Fig. 01 – Rhino to Nano Banana Interior View

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CPLX

Cave Pulse Light Experiment

AR122

1:1 Interactive Architecture Prototypes

27/03/2026

1 LOCATION | **DESIGN CHALLENGE**

- Antarctica is the coldest, windiest, and driest continent on Earth

- −10°C (Coast) to −60°C (Interior)
- Katabatic winds (Wind speeds can exceed 100 km/h for days at a time)
- Blizzards (Temperature is less than 0°C and visibility is reduced to 100 m or less)

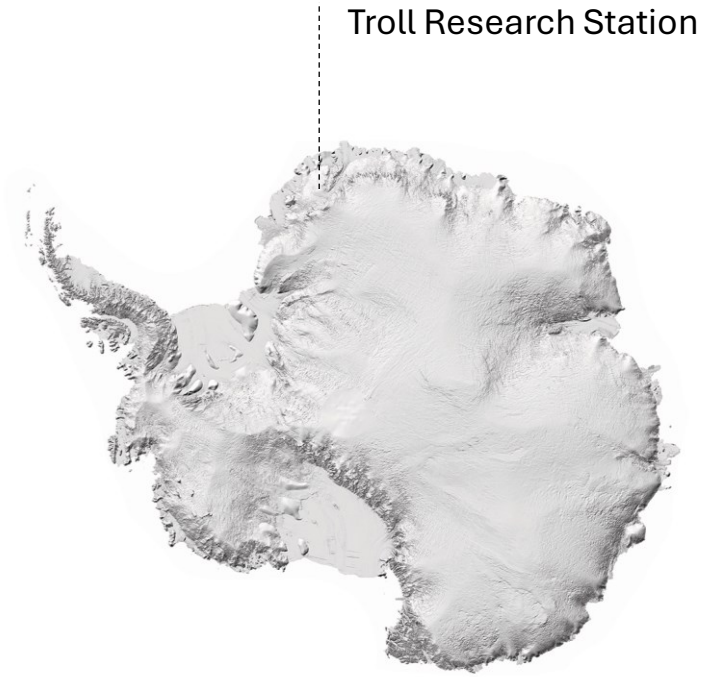


Fig. 03 – Map Terrain Antarctica

Fig. 02 – Blizzard at a station in Antartica

1 LOCATION | **DESIGN CHALLENGE**

- Approx. 50 days of polar daylight in summer
  (November to January)
- Approx. 60 days of polar night
  (May to July)

- 63% of expeditioners reported:
  - Difficulty falling asleep
  - Feeling sleepy during the daytime
  - Delayed sleep onset and offset time
  - Reduced sleep duration
  - Decreased sleep efficiency
  - Aggravated sleep fragmentation
  - And altered sleep architecture

Source: Liu et al., 2024, Nature magazine

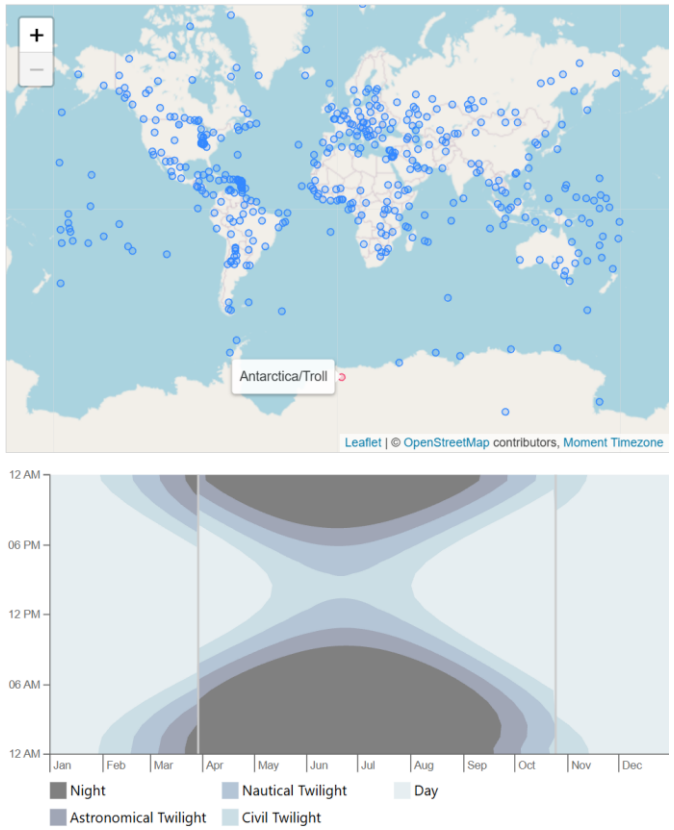


Fig. 05 – Daylight conditions – Troll station

Fig. 04 – Polar night / Aurora australis on Antarctica

INTRODUCTION

1 INTRODUCTION | **PROJECT GOAL**

CHALLENGES

Weather conditions

- Severe Temperatures
- Strong Catabatic Winds
- Minimal Precipitation
- Low Humidity

Arctic seasons

- Extreme Light Cycles

Lighting conditions

- Circadian Rhythm Disruption
- Reduced Work Efficiency
- Sleep & Mood issues

Spatial limitation

- Lack of Privacy
- Lower Productivity
- Stress and Discomfort
- Design compromises

IMPACT ON
PHYSICAL AND MENTAL HEALTH

Fig. 07 – Functional division

Fig. 06 – Troll Research Station, Norsk Polarinstitutt

Autonomy	Impact	Stimulation
Beauty	Morality	Security
Comfort	Purpose	Fitness
Community	Recognition	
Competence	Relatedness	

Fig. 08 – Fundamental needs

Fig. 06 – Troll Research Station, Norsk Polarinstitutt

Autonomy	Impact	**Stimulation**
Beauty	Morality	Security
Comfort	Purpose	**Fitness**
Community	Recognition	
Competence	Relatedness	

Fig. 08 – Fundamental needs

Fig. 06 – Troll Research Station, Norsk Polarinstitutt

1 INTRODUCTION | **PROJECT GOAL**

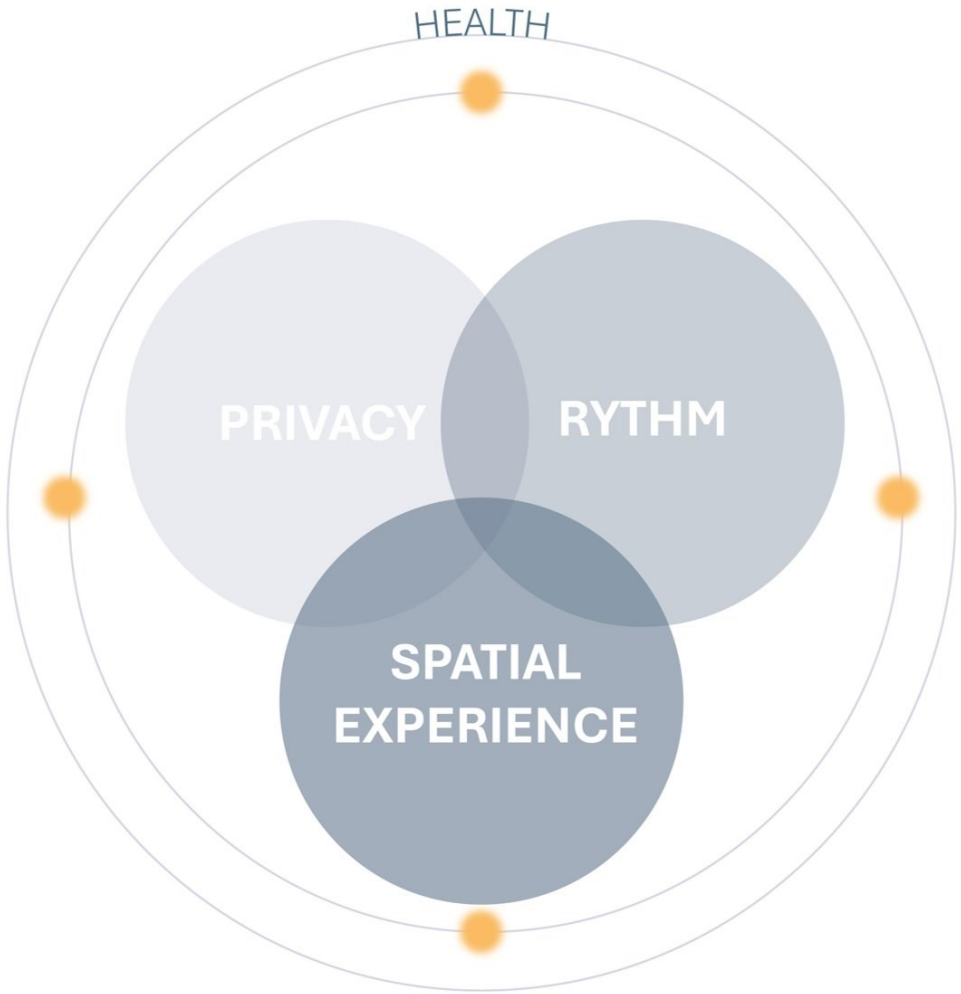


Fig. 09 – Project goals

Fig. 06 – Troll Research Station, Norsk Polarinstitutt

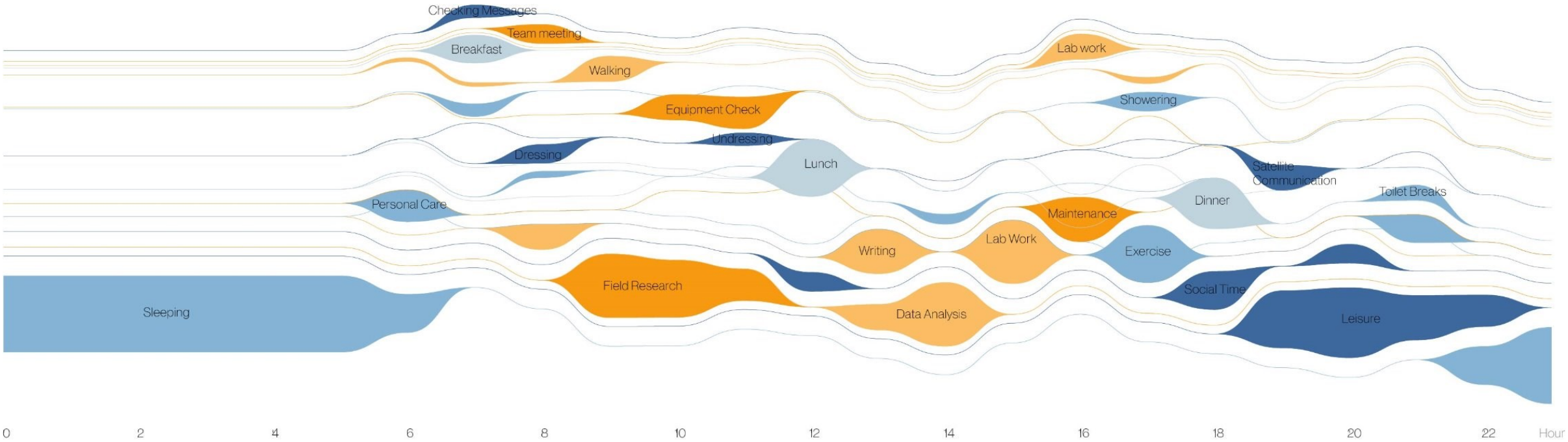
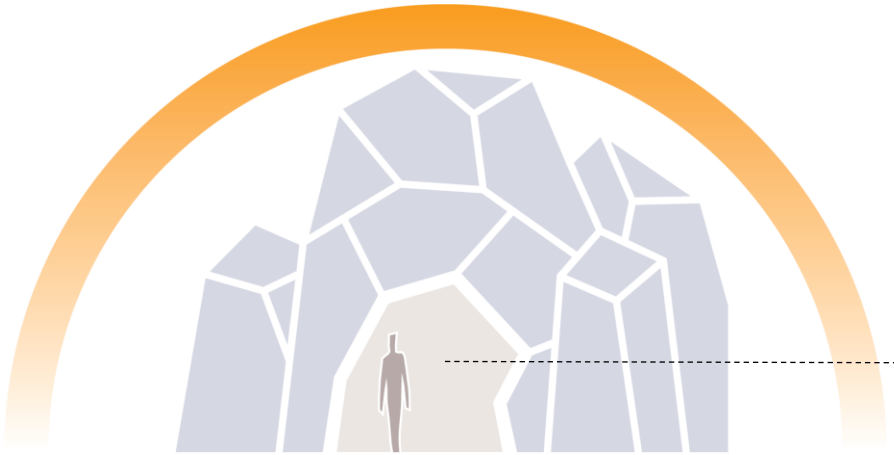


Fig. 10 – 24h activity mapping

DESIGN CONCEPT

2 DESIGN CONCEPT | **THE CAVE EXPLORATION**



CAVE | Protective space

Fig. 11 – Concept: Cave

Fig. 06 – Troll Research Station, Norsk Polarinstitutt

2 DESIGN CONCEPT | **STACKING**

- Spatial Varity
- Amplify the quality of each function
- Vertical corridor
- Reduced footprint
- Less foundation

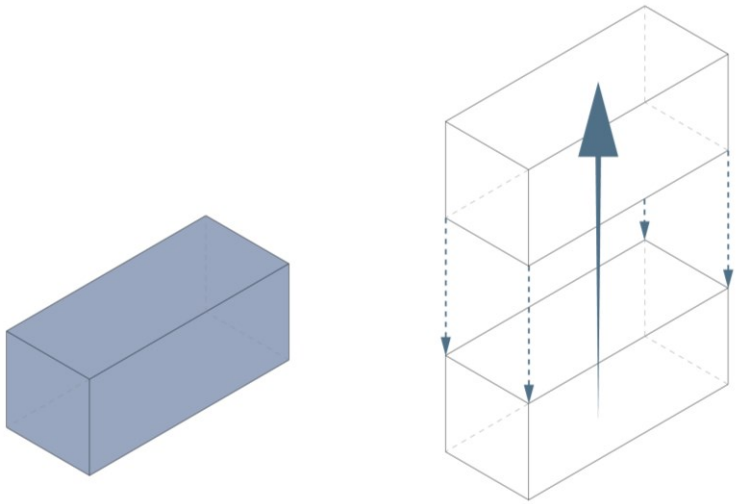


Fig. 14 – Diagram stacking

Fig. 12 – Exterior Vision, AI generated (Nano Banana)

2 DESIGN CONCEPT | **ARRAYING**

- Air Lock as a horizontal connector

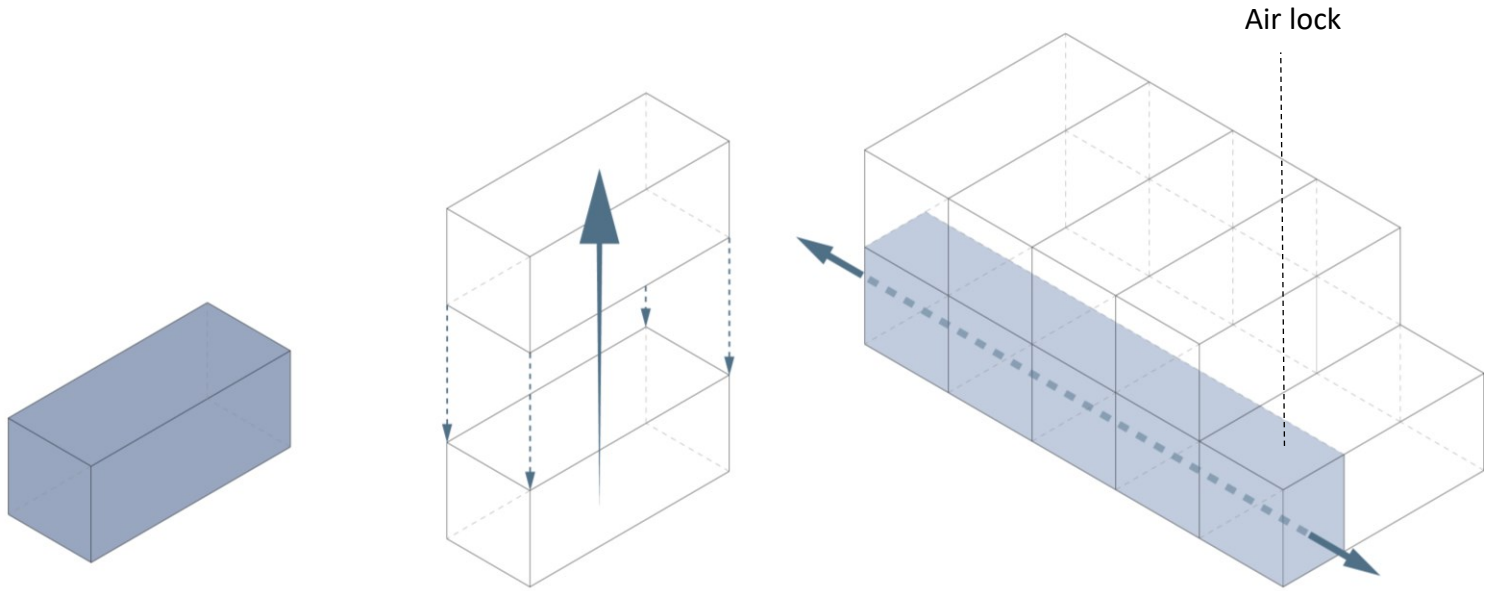
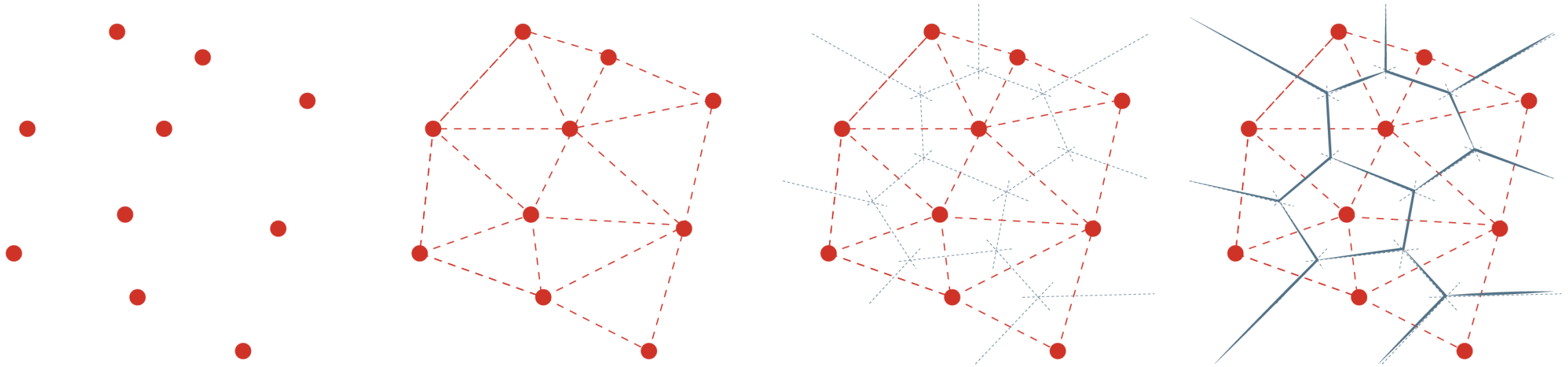


Fig. 14 – Diagram stacking & arraying

Fig. 12 – Exterior Vision, AI generated (Nano Banana)

METHODS



1) Seed distribution within the design domain (adaptive node definition)

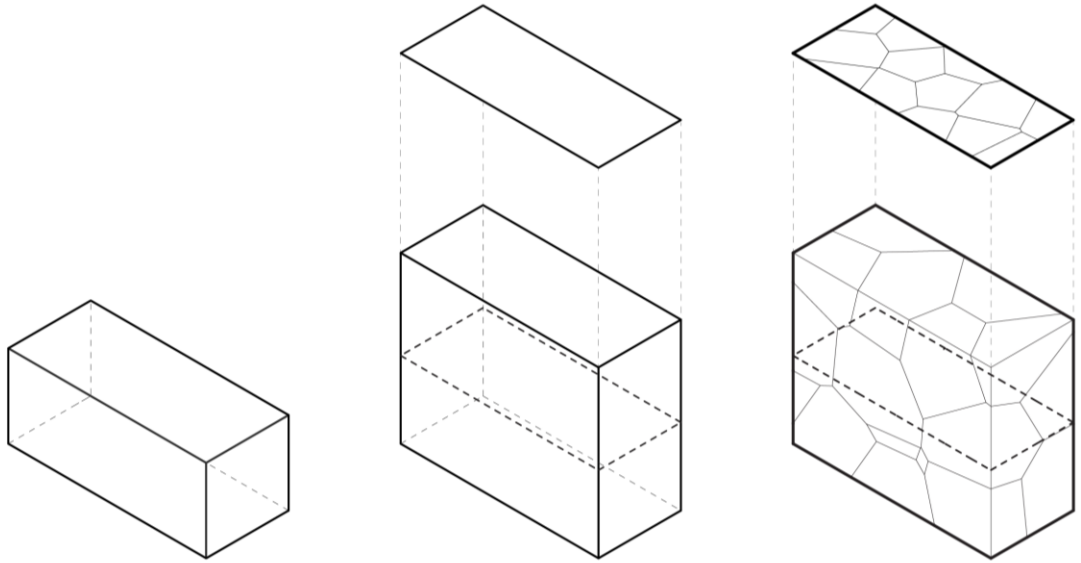
2) Delaunay triangulation

3) Bisector line identification

4) Voronoi tessellation - (2d polygons)

Fig. 13 – Voronoi principle

3 METHODS | **TOOLBOX**



Create container

Stack and add floor

Apply voronoi for zoning

Fig. 14 – Diagram form finding script

Fig. 12 – Exterior Vision, AI generated (Nano Banana)

AR122 1:1 Interactive Architecture Prototypes

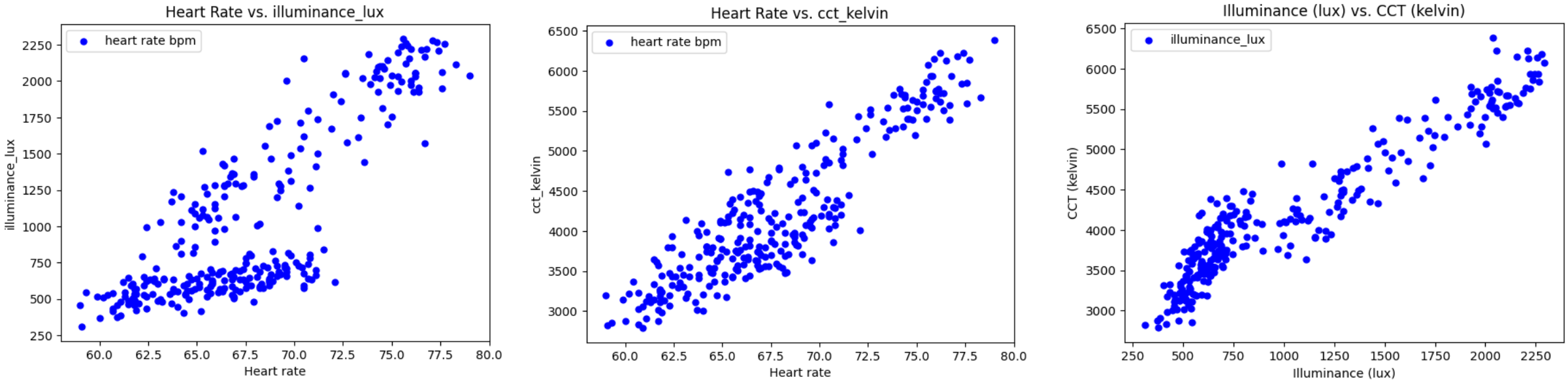


Fig. 15 – DATA output

3 METHODS | **AI**

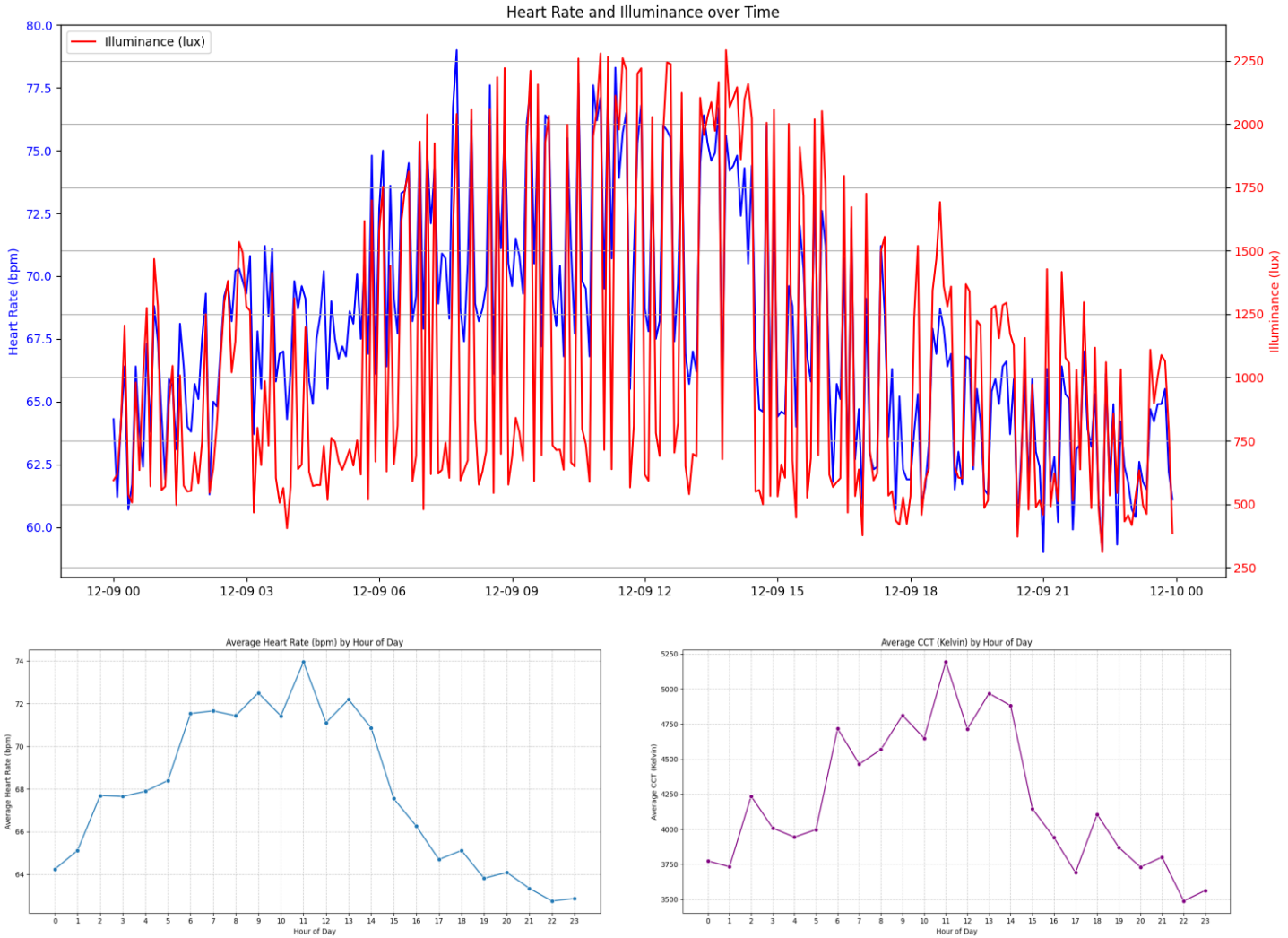


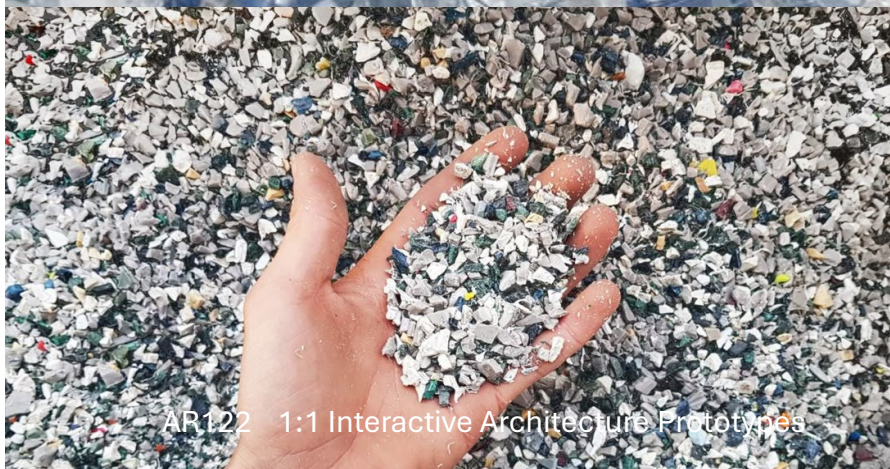
Fig. 16 – DATA output

Fig. 12 – Exterior Vision, AI generated (Nano Banana)

3 METHODS | **MATERIAL**

Raw materials
- **Bottles** (PET)
- **Food packaging** (ABS, PET, PLA, PP)
- Food waste (more useful for growing plants)
- Kerosine containers (contamination issue)

Fig. 13 – Waste Products



3 METHODS | **D2RP**

- The project is focused on creating and building with artificial intelligence (AI)-supported
- Design-to-Robotic-Production and Operation (D2RP&O)

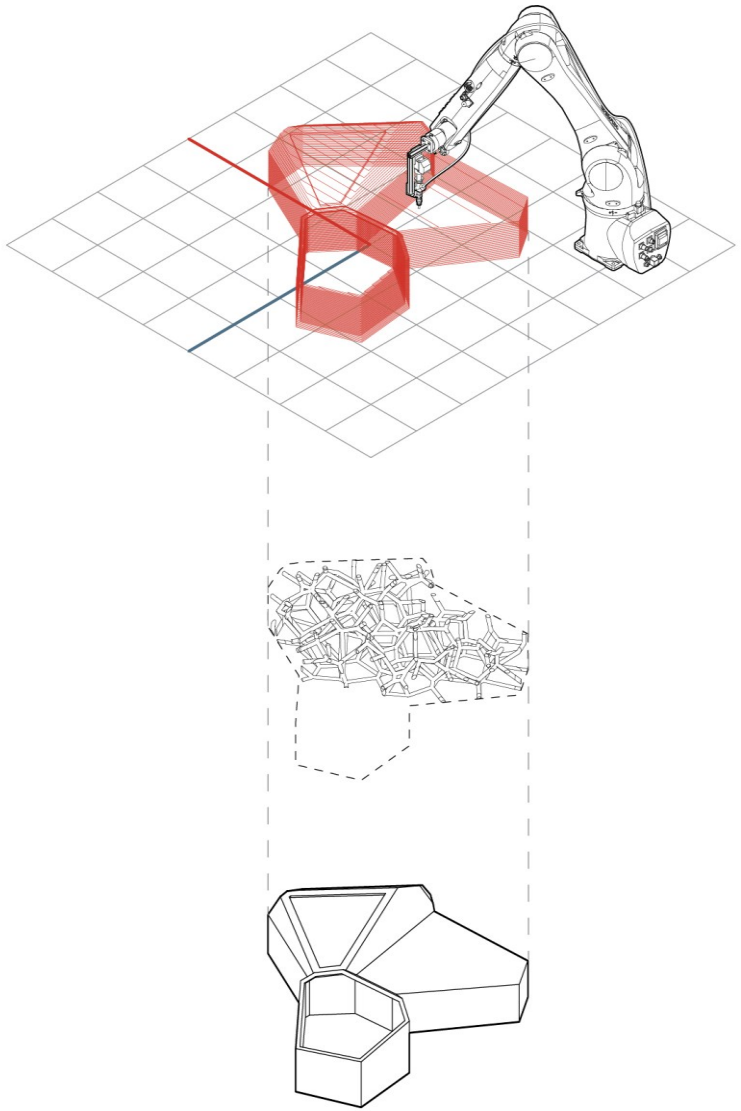


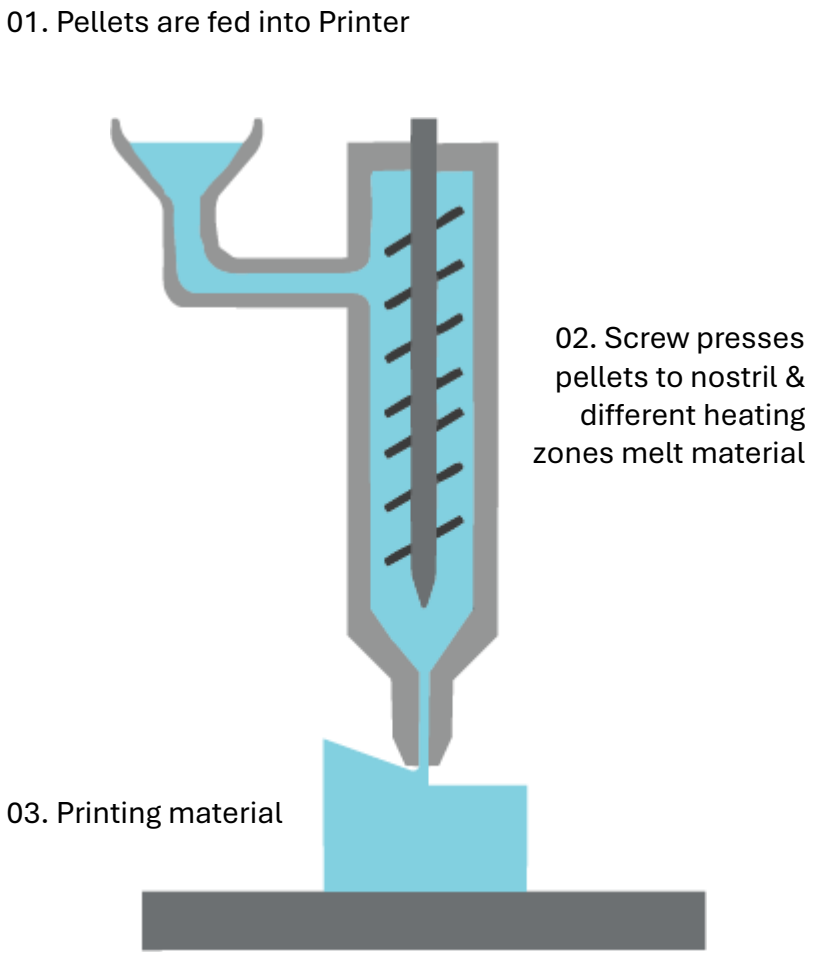
Fig. 15 – Schematic Print Process Fragment

Fig. 14 – KUKA Robot Additive Manufacture

3 METHODS | **EXTRUTION TECHNIQUES**

Extrusion techniques
- Fused Filament Fabrication (FFF/FDM) -> Filament or pellets
- **Fused particle or pellet fabrication** -> shredded or pelletized waste

Fig. 16 – Fused particle fabrication scheme



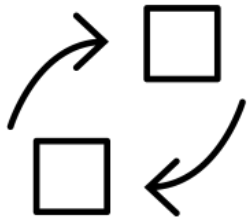
Step 1

Bluetooth
The Polar H10 sensor transmits live physiological data using Bluetooth Low Energy (BLE)

Step 2

Heart rate reception
Python script receives the data, reads the heart rate, maps physiological changes to variations in color temperature (CCT)

Step 3



CCT to RGB
A data bridge streams the processed RGB data continuously

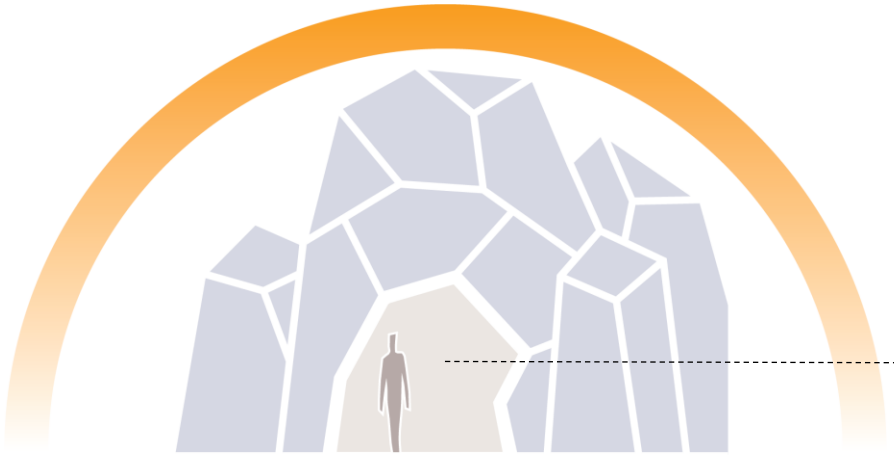
Step 4

Grasshopper
Grasshopper connects to the RGB output using a client component: GhPython

Fig. 17 – Data implementation steps, source: Python script PolarH10

DESIGN DEVELOPMENT

4 DESIGN DEVELOPMENT | **RECAP**



CAVE | Protective space

Fig. 19 – Spatial configuration

Fig. 18 – Interior perspective

4 DESIGN DEVELOPMENT | **SPATIAL CONFIGURATION**

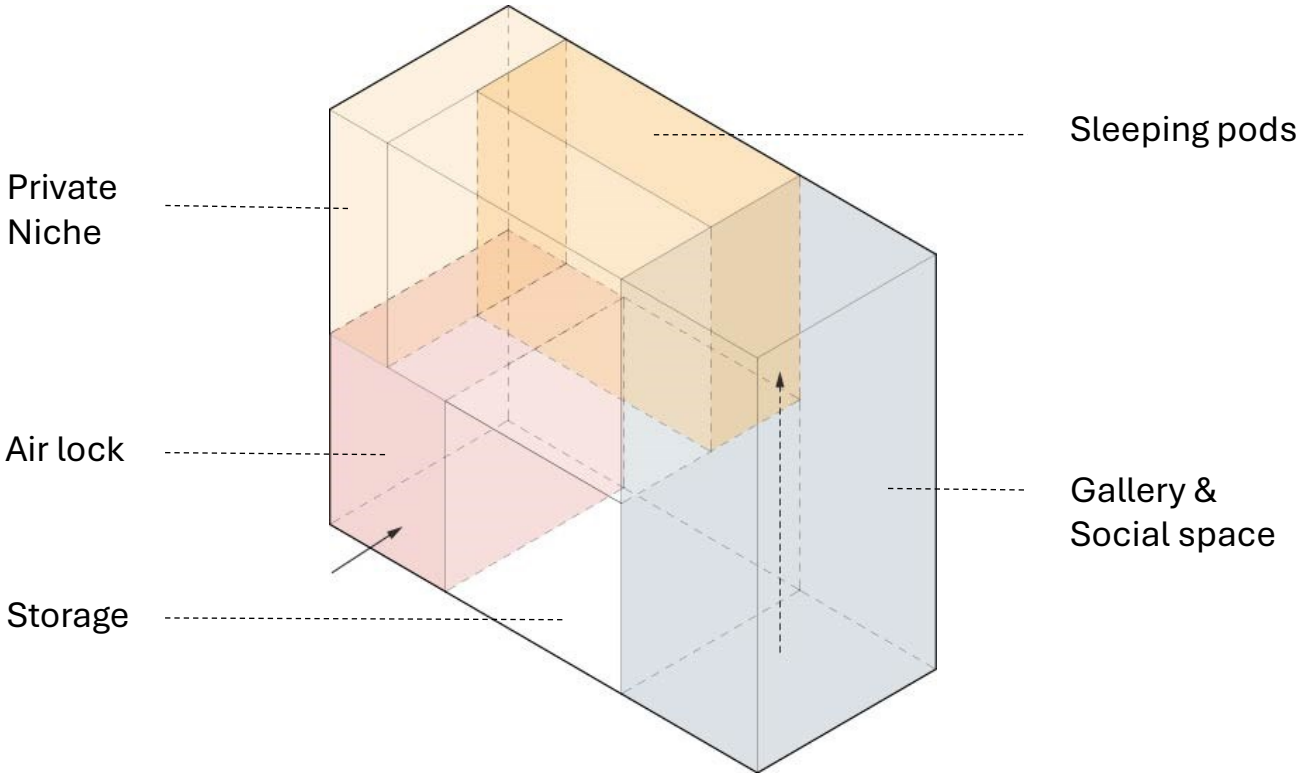
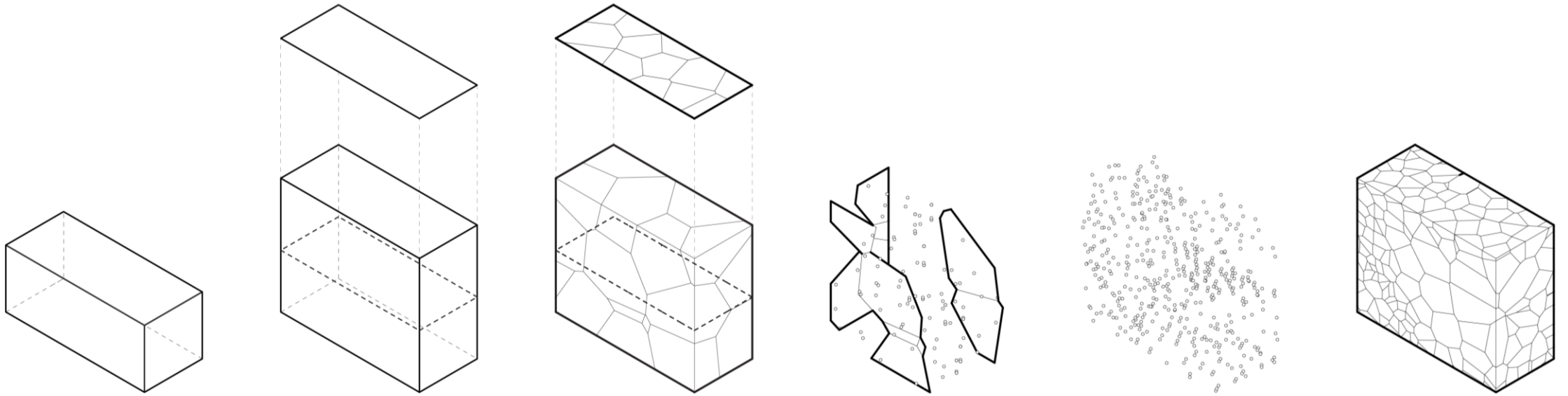


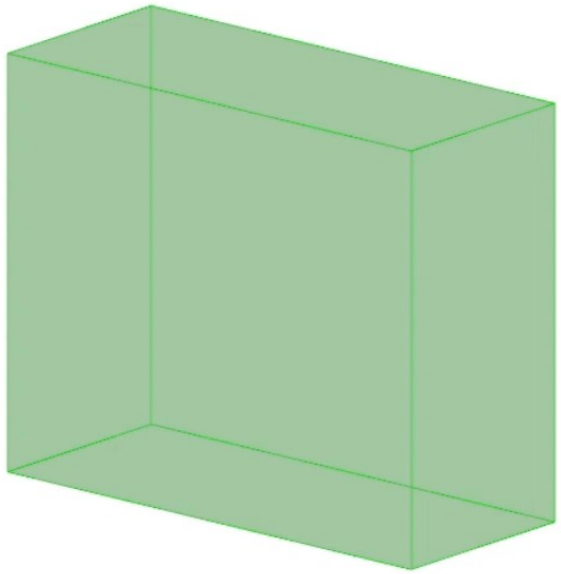
Fig. 20 – Diagram form finding script

Fig. 18 – Interior perspective



Create container | **Stack and add floor** | **Apply vonoroi for zoning** | **Pick cells for each density (S, M, L, XL) and populate** | **Adjust points manually** | **Create spacial vonoroi**

Fig. 21 – Diagram form finding script



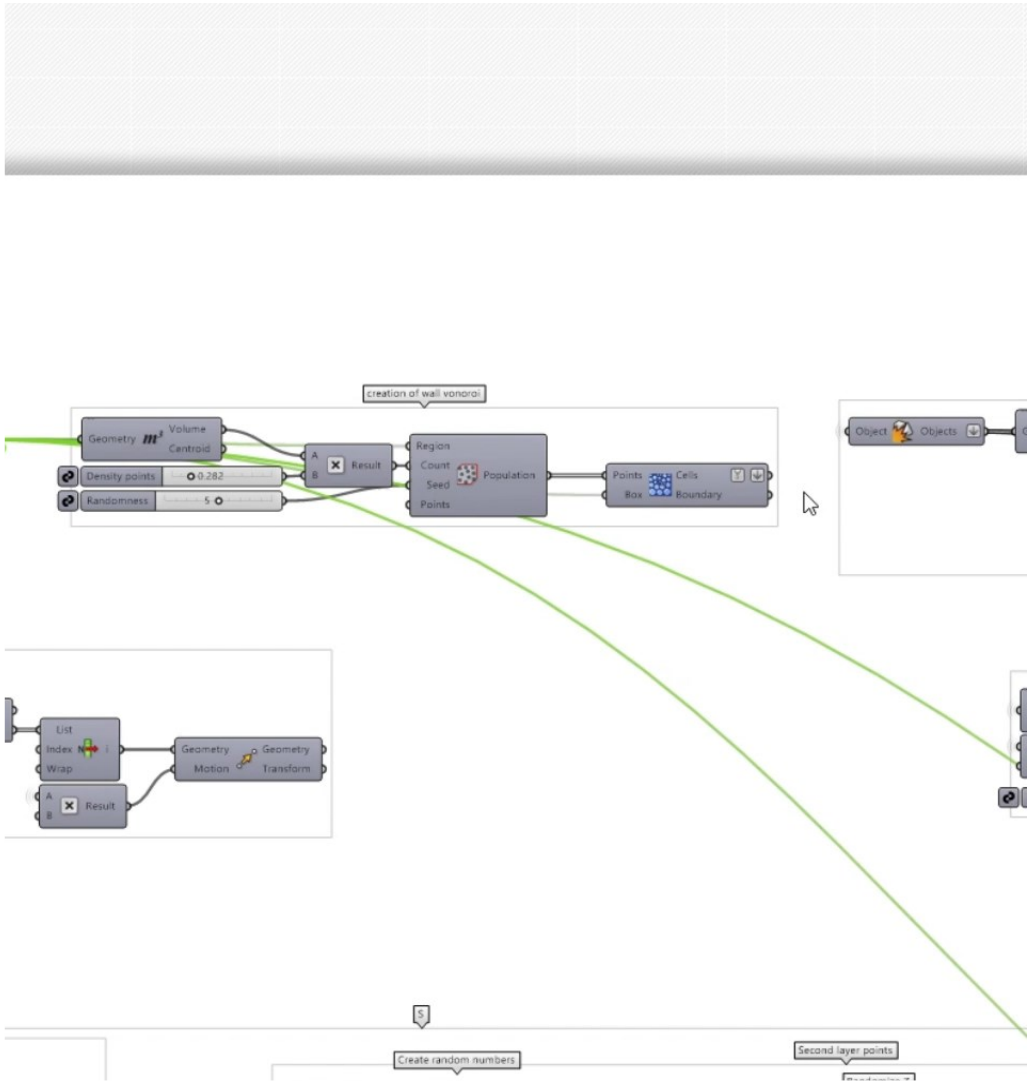


Fig. 22 – Video form finding script

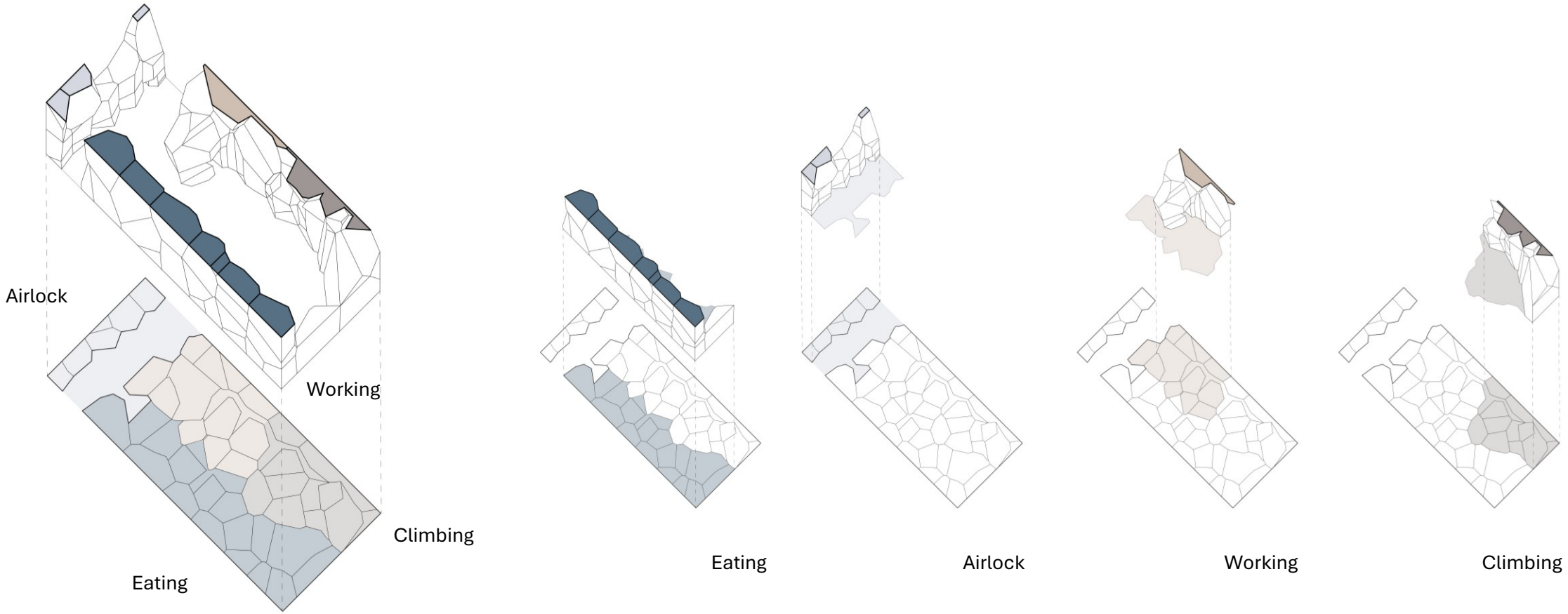


Fig. 23 – Lower Floor Spatial Configuration

Fig. 24 – Upper Floor Spatial Configuration

4 DESIGN DEVELOPMENT | **FLOOR PLANS**

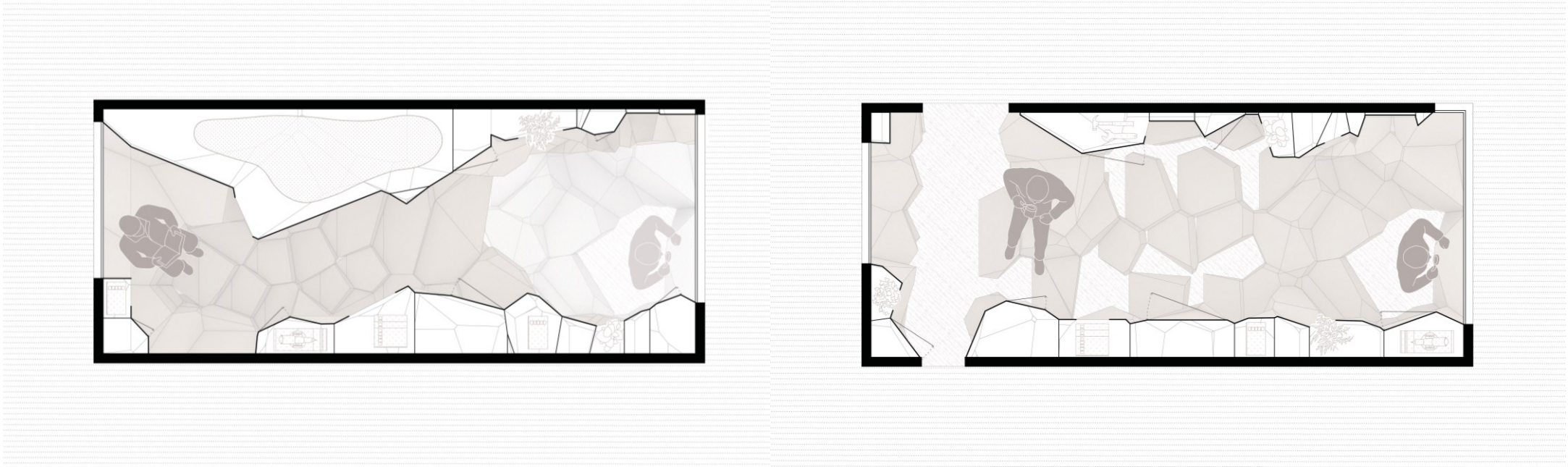


Fig. 25 – Upper and lower floor plans

4 DESIGN DEVELOPMENT | **SECTIONS**

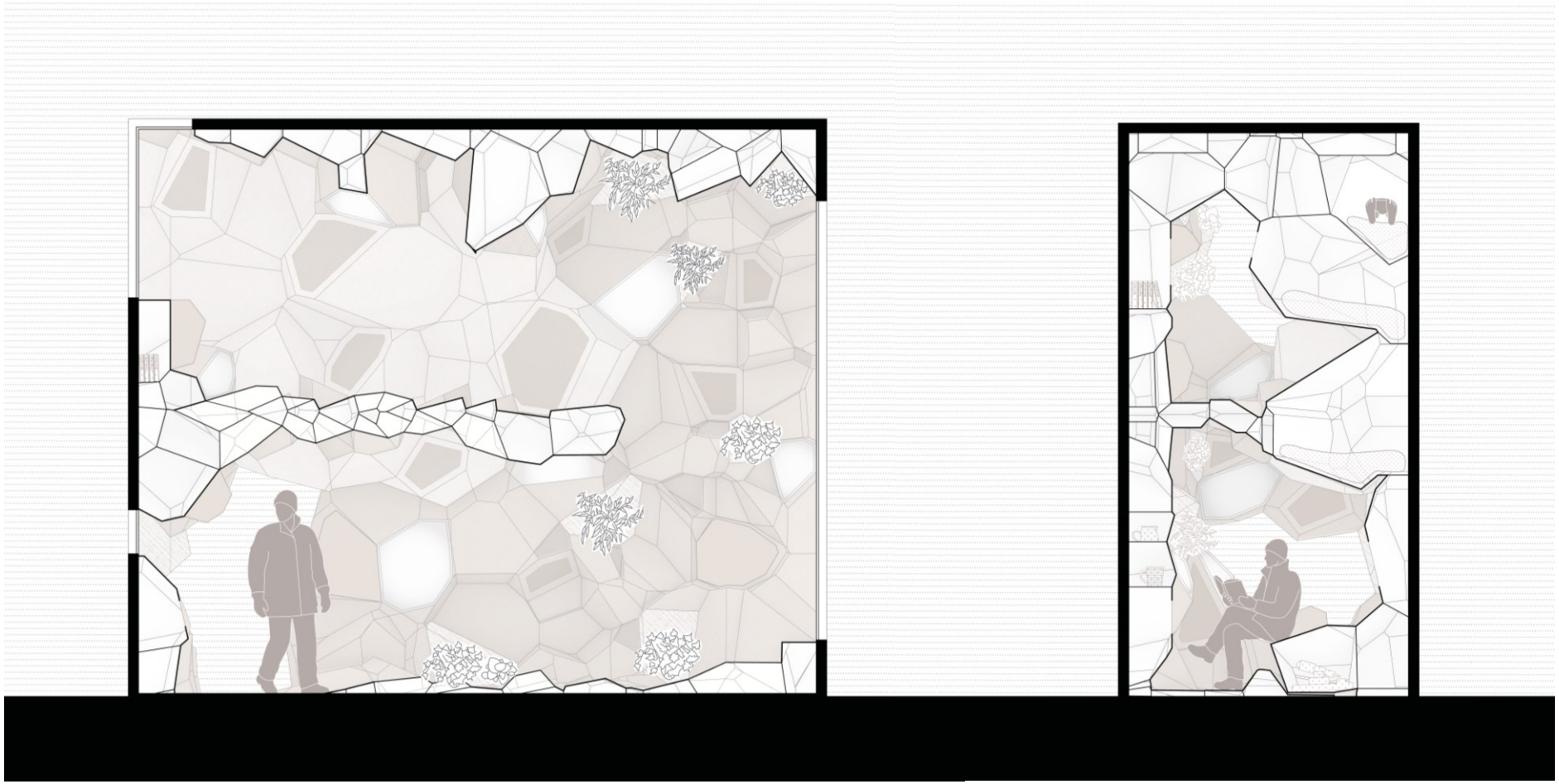


Fig. 26 – Longitudinal and cross sections

4 DESIGN DEVELOPMENT | **SPATIAL CONFIGURATION**

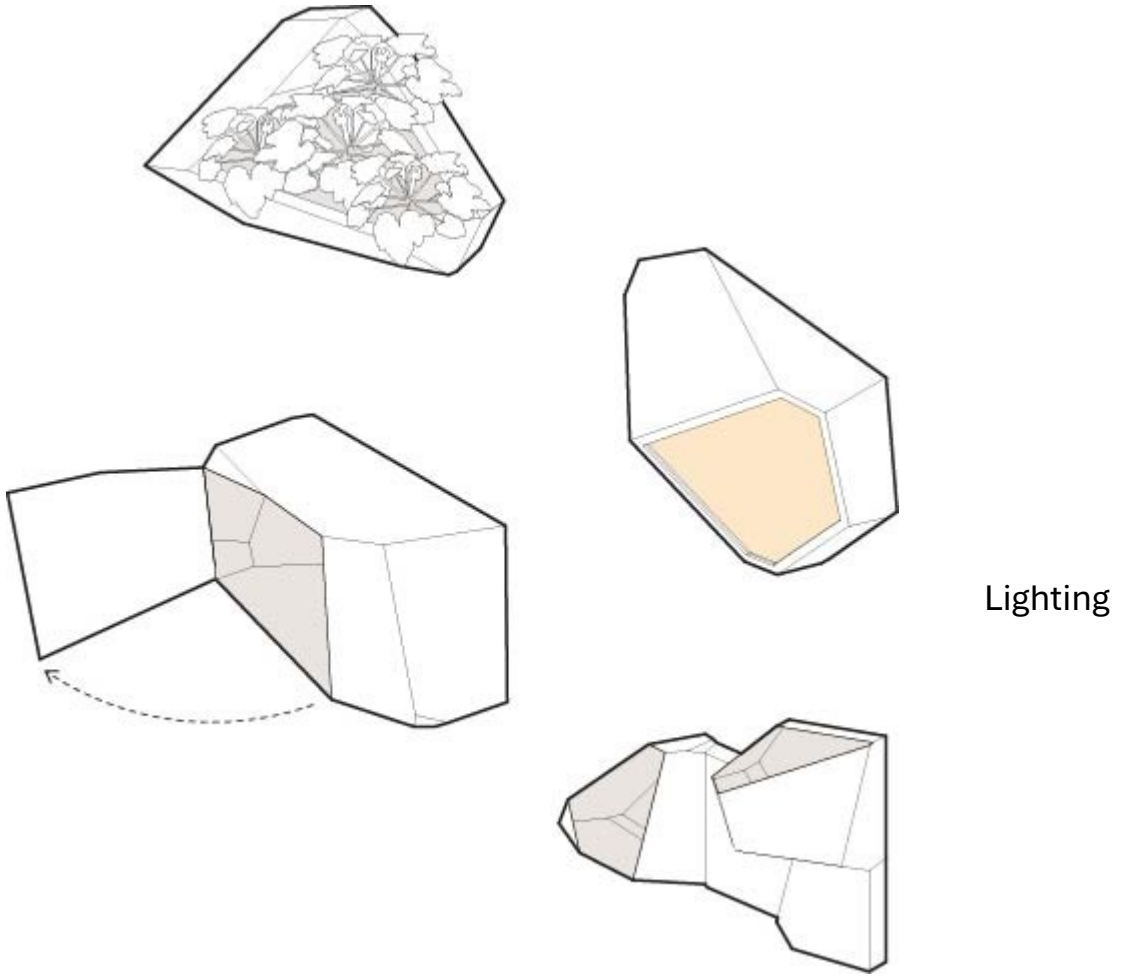


Fig. 27 – Voronoi typologies

Fig. 18 – Interior perspective

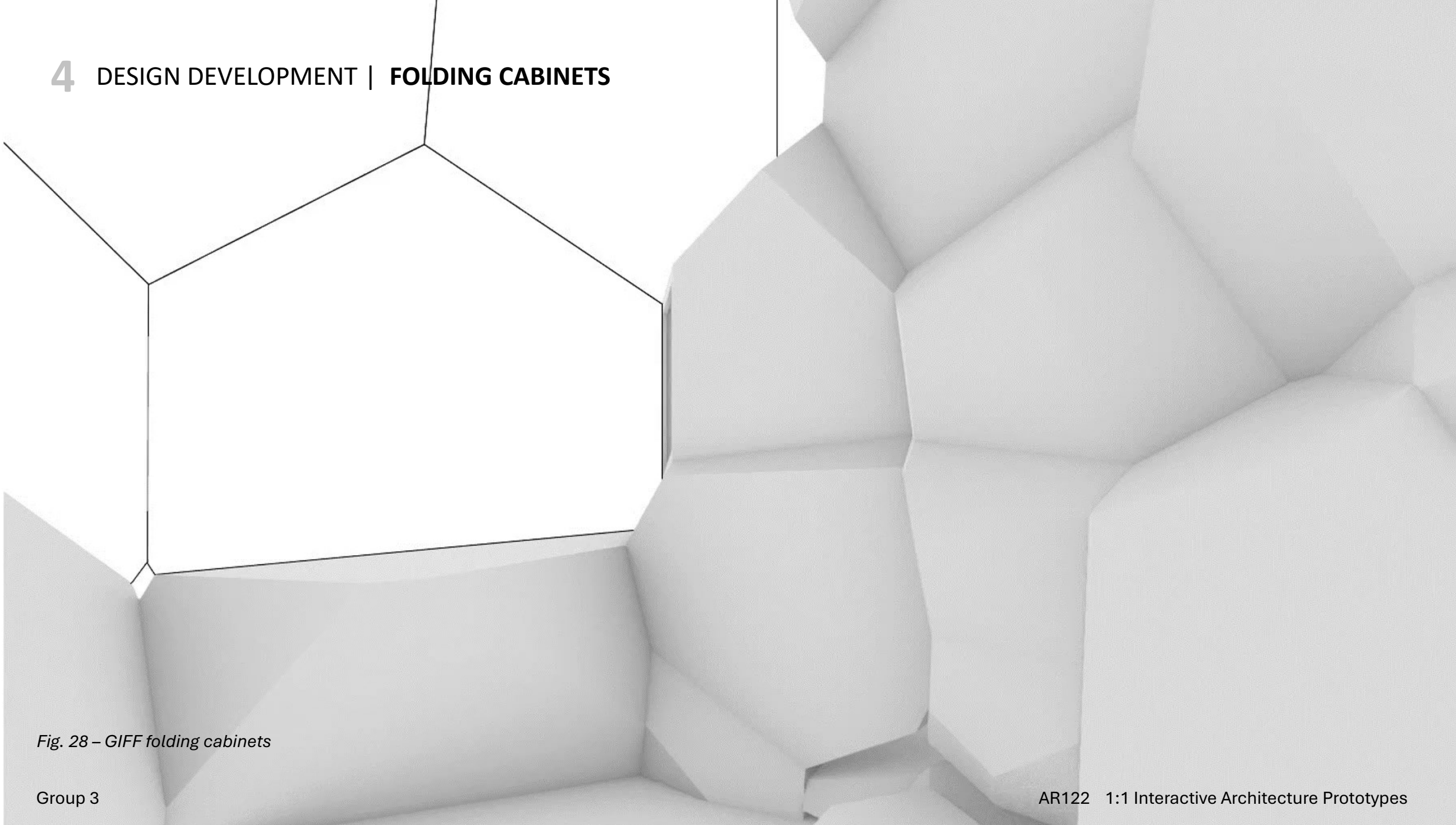


Fig. 28 – GIFF folding cabinets

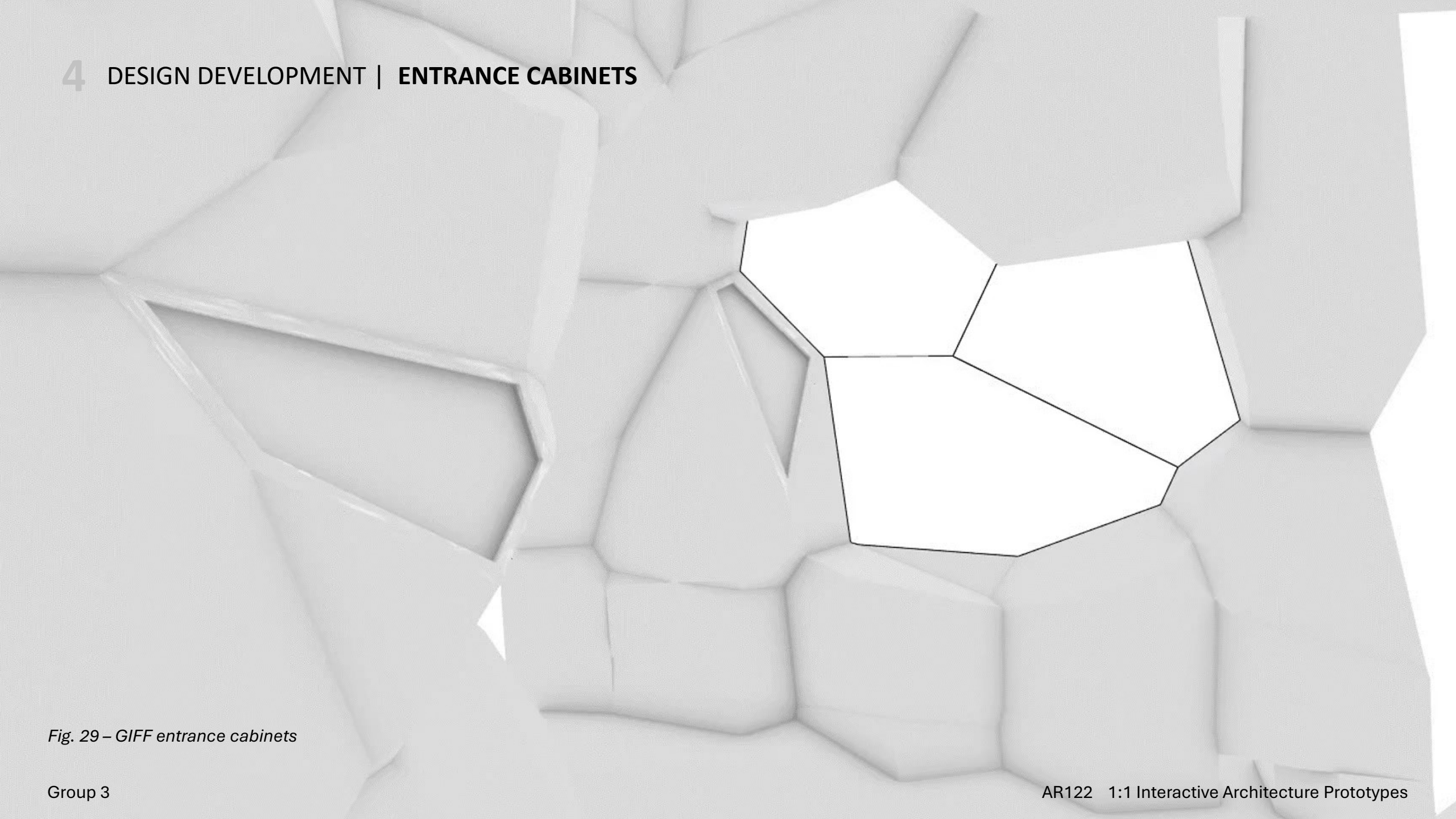


Fig. 29 – GIFF entrance cabinets

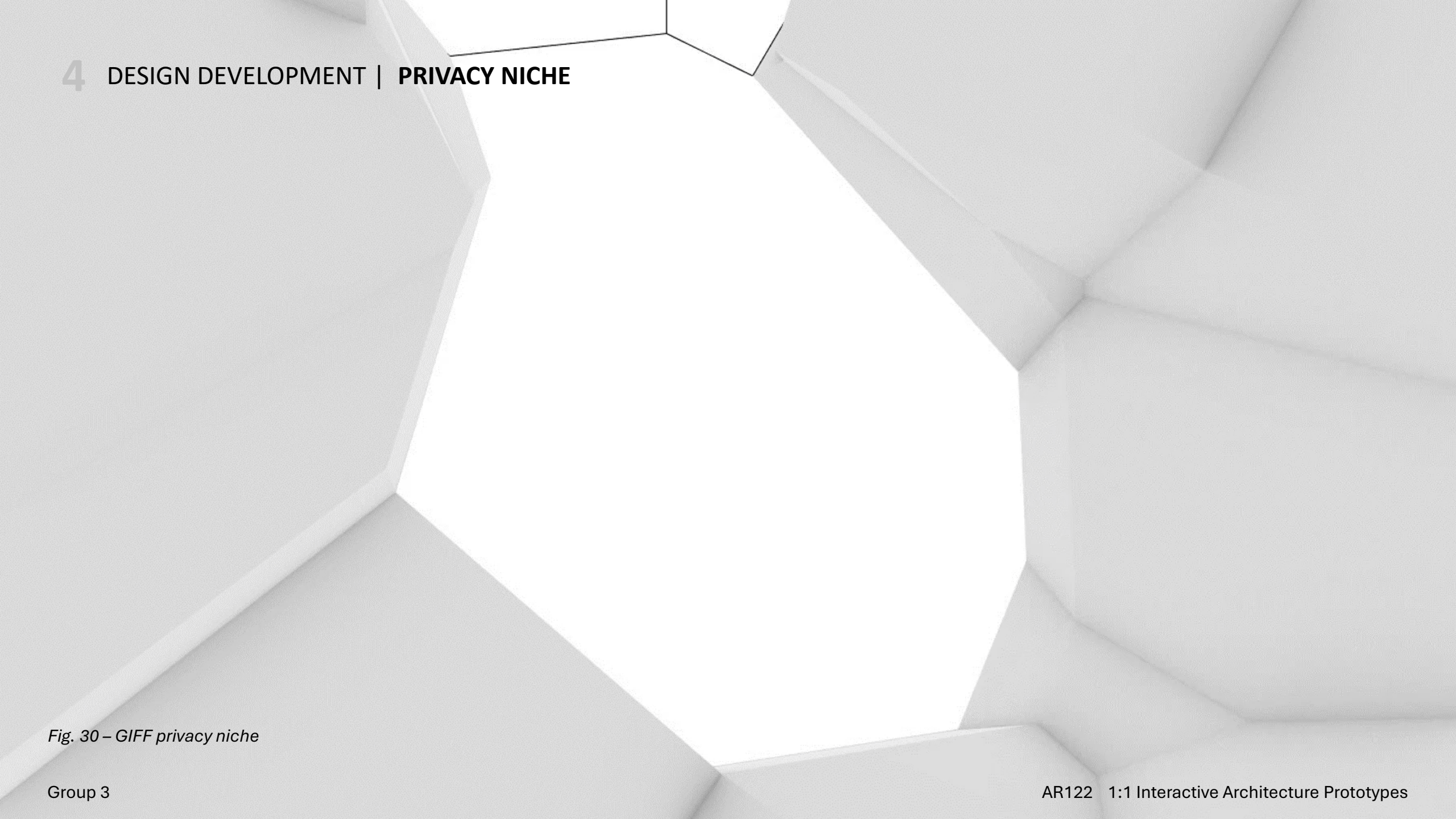


Fig. 30 – GIFF privacy niche

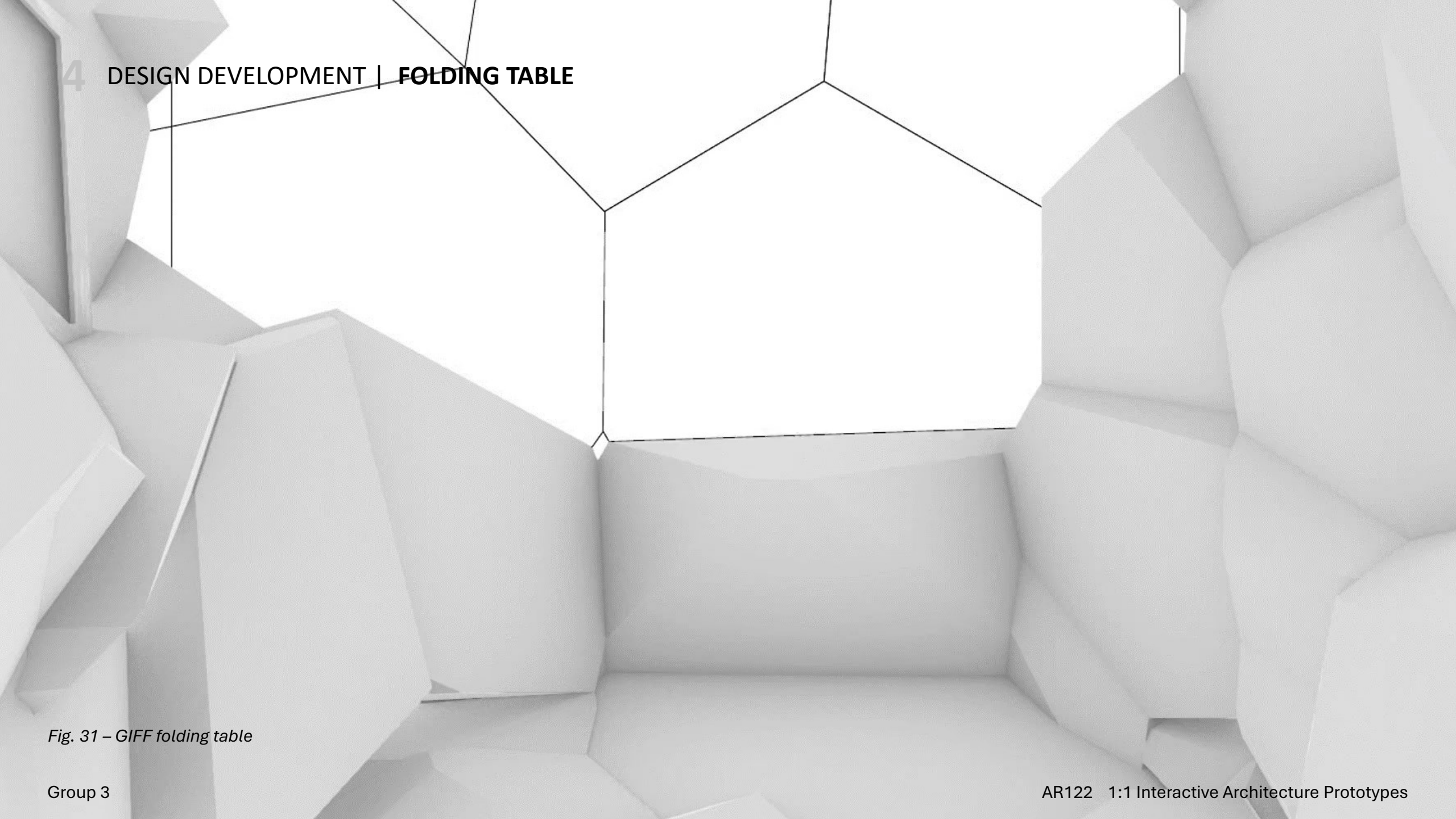


Fig. 31 – GIFF folding table

LIGHTING

5 LIGHTING | **CONCEPT**

•Simulate circadian rhythm
•Use a high CCT during daytime and working hours
•Gradually shift to low CCT in the morning and evening

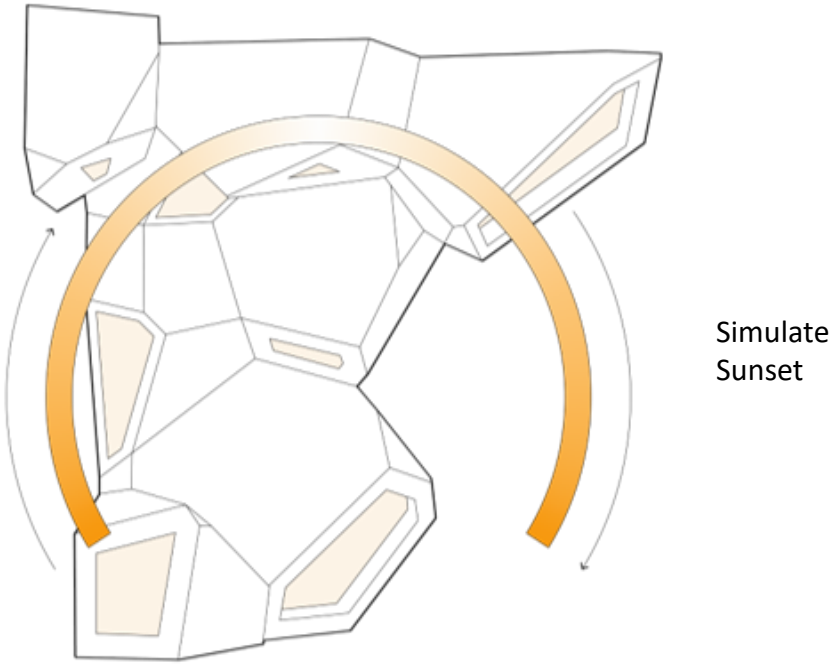


Fig. 32 – Lighting principle

Fig. 33 – Lighting principle, V-Ray Ren

5 LIGHTING | **CONCEPT**

- Implement heart rate responsive lighting
- When heart rate is lower, the system shifts to a higher CCT
  Increased Alertness
- When heart rate is elevated, the system shifts to a lower CCT
  Calm Atmosphere

Fig. 34 – Equalizing heartrates

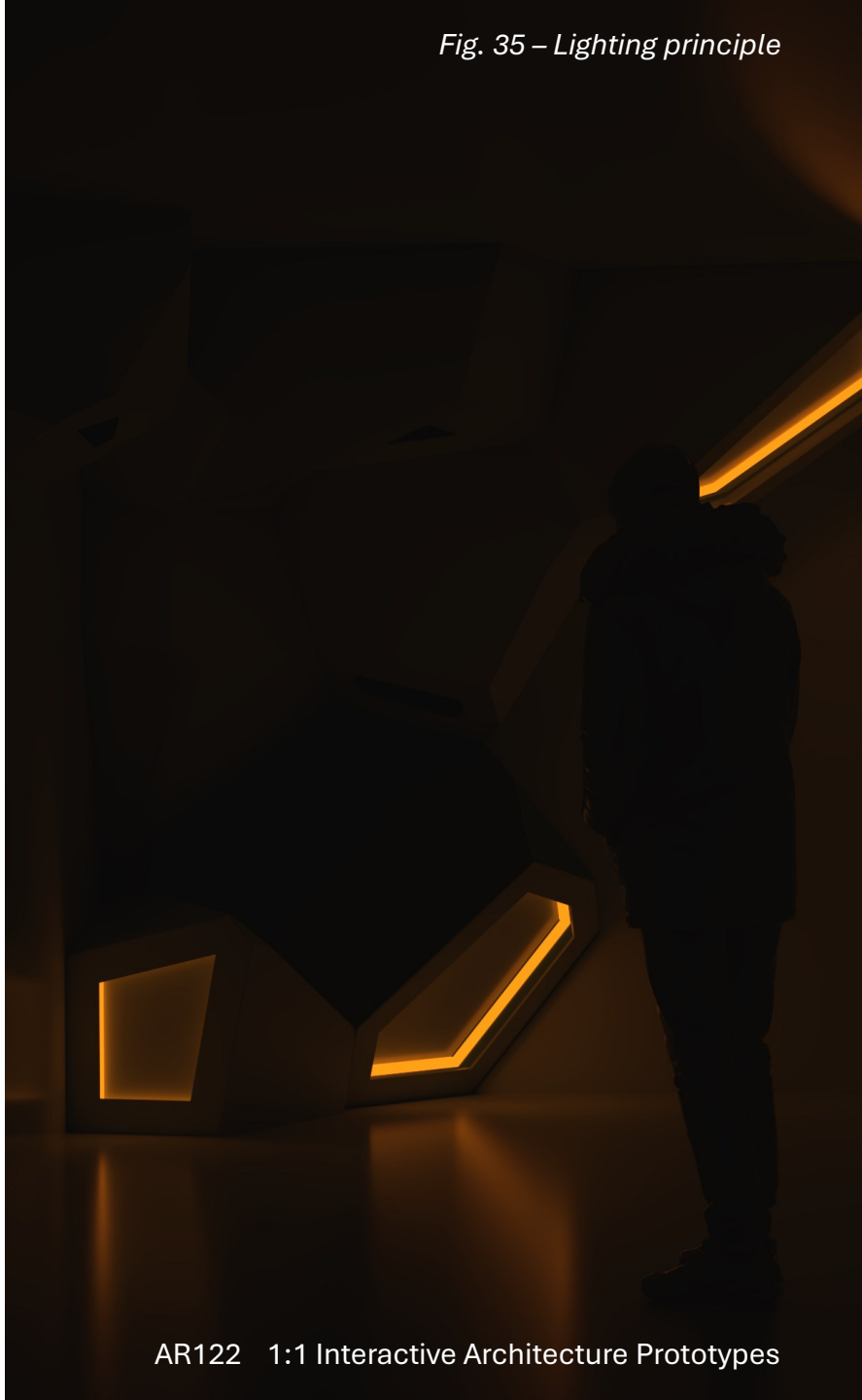
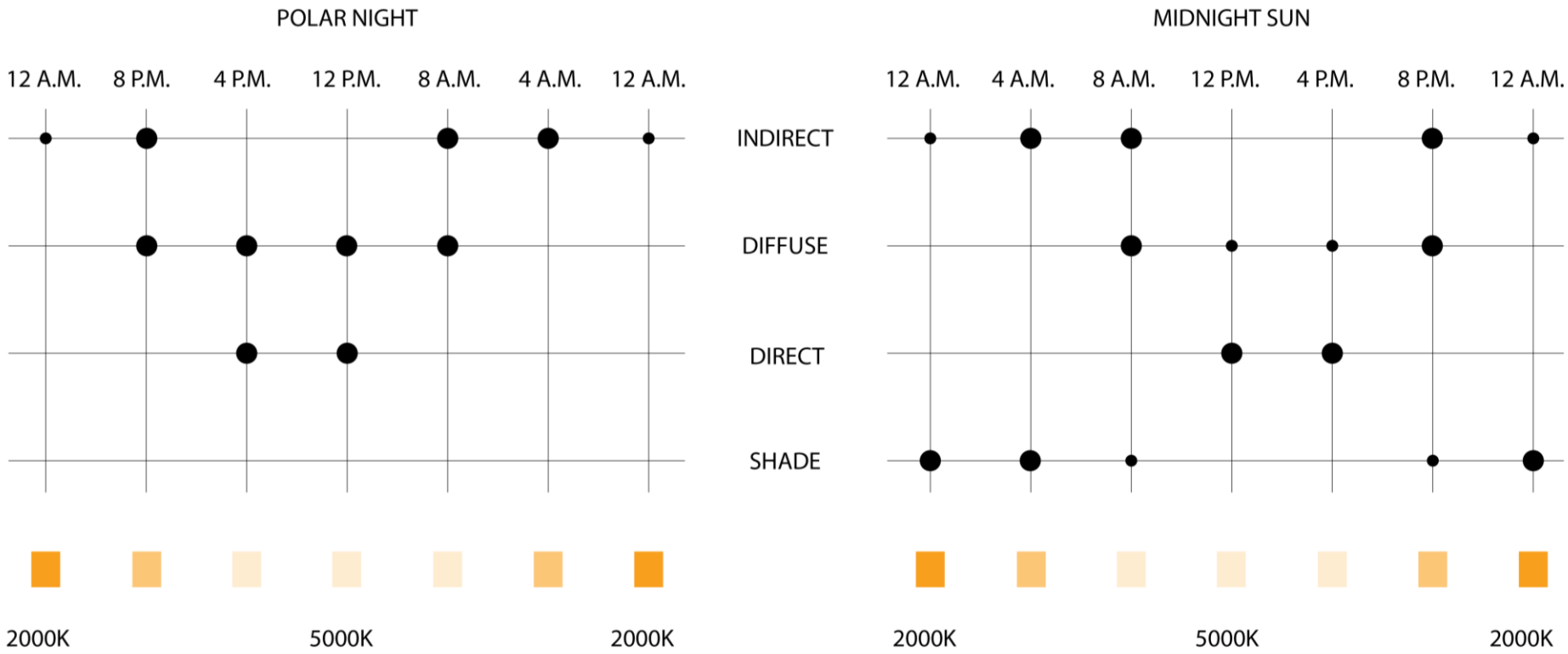


Fig. 35 – Lighting principle

5 LIGHTING | CONCEPT



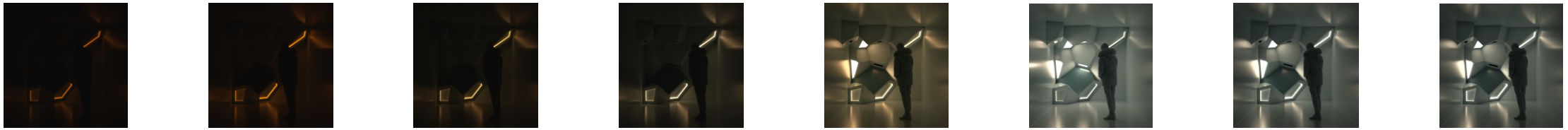


Fig. 36 – CCT adjustment based on activity mapping

5 LIGHTING | **GH SCRIPT**

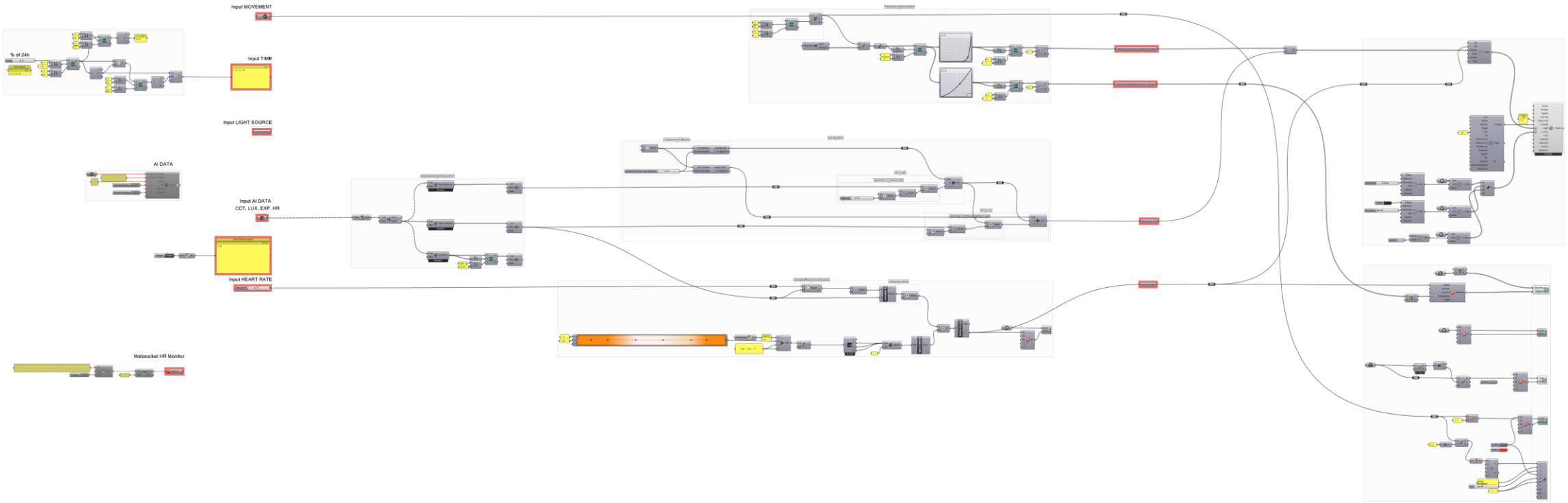


Fig. 37 – Lighting Script Grasshopper - Overview

5 LIGHTING | **GH SCRIPT**

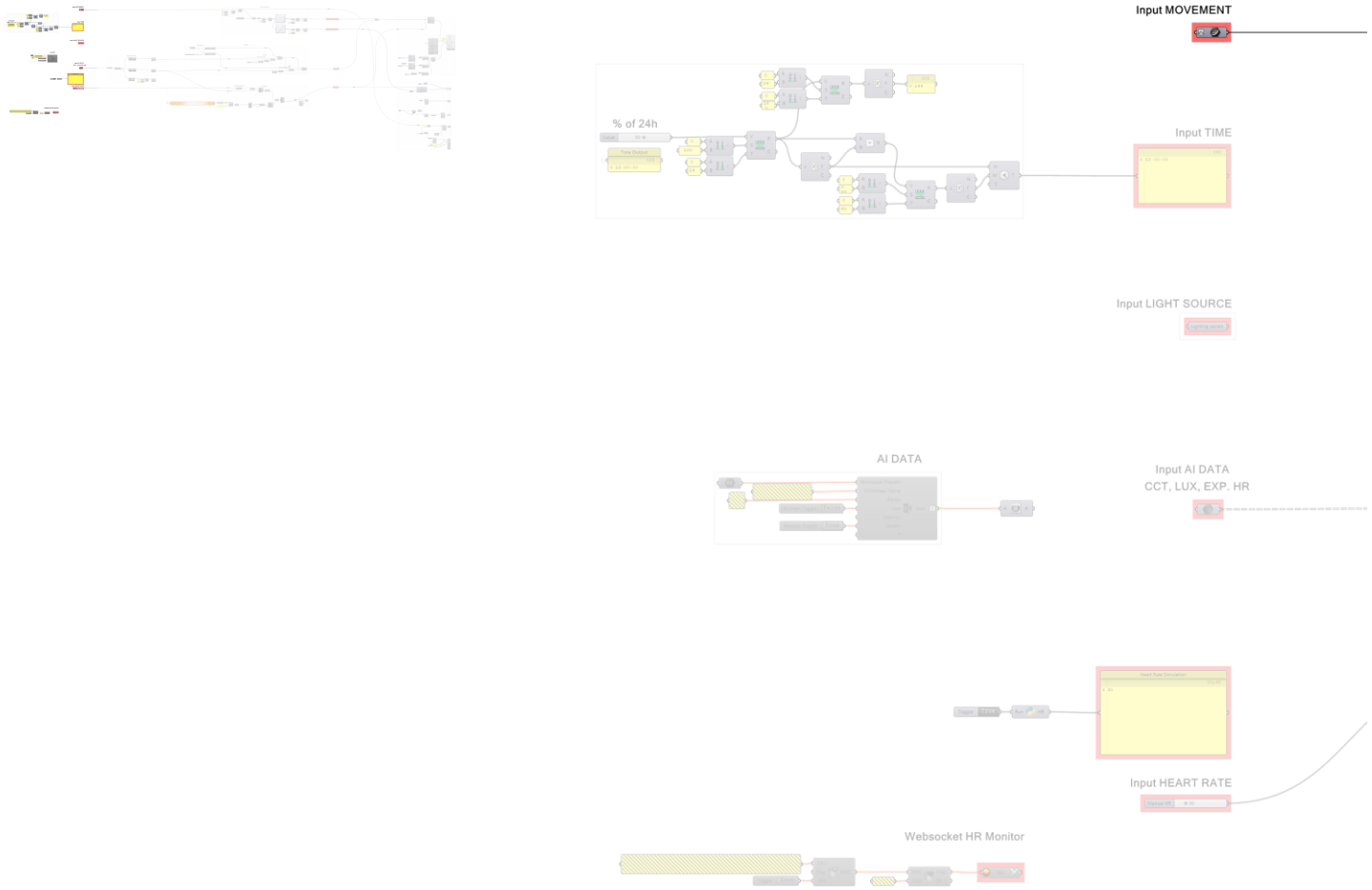


Fig. 38 – Lighting Script Grasshopper – Input Parameters

5 LIGHTING | **GH SCRIPT**

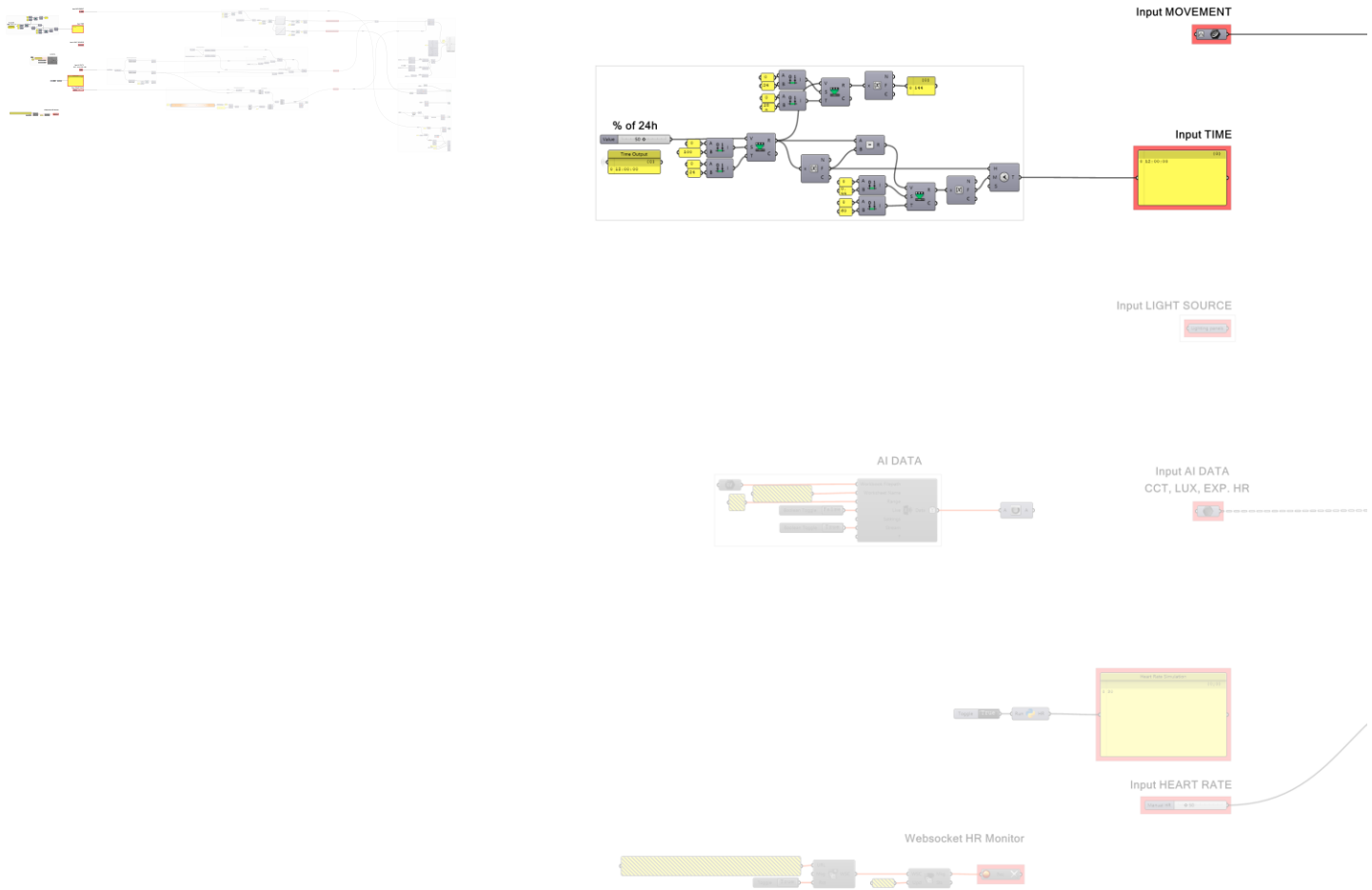


Fig. 38 – Lighting Script Grasshopper – Input Parameters

5 LIGHTING | **GH SCRIPT**

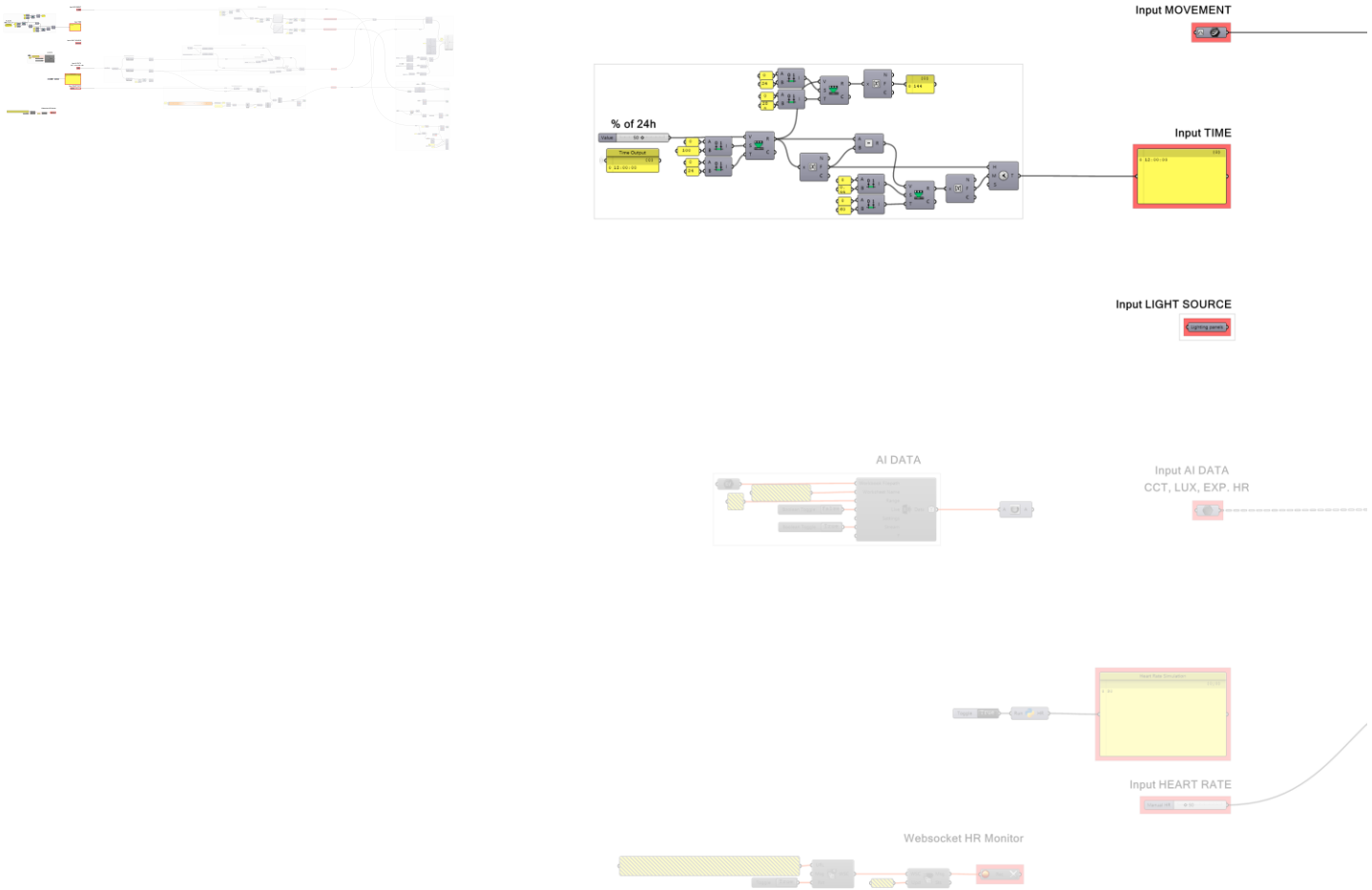


Fig. 38 – Lighting Script Grasshopper – Input Parameters

5 LIGHTING | **GH SCRIPT**

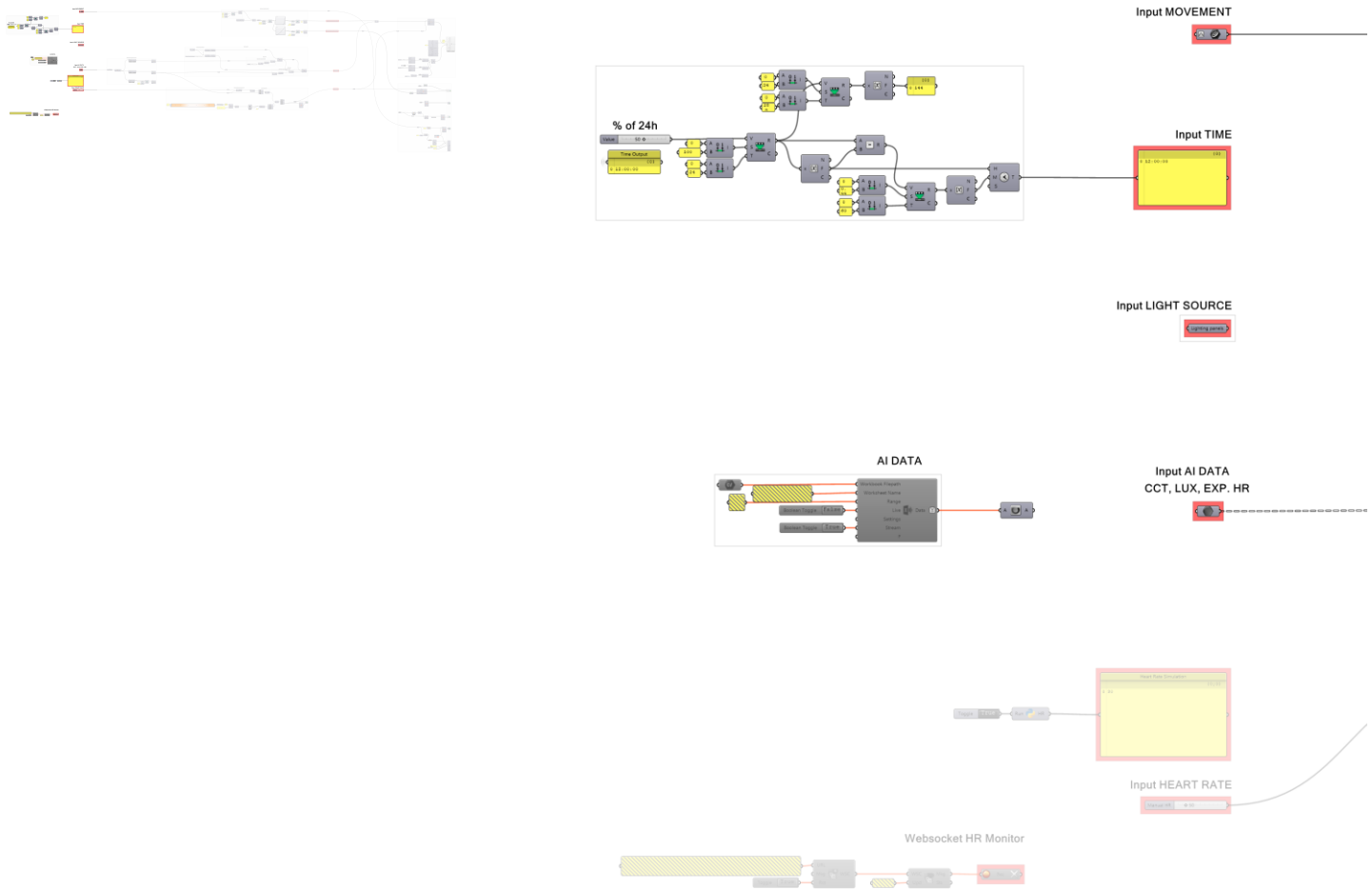
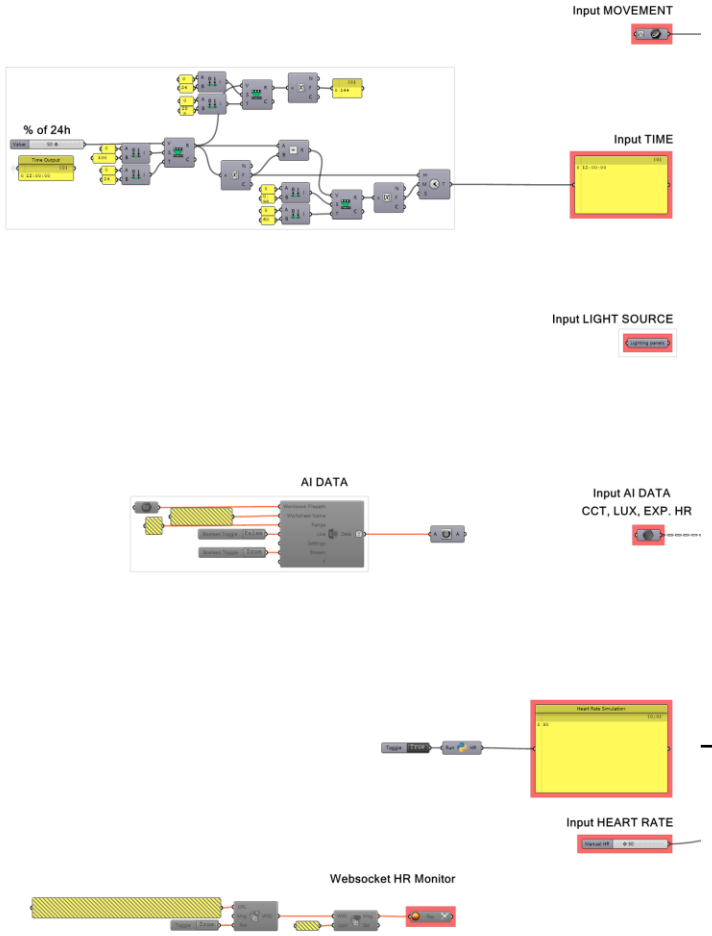
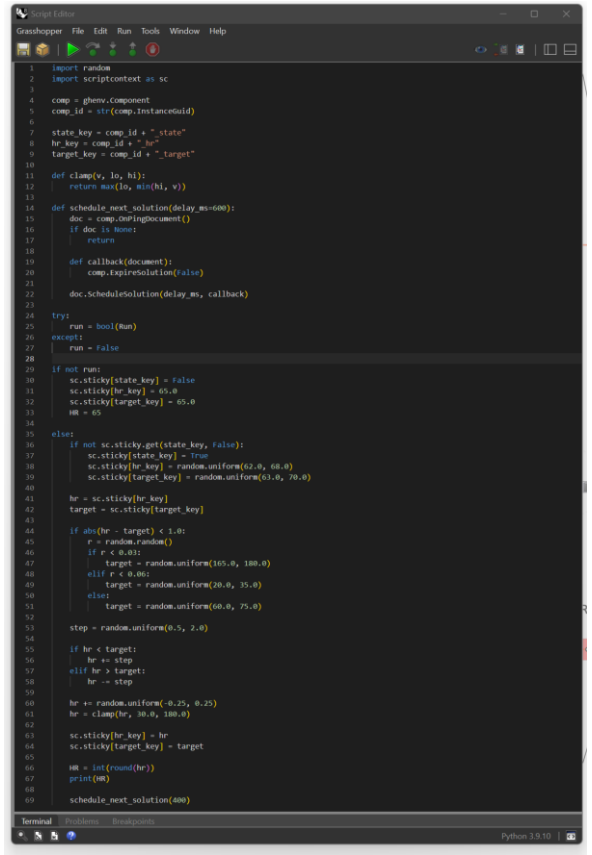


Fig. 38 – Lighting Script Grasshopper – Input Parameters

5 LIGHTING | **GH SCRIPT**

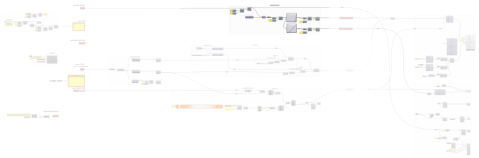




```
import random
import scriptcontext as sc

comp = ghenv.Component
comp_id = str(comp.InstanceGuid)

state_key = comp_id + "_state"
hr_key = comp_id + "_hr"
target_key = comp_id + "_target"

def clamp(v, lo, hi):
    return max(lo, min(hi, v))

def schedule_next_solution(delay_ms=600):
    doc = comp.OnPingDocument()
    if doc is None:
        return

    def callback(document):
        comp.ExpireSolution(False)

    doc.ScheduleSolution(delay_ms, callback)

try:
    run = bool(Run)
except:
    run = False

if not run:
    sc.sticky[state_key] = False
    sc.sticky[hr_key] = 65.0
    sc.sticky[target_key] = 65.0
    HR = 65

else:
    if not sc.sticky.get(state_key, False):
        sc.sticky[state_key] = True
        sc.sticky[hr_key] = random.uniform(62.0, 68.0)
        sc.sticky[target_key] = random.uniform(63.0, 70.0)

    hr = sc.sticky[hr_key]
    target = sc.sticky[target_key]

    if abs(hr - target) < 1.0:
        r = random.random()
        if r < 0.03:
            target = random.uniform(165.0, 180.0)
        elif r < 0.06:
            target = random.uniform(20.0, 35.0)
        else:
            target = random.uniform(60.0, 75.0)

    step = random.uniform(0.5, 2.0)

    if hr < target:
        hr += step
    elif hr > target:
        hr -= step

    hr += random.uniform(-0.25, 0.25)
    hr = clamp(hr, 30.0, 180.0)

    sc.sticky[hr_key] = hr
    sc.sticky[target_key] = target

    HR = int(round(hr))
    print(HR)

    schedule_next_solution(600)
```

Fig. 38 & 39– Lighting Script Grasshopper – Input Parameters, Python Script HR Simulation

5 LIGHTING | **GH SCRIPT**



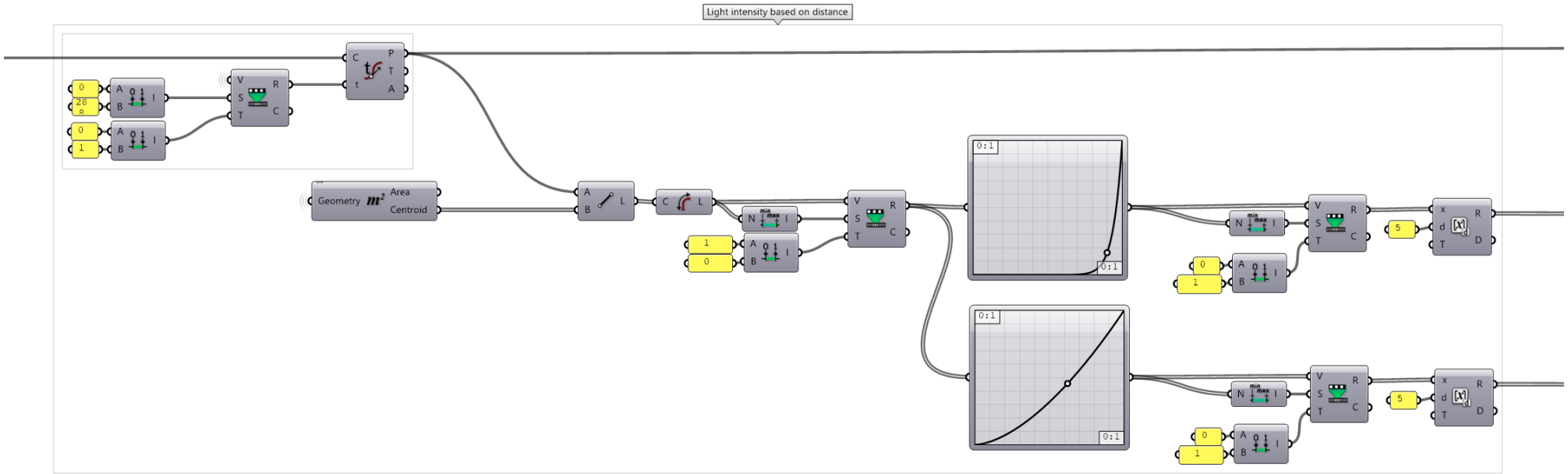
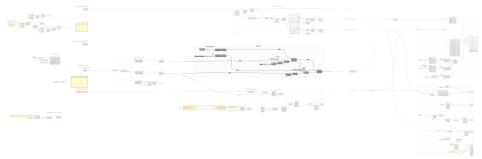


Fig. 40 – Lighting Script Grasshopper – Proximity amplification

5 LIGHTING | **GH SCRIPT**



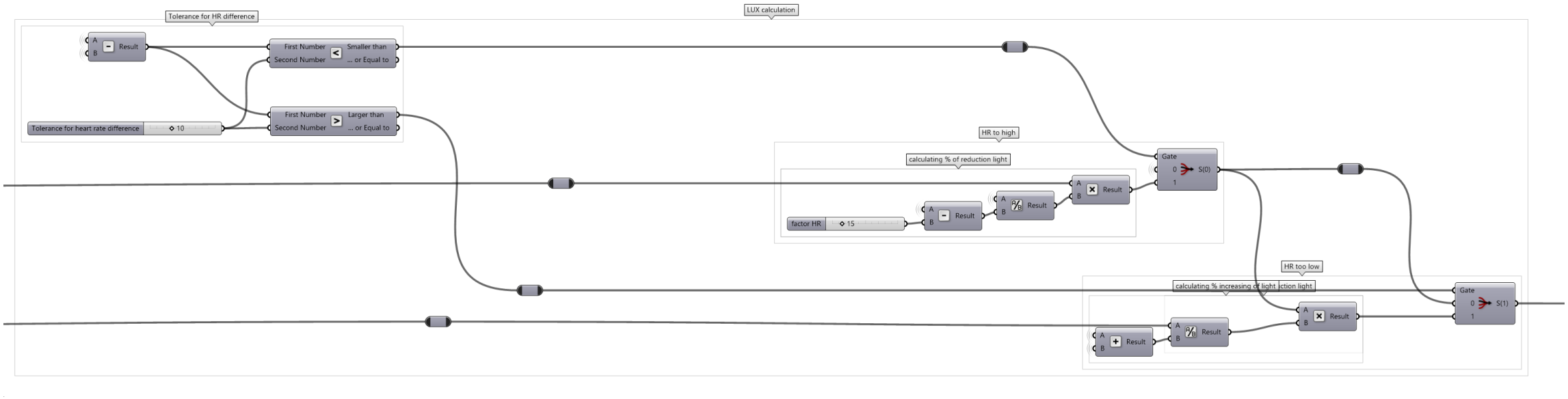
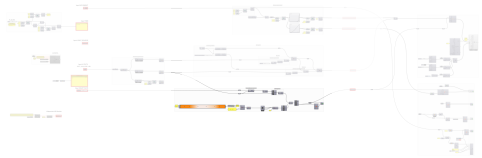


Fig. 41 – Lighting Script Grasshopper – Calculation tolerance threshold

5 LIGHTING | **GH SCRIPT**



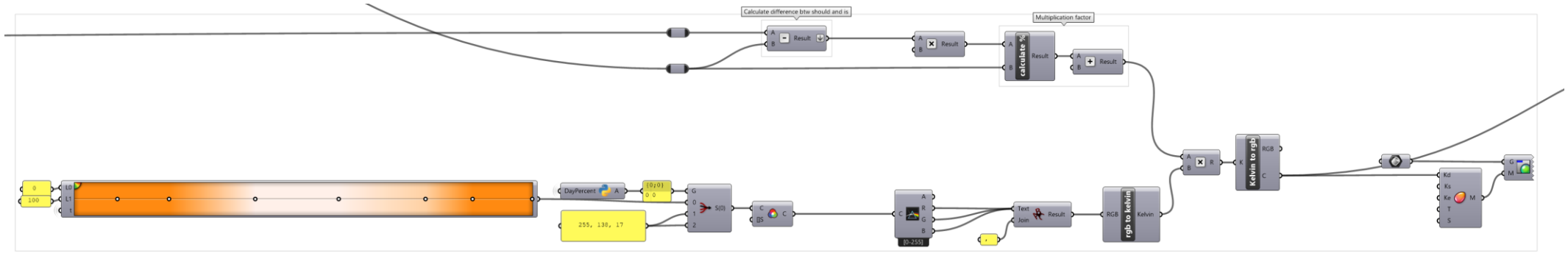
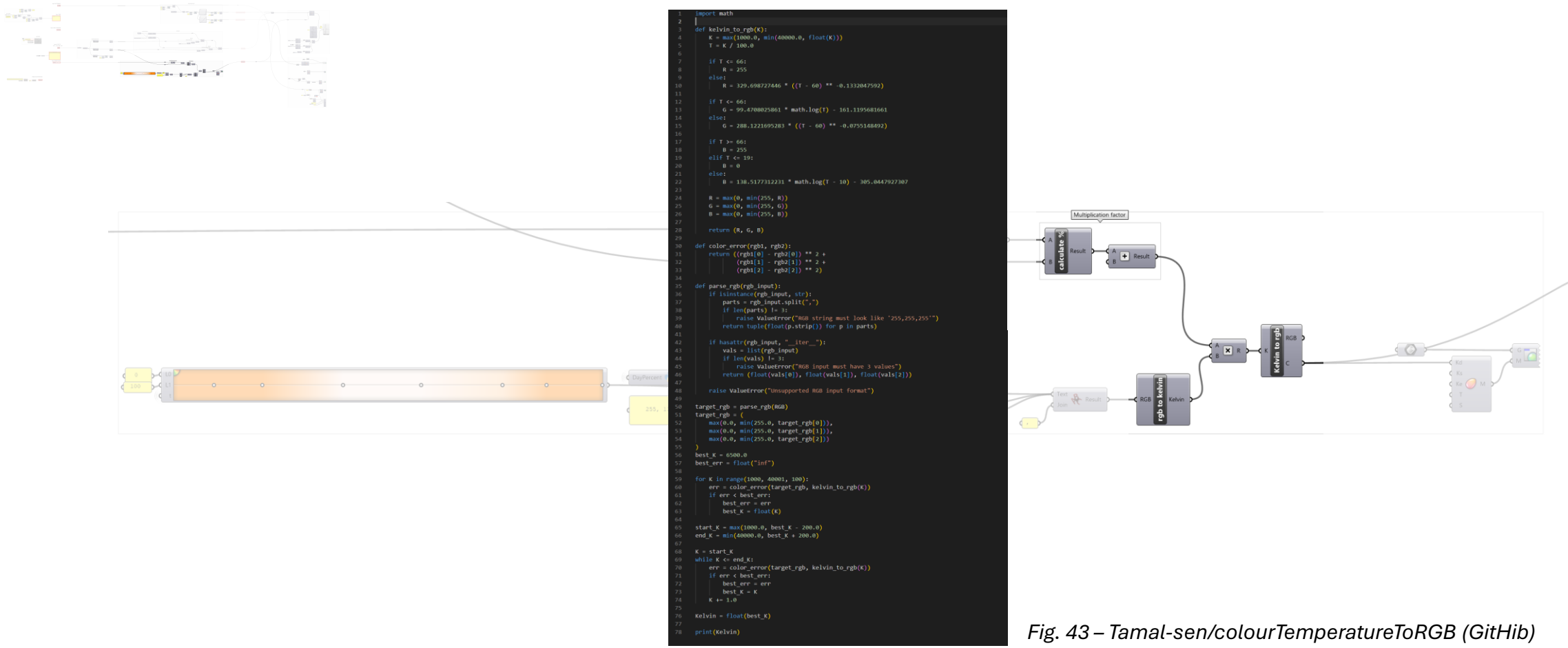


Fig. 42 – Lighting Script Grasshopper - Heart Rate–Driven colour temperature adjustment

5 LIGHTING | **GH SCRIPT**

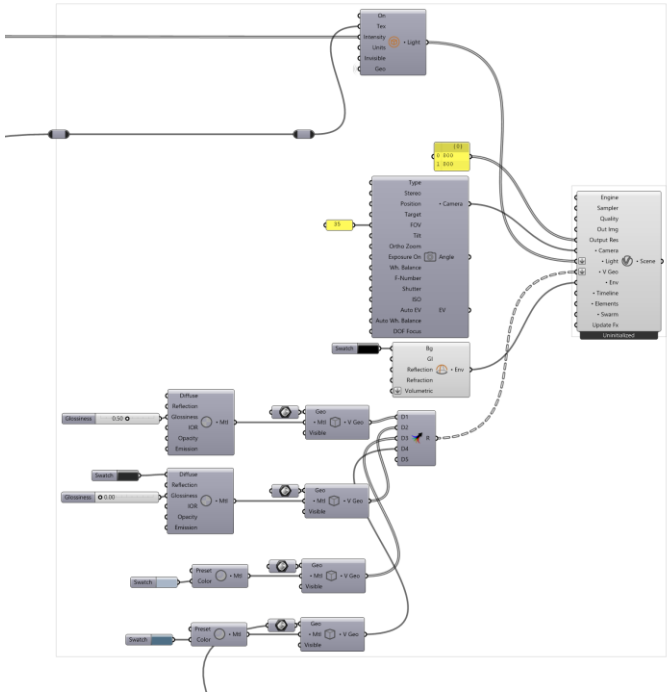


```python
import math

def kelvin_to_rgb(K):
    K = max(1000.0, min(40000.0, float(K)))
    T = K / 100.0

    if T <= 66:
        R = 255
    else:
        R = 329.698727446 * ((T - 60) ** -0.1332047592)

    if T <= 66:
        G = 99.4708025861 * math.log(T) - 161.1195681661
    else:
        G = 288.1221695283 * ((T - 60) ** -0.0755148492)

    if T >= 66:
        B = 255
    elif T <= 19:
        B = 0
    else:
        B = 138.5177312231 * math.log(T - 10) - 305.0447927307

    R = max(0, min(255, R))
    G = max(0, min(255, G))
    B = max(0, min(255, B))

    return (R, G, B)

def color_error(rgb1, rgb2):
    return ((rgb1[0] - rgb2[0]) ** 2 +
            (rgb1[1] - rgb2[1]) ** 2 +
            (rgb1[2] - rgb2[2]) ** 2)

def parse_rgb(rgb_input):
    if isinstance(rgb_input, str):
        parts = rgb_input.split(",")
        if len(parts) != 3:
            raise ValueError("RGB string must look like '255,255,255'")
        return tuple(float(p.strip()) for p in parts)

    if hasattr(rgb_input, "__iter__"):
        vals = list(rgb_input)
        if len(vals) != 3:
            raise ValueError("RGB input must have 3 values")
        return (float(vals[0]), float(vals[1]), float(vals[2]))

    raise ValueError("Unsupported RGB input format")

target_rgb = parse_rgb(RGB)
target_rgb = (
    max(0.0, min(255.0, target_rgb[0])),
    max(0.0, min(255.0, target_rgb[1])),
    max(0.0, min(255.0, target_rgb[2]))
)
best_K = 6500.0
best_err = float("inf")

for K in range(1000, 40001, 100):
    err = color_error(target_rgb, kelvin_to_rgb(K))
    if err < best_err:
        best_err = err
        best_K = float(K)

start_K = max(1000.0, best_K - 200.0)
end_K = min(40000.0, best_K + 200.0)

K = start_K
while K <= end_K:
    err = color_error(target_rgb, kelvin_to_rgb(K))
    if err < best_err:
        best_err = err
        best_K = K
    K += 1.0

Kelvin = float(best_K)

print(Kelvin)
```

Fig. 43 – Tamal-sen/colourTemperatureToRGB (GitHib)

Fig. 42 – Lighting Script Grasshopper - Heart Rate–Driven colour Temperature Adjustment

5 LIGHTING | **GH SCRIPT**



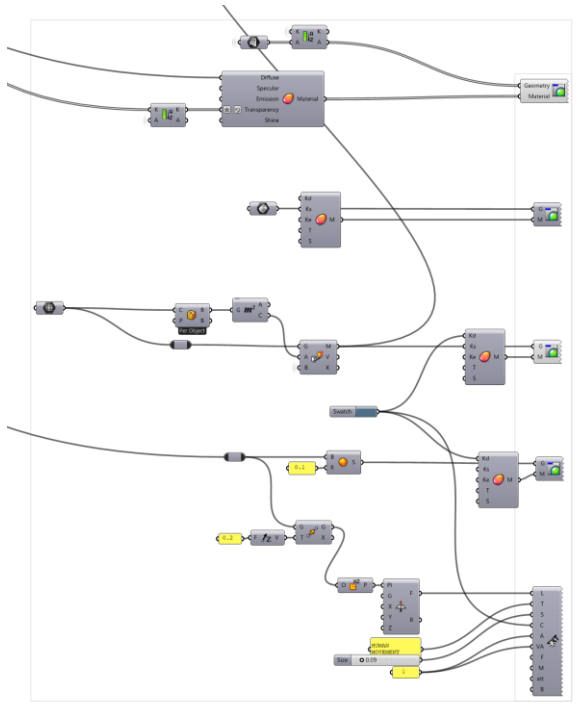


Fig. 44 – Overview Lighting Script Grasshopper - Visualisation using Chaos V-Ray & Rhino Preview

5 LIGHTING | **GH SCRIPT**

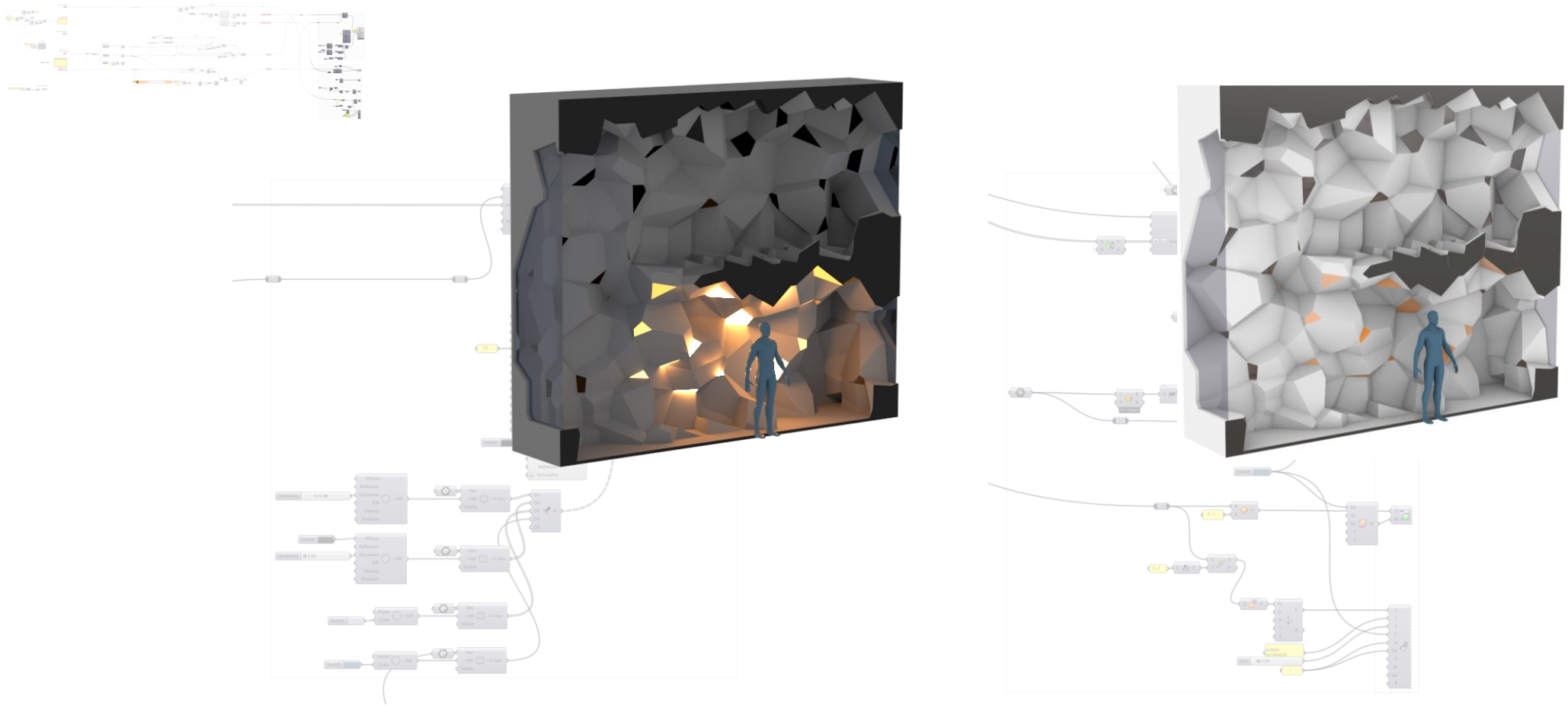


Fig. 45 – Chaos V-Ray & Rhino Preview

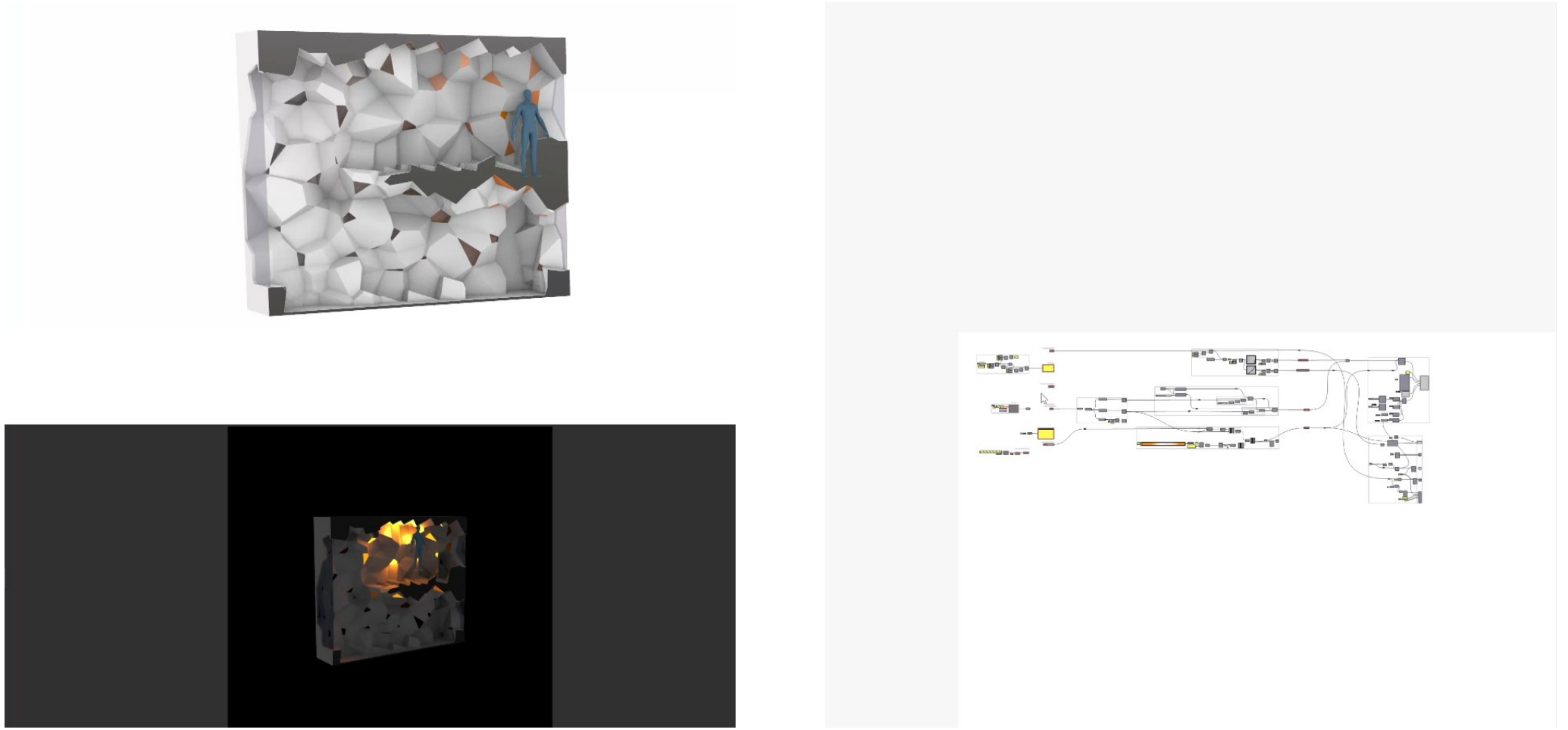


Fig. 46 – Lighting Script Grasshopper – Lighting script demonstration

CPLX

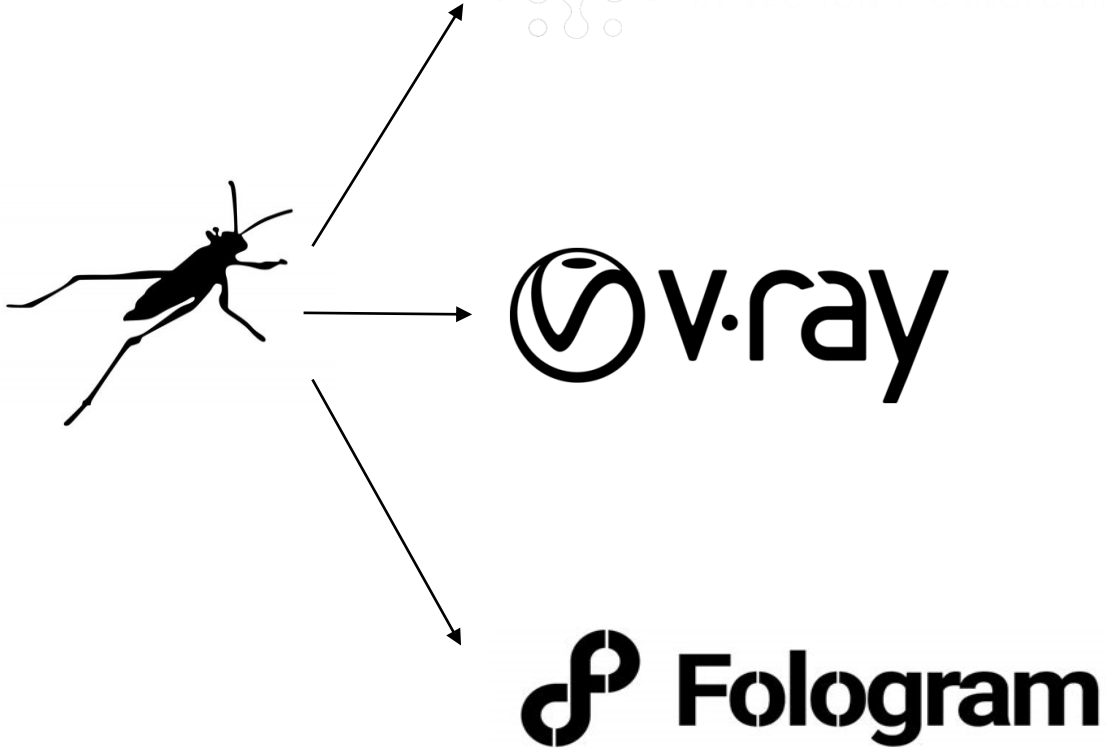
Cave Pulse Light Experiment

Group 3

AR122 1:1 Interactive Architecture Prototypes

LIMITATION

LIMITATIONS | LIGHT VISUALIZATION



+

UNREAL ENGINE

V-RAY

Fologram

ISSUES

No option for light preview, only material display

No live connection for lighting

No option for light preview, only material display

Fig. XX – Limitations in light visualization tools

CPLX

Cave Pulse Light Experiment

THE GOAL

IS

To design

a **human-centered** interior

for the

TROLL Norwegian Research Station in Antarctica

using

6m x 2.5m shipping **container** modules

THE NECESSITY

IS

To improve HEALTH by

- **Mitigating Chronic Stress**
caused by
Extreme Isolation

- **Aligning Circadian Disruption**
caused by
Lack of natural day-night cycles

- **Prioritizing Experience-First Design**

THE STRATEGY

IS

To use

- **Voronoi-based geometry**
as a
Reconfigurable Design Logic

- **AI-assisted lighting**
with an
Adaptive Pulse system

- **Circular Fabrication**
to
Convert plastic waste into 3D-printing filament

THE OUTPUT

IS

To provide

- **Cave interior** supporting sleeping, working, socializing
with
Biophilic elements and integrated climbing

- **Interactive Lighting**
with
heart rate and circadian monitoring

- **The Prototype**
of a
3D-printed cell fragment

Q&A

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External source or adapted reference
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Visualization produced by the authors
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