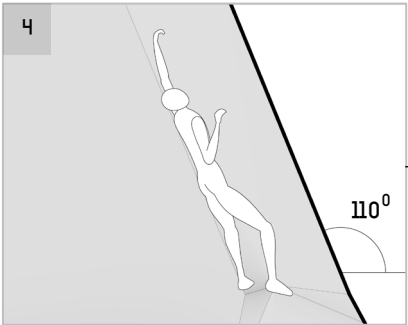
5-25 DEG. NEUTRAL WALK



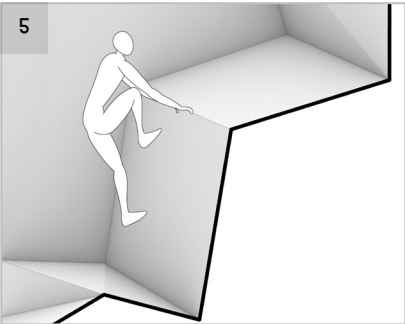
60 DEG. CLIMB



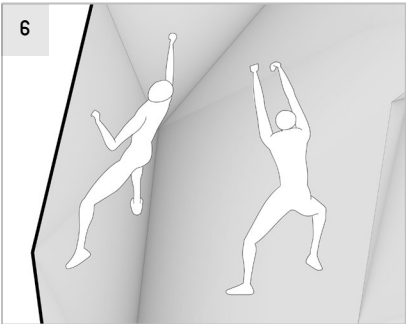
90 DEG. CLIMB



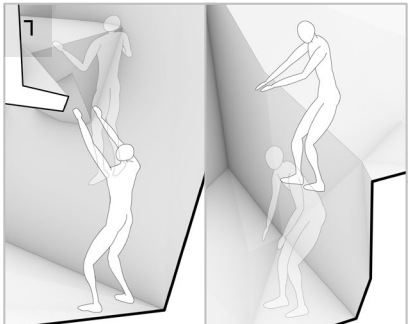
110 DEG. CLIMB



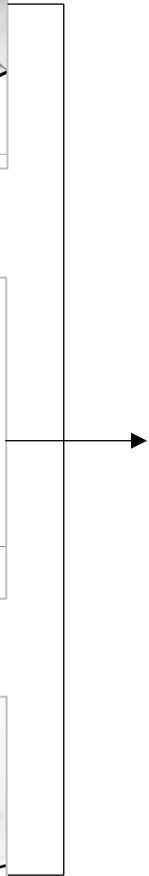
SHORT CLIMB



MULTIPLE CREW CLIMB



JUMP UP & DOWN



DESIGN

sections

ARCHITECTURAL ELEMENTS -
VIEWS, BODY ENGAGEMENT



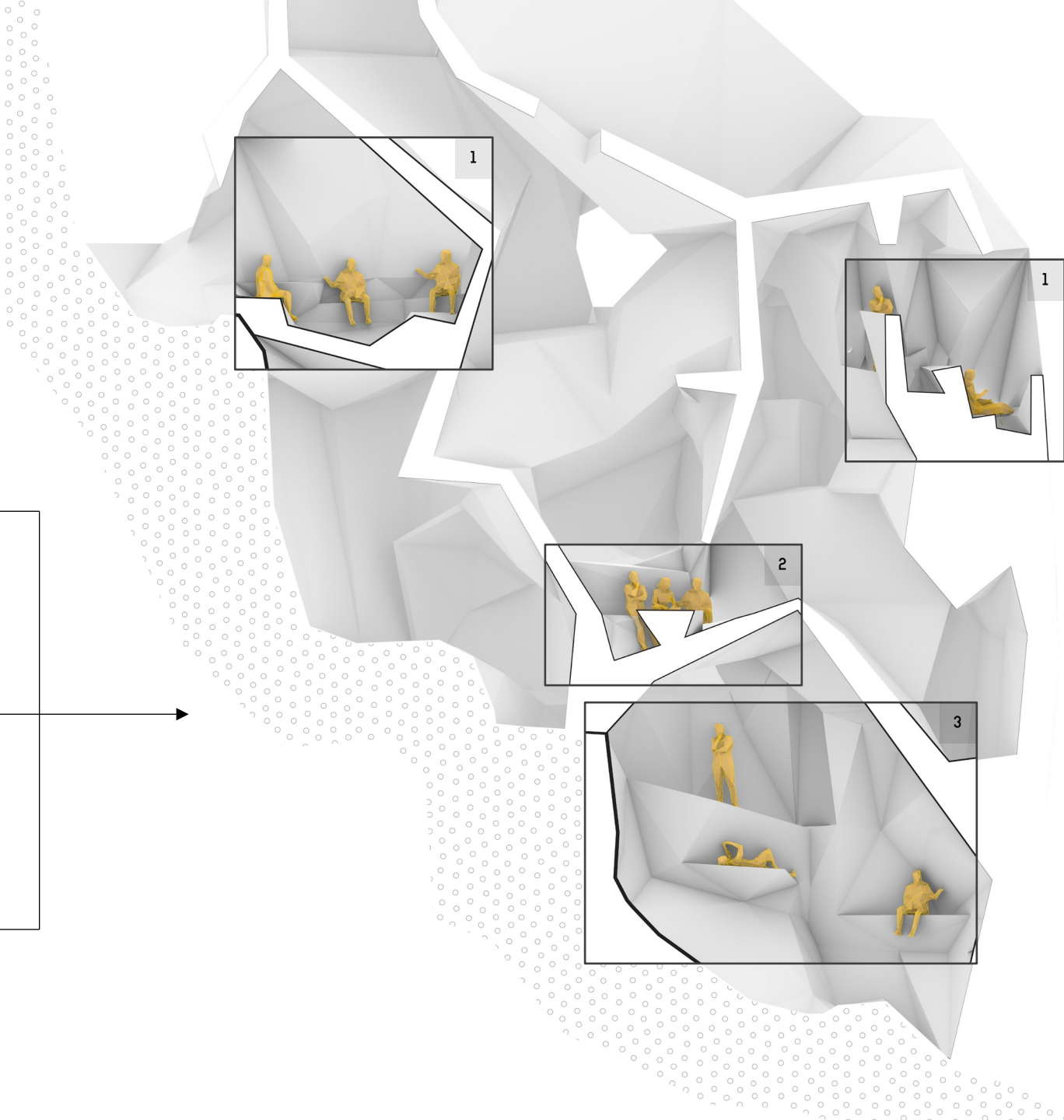
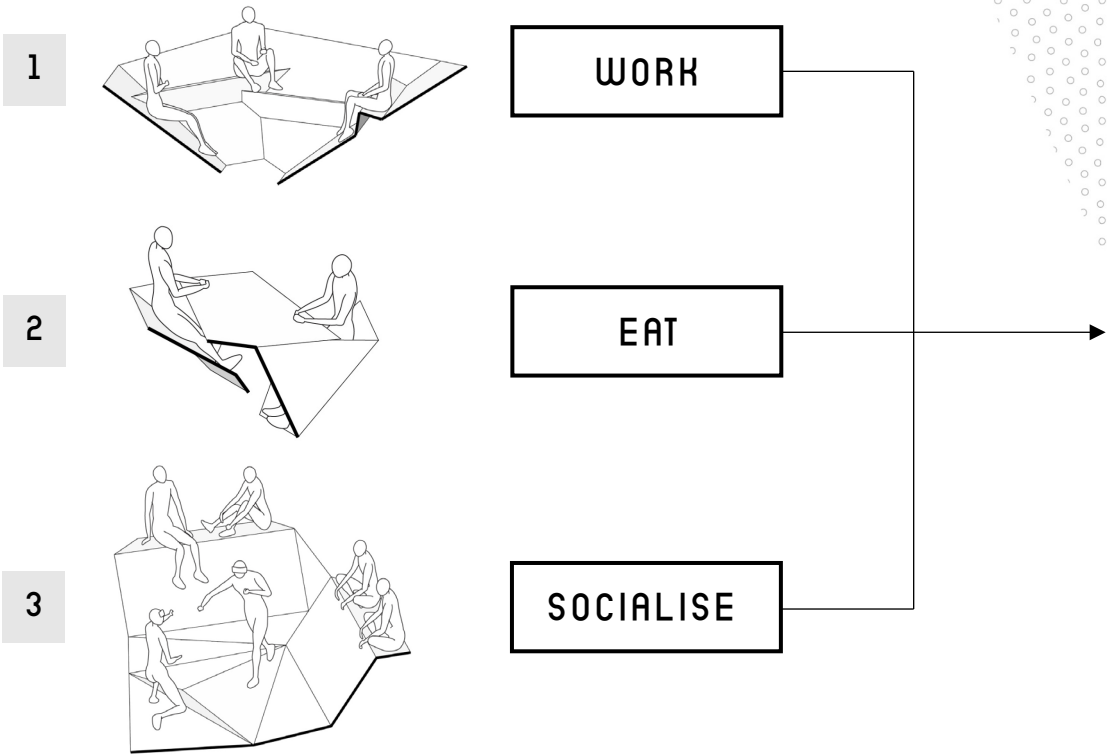
- 1 WORK ZONE
- 2 EAT ZONE
- 3 SOCIALISE ZONE
- 4 INTERNAL RAMPWAY

SECTION 2

activities to furniture integration

(zoom in to 1:50)

HUMAN BASIC ACTIVITIES AT THE MAIN ATRIUM



furniture integration design: levels and zoning

RESOLUTION/ SPECIFICITY OF SURFACES

STABLE SURFACES I.E. FOR FOOD/ LAPTOP

SPATIAL ZONING

PRIVACY LEVELS

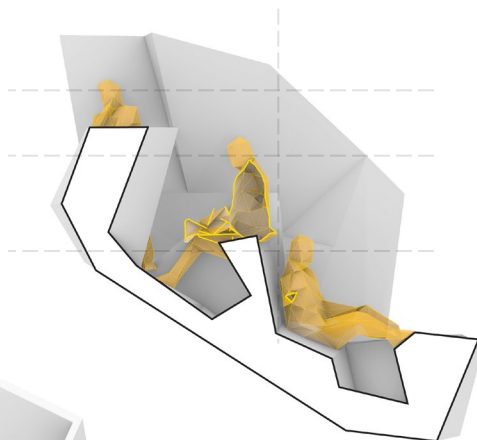
SPECIFIC PREDETERMINED FUNCTION US

FLEXIBILITY FOR FURTHER DEVELOPMENT

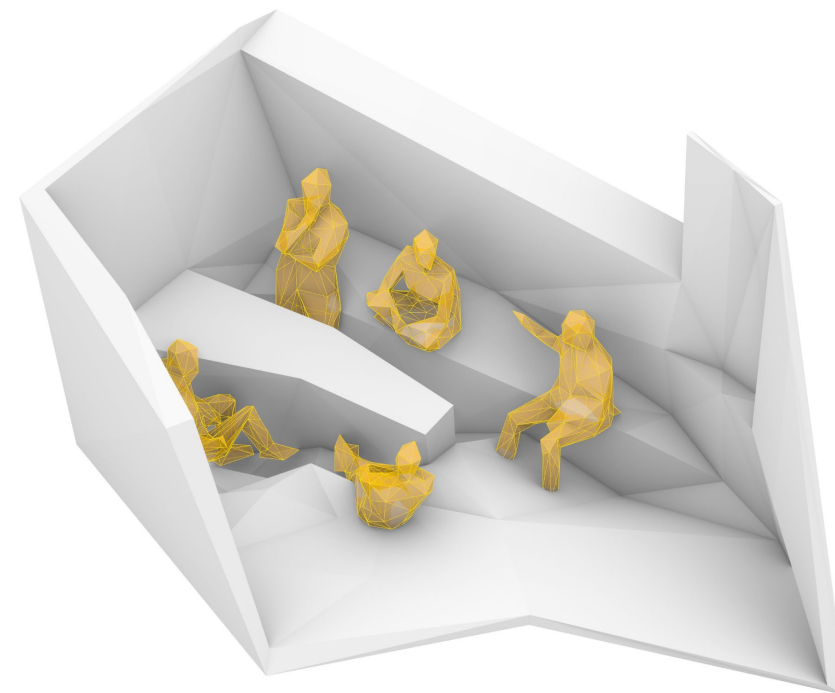
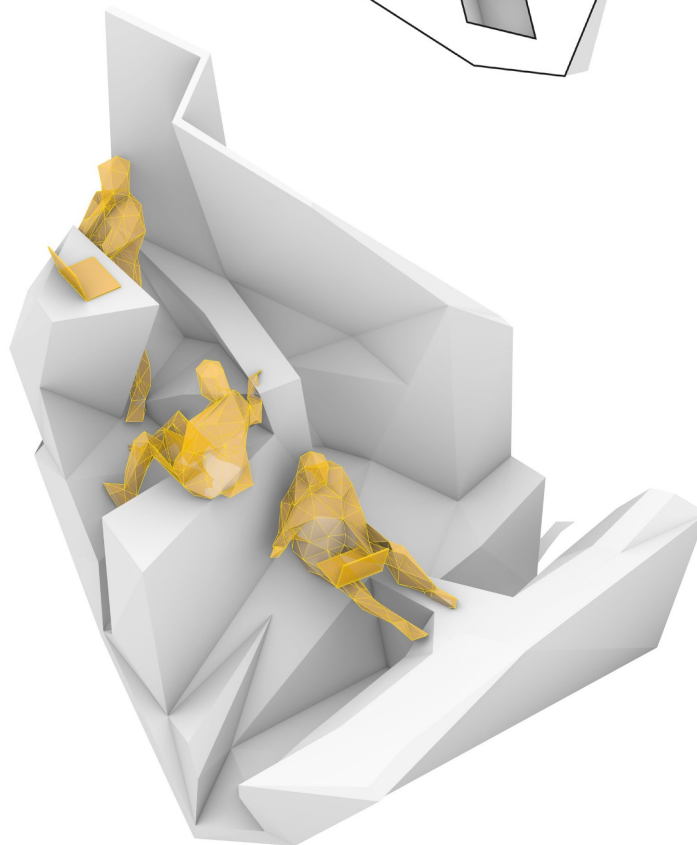
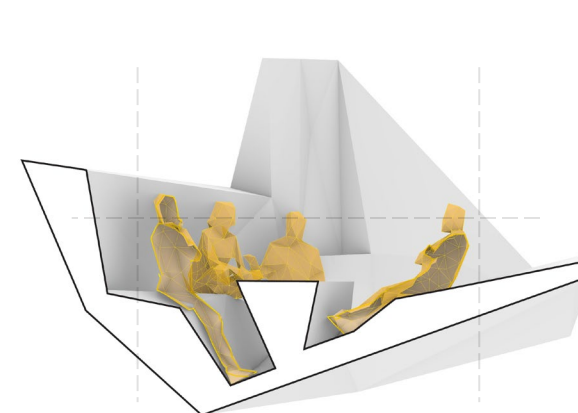
SPACE ↔ BODY

SIZE, LEVEL DIFFERENCE,
DEGREE OF OPENNESS

WORK (DESKTOP)



EAT



furniture integration design: levels and zoning

RESOLUTION/ SPECIFICITY OF SURFACES

STABLE SURFACES I.E. FOR FOOD/ LAPTOP

SPATIAL ZONING

PRIVACY LEVELS

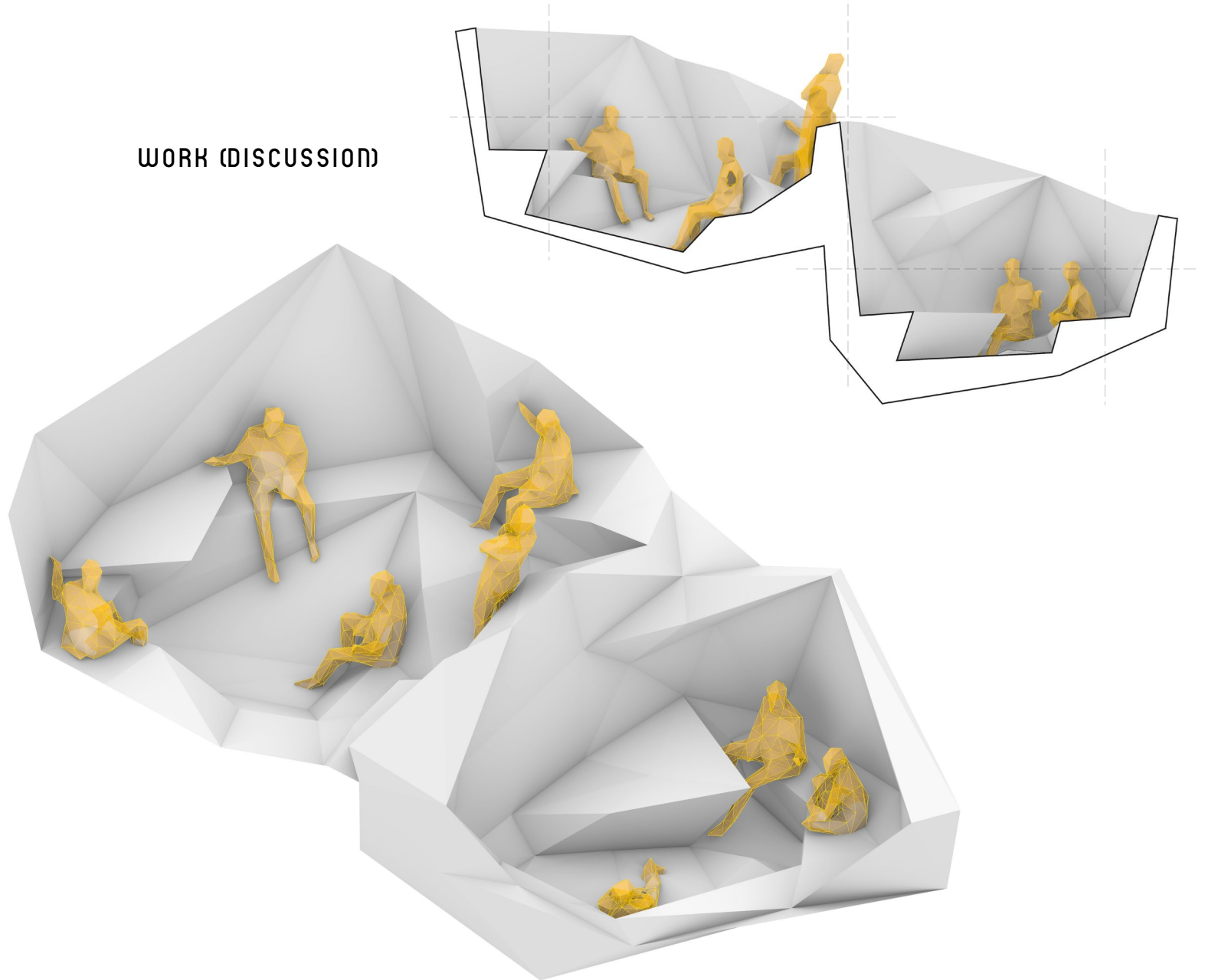
SPECIFIC PREDETERMINED FUNCTION VS

FLEXIBILITY FOR FURTHER DEVELOPMENT

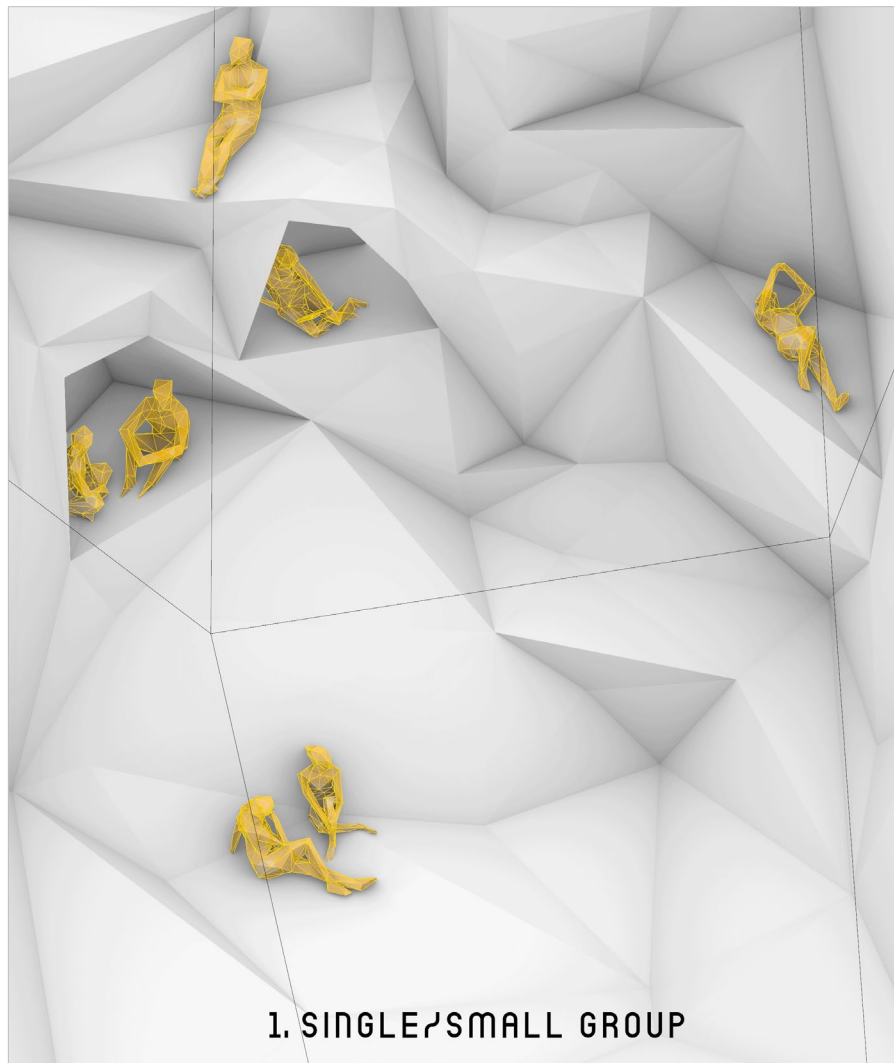
SPACE ↔ BODY

SIZE, LEVEL DIFFERENCE,
DEGREE OF OPENNESS

WORK (DISCUSSION)



furniture design: various configurations



RESOLUTION / SPECIFICITY OF SURFACES

SPATIAL ZONING

SPACE ↔ BODY

VARIOUS SURFACES LEAD TO PERSONAL
INTERPRETATIONS & PREFERENCES OF
STATIONARY POSTURES

1. SINGLE / SMALL GROUP



SMALL GROUP



MOVIE



ARENA / VR GAMES

DESIGN

impressions



VERTICAL CONTINUITY



DESIGN

impressions



THICK WALL CIRCULATION

DESIGN

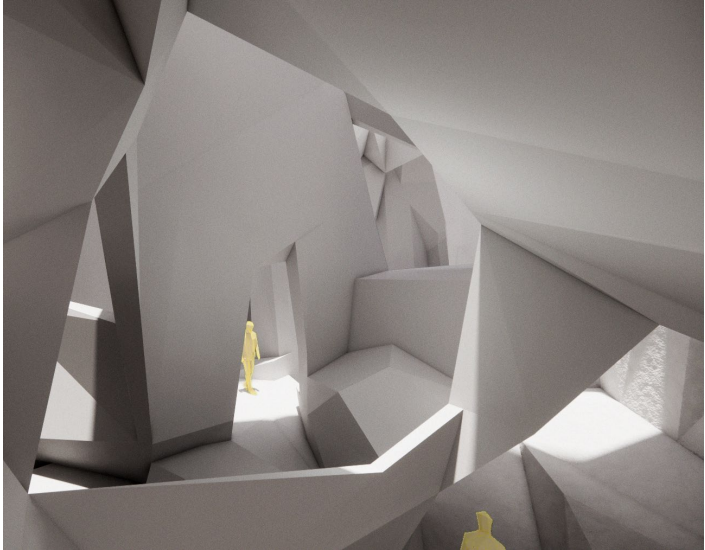
impressions



LIGHT FROM VERTICAL SHAFT

DESIGN

impressions

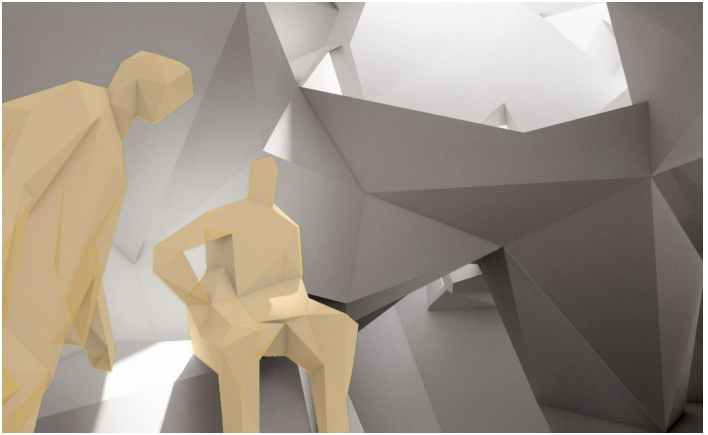
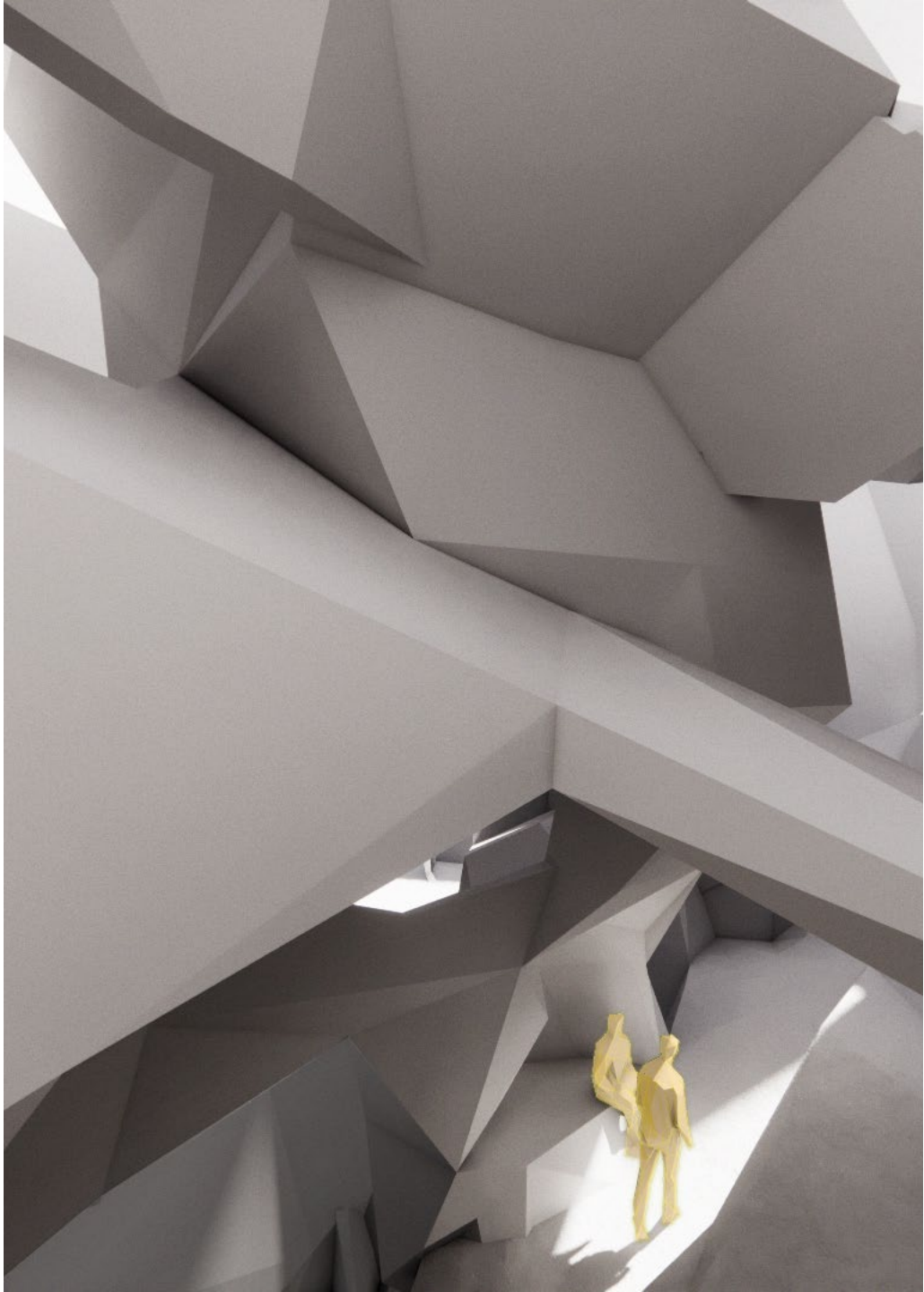


FRAMES AND OPENINGS



DESIGN

impressions

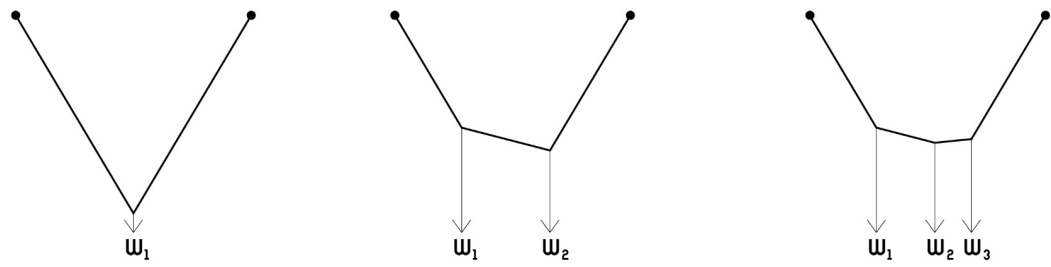


MEETING AND SOCIALISING

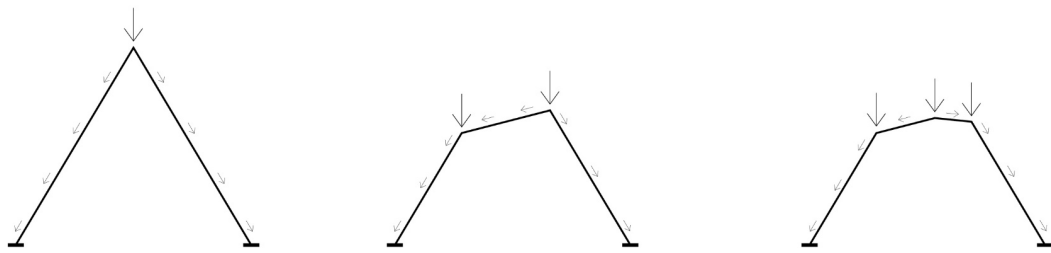
construction & materialisation



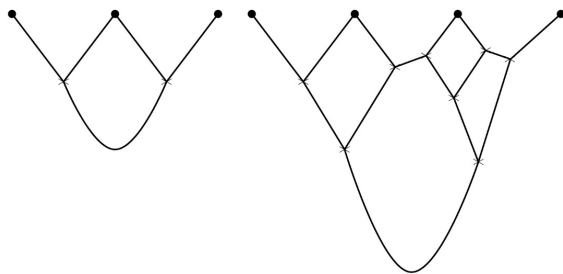
(inverted) catenary structure relationship



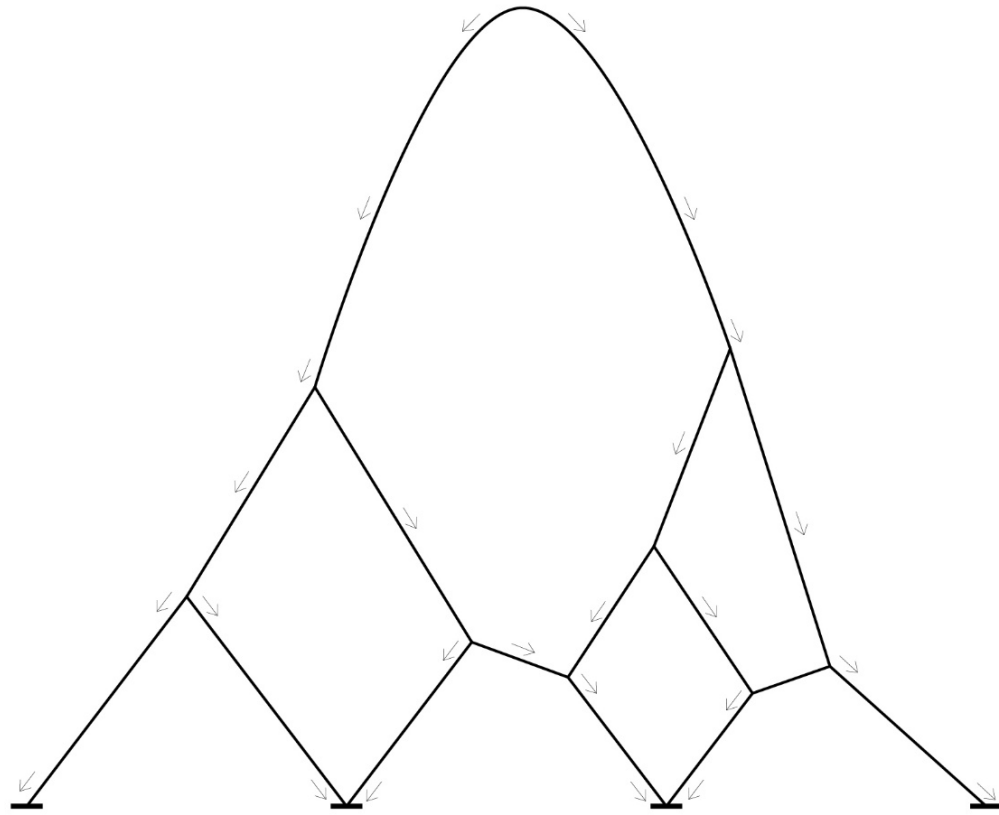
HANGING CHAINS (CATENARIES)



INVERTED CATENARIES = VORONOI THRUST LINES



NESTED CATENARIES



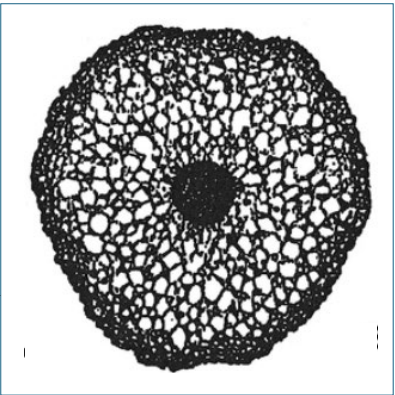
INVERTED NESTED CATENARIES

inverted nested catenaries in nature

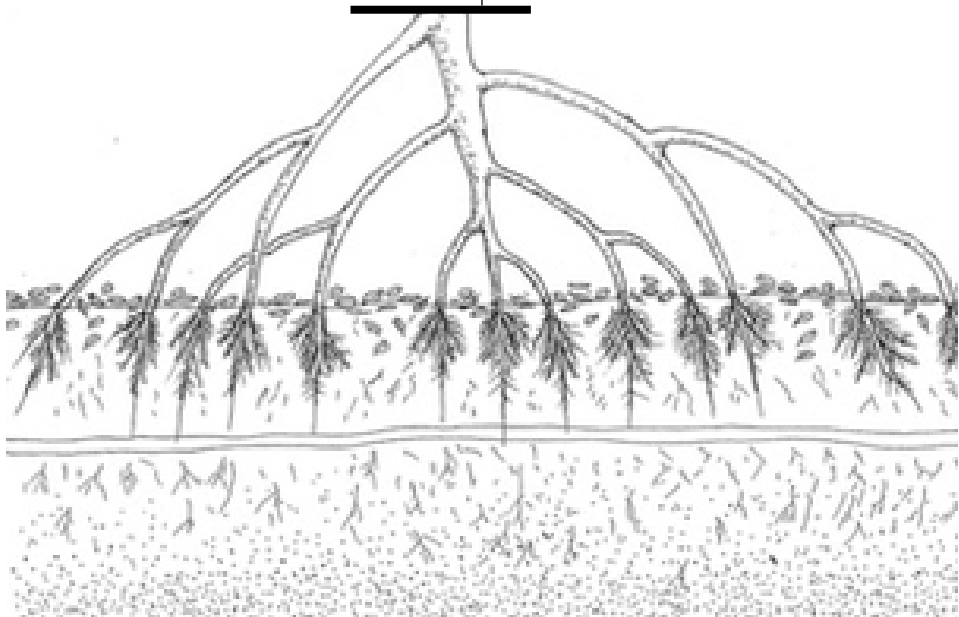


MANGROVE TREE ROOTS

SOURCE: JOURNAL OF PLANT RESEARCH (2004), PLANTSNAP



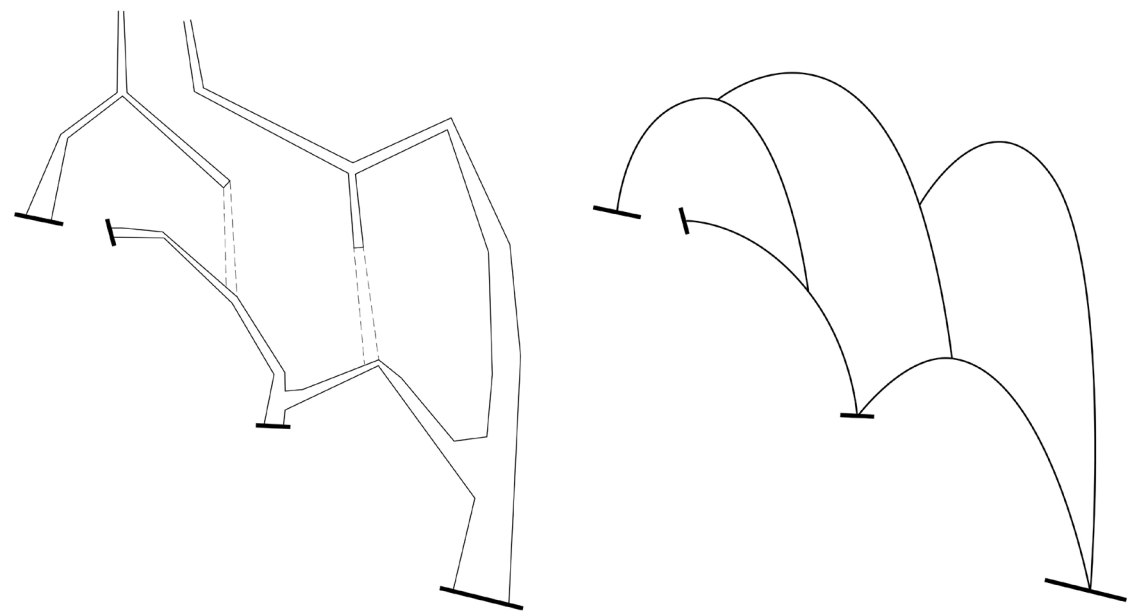
MICRO-STRUCTURE THAT RESEMBLES VORONOI



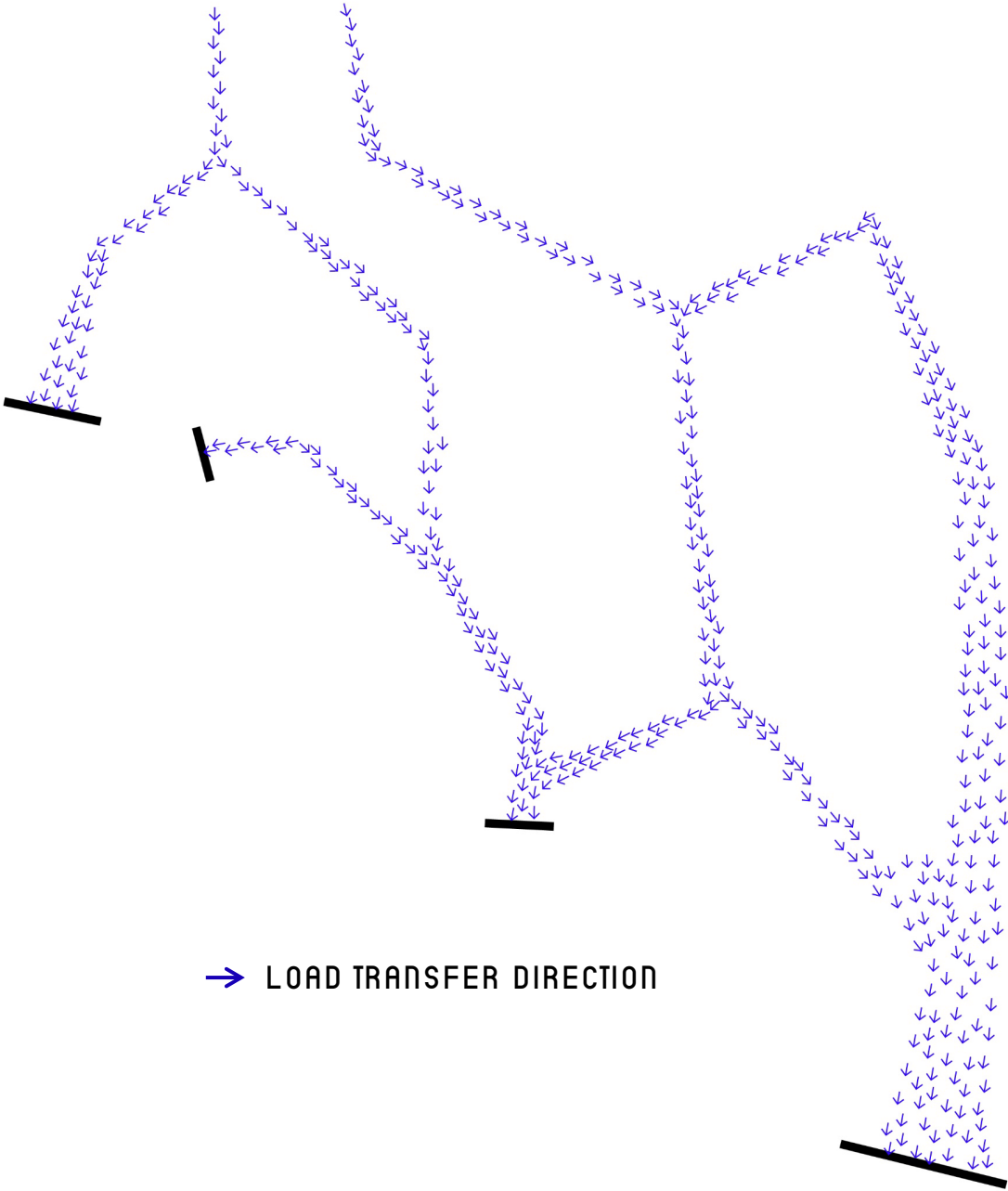
STILT-ROOT = STRUCTURE THAT GROWS AND EXPANDS OVER TIME

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

overall structural logic

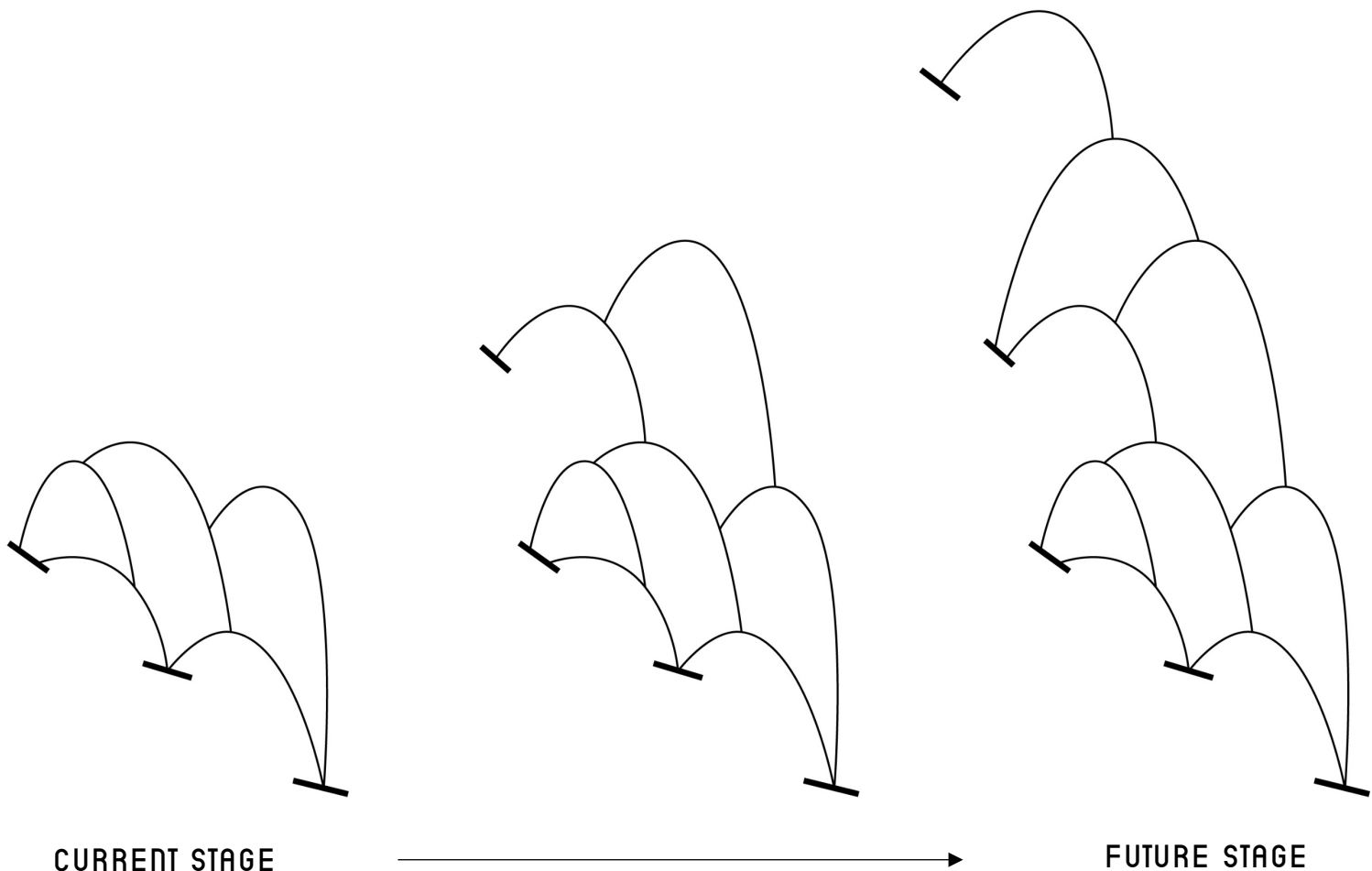


INVERTED NESTED CATENARIES TRANSLATION



→ LOAD TRANSFER DIRECTION

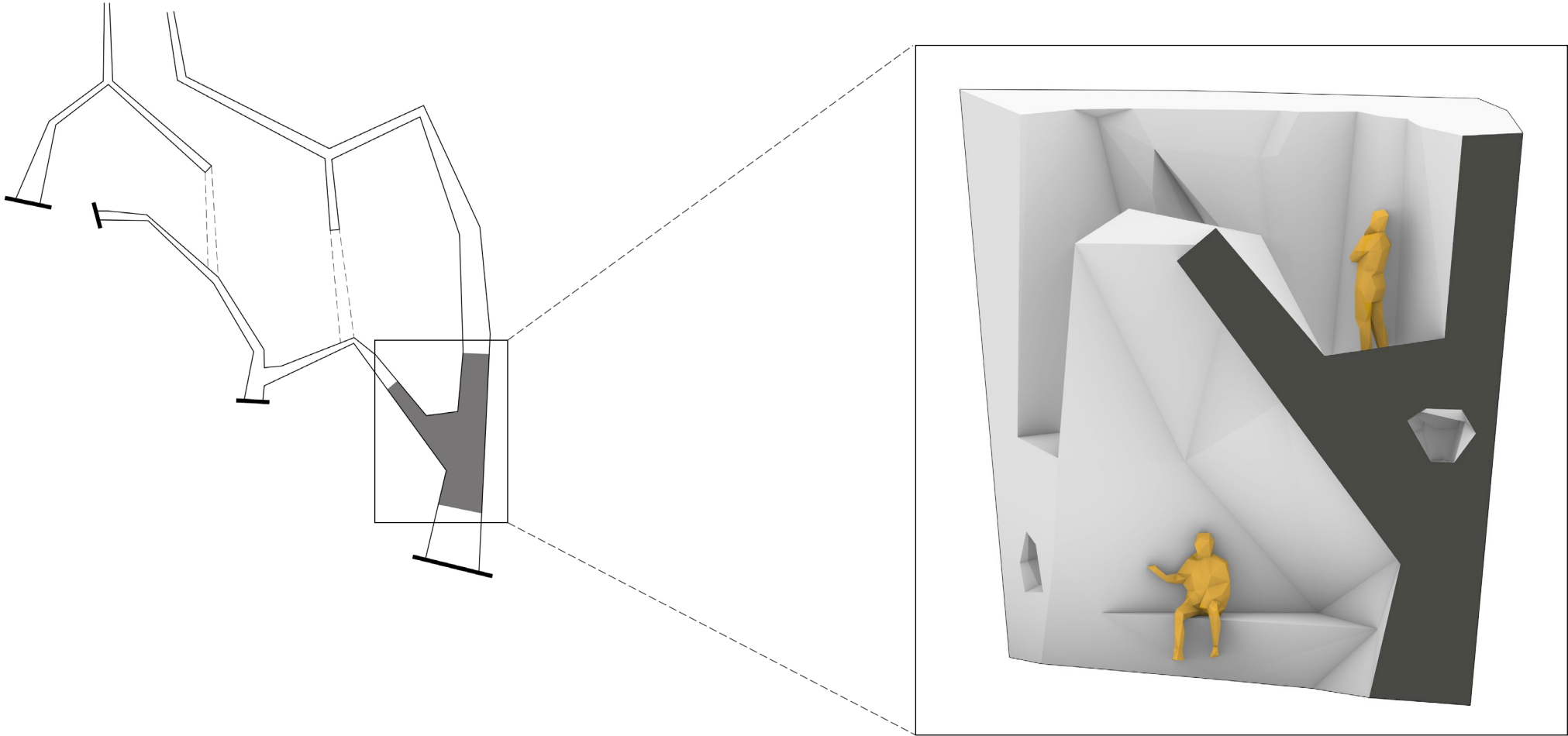
habitat expansion overtime



NESTED CATENARIES STRUCTURE IS EXPANDABLE OVERTIME

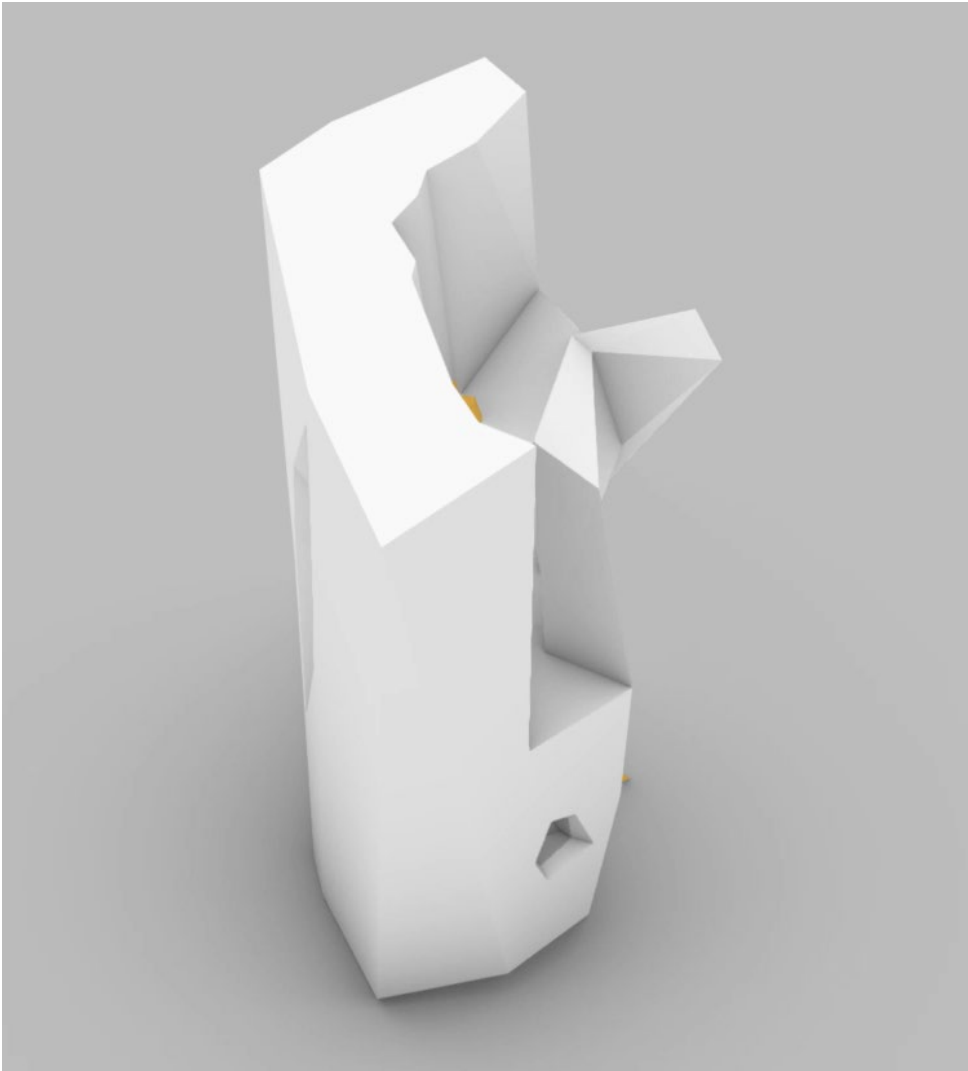
wall fragment for assembly

(zoom in to 1:20)

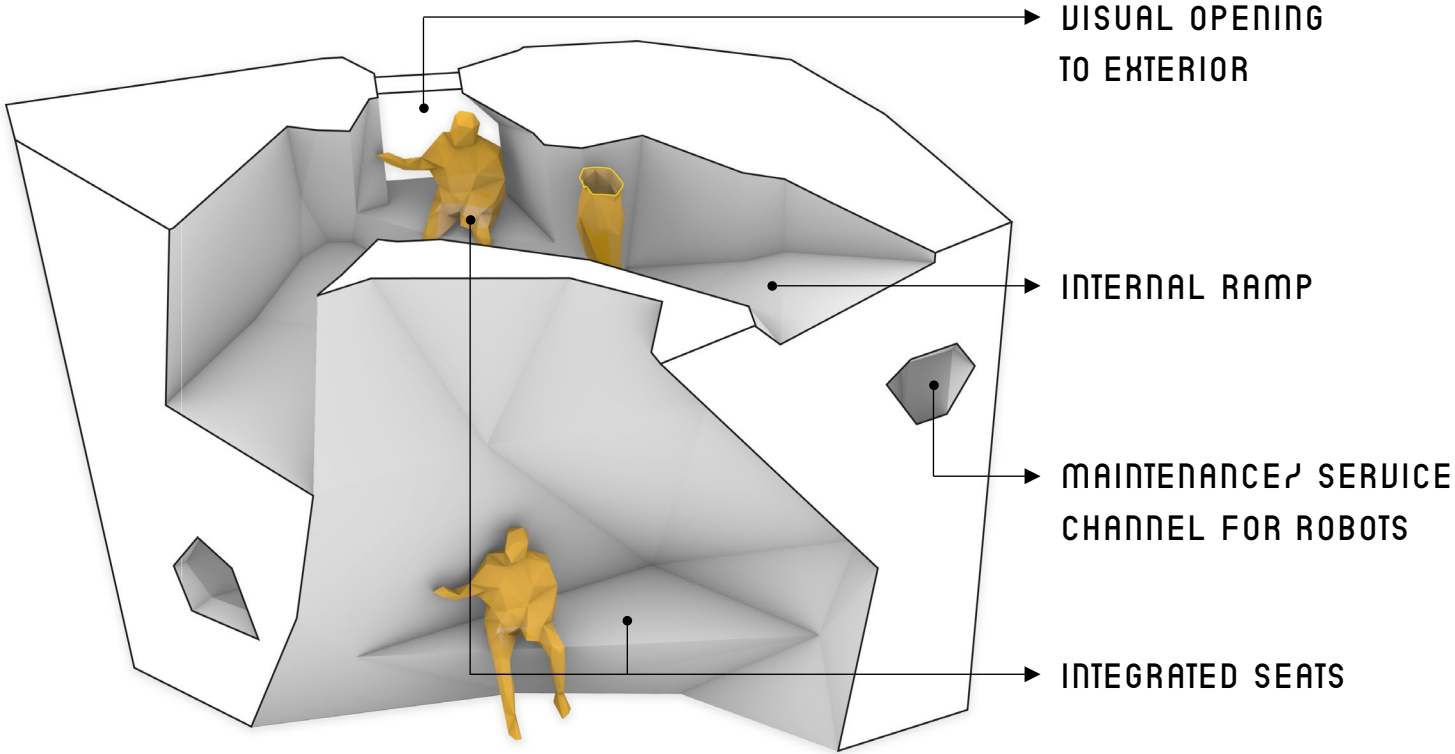


SELECTED WALL FRAGMENT

wall fragment for assembly



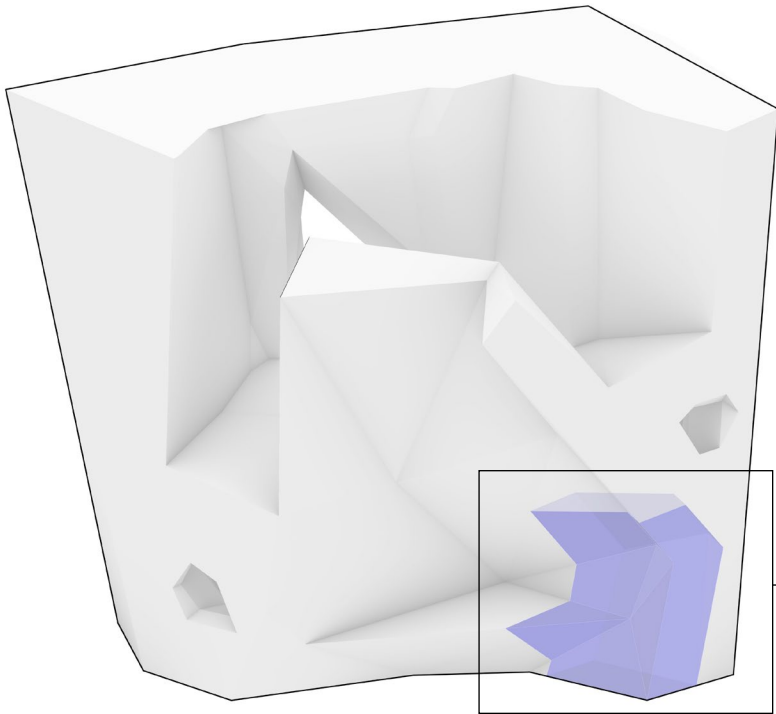
WALL FRAGMENT OVERVIEW



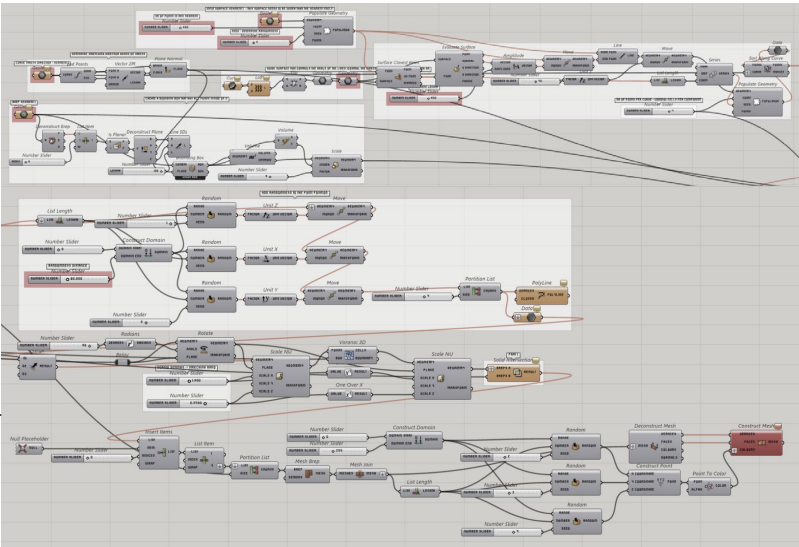
INTEGRATED FUNCTIONS

components design generation

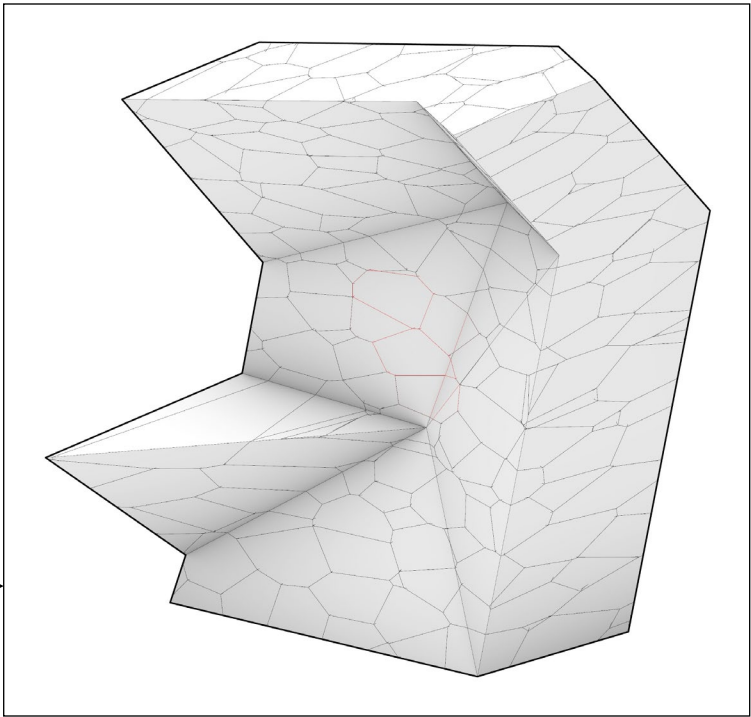
(zoom in to 1:5)



SUB-FRAGMENT SELECTION

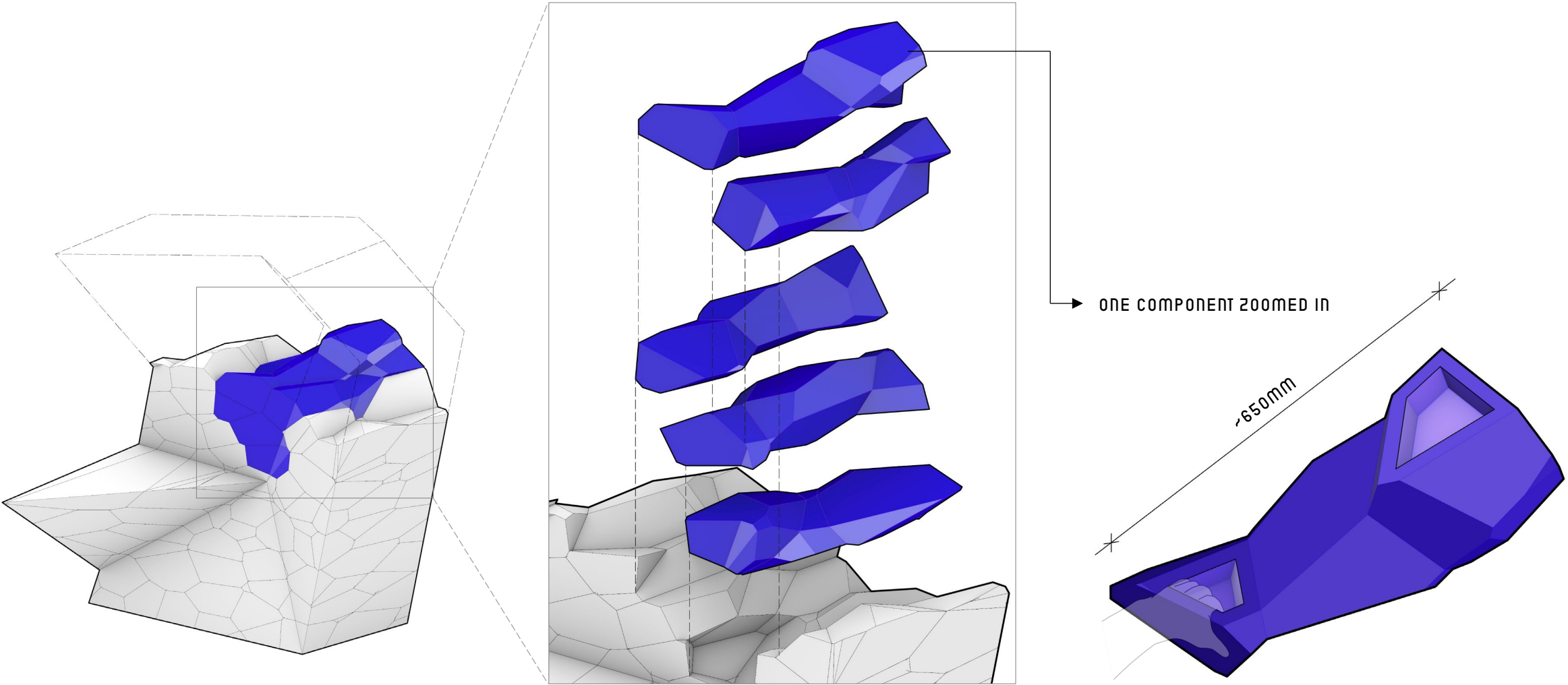


COMPUTATIONAL SCRIPT TO GENERATE COMPONENTS



COMPONENTS RESULTS

component integration details



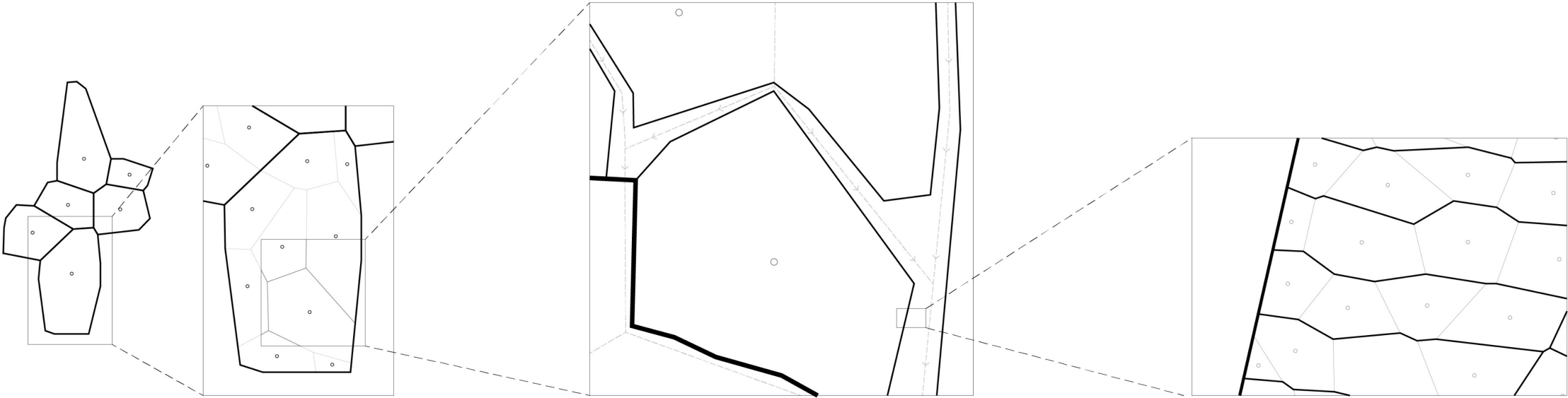
COMPONENTS ARE STACKED & 3D INTERLOCKED GEOMETRICALLY

SOURCE: FANG CHE CHENG ET AL.(2016)

HOLE FOR GRABBING THE COMPONENTS

Voronoi as the overarching design system

DESIGN LANGUAGE CONSISTENCY ON RAPID COMPUTATION IN THE OVERALL DESIGN SCALES



ARCHITECTURAL DESIGN

- SCALABLE/ RE-SIZEABLE SYSTEM WITH ADJACENCIES
- FLEXIBLE INTEGRATION WITH VARIOUS ELEMENTS (I.E. FURNITURE)

STRUCTURAL DESIGN

- RESEMBLANCE TO NATURE
- ADEQUATE STRUCTURAL INTEGRITY ON GENERATED FORMS (RESEMBLANCE TO CATENARY ACTIONS)

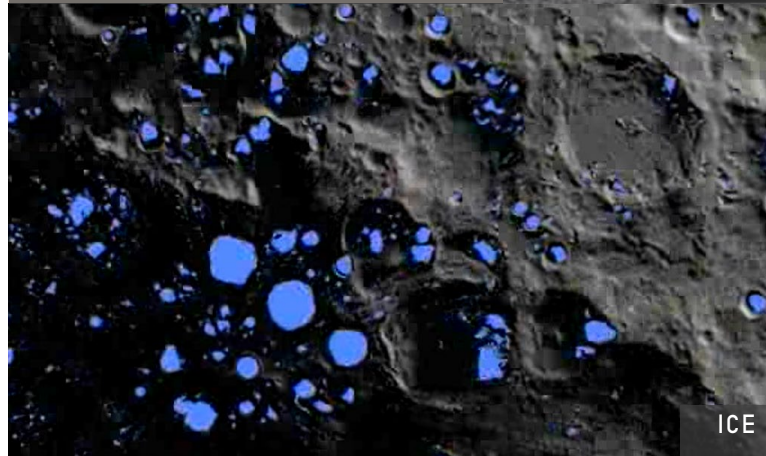
MATERIAL DESIGN

- EFFECTIVE MATERIAL USE (WITH TOOLPATH DESIGN IN CASE OF 3D PRINTING)
- INTERLOCKING PROPERTIES SUITABLE FOR STACKING

In Situ Resource Utilisation (ISRU)



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



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)

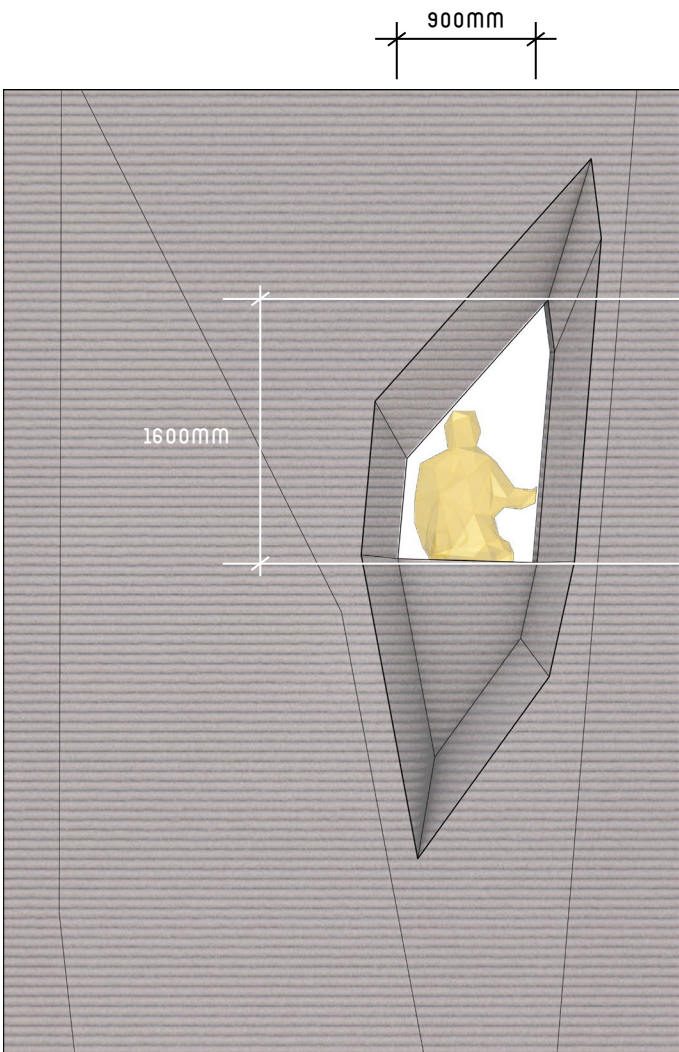
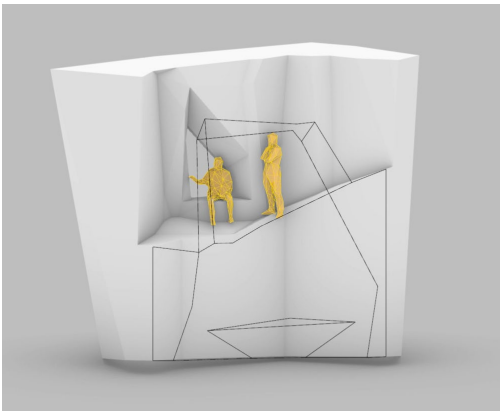
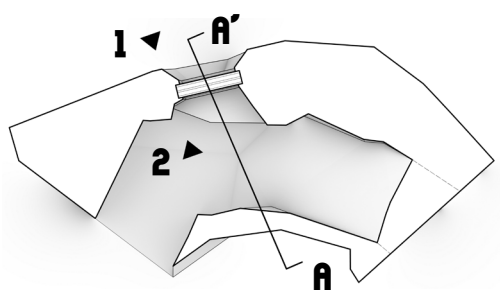
EXTRACTED FROM REGOLITH =

- 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

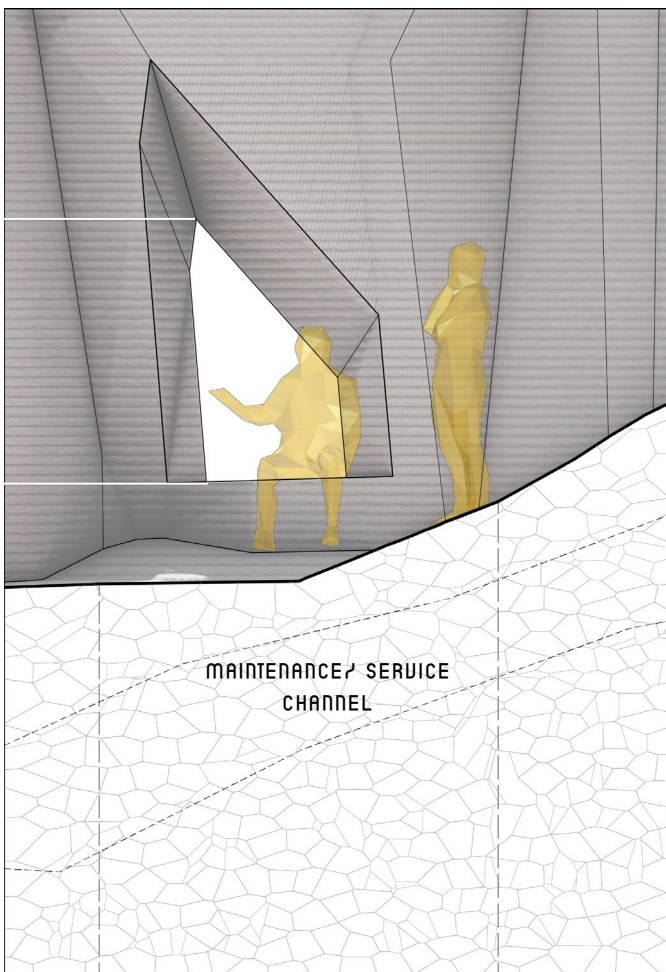
ICE =

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

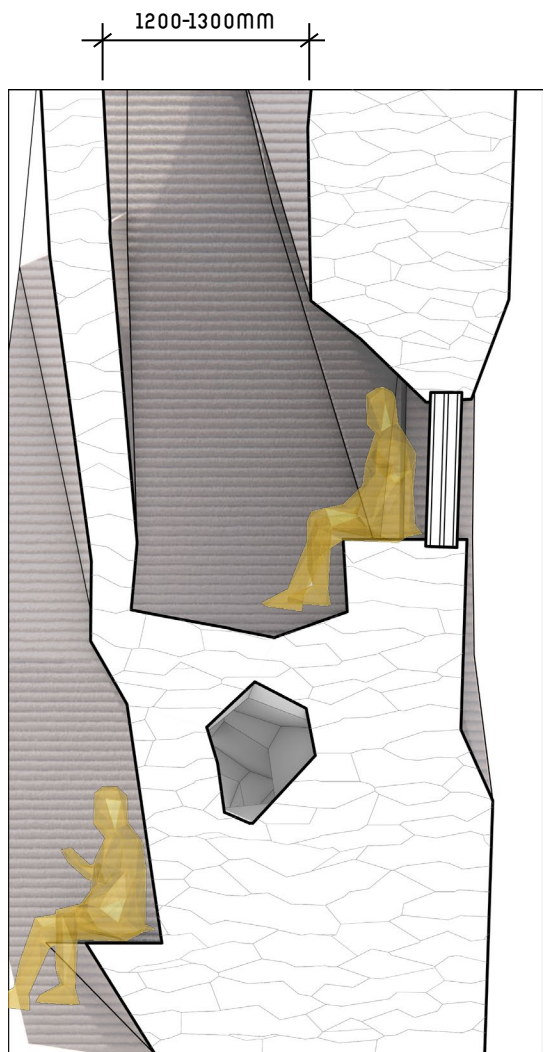
wall fragment



1. EXTERIOR FACADE

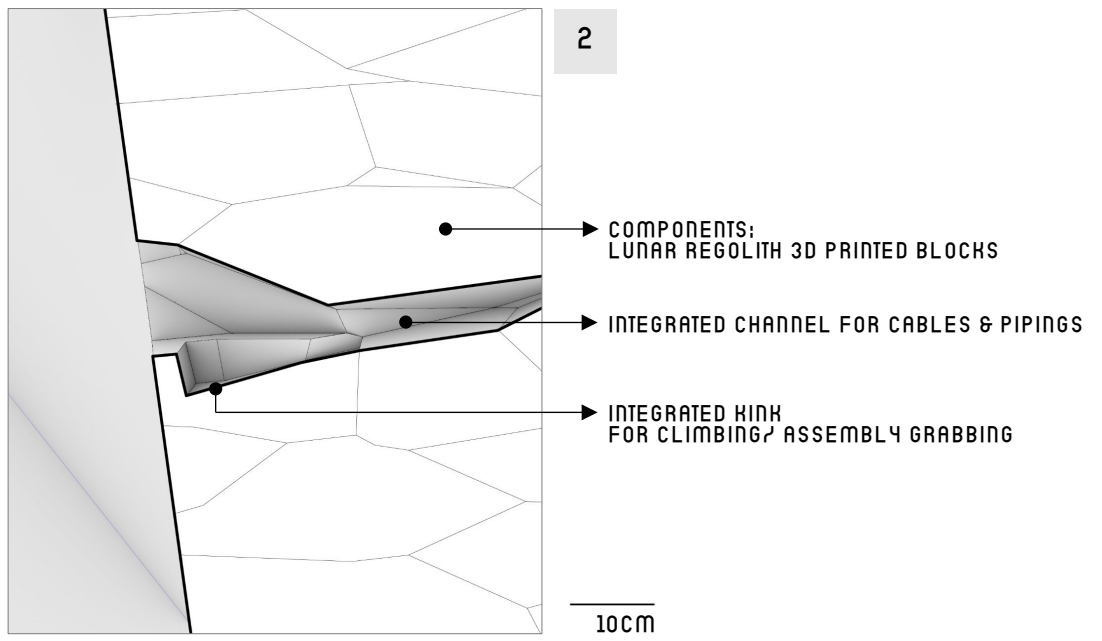
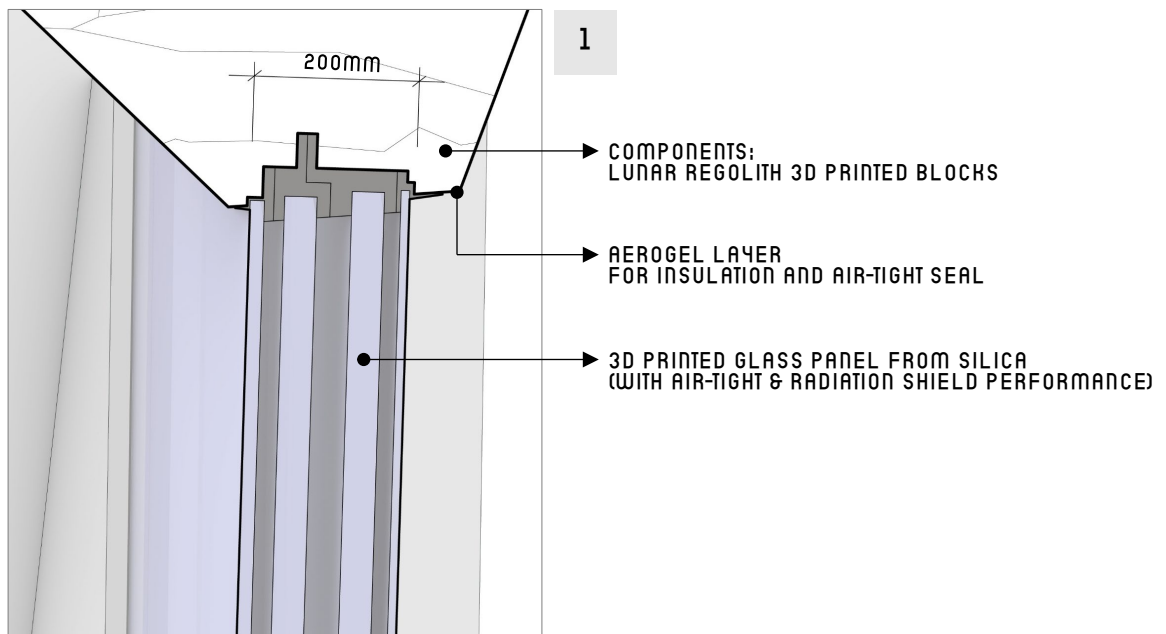
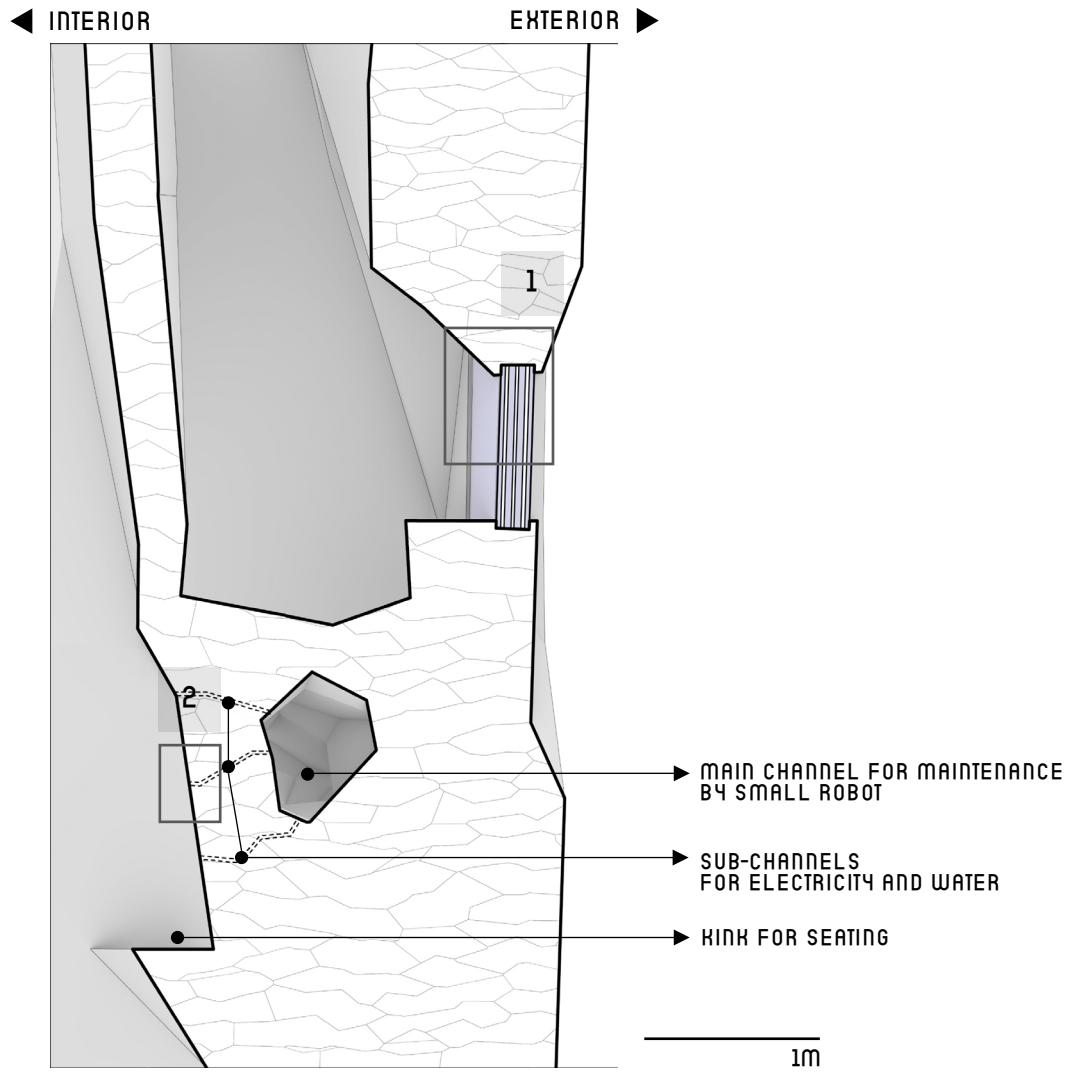


2. INTERIOR FACADE



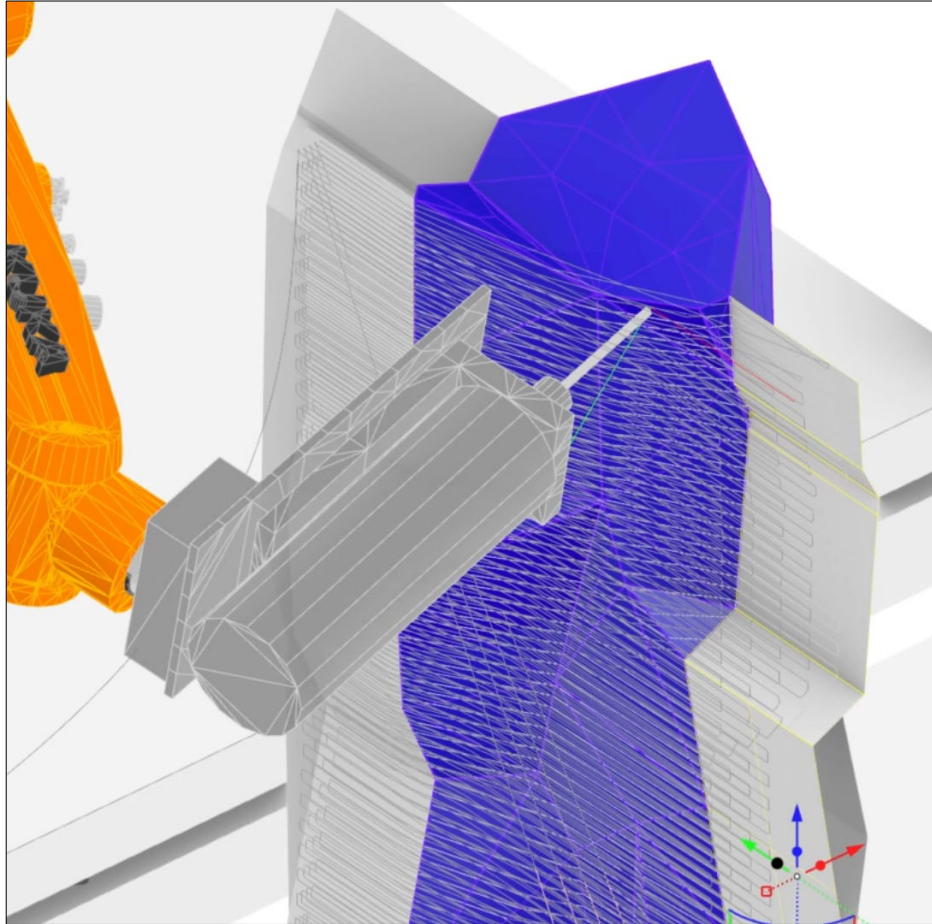
SECTION A-A'

fragment details



fabrication: mock-up

(zoom in to 1:1)



1:1 FABRICATION MOCK-UP (EPS FOAM)



SUBTRACTIVE PROCESS
(MILLING OUT MATERIAL)

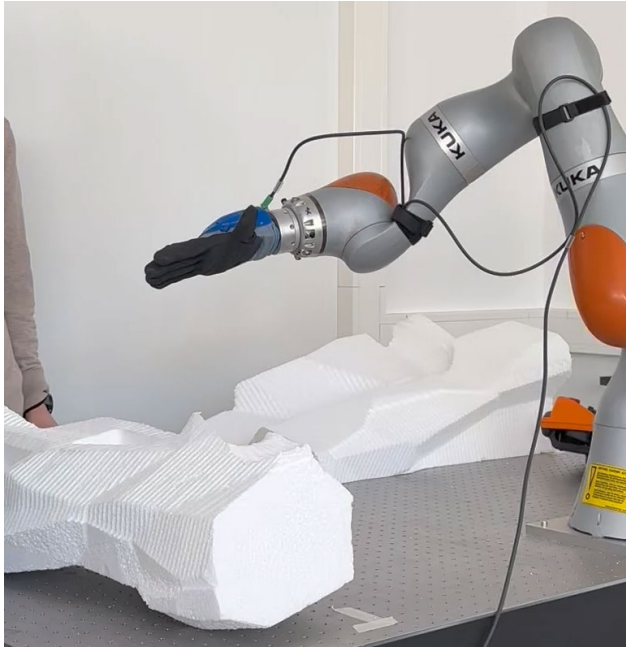
fabrication: 3D printing technology



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

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

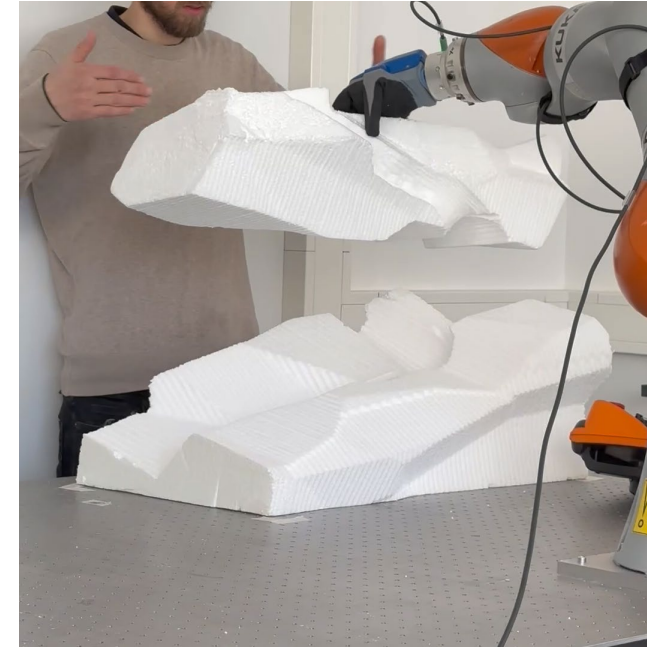
ROBOTIC PROCESS SUPPORTED BY COMPUTER VISION (CV)



1. APPROACHING COMPONENT

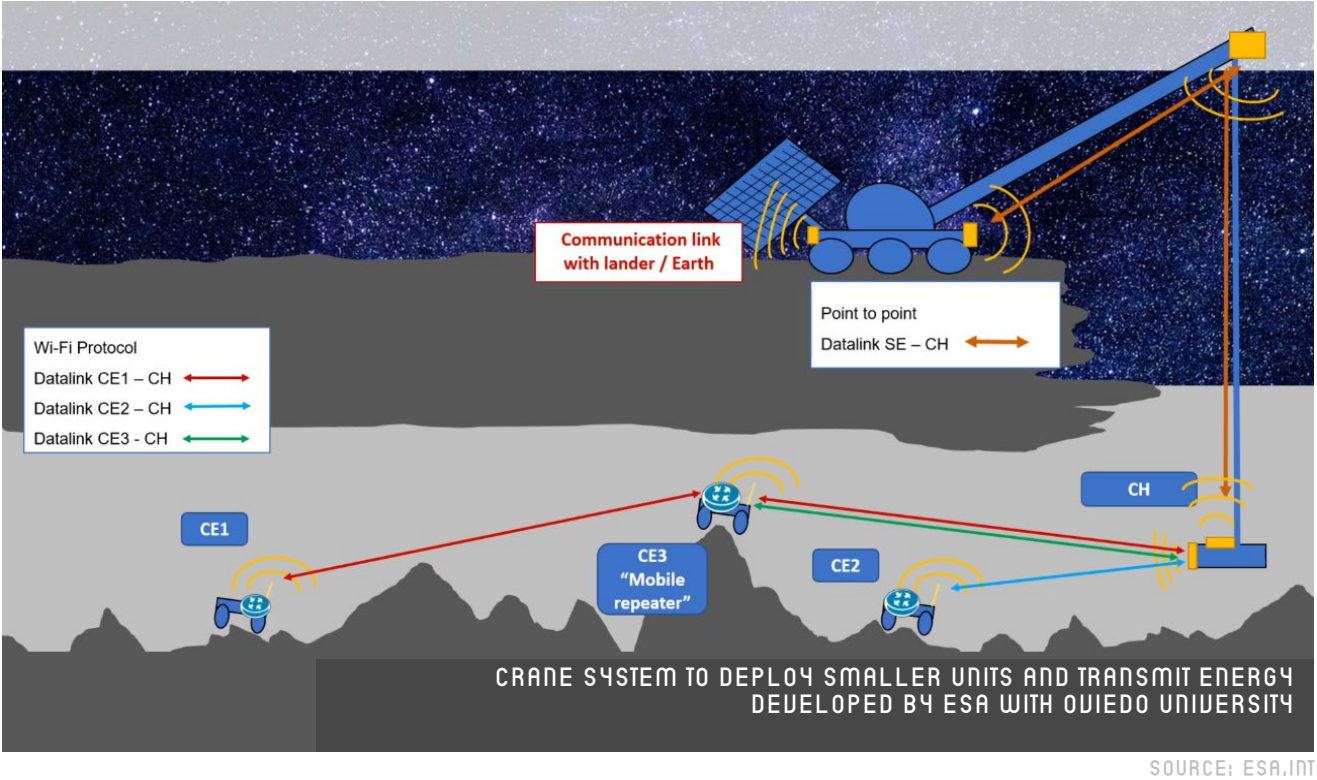


1. APPROACHING COMPONENT
2. PICKING COMPONENT (ASSISTED)
3. TRANSPORTING COMPONENT TO DESIGNATED POINT



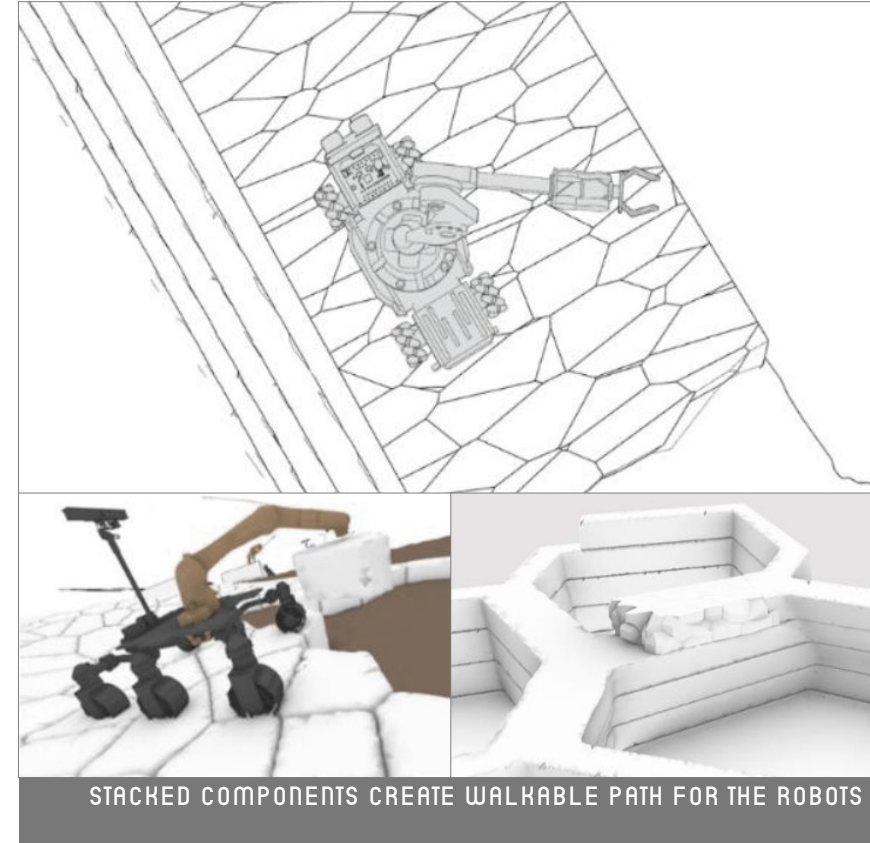
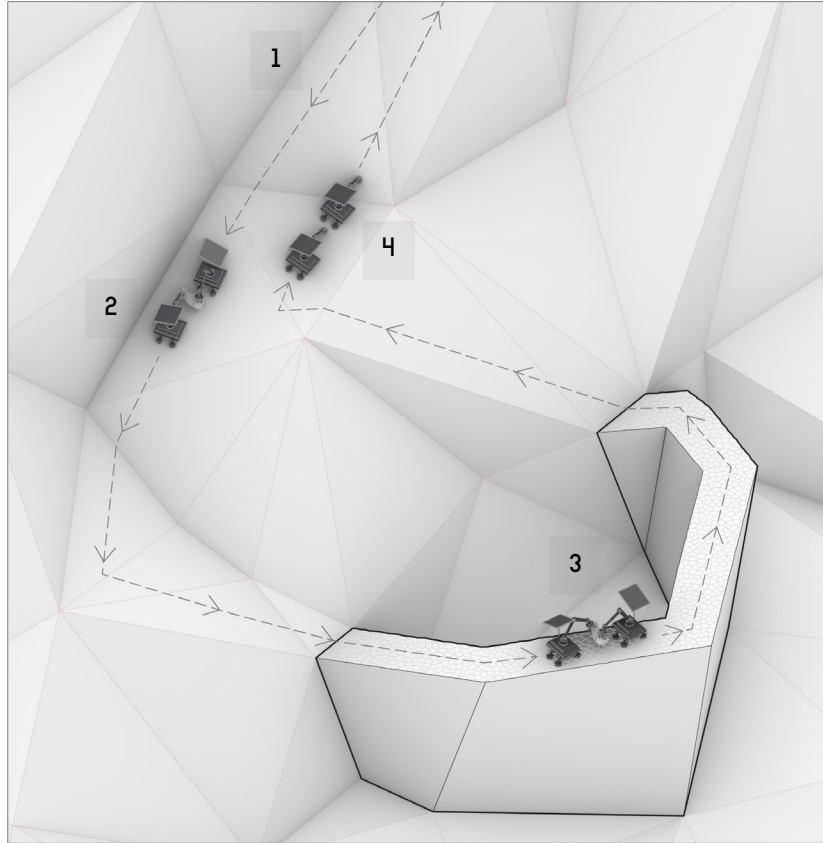
1. APPROACHING COMPONENT
2. GRABBING COMPONENT (ASSISTED)
3. TRANSPORTING COMPONENT TO DESIGNATED POINT
4. ADJUSTING COMPONENT
5. PLACING COMPONENT (ASSISTED)

robotic crane and climbing robots



PROPOSED SYSTEMS FOR EXPLORING LUNAR UNDERGROUND PITS

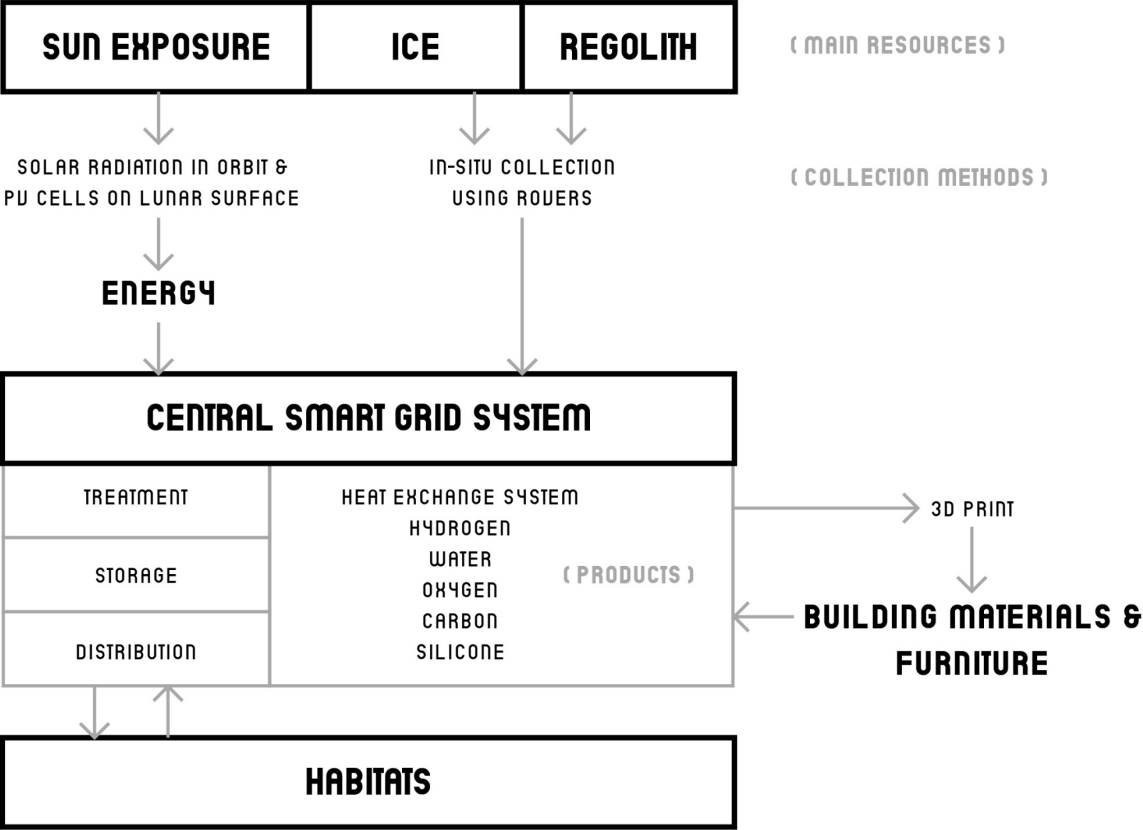
assembly during construction



SOURCE: FANG CHE CHENG ET AL.(2016)

1. DEFINING PATH & CREATING MINOR SITE ADJUSTMENTS
2. TWO ROBOTS TRANSPORTING ONE COMPONENT DOWN
3. PLACING COMPONENTS AT DESIGNATED PLACE
4. RETURNING UP & PICKING NEXT COMPONENT, REPEAT

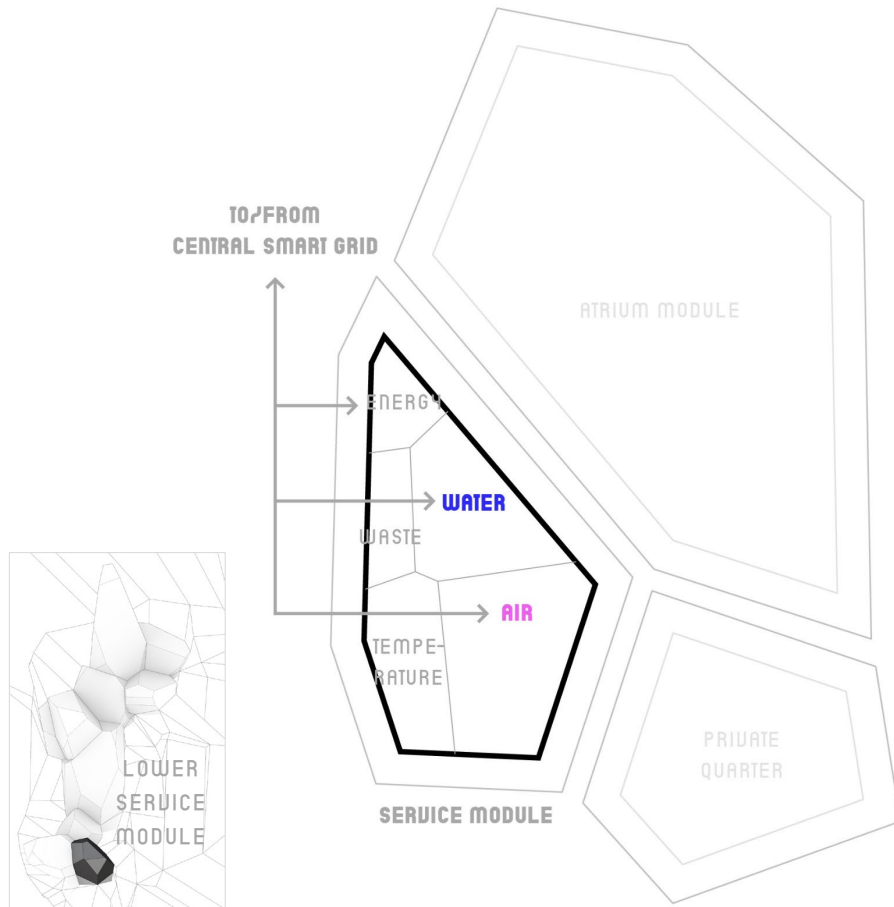
energy & resources collection/ distribution



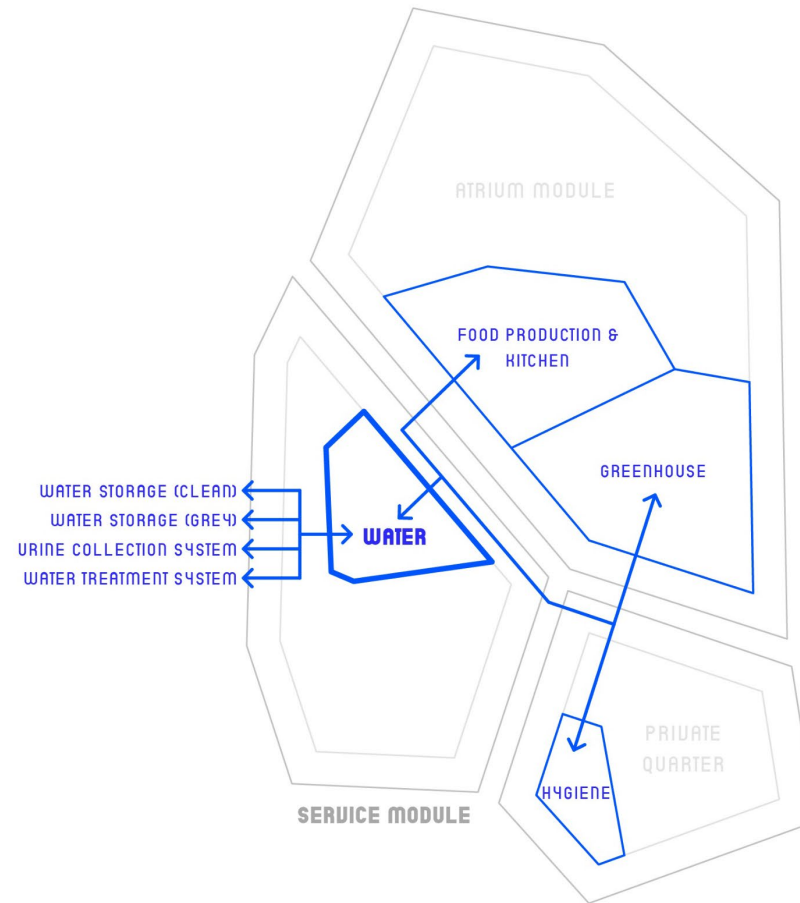
SOURCE: [YOUTUBE.COM?WATCH?v=DUGJFA44ECE](https://www.youtube.com/watch?v=DUGJFA44ECE)

building service/ life support systems

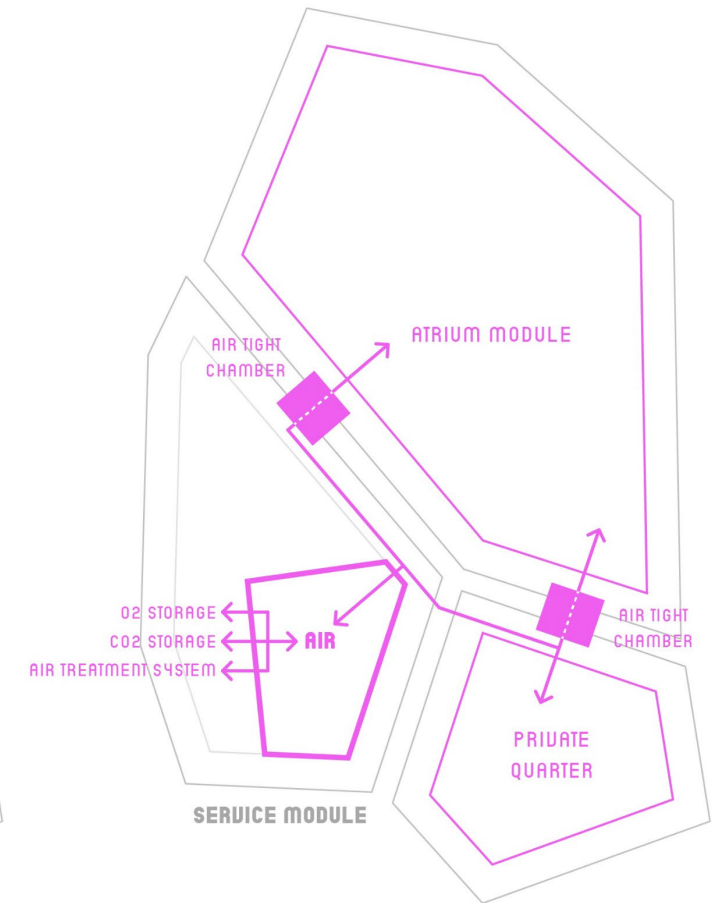
OVERALL SYSTEM



WATER REGULATION SYSTEM

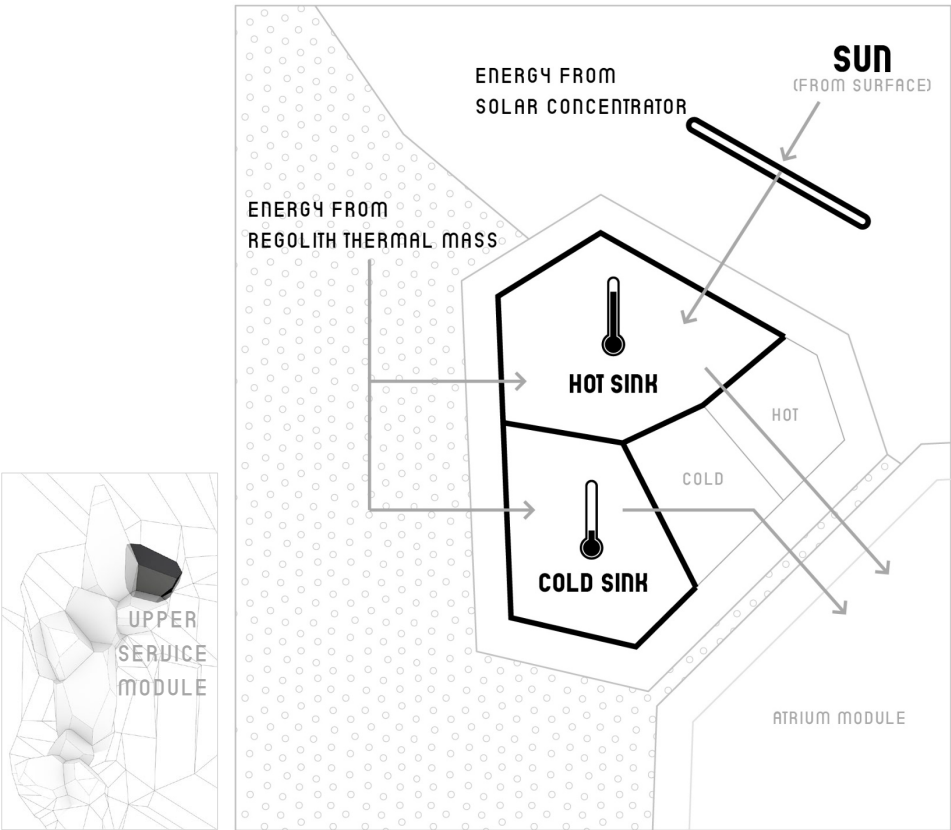


AIR REGULATION SYSTEM



climate control strategy

PROPOSED HEAT EXCHANGE SYSTEM



SOURCE: ESA

(MACRO)

HEAT EXCHANGE SYSTEM

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

SITE & BUILDING ENVELOPE

LAVA TUBE, THICK REGOLITH WALLS
AEROGEL INSULATION LAYER

FURNITURE-INTEGRATED SYSTEM

ADJUSTABLE POWER FOR SMALL ENVIRONMENT

CLOTHING-INTEGRATED FEATURES & WEARABLE SENSORS

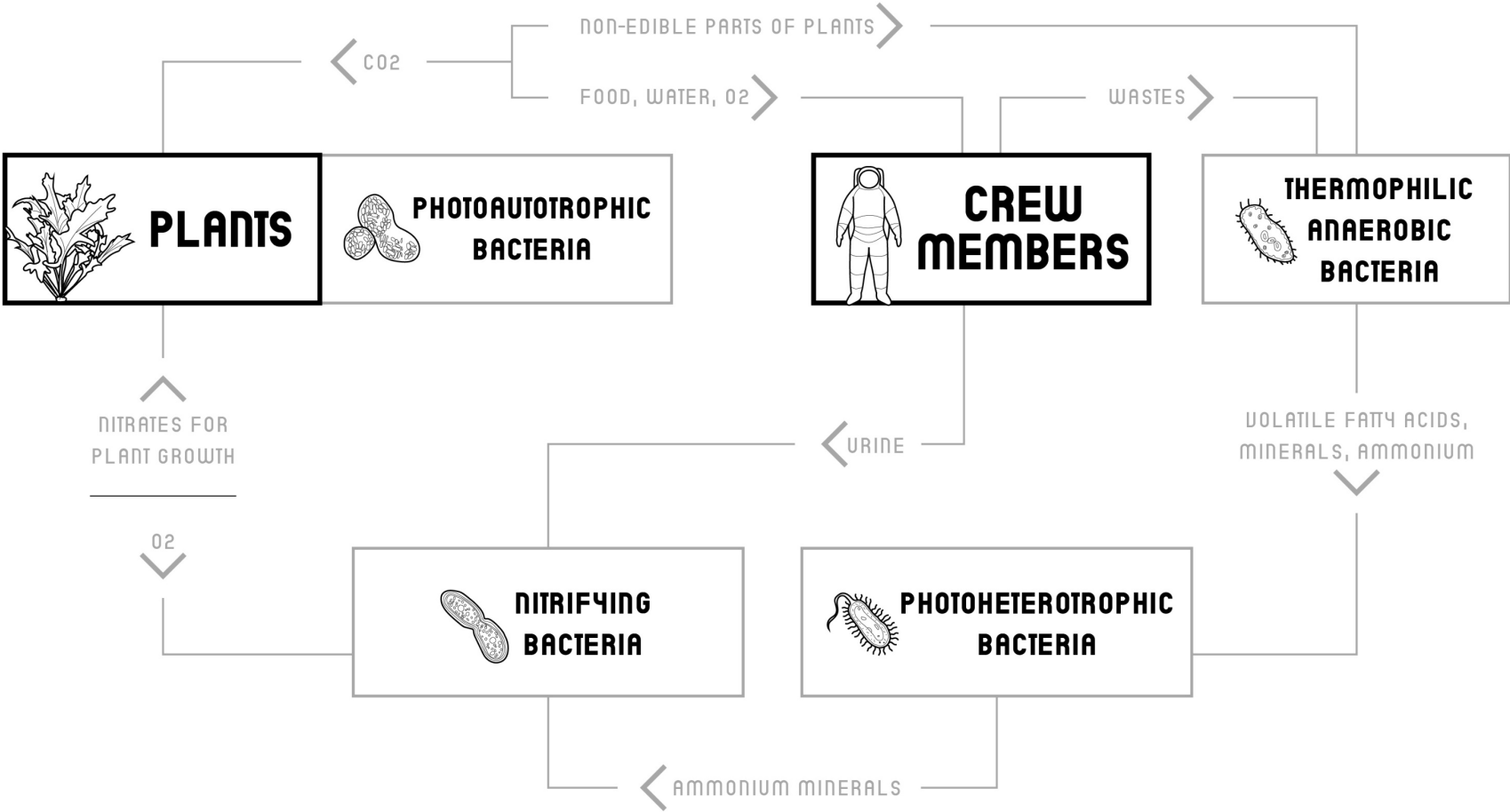
ANTI-BACTERIAL PROPERTIES
HEAT TRANSFER & SWEAT MANAGEMENT

(MICRO)

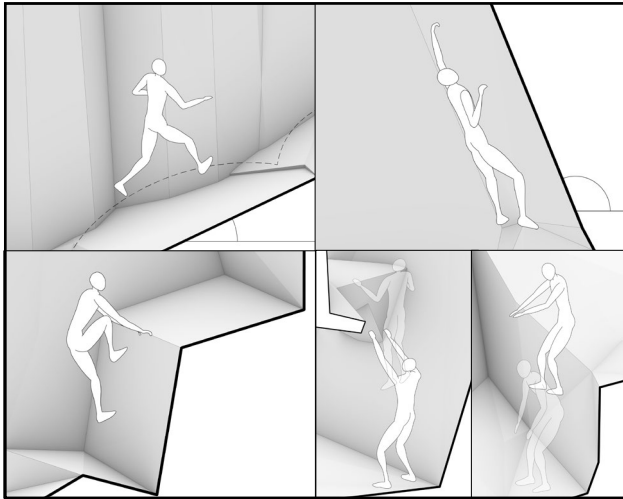
SOURCE: NASA

closed-loop life support system

The Micro-Ecological Life Support System Alternative (MELiSSA)



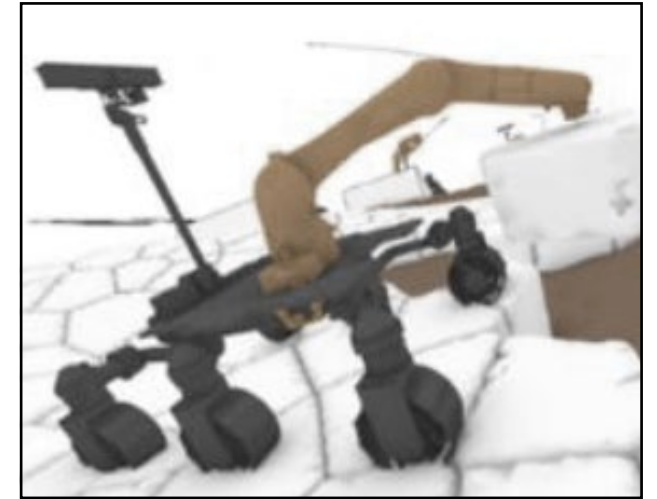
summary & takeaways



BODY & MUSCLES INTEGRATION
IN SPATIAL DESIGN

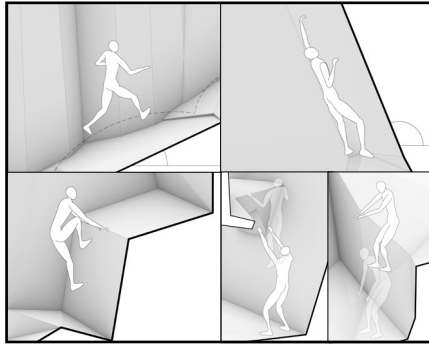


IN-SITU RESOURCE UTILISATION (ISRU) &
CLOSED-LOOP LIFE CYCLE

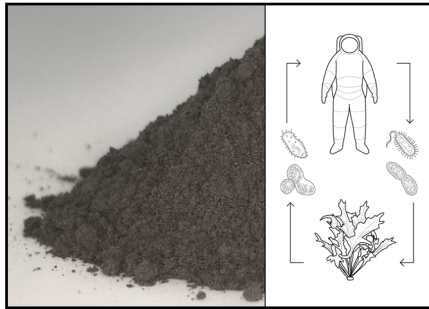


ROBOTIC &
CLEAN CONSTRUCTION

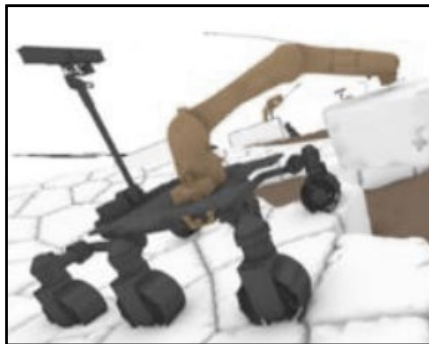
societal relevance



BODY & MUSCLES INTEGRATION



ISRU



ROBOTIC CONSTRUCTION



KNOWLEDGE TRANSFER LOOP

TO
ON/OFF-EARTH
ARCHITECTURE



ERGONOMICS & HUMAN BODIES:

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

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

Q & A

