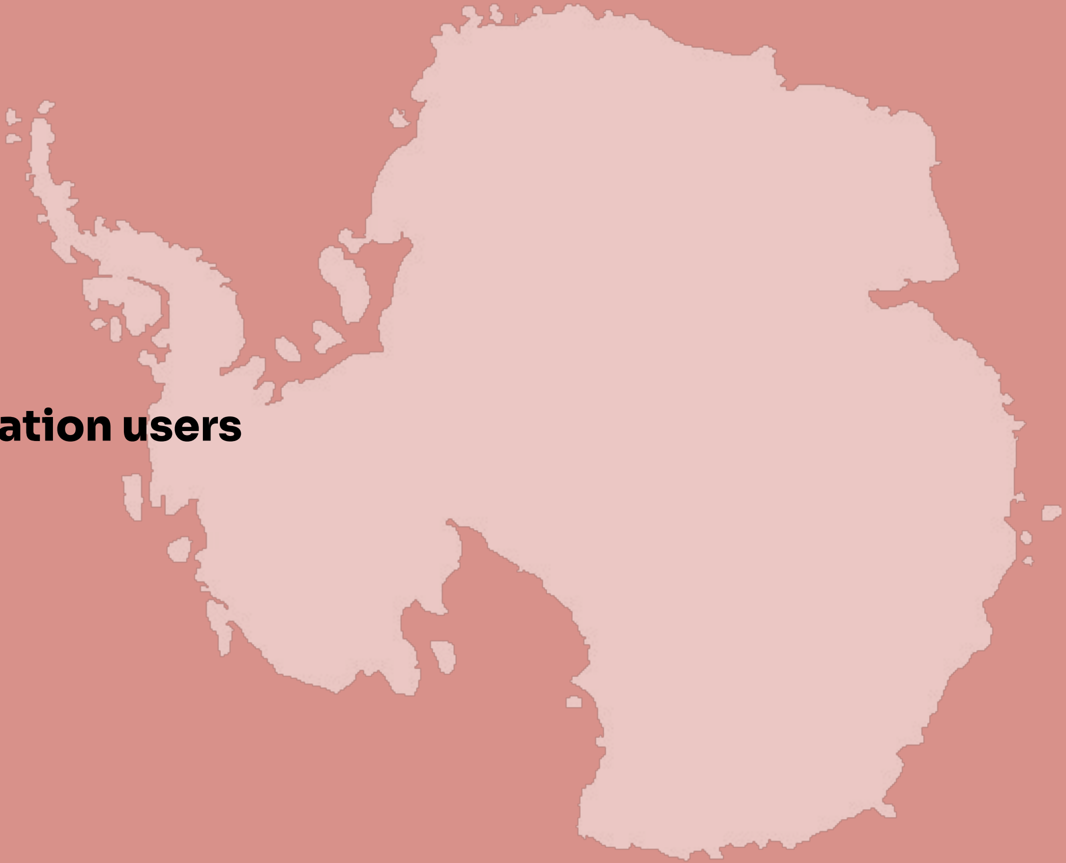
Troll Research Station
Midterm Presentation

Group 4

Anaelle Mathieu, Niels Koenraad, Luca Marchetti, Aashna Singh, Sohyun Park, Ilai Debazi

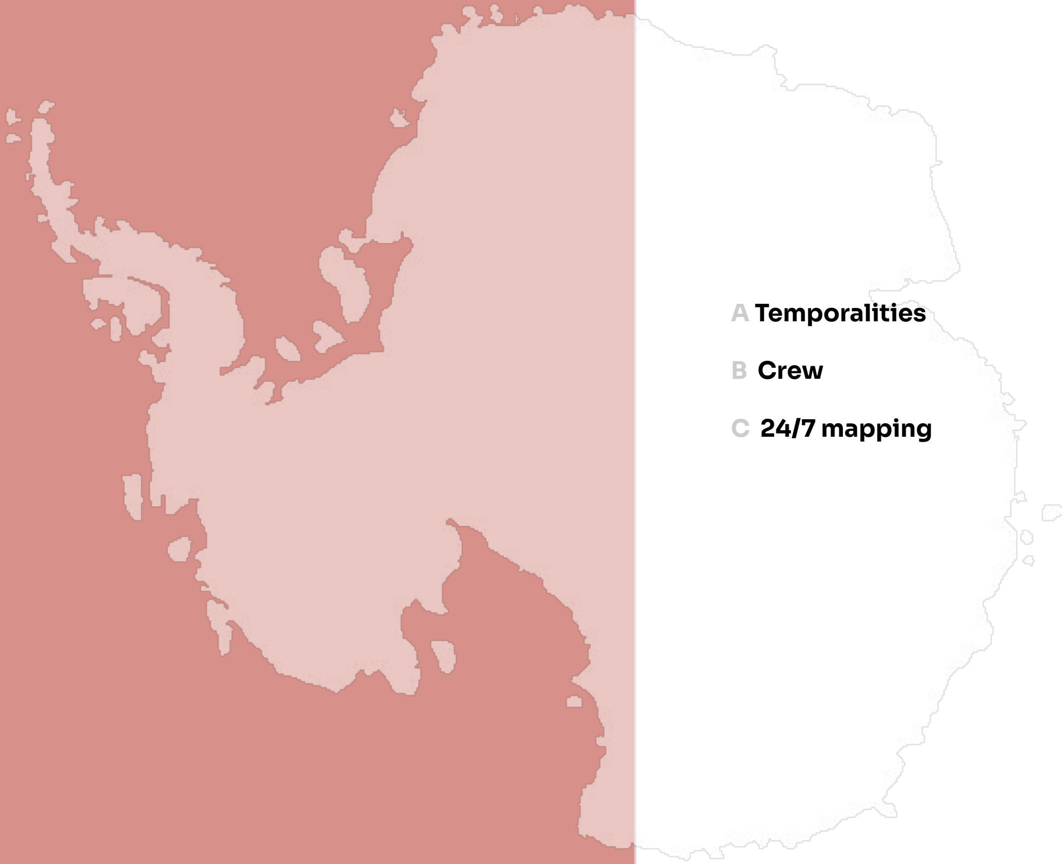
01

Research station users



01

Context



A Temporalities

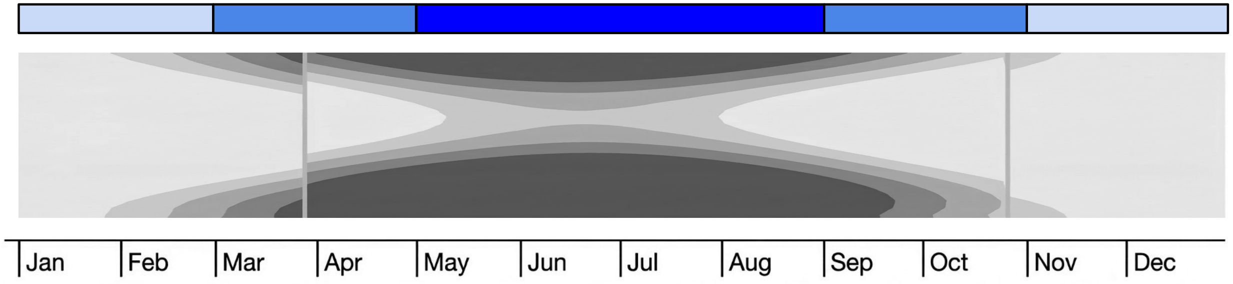
B Crew

C 24/7 mapping

Temporalities

- Antarctic Summer (4 months)
- Antarctic Winter (4 months)
- Transition (Spring+Autumn, 4 months)

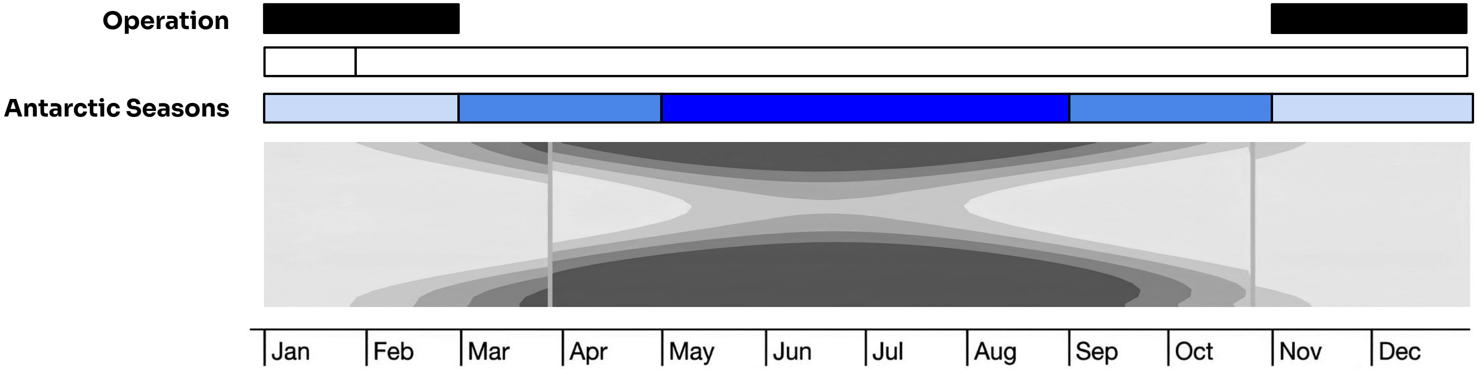
Antarctic Seasons



Temporalities

- ■ Summer-crew (40-70 people)
- □ Overwintering-crew (6 people)

- Antarctic Summer (4 months)
- Antarctic Winter (4 months)
- Transition (Spring+Autumn, 4 months)

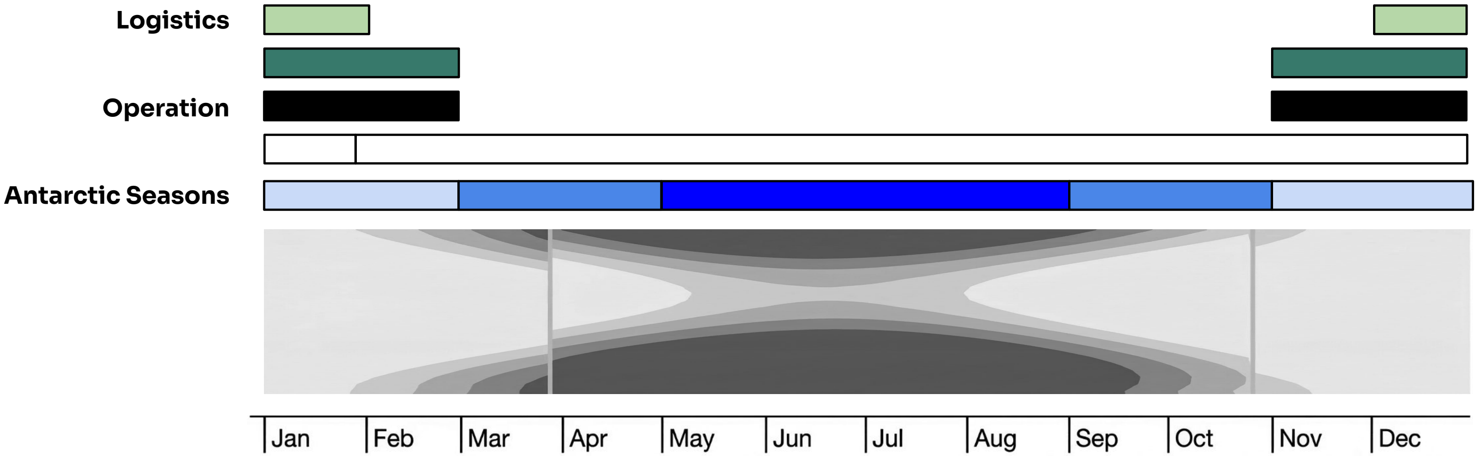


Temporalities

- Yearly re-supply ship
- Reachable via aircraft

- Summer-crew (40-70 people)
- Overwintering-crew (6 people)

- Antarctic Summer (4 months)
- Antarctic Winter (4 months)
- Transition (Spring+Autumn, 4 months)



Status quo

Overwintering crew

01
Station Leader

- Station Coordination
- Safety Oversight
- Norway & Mission Control Communication
- Operational Planning
- Emergency Decision-Making
- Infrastructure Inspections

02
Mechanical Engineer/Technician

- monitoring electrical systems
- maintaining sensors and scientific instruments
- troubleshooting electronic equipment
- supporting station technical infrastructure

03
Electrical Engineer/Systems Technician

- maintenance of generators
- heating and fuel systems
- repair of vehicles and mechanical equipment
- inspection of infrastructure
- workshop maintenance and spare part preparation

04
Atmospheric Scientist/ Meteorologist

- weather observations
- atmospheric measurements
- operation of monitoring instruments
- climate data analysis and reporting to international network

05
Cook/Logistics Coordinator

- meal preparation for crew
- management of food storage and inventory
- kitchen hygiene
- monitoring long-term food supplies

06
Communications + Medical officer

- operation of communication systems
- management of satellite links and IT infrastructure
- coordination of external communication
- medical monitoring and emergency response

Overwintering crew

01
Station Leader

Niels

+ Station Coordination
+ Safety Oversight
+ Norway & Mission Control Communication
+ Operational Planning
+ Emergency Decision-Making
+ Infrastructure Inspections

02
Mechanical Engineer/Technician

Sohyun

+ monitoring electrical systems
+ maintaining sensors and scientific instruments
+ troubleshooti electronic equipment
+ supporting station techni infrastructure

03
Electrical Engineer/Systems Technician

Luca

+ maintenance of

04
Atmospheric Scientist/ Meteorologist

Aashna

+ weather

05
Cook/Logistics Coordinator

Ilai

+ meal preparation for crew
+ management of food storage and inventory
+ kitchen hygiene
+ monitoring long-term food supplies

06
Communications + Medical officer

Anaelle

+ operation of communication systems
+ management of satellite links and IT infrastructure
+ coordination of external communication
+ medical monitoring and emergency response

1) Daily Rhythm
2) Spatial Needs
3) Lighting Preferences
4) Acoustic Sensitivity
5) Environmental Comfort
6) Storage demand and ownership
7) Conflict management
8) Individual Needs / Rituals:
9) Private Time Demand
10) Sleep Window

Occupancy of container

01
Station Leader

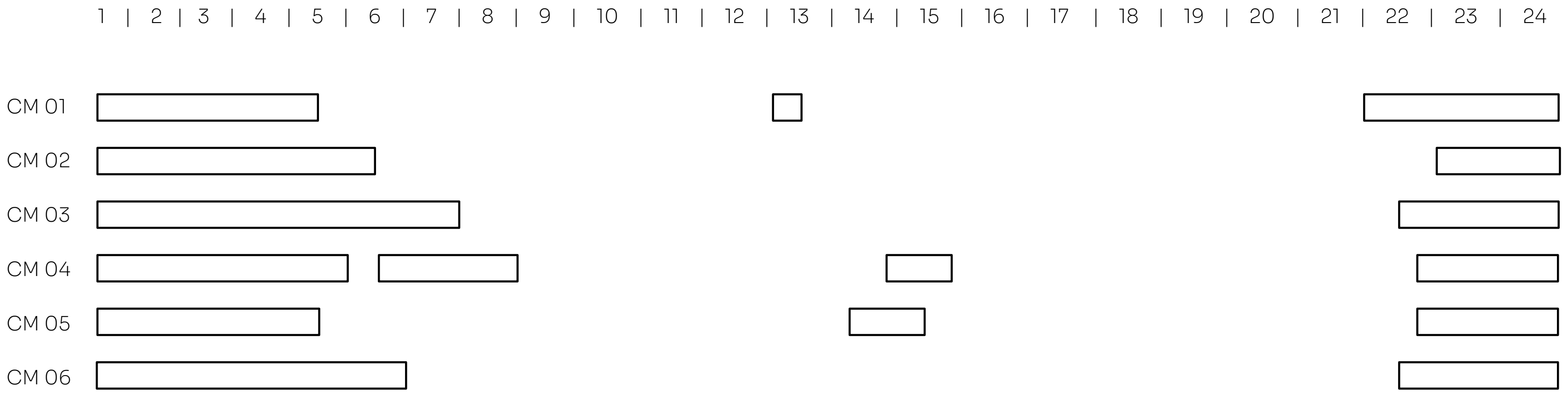
02
Mechanical Engineer/Technician

03
Electrical Engineer/Systems Technician

04
Atmospheric Scientist/ Meteorologist

05
Cook/Logistics Coordinator

06
Communications + Medical officer



Occupancy of container

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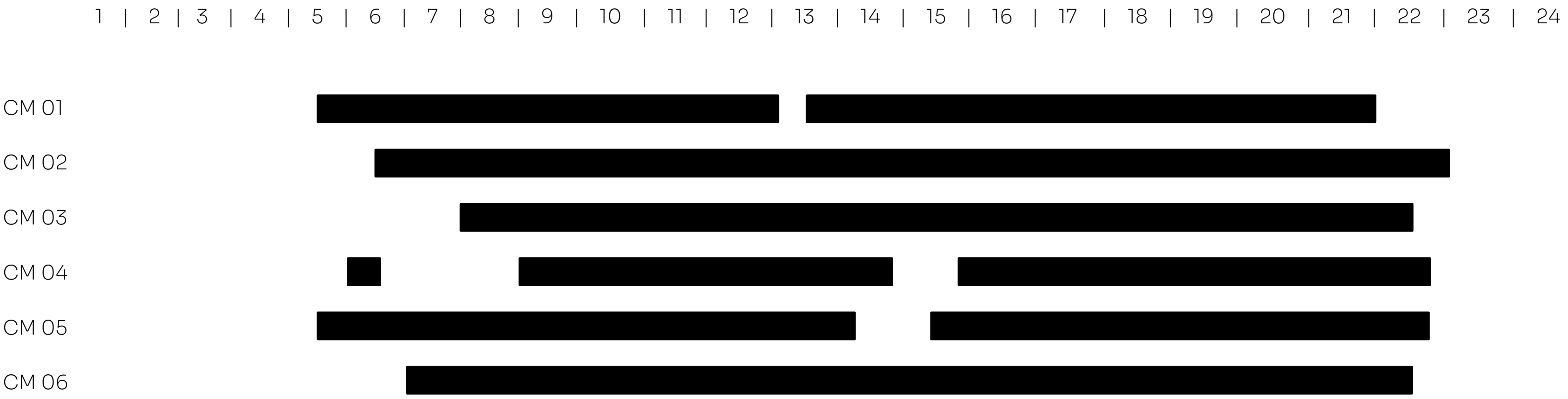

Occupancy of container

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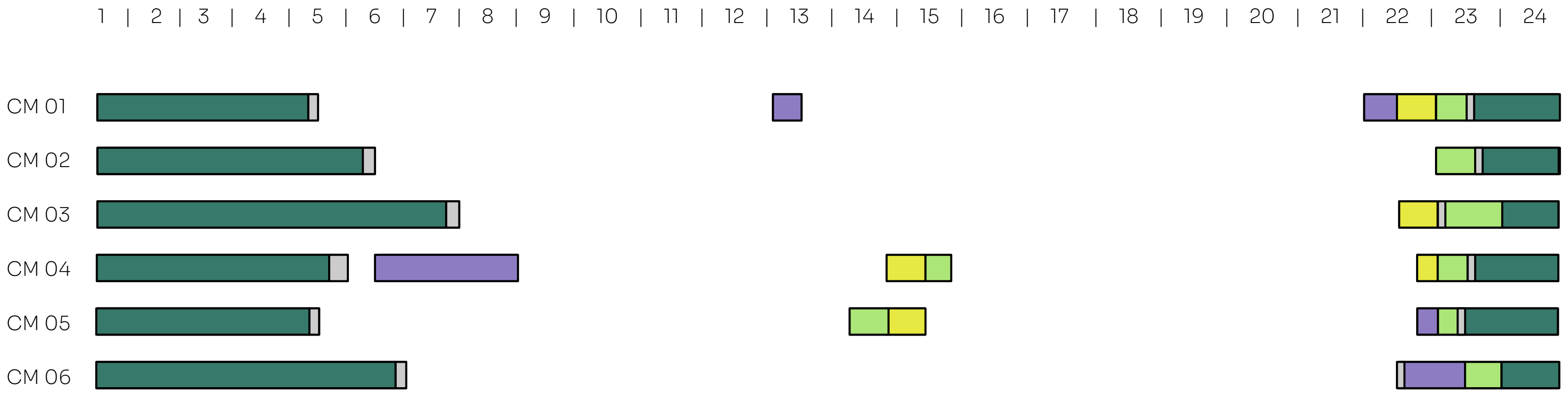

Micro-socializing Sleeping Resting Individual Task Personal storage

Occupancy of container

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Station Leader

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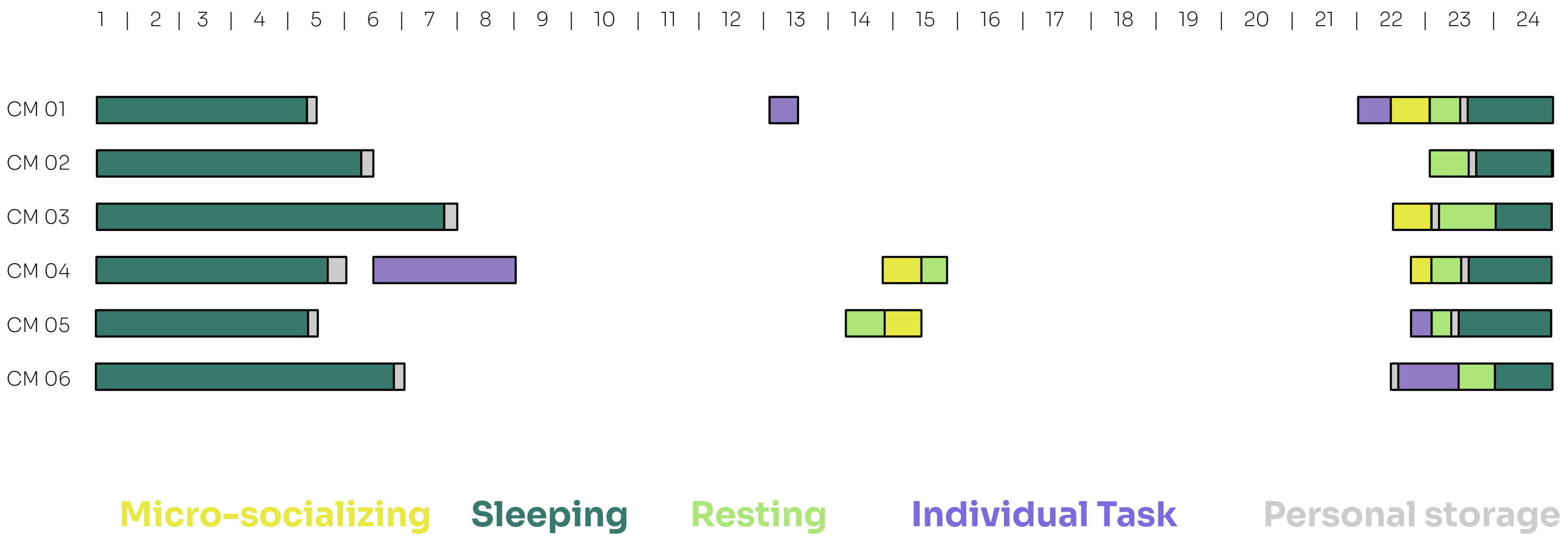


Conceptual idea

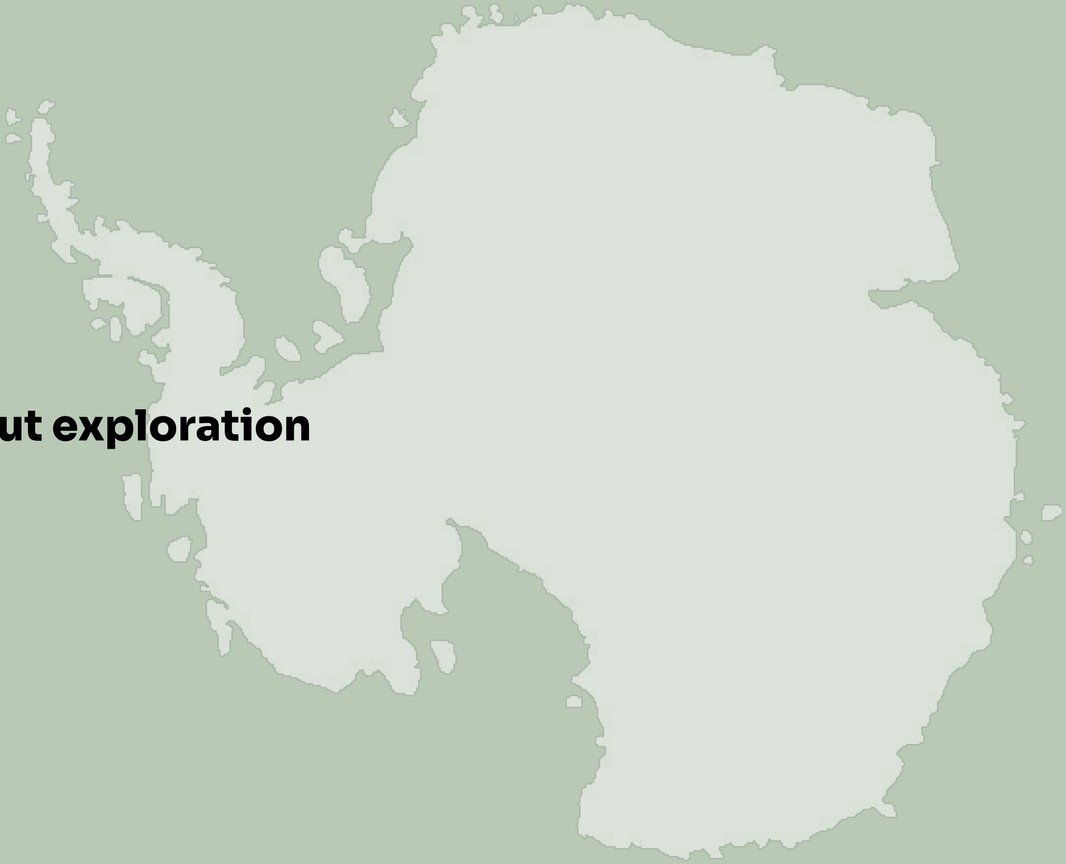
Not your workstation
Not your gym
Not your sauna
Not your dinner table
...

It's a place for micro-socialising and retreating,
It boosts you physiological and psychological well-being

In favour of you, your team and the mission.

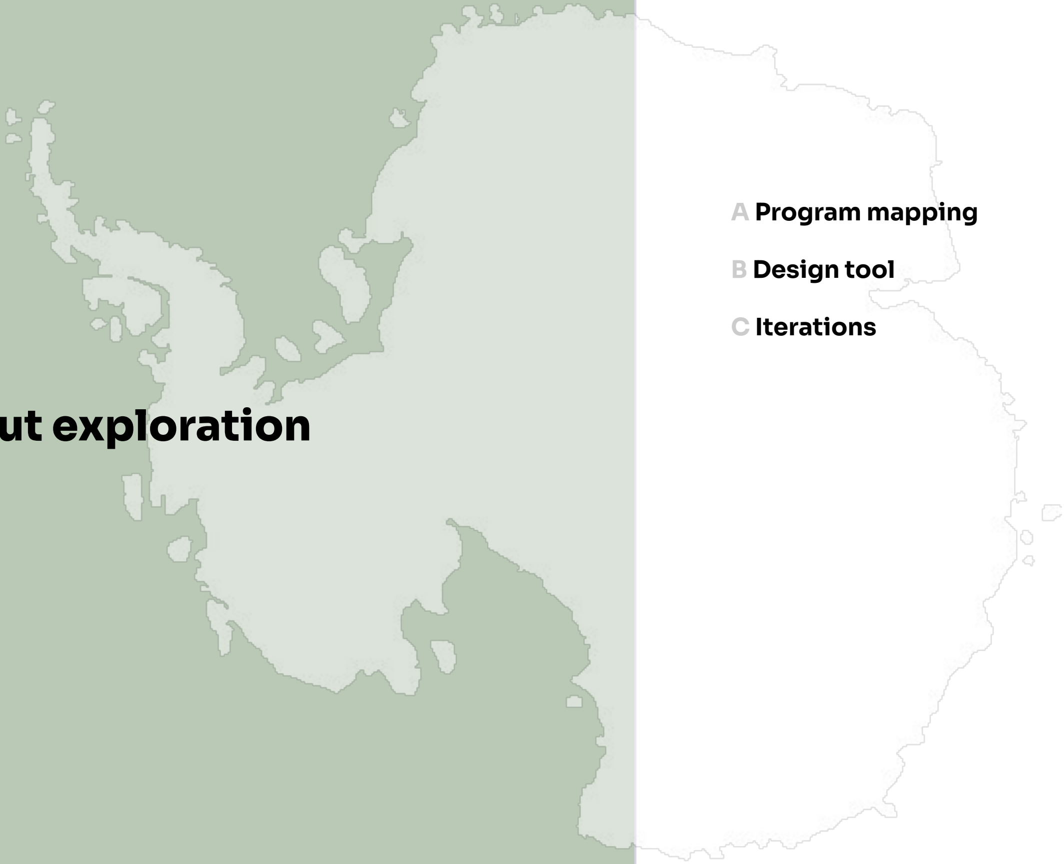
02

Spatial layout exploration



02

Spatial layout exploration



A **Program mapping**

B **Design tool**

C **Iterations**

Activities in the container

Shared space

Sleeping

Lounging

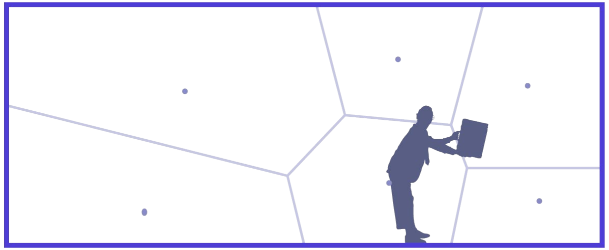
Individual Work

Storage

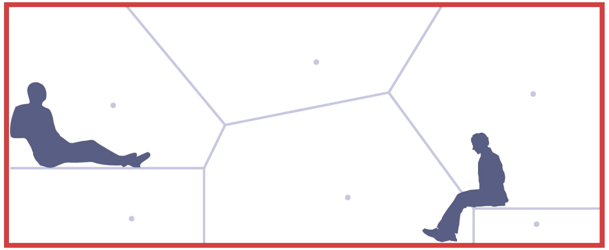
02 Spatial layout exploration **Design tool**

Plan
The plan is divided into a couple of sections through which the 3D voronoi can be manipulated

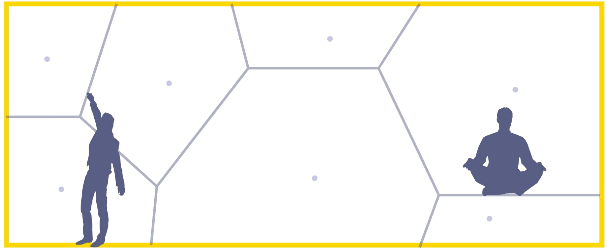
Section 01



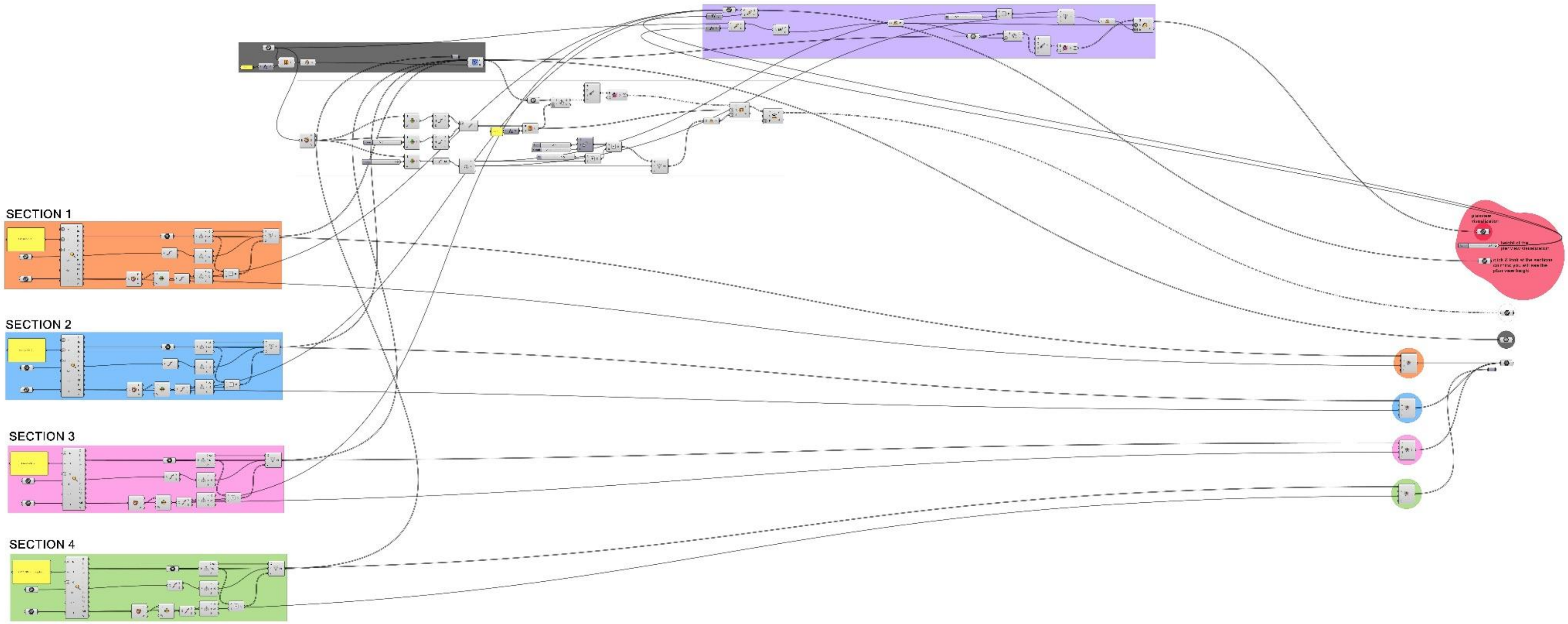
Section 02



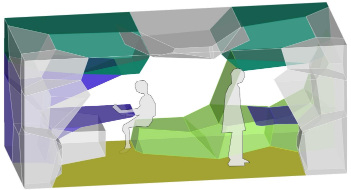
Section 03



02 Spatial layout exploration **Design tool**



02 Design Process **Iterations**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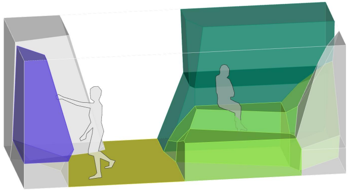
02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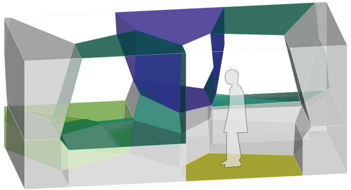
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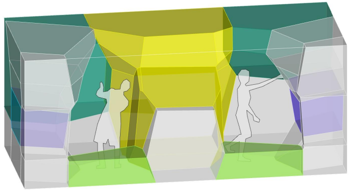
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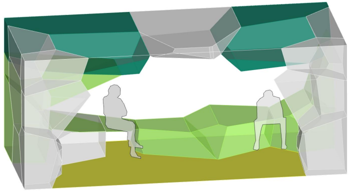
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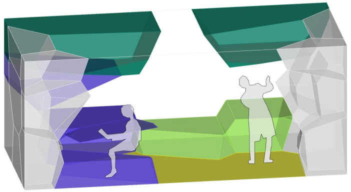
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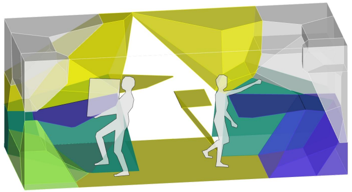
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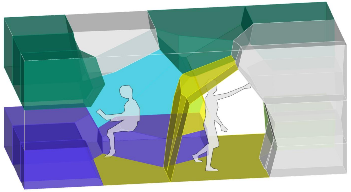
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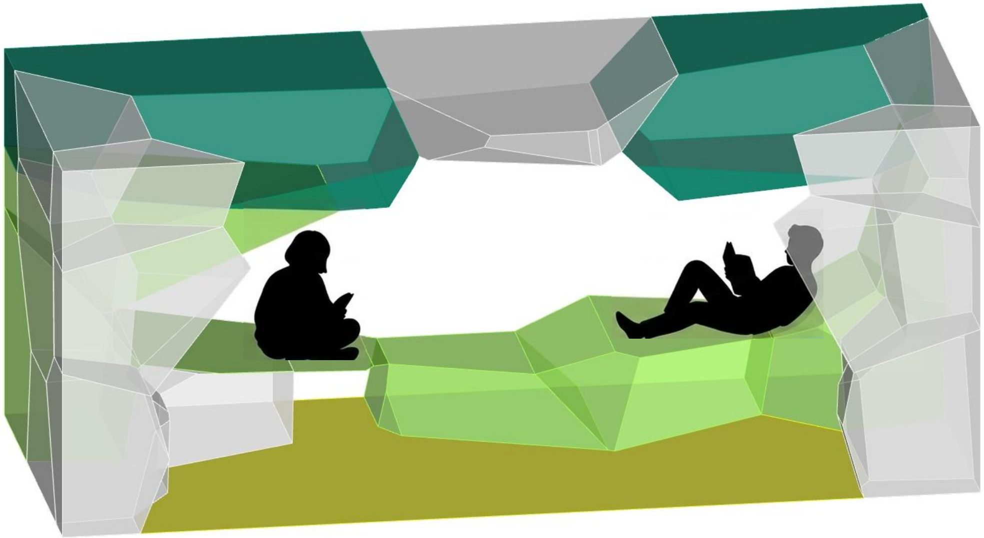
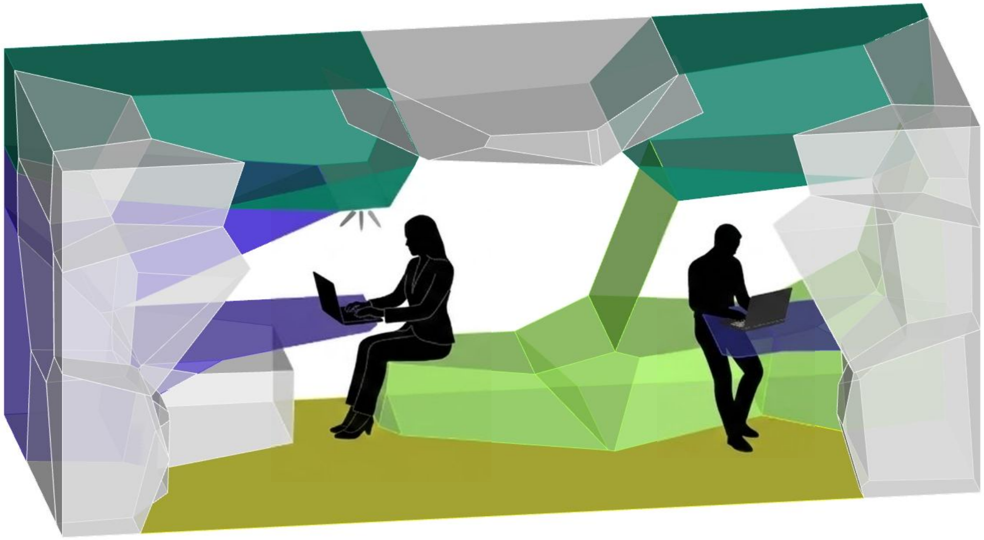
- **Shared space**
- **Sleeping**
- **Lounging**
- **Individual work**
- **Storage**

02 Design Process **Iterations**



- Shared space
- Sleeping
- Lounging
- Individual work
- Storage

 Iterations



- Shared space
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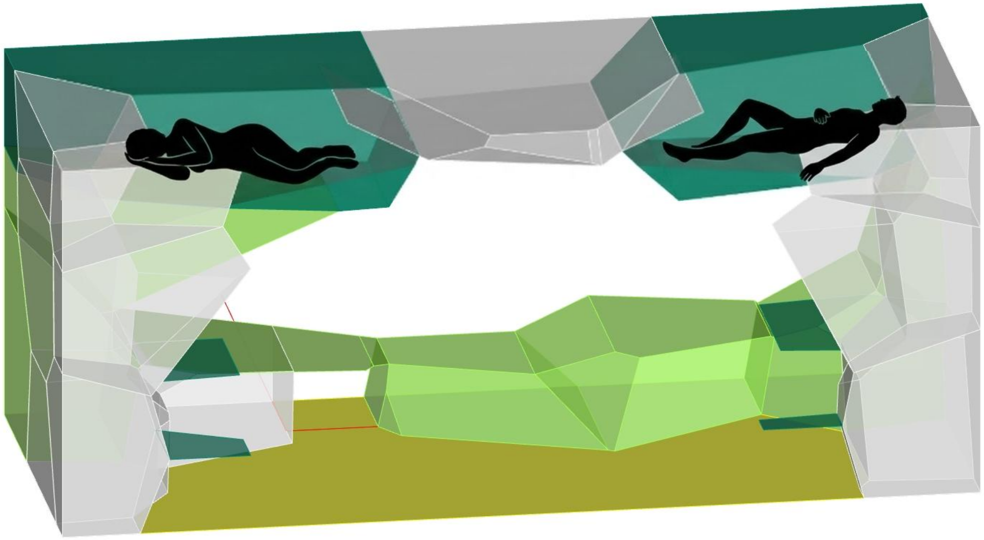


- Shared space
- Sleeping
- Lounging
- Individual work
- Storage

03

Design

03

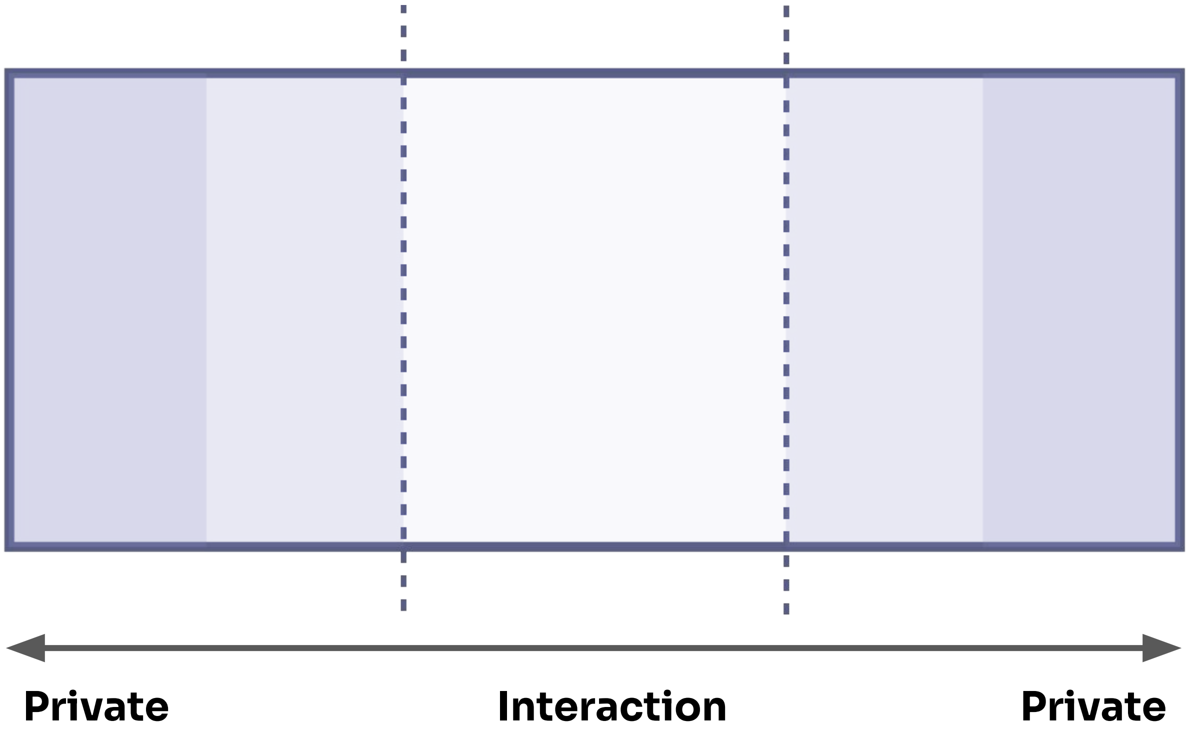
Design

A Spatial modulation & reconfigurability

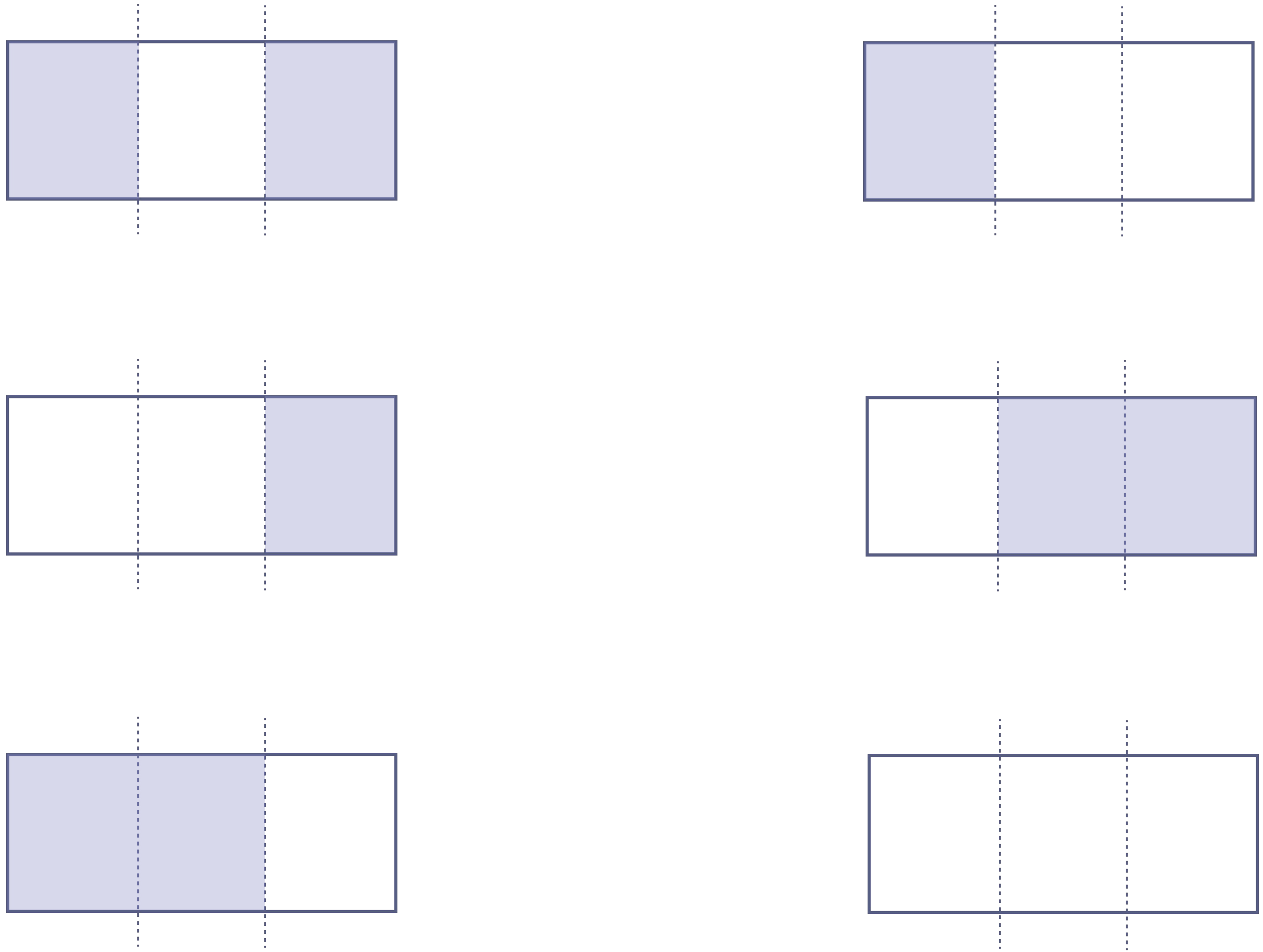
B 3D Voronoi

C Individual reconfiguration

Activities Gradient

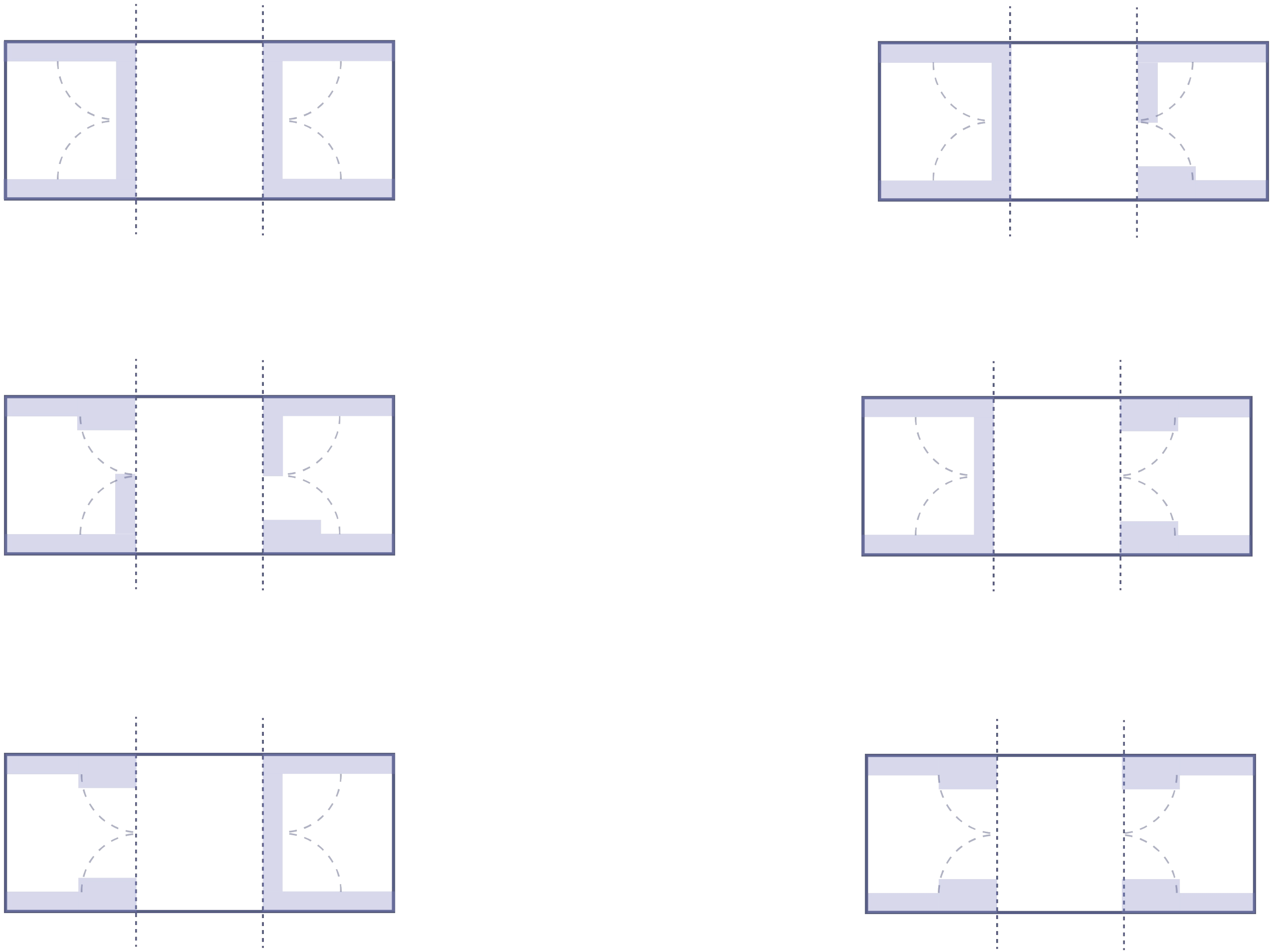


Scale 01 – Spatial modulation

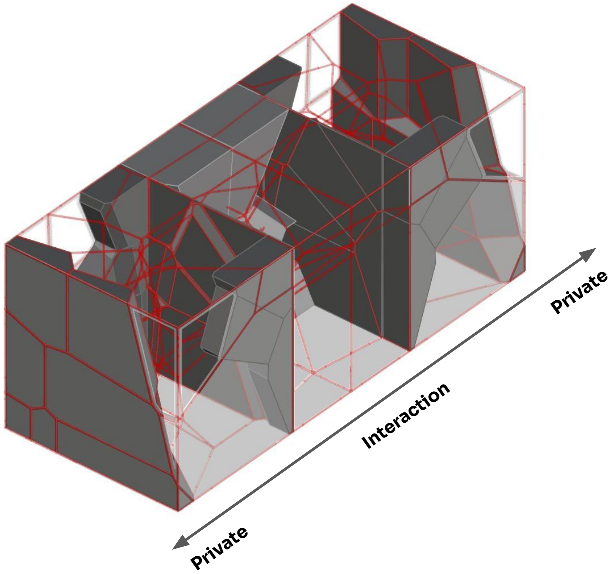


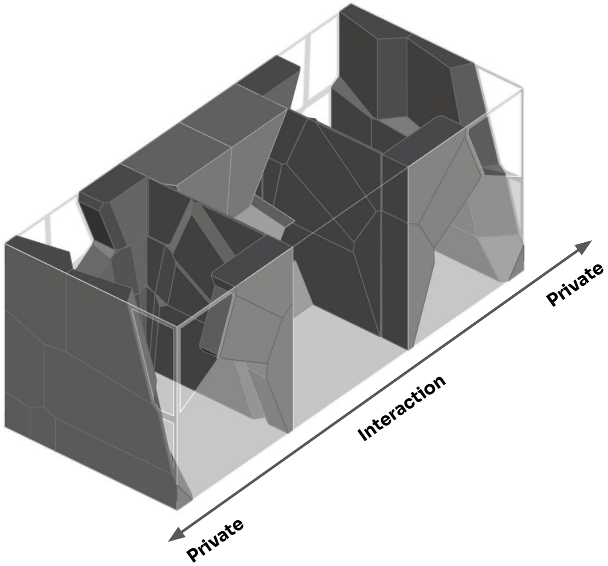
□ **Interaction**
■ **Private**

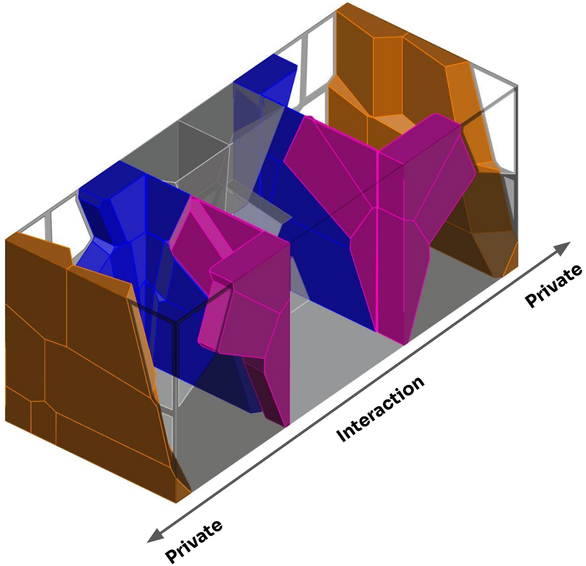
Scale 02 – Reconfigurability



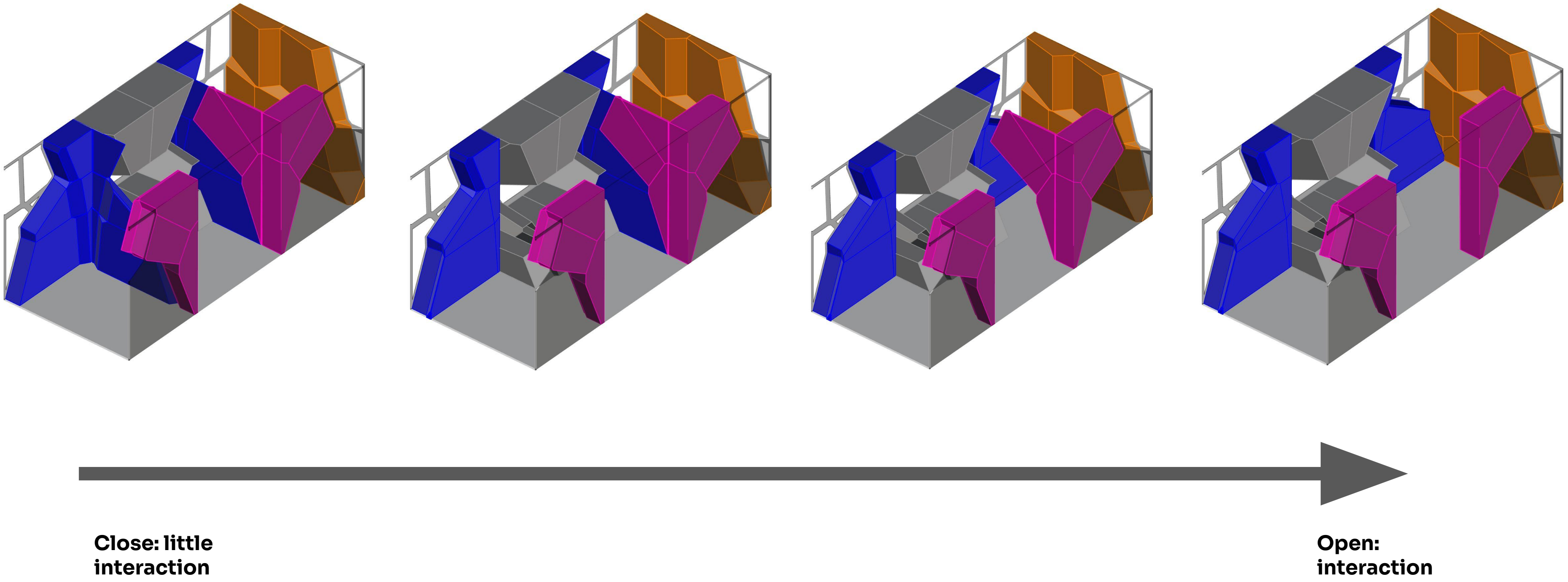
03 Design Scale 02 – from voronoi to container



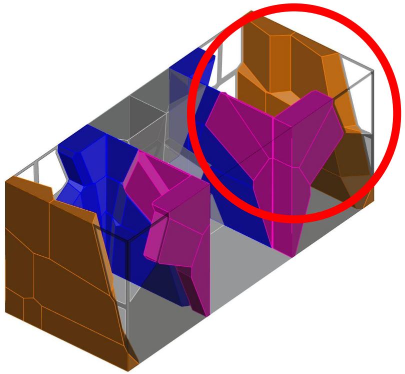


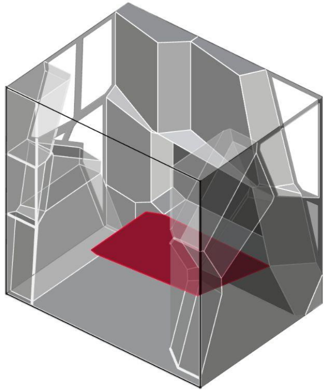


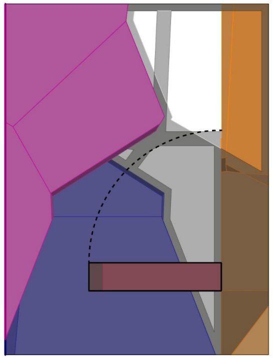
03 Design Scale 02 – Reconfigurability



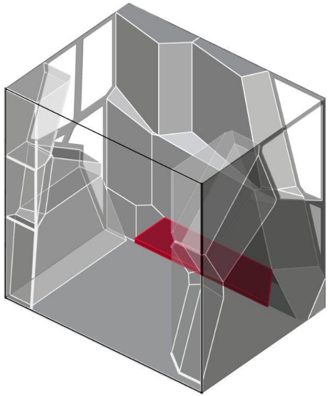
03 Design **Scale 02 - Reconfigurability**

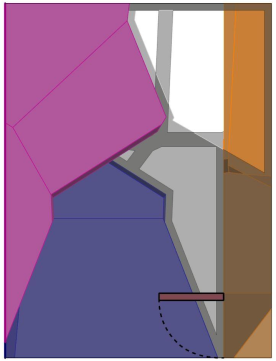






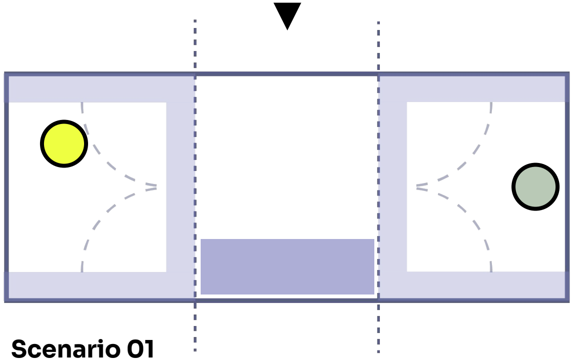
Reconfigurable bed



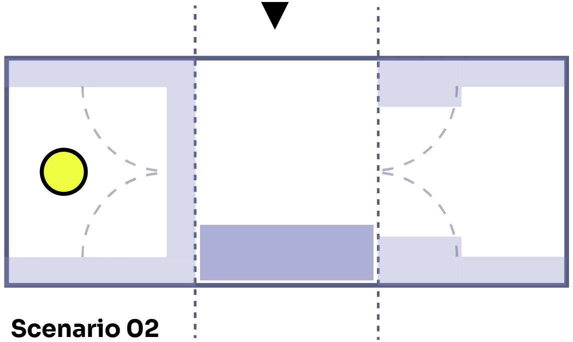


Reconfigurable lounge

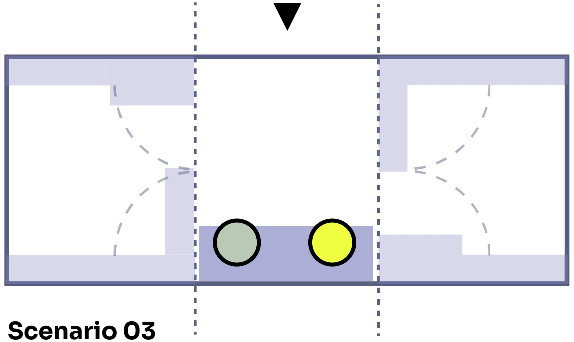
Scale 02 – Individual reconfiguration



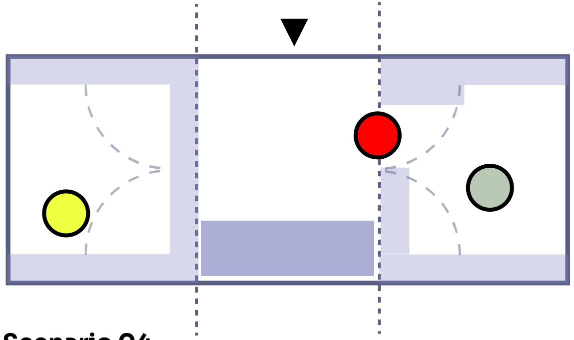
Scenario 01
7:00 AM
Bob and Sigrid just woke up and are getting out of bed without disturbing each other



Scenario 02
12:00 PM
Bob is taking a nap

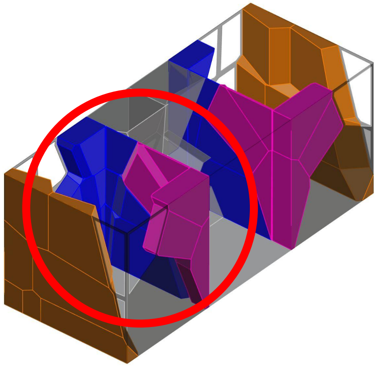


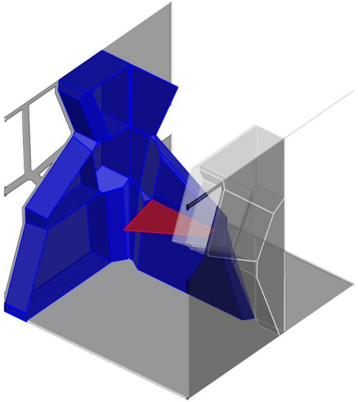
Scenario 03
12:30 PM
Bob just woke up, Sigrid and Bob have a briefing together in the common space.



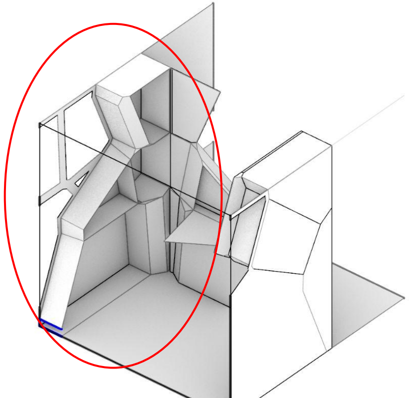
Scenario 04
21:30 PM
Bob is calling his partner. Sigrid is having a friend over

03 Design **Scale 02 - Reconfigurability - wall**



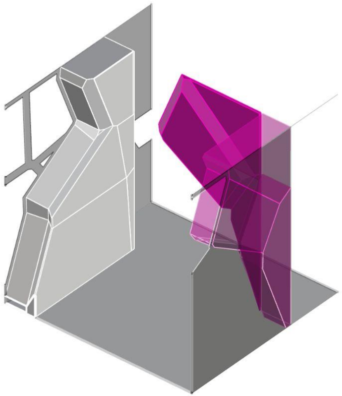


Desk



Desk storage

Reconfigurable wall 1: workstation



Reconfigurable wall 2: wardrobe & privacy screen

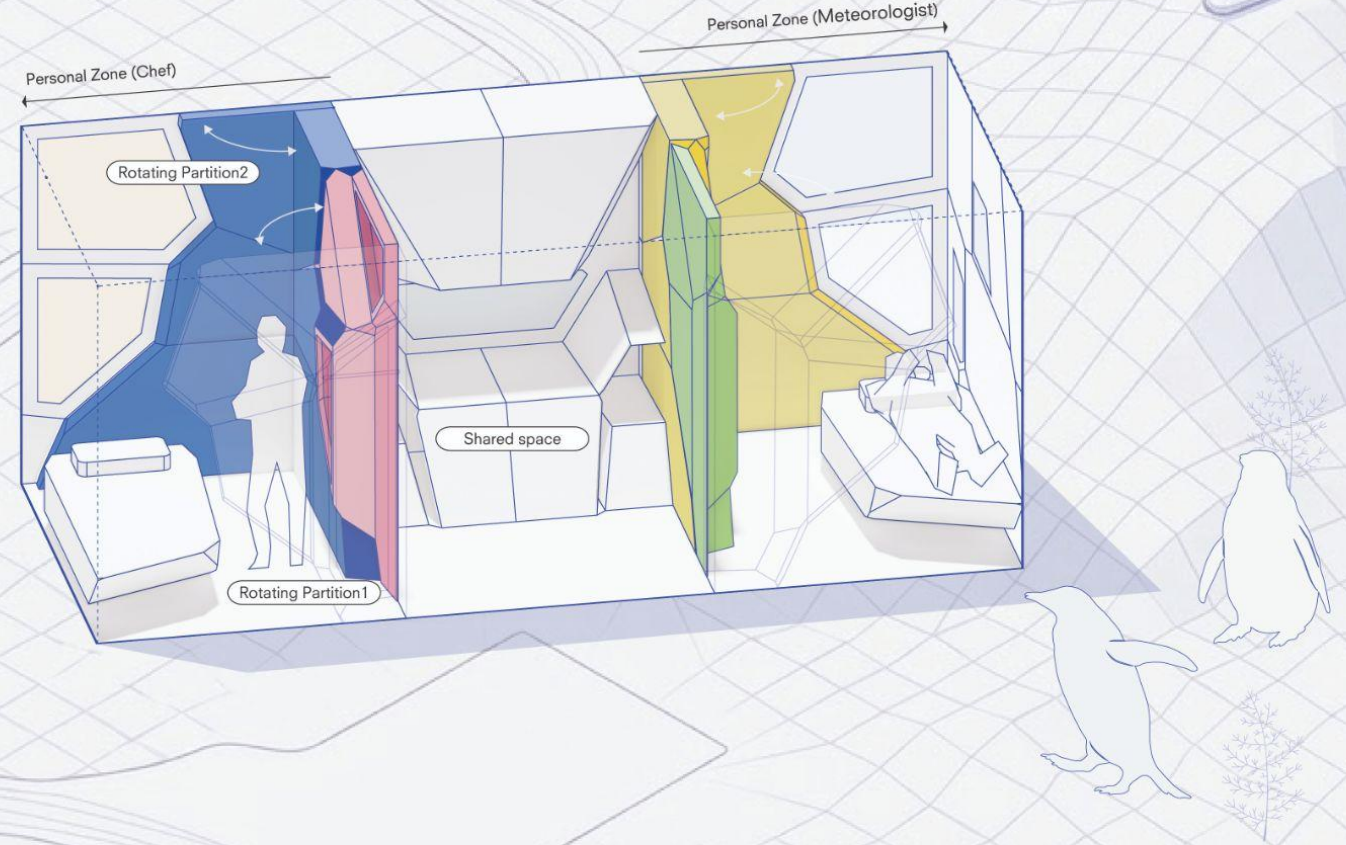
 Scale 03 - Reconfigurable Element

(3) Scale

Zoom in on 1 Elemtent
(partitioning wall= most
important spatial element)

Folding table,
Wardrobe
Bed
Workstation

Anaelle



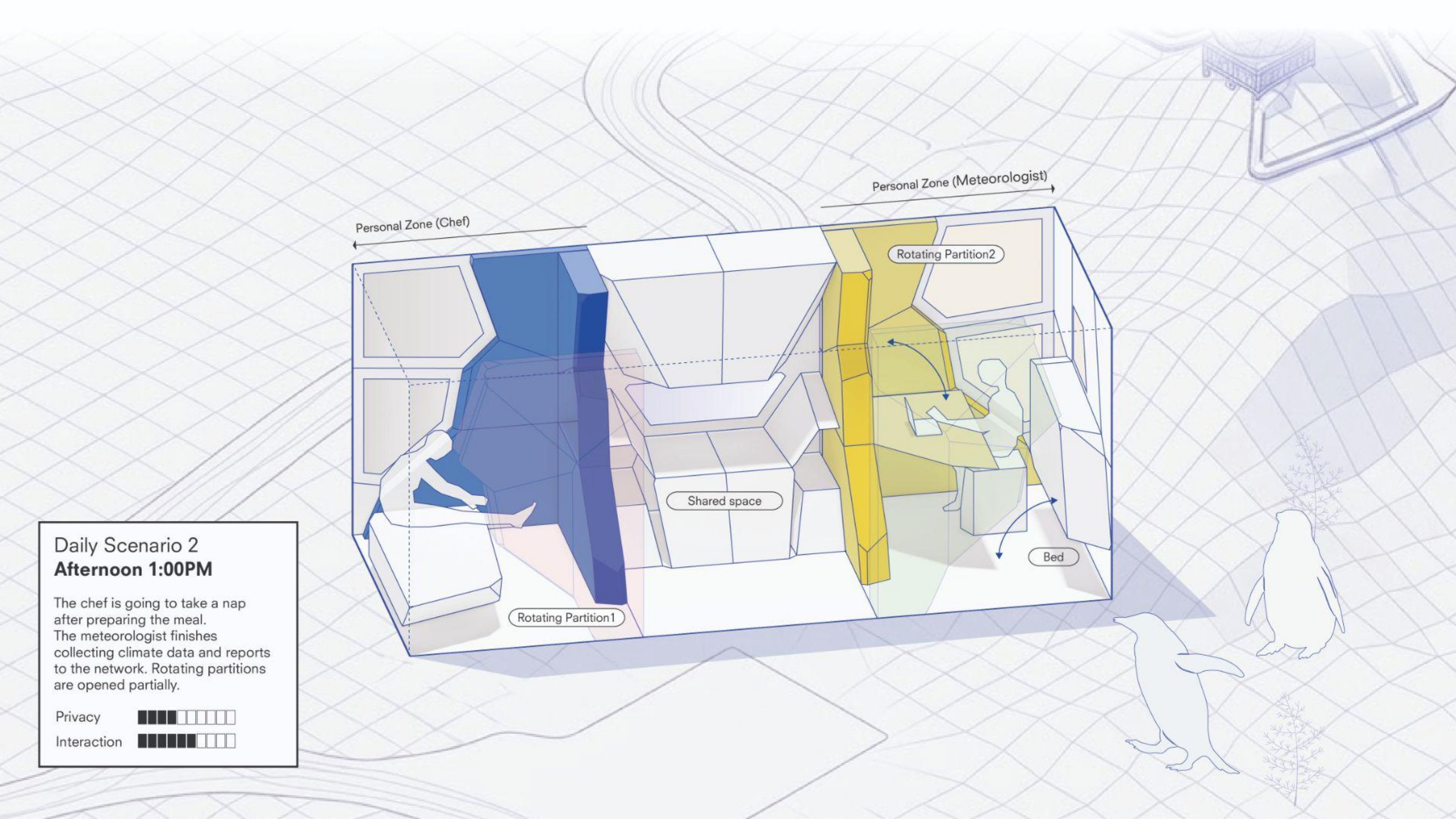
Daily Scenario 1

Morning 5:00AM

The chef wakes up and gets dressed at the wardrobe. The meteorologist sharing the room is still asleep. All rotating partitions are closed, keeping individual privacy

Privacy ■■■■■■■■■□

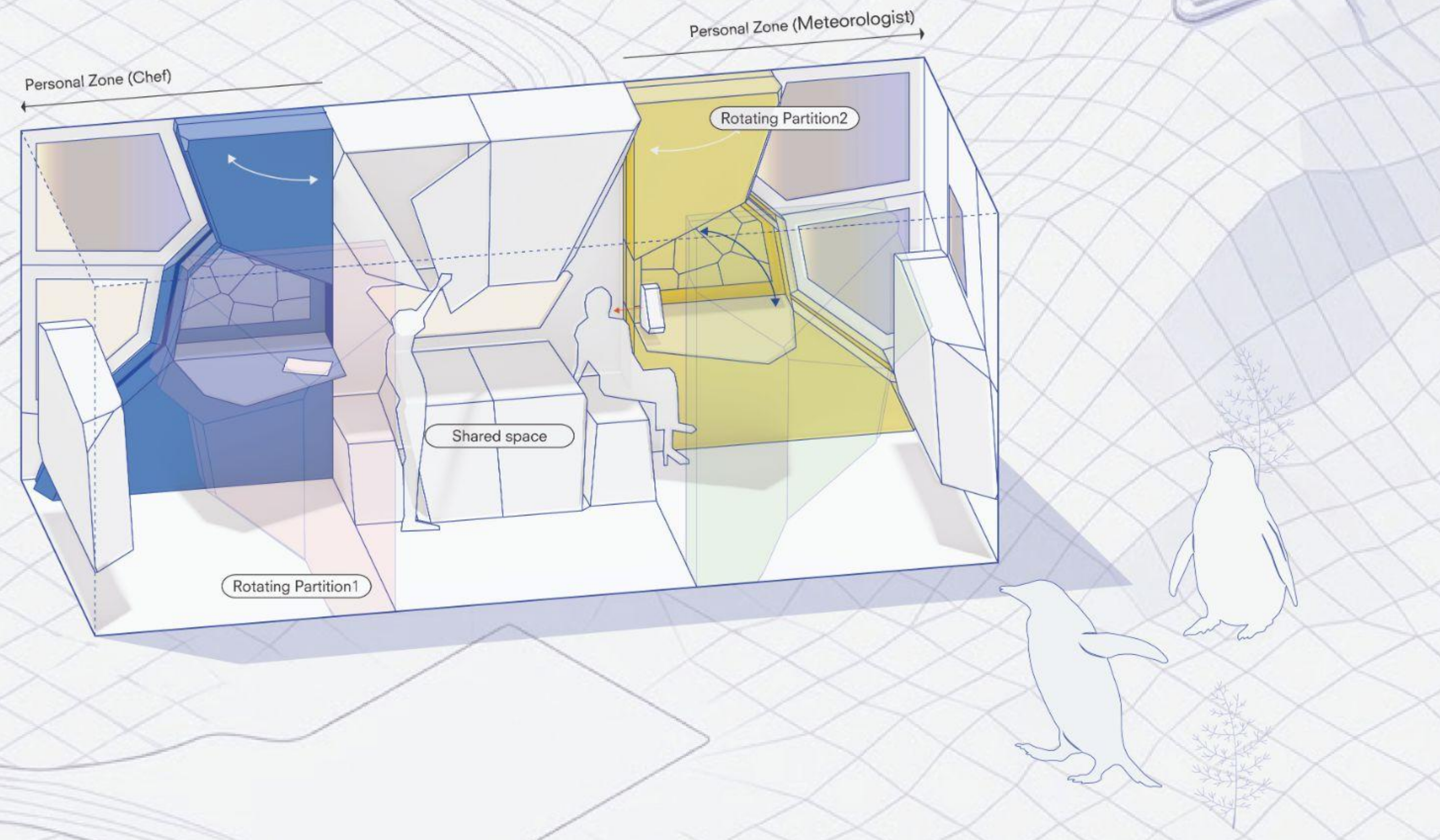
Interaction ■■■□□□□□□□



Daily Scenario 2
Afternoon 1:00PM

The chef is going to take a nap after preparing the meal. The meteorologist finishes collecting climate data and reports to the network. Rotating partitions are opened partially.

Privacy ■■■■□□□□□□
Interaction ■■■■■■□□□□



Daily Scenario 3
Evening 8:00PM

After finishing all daily tasks, two residents take time to rest.
The meteorologist enjoys lighting therapy, and the chef opens the shelf to look for a camera.

Privacy
Interaction

04

Lighting and AI integration

04

Lighting and AI integration

A **Integration of Light in Design**

- Skylight (ceiling)
- Light as a Spectacle (windows and walls)
- Individual Light
- Light Therapy

B **Goals**

C **Training the model**

- Scatter plots
- Model training
- Evaluation of model
- Visualisation of model

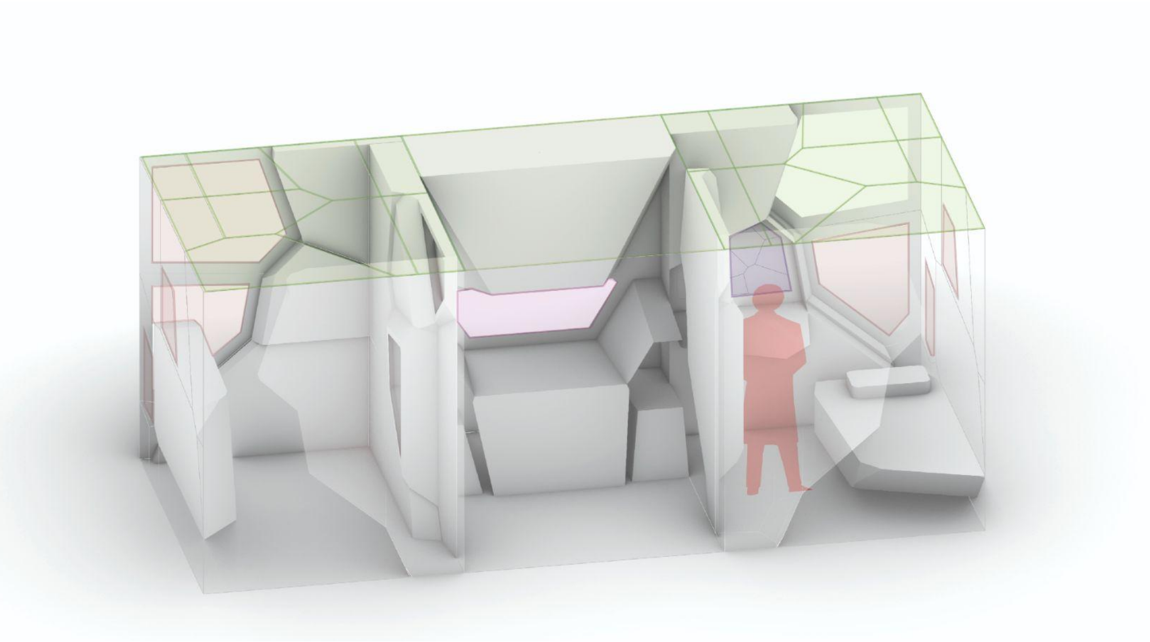
Lighting types

(I) Skylight

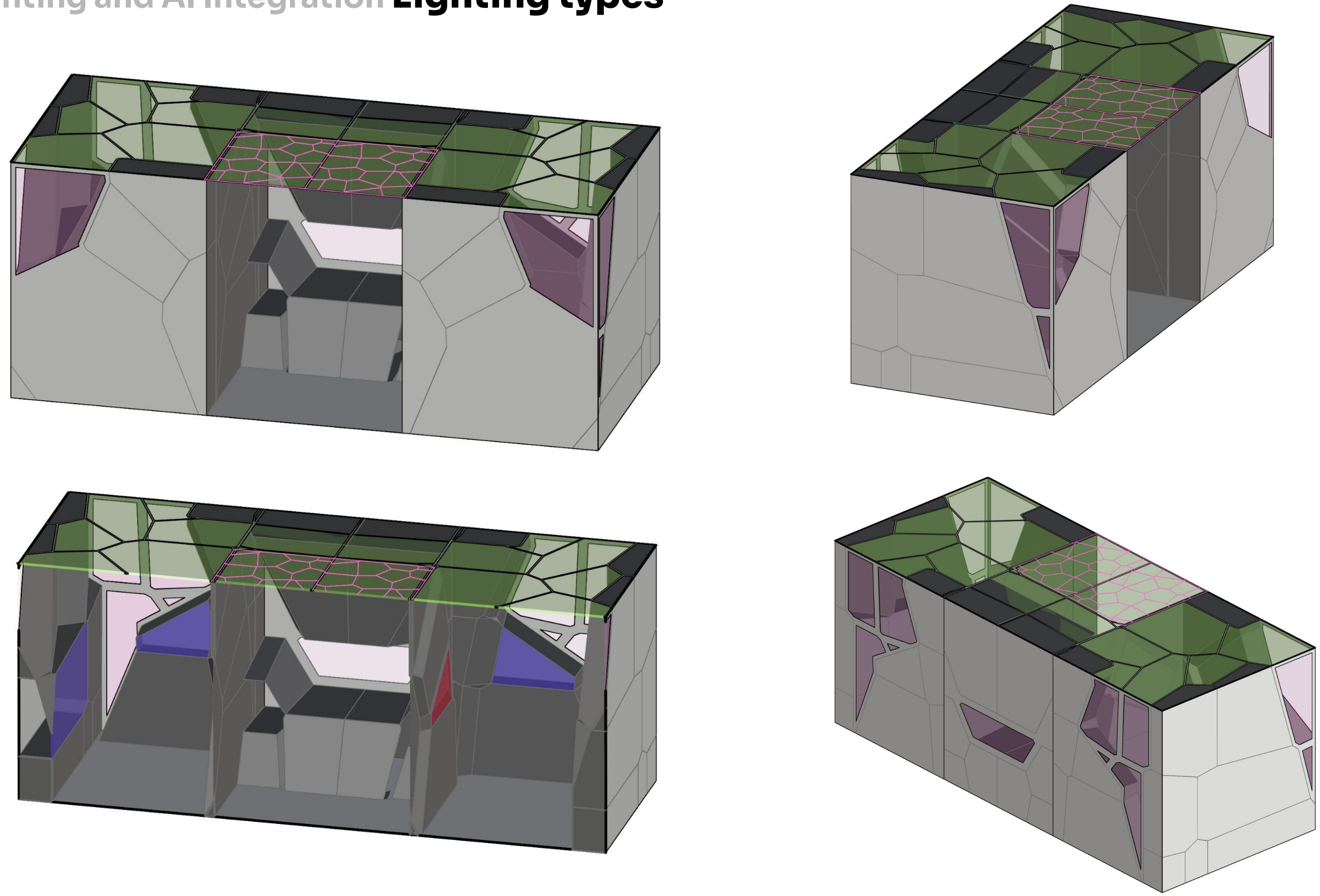
(II) Light as Spectacle

(III) Individual Lighting

(IV) Light Therapy



04 Lighting and AI Integration **Lighting types**



(I) Skylight

(II) Light as Spectacle

(III) Individual Lighting

(IV) Light Therapy

 Lighting types

(I) Skylight

+ Human Activity Recognition (HAR)
+ Reacting to a daylight cycle
+ Performative Uses (i.e. Wind blowing through leaves

(II) Light as Spectacle

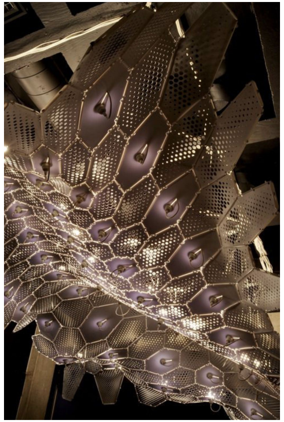
+ Computer Vision (CV) translates outdoor environment into spectacle
+ Performative
+ Cognitive Stimulation and Psychological orientation
+ Shows live from outside

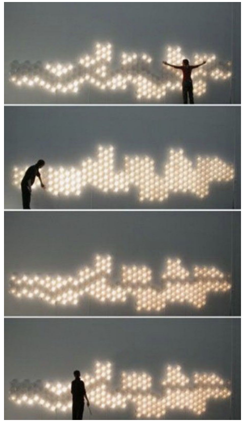
(III) Individual Lighting

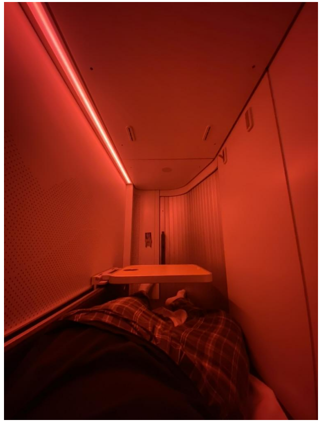
+ Autoregressive (AR)
+ Personalized circadian cycle
+ Personalized atmospheric lighting
+ Reaction to physiological factors eg. heart rate

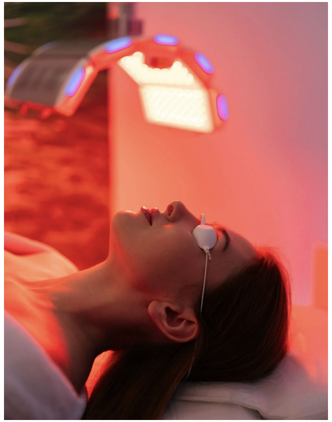
(IV) Light Therapy

+ Red-light (630–850nm) for recovery + mood
+ 10,000 lux daylight therapy for winter activation









Summary of tutorial

Supervised learning:

+ Input variables / features (weather data and physiological data)
+ Output values / labels (lighting condition generation)

Data Visualization:

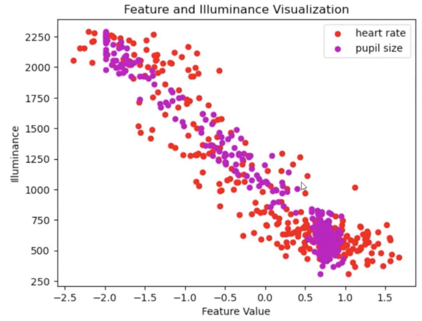
+ Visualizing data sets using scatter plots (show correlations in the data)
+ Understanding the data before training the model for more accuracy

Training the model:

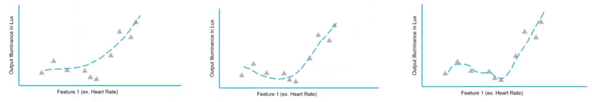
+ Supervised learning regression: learning to predict from data
+ Poor or limited datasets can cause the model to learn incorrect patterns and produce unreliable results

Evaluation of model performance:

+ R square score (MSE, MAE)
+ Evaluation of how well the model is trained to reflect the data accurately



Supervised Learning Regression



Goals for AI integration

01: Circadian Rhythm Preservation

+ Simulates a full Delft daylight cycle inside the container
+ Any date selectable — captures seasonal variation across the year
+ Maintains sleep, melatonin and mood cycles during polar night

(I) Skylight

(II) Light as Spectacle

02: Environmental Energy Optimisation

+ Outdoor conditions drive indoor light levels automatically
+ Bright sun outside —-> dims indoor lights
+ Heavy cloud / polar darkness —-> boosts indoor light
+ Minimises energy use

(I) Skylight

03: Personalised Physiological Response

+ Neural network predicts ideal light from body signals
+ High stress detected —-> warm dim light to lower heart rate
+ Balanced state —-> model prediction applied directly
+ Lighting actively responds to each researcher's biological state

(III) Individual Lighting

(IV) Light Therapy

04: Ability to choose own lighting

+ Overrides system lighting for user needs (Have 4 simulation modes for users to choose from - or full RGB range)

(I) Skylight

(III) Individual Lighting

Step 1: Data groupings and scatter maps

DATA

A

WEATHER

Outdoor temp,direct normal radiation, rel humidity, diffuse, normal radiation, global horizontal radiation,infrared radiation, direct normal Illumination diffuse_horizontal illumination, global horizontal illumination, total sky cover

B

PHYSIOLOGICAL

Hrv rmssd ms, heart rate bpm, pupil mm, blink rate per min, skin conductance uS, Respiratory rate bpm

GROUP 1: SOLAR RADIATION FEATURES:

Direct normal radiation, diffuse normal radiation, global horizontal radiation

(Measures total solar energy form different angles)

GROUP 2: VISIBLE LIGHT FEATURES

Direct normal illumination, diffuse horizontal illumination, global horizontal illumination

(Visible portion of light to human eye)

GROUP 3: ATMOSPHERIC CONDITIONS

Outdoor temp, relative humidity, infrared radiation, total sky cover

(overall atmosphere and weather)

GROUP 4: PHYSIOLOGICAL STRESS INDICATORS

HRV rmssd ms, heart rate, skin conductance, respiratory rate

(reflect stress and nervous system)

GROUP 5: EYE RESPONSE METRICS

Pupil diameter, blink rate

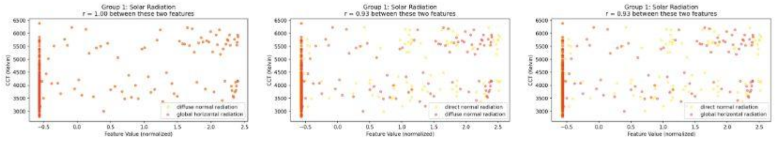
(visual strain and fatigue measurements)

 Training the model

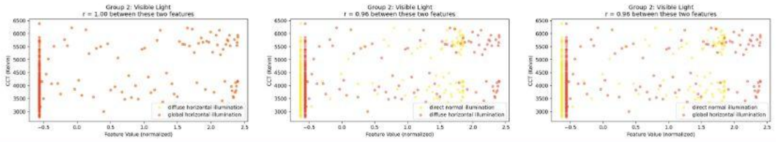
Step 1: Data groupings and scatter maps

Between CCT (kelvins) and features (inputs(weather data+physiological data))

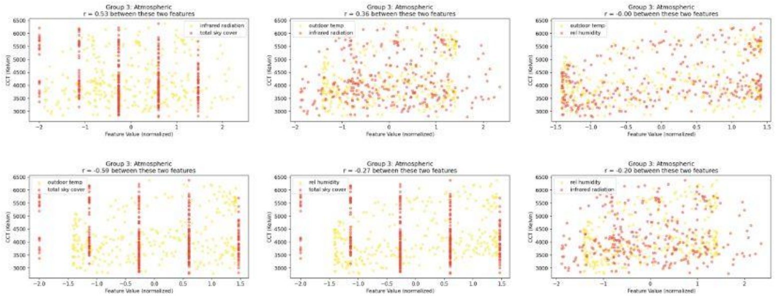
GROUP 1: SOLAR RADIATION FEATURES



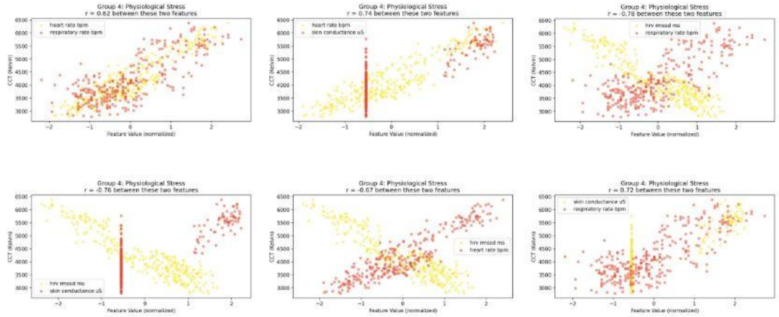
GROUP 2: VISIBLE LIGHT FEATURES



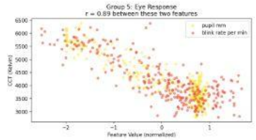
GROUP 3: ATMOSPHERIC CONDITIONS



GROUP 4: PHYSIOLOGICAL STRESS INDICATORS



GROUP 5: EYE RESPONSE METRICS

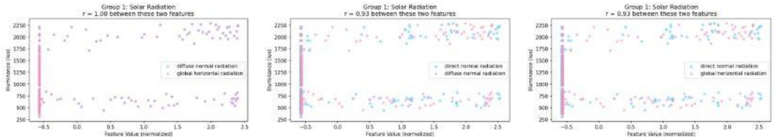


04 Lighting and AI Integration **Training the model**

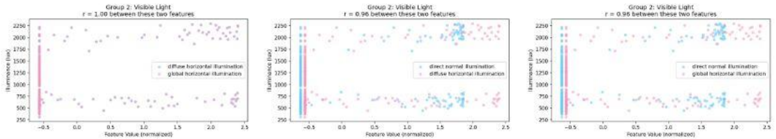
Step 1: Data groupings and scatter maps

Between Illuminance and features (inputs(weather data+physiological data))

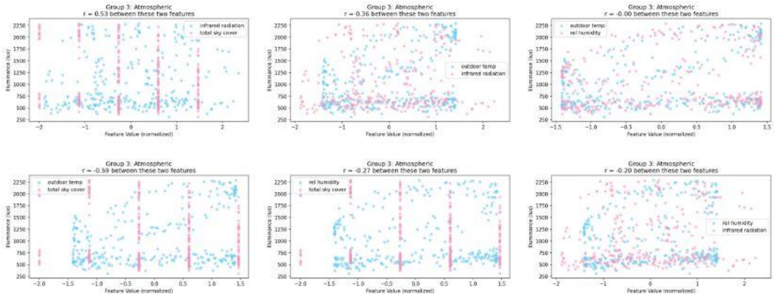
GROUP 1: SOLAR RADIATION FEATURES



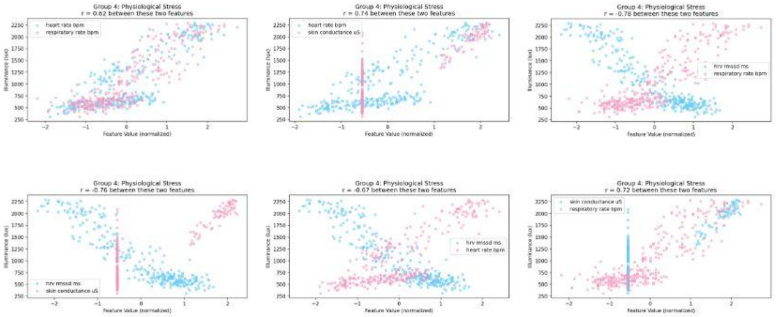
GROUP 2: VISIBLE LIGHT FEATURES



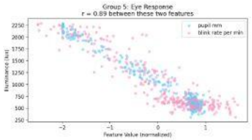
GROUP 3: ATMOSPHERIC CONDITIONS



GROUP 4: PHYSIOLOGICAL STRESS INDICATORS



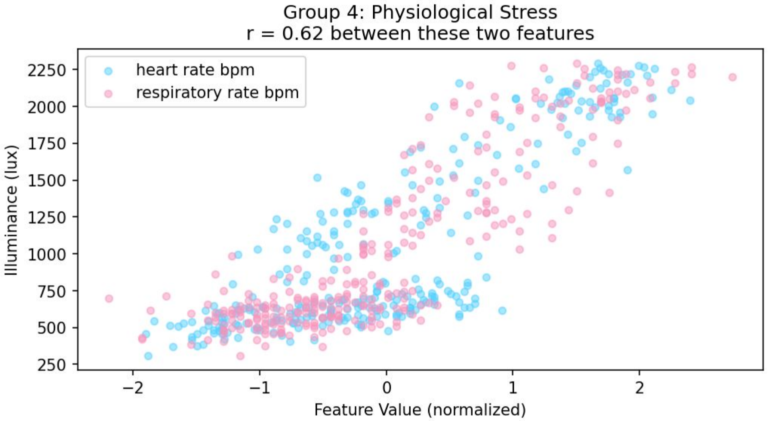
GROUP 5: EYE RESPONSE METRICS

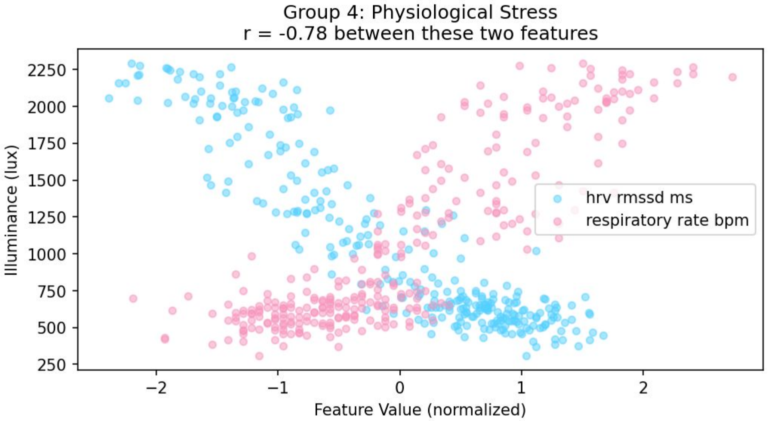


Training the model

Step 1: Data groupings and scatter maps

Between Illuminance and features (inputs(weather data+physiological data))





04 Lighting and AI Integration **Training the model**

Step 1: Data groupings and scatter maps

Summary of findings

Group 01: Solar Radiation features
- All features show similar trends
- Keep **Direct normal radiation** (Most direct measurement of incoming solar energy)

Group 02: Visible light features
- All features show similar trends
- Keep **Direct normal illumination** (Visible spectrum)

Group 03: Atmospheric conditions
- Weak to moderate correlations
- Keep **Outdoor temp and Total sky cover** (Most important for energy savings mode)

Group 04: Physiological stress indicators
- Weak to moderate correlations - keep more features
- Keep **hrv rmssd ms, heart rate bpm, skin conductance** (most relevant features and capture opposite ends of spectrum)

Group 05:
- Similar trends
- Keep **pupil size** (most able to reflect lighting)

Final features model was trained on:
- Direct Normal Radiation
- Direct Normal Illumination
- Outdoor Temp
- Total Sky Cover
- HRV RMSSD MS
- Heart Rate BPM
- Skin Conductance
- Pupil size

 Training the model

Step 2: Training the model

```
[25]: #Remove or add features to the weather and physiological features list here usein the All Feature and Label Options list above as reference,

#Weather Features
weather_data_all = ['outdoor_temp', 'direct_normal_radiation', 'direct_normal_illumination', 'total_sky_cover']

#Physiological featrues
physiological_data_all = ['hrv_rmssd_ms', 'heart_rate_bpm', 'pupil_mm', 'skin_conductance_uS']
#Label Options
illuminance = 'illuminance_lux'
cct = 'cct_kelvin'
```

```
# Import train_test_split function
from sklearn.model_selection import train_test_split

# Split dataset into training set and test set
X_2_train, X_2_test, y_2_train, y_2_test = train_test_split(X_2_norm, y_2, test_size=0.3,random_state=42) # 70% training and 30% test


#Train a regression model using the MLPRegressor function
#https://scikit-learn.org/stable/modules/generated/sklearn.neural_network.MLPRegressor.html#sklearn.neural_network.MLPRegressor

from sklearn.neural_network import MLPRegressor

mlp_2 = MLPRegressor(hidden_layer_sizes=(50, 50, 50, 50), activation='relu', solver='adam', max_iter=1000)
mlp_2.fit(X_2_train, y_2_train)

predict_train_2 = mlp_2.predict(X_2_train)
y_pred_2 = mlp_2.predict(X_2_test)

print('training complete')
```

```
training complete
```

Training the model

Step 3: Evaluation of model

Evaluation tools:

- **R-squared:** Accuracy of model in %
- **Root mean squared error:** Average size of prediction errors in %
- **Mean absolute error:** typical prediction error in units

Illuminance:

- r-squared is 0.9635652190910206
- root mean squared error is 112.47336167325606
- mean absolute error is 86.35875507688202

96% accurate: Strong predictive performance

CCT:

- r-squared is 0.8595488325766288
- root mean squared error is 335.2328948281677
- mean absolute error is 242.07912366948045

85% accurate: Good predictive performance

 Training the model

Step 4: Adding complexity to model

Daylight Simulation model

+ Training model on Netherlands Bilt Data (For seasonal variation)

```
**DAYLIGHT ILLUMINANCE/CCT PER MONTH AND HOUR**
```

```
[55]: import warnings
import numpy as np
warnings.filterwarnings('ignore')

month = 12
hour  = 12

sunrise = {1:8, 2:8, 3:7, 4:6, 5:5, 6:5, 7:5, 8:6, 9:7, 10:7, 11:7, 12:8}
sunset  = {1:17, 2:18, 3:19, 4:20, 5:21, 6:22, 7:21, 8:20, 9:19, 10:18, 11:17, 12:16}

if hour < sunrise[month] or hour >= sunset[month]:
    print(f'Predicted illumination: 0 lux (night)')
else:
    solar_noon = (sunrise[month] + sunset[month]) / 2
    day_length = sunset[month] - sunrise[month]
    # simpler linear falloff from noon
    sun_angle  = 1 - abs(hour - solar_noon) / (day_length / 2)
    sun_angle  = max(0, sun_angle)

    defaults   = monthly_defaults[month]
    prediction = mlp_daylight.predict(scaler_daylight.transform([[
        month, hour,
        defaults['outdoor_temp'],
        defaults['total_sky_cover'],
        defaults['global_horizontal_radiation'] * sun_angle
    ]]))

    final_lux = max(0, prediction[0] * sun_angle)
    print(f'Predicted illumination: {final_lux:.0f} lux')

Predicted illumination: 2221 lux
```

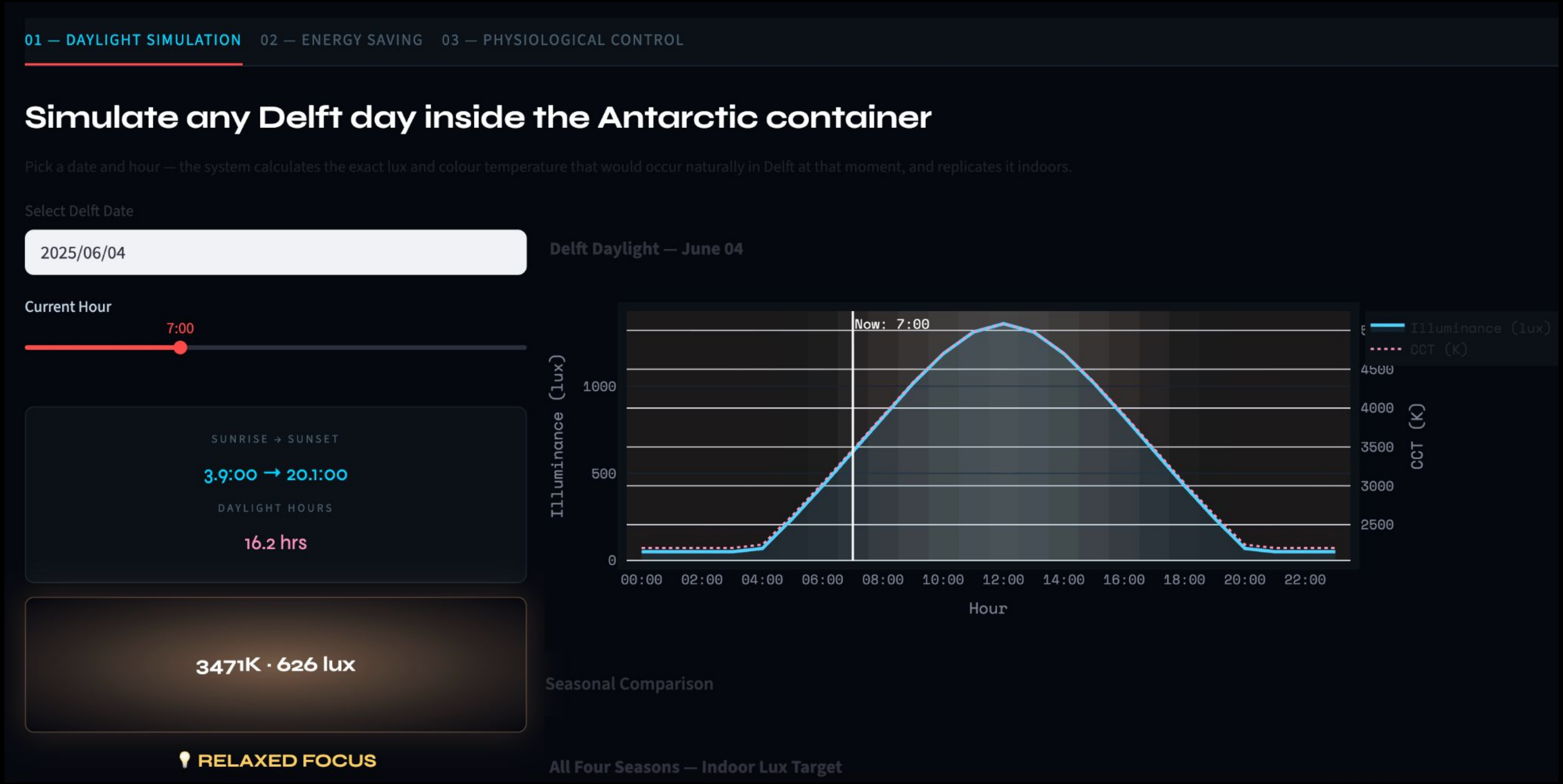
```
[56]: # Direct CCT calculation from lux — no model needed
# Low lux = warm (2700K), high lux = cool (6500K)
max_outdoor_lux = 20000  # June noon max
final_cct = int(2700 + (final_lux / max_outdoor_lux) * (6500 - 2700))
final_cct = max(2700, min(6500, final_cct))

print(f'Predicted illumination: {final_lux:.0f} lux')
print(f'Predicted CCT: {final_cct}K')

Predicted illumination: 2221 lux
Predicted CCT: 3121K
```

```
[ ]:
```

+ The model predicts both illuminance and colour temperature, replicating how light changes across seasons and times of day. **Can modify hour/month**

04 Lighting and AI Integration **Training the model**

Step 5: Visualization of model



04 Lighting and AI Integration **Training the model**

Step 5: Visualization of model

04 Lighting and AI Integration **Training the model**

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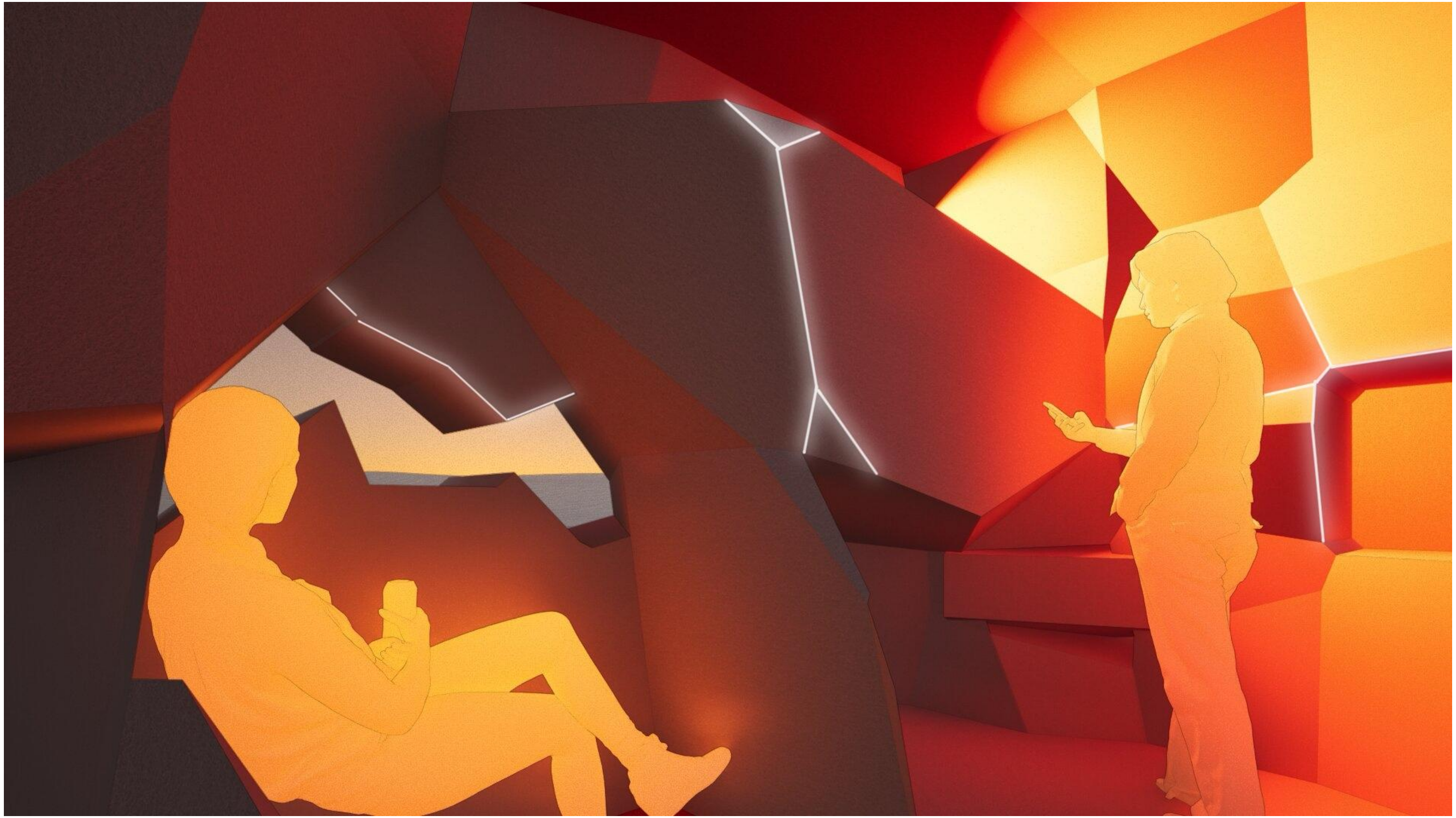
04 Lighting and AI Integration **Training the model**

Step 5: Visualization of model

2/03)



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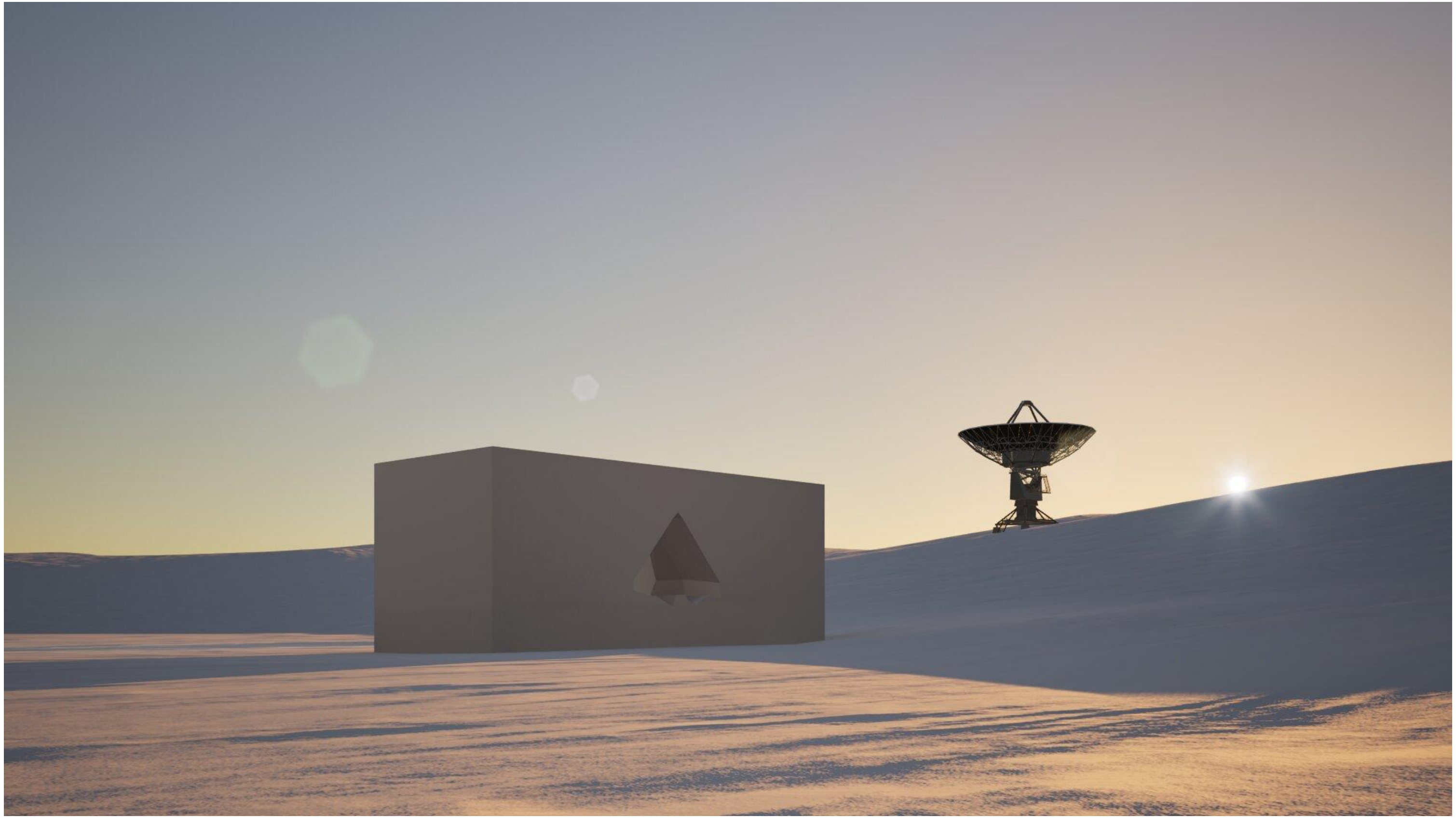
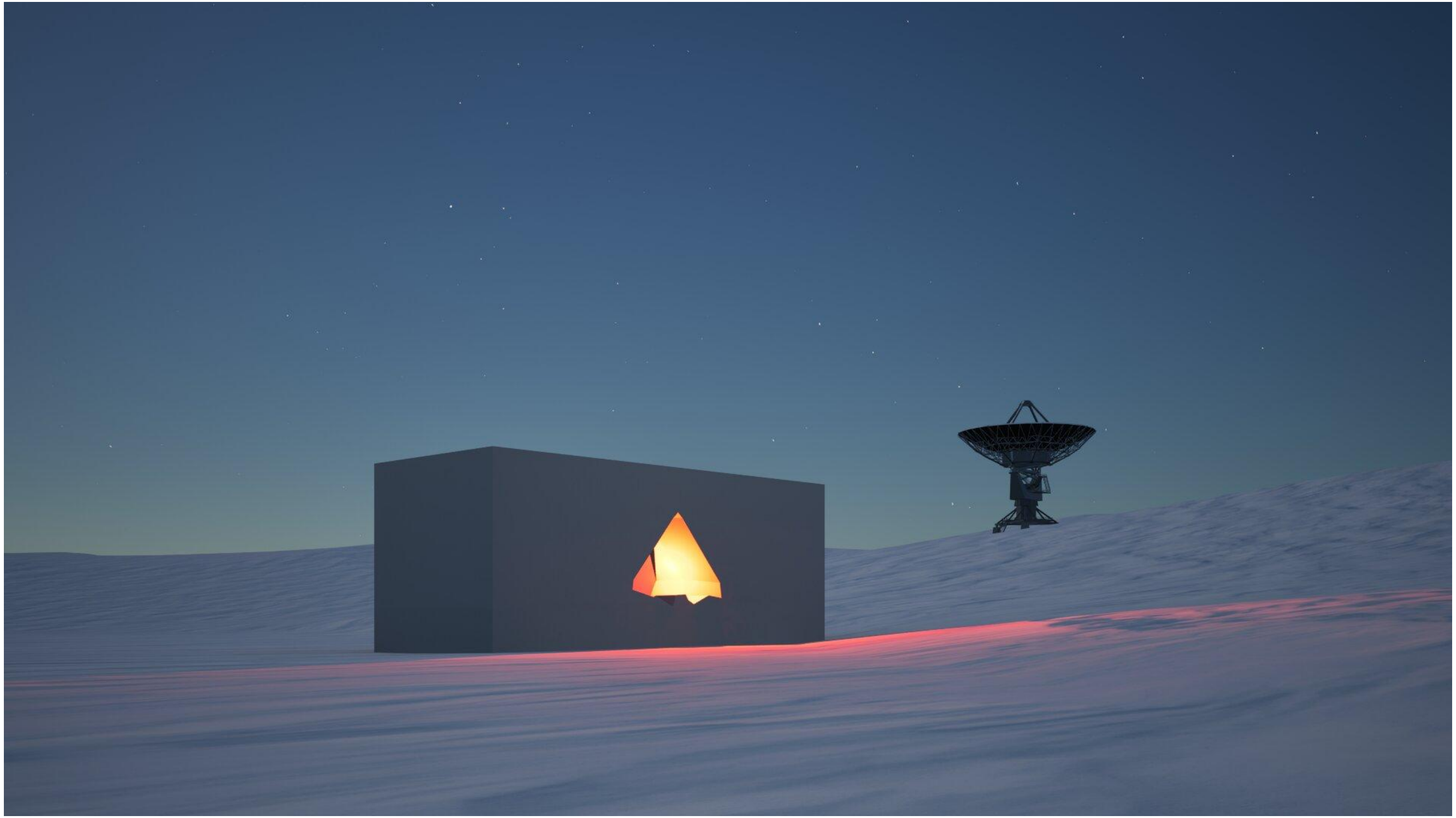


2/03)



Thank you

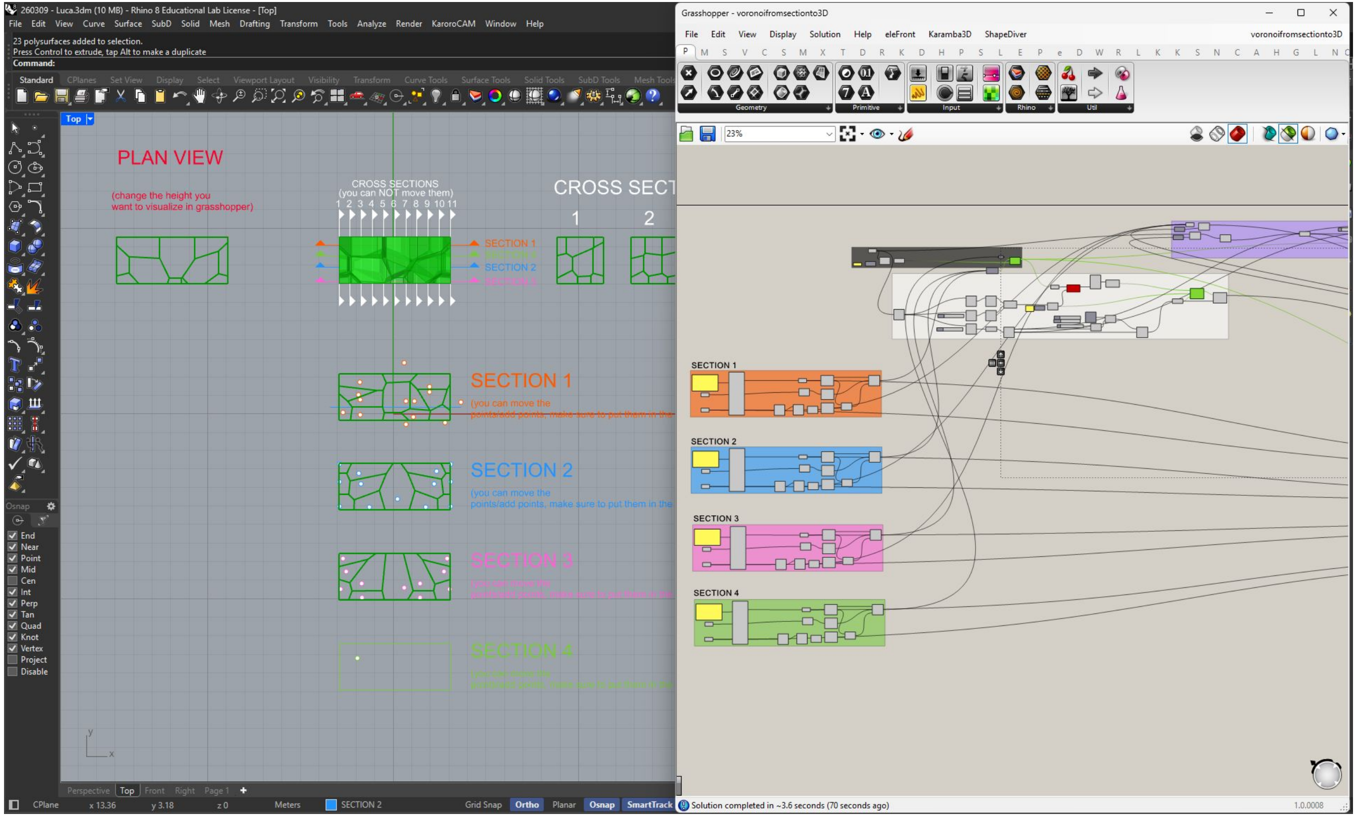
: >]

EXTRA SLIDES/OLD SLIDES

04 Design Process **Iterations**

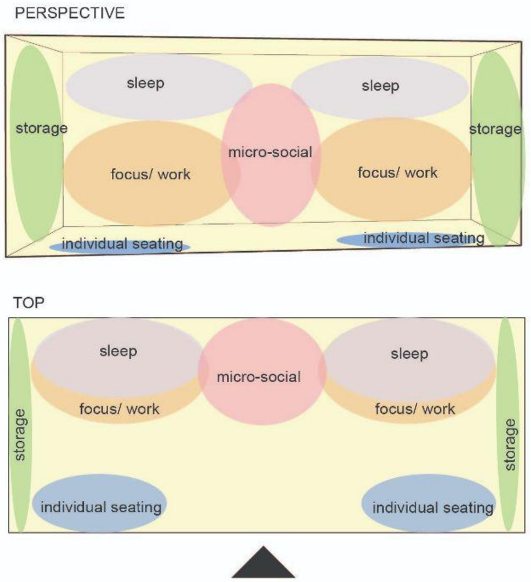
Iterations of zoning possibilities (translated in 3D and 2D Diagrams)

- Shared space
- Sleeping
- Lounging
- Individual Work
- Storage

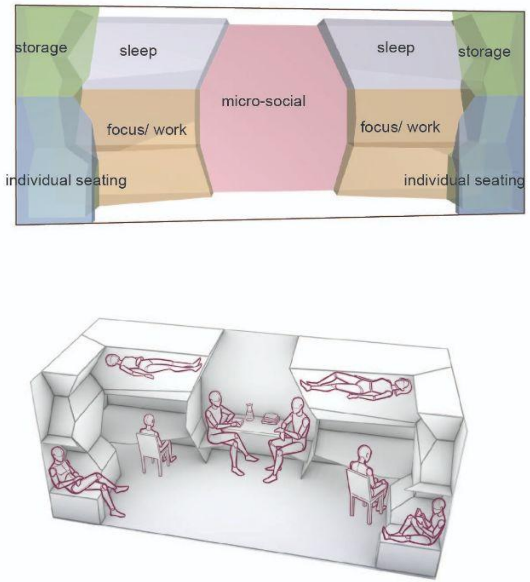


04 Design Process: **from concept diagram to concept voronoi**

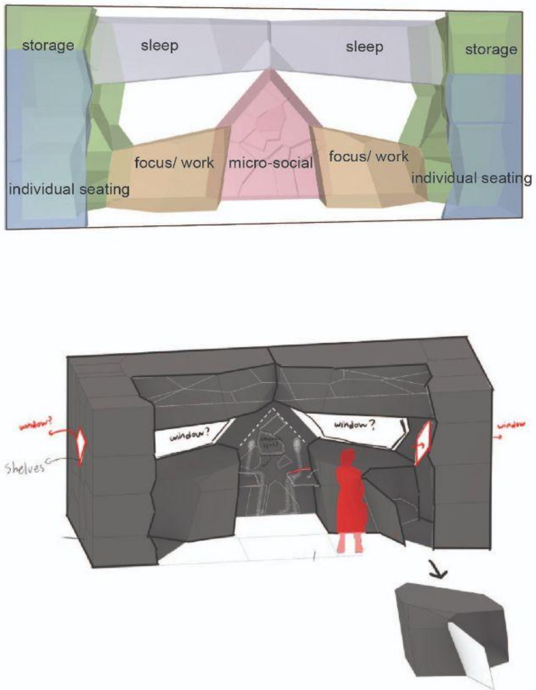
concept diagram



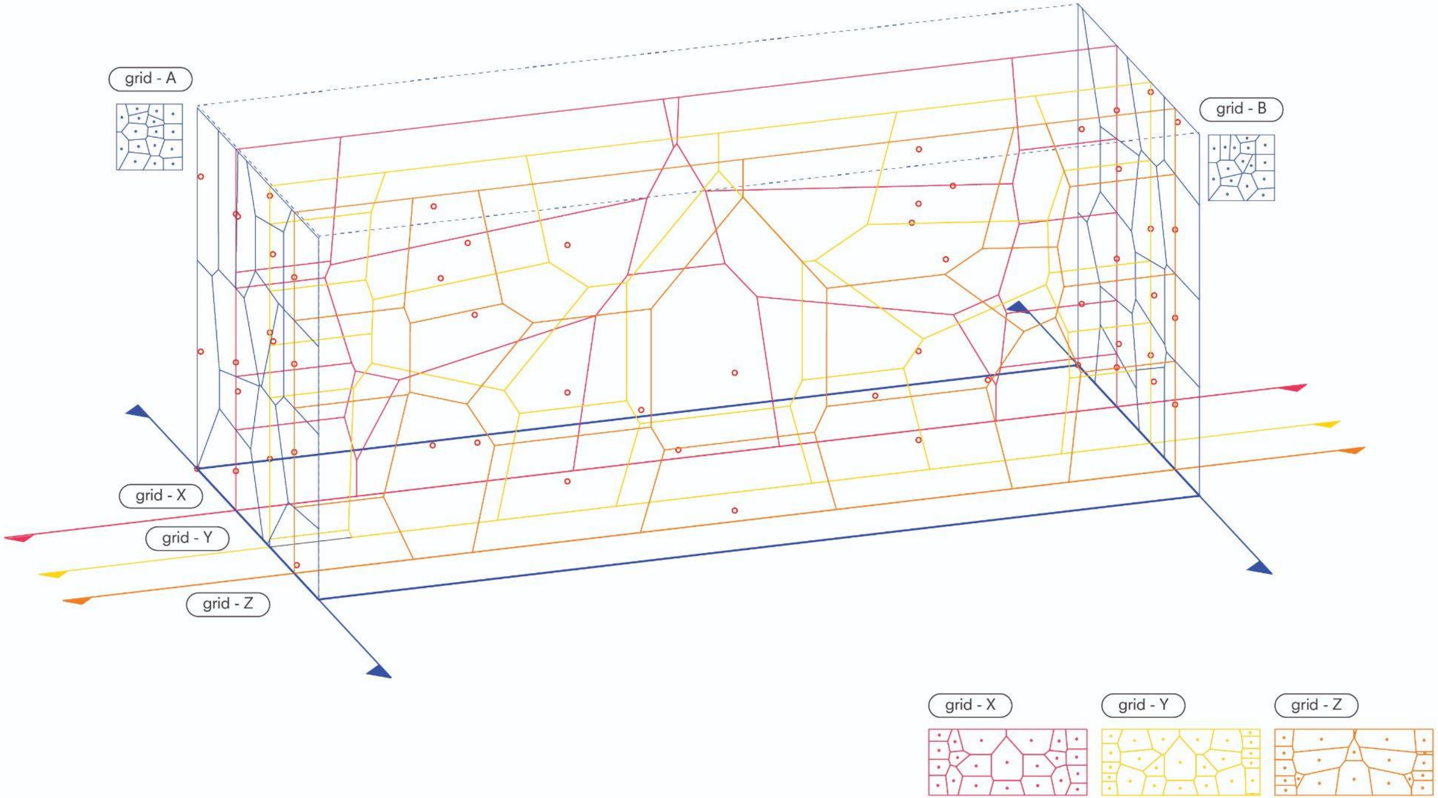
concept voronoi



concept voronoi



03 Design **2D → 3D**



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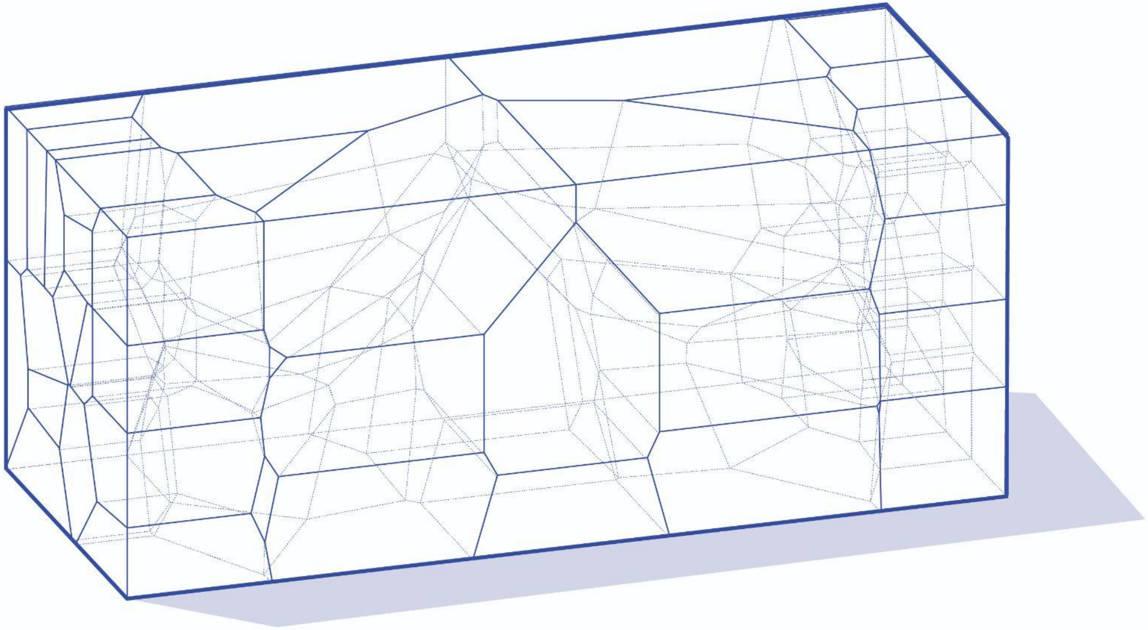
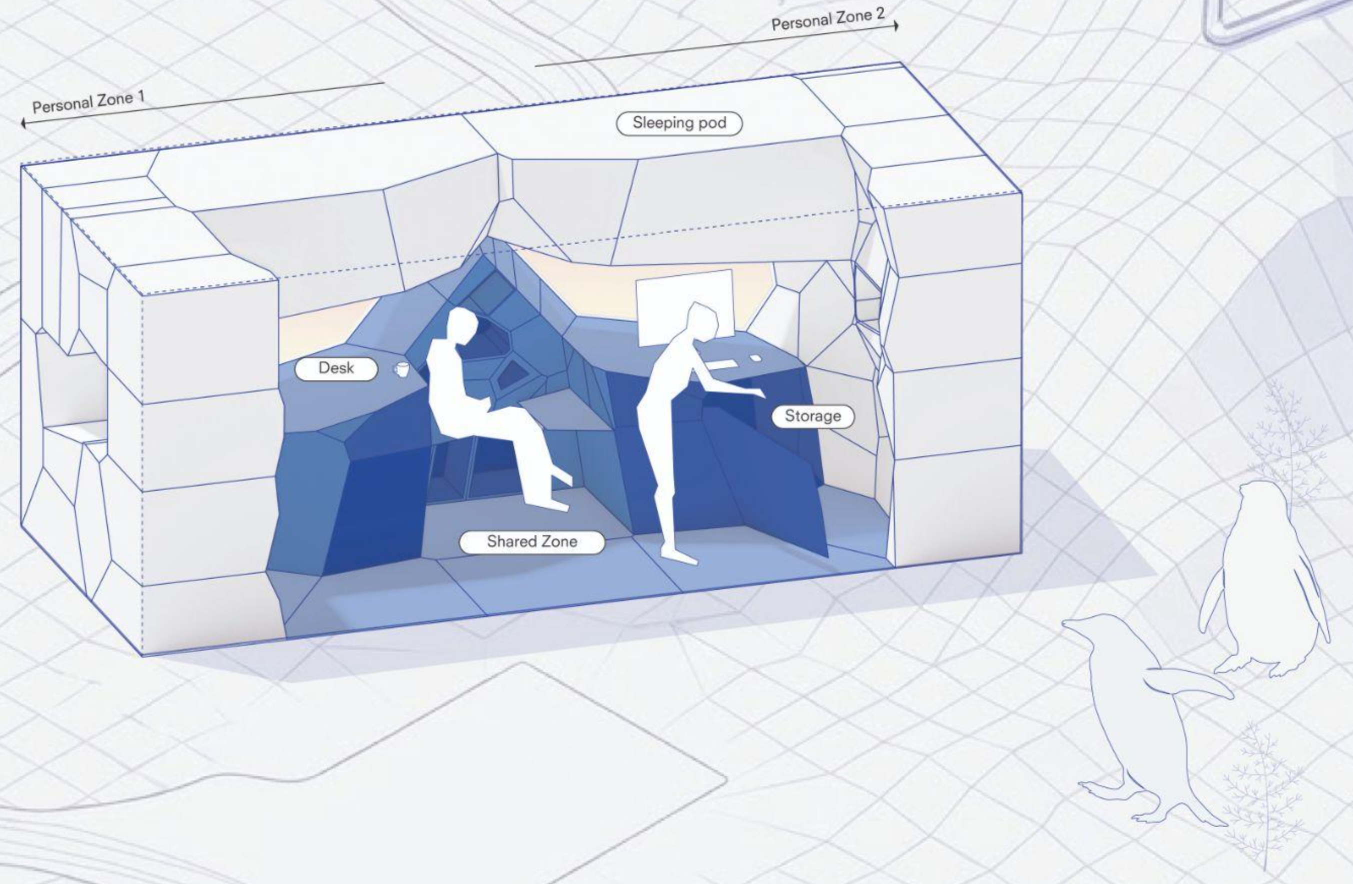


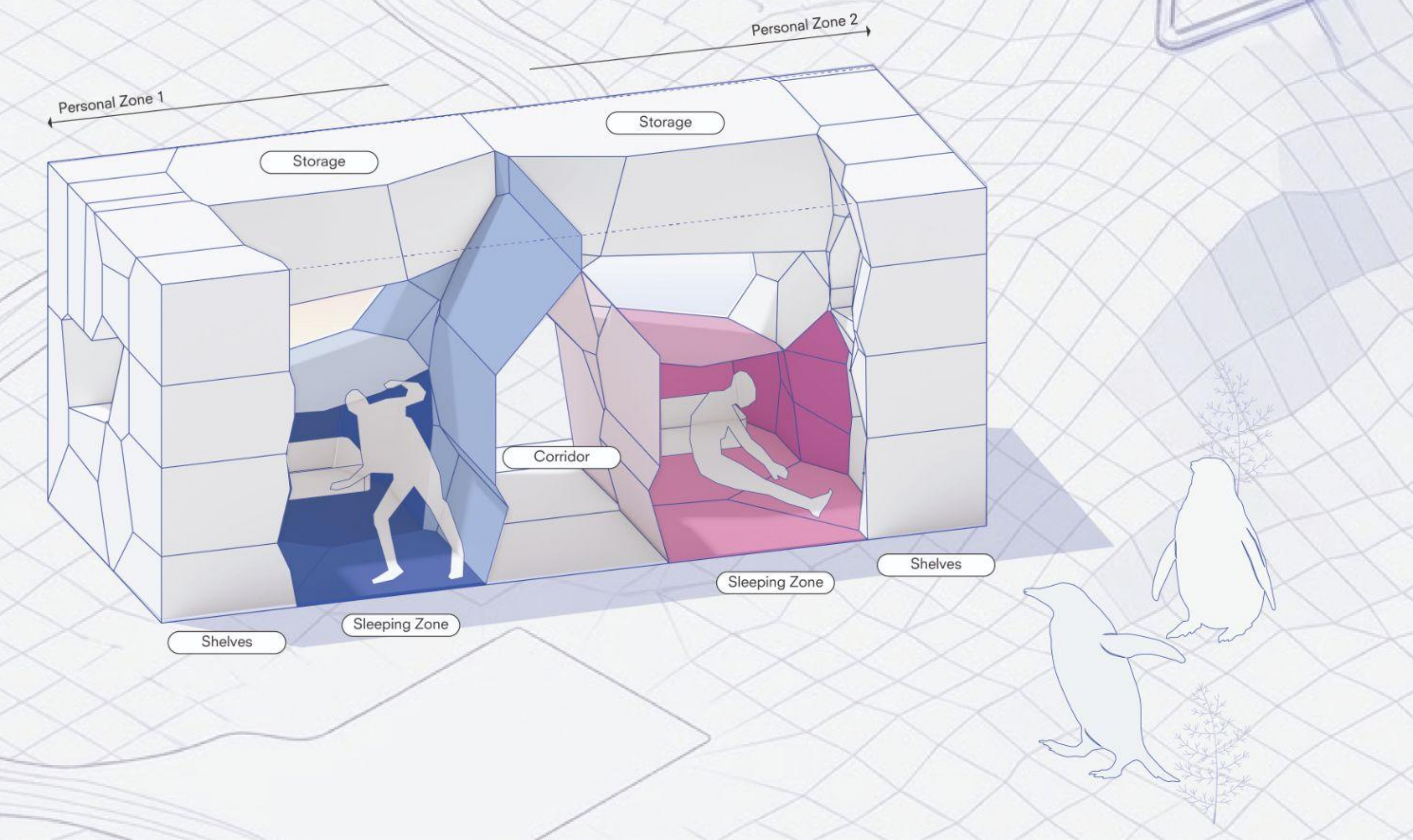
03 Design **2D → 3D**



Scenario 1
Everyday Relaxation

Two residents spend time relaxing in the shared central area.
They rest around the central shelves and small seating area, or enjoy leisure activities at their individual desks.

Privacy ■■■□□□□□□□
Interaction ■■■■■■■□□□



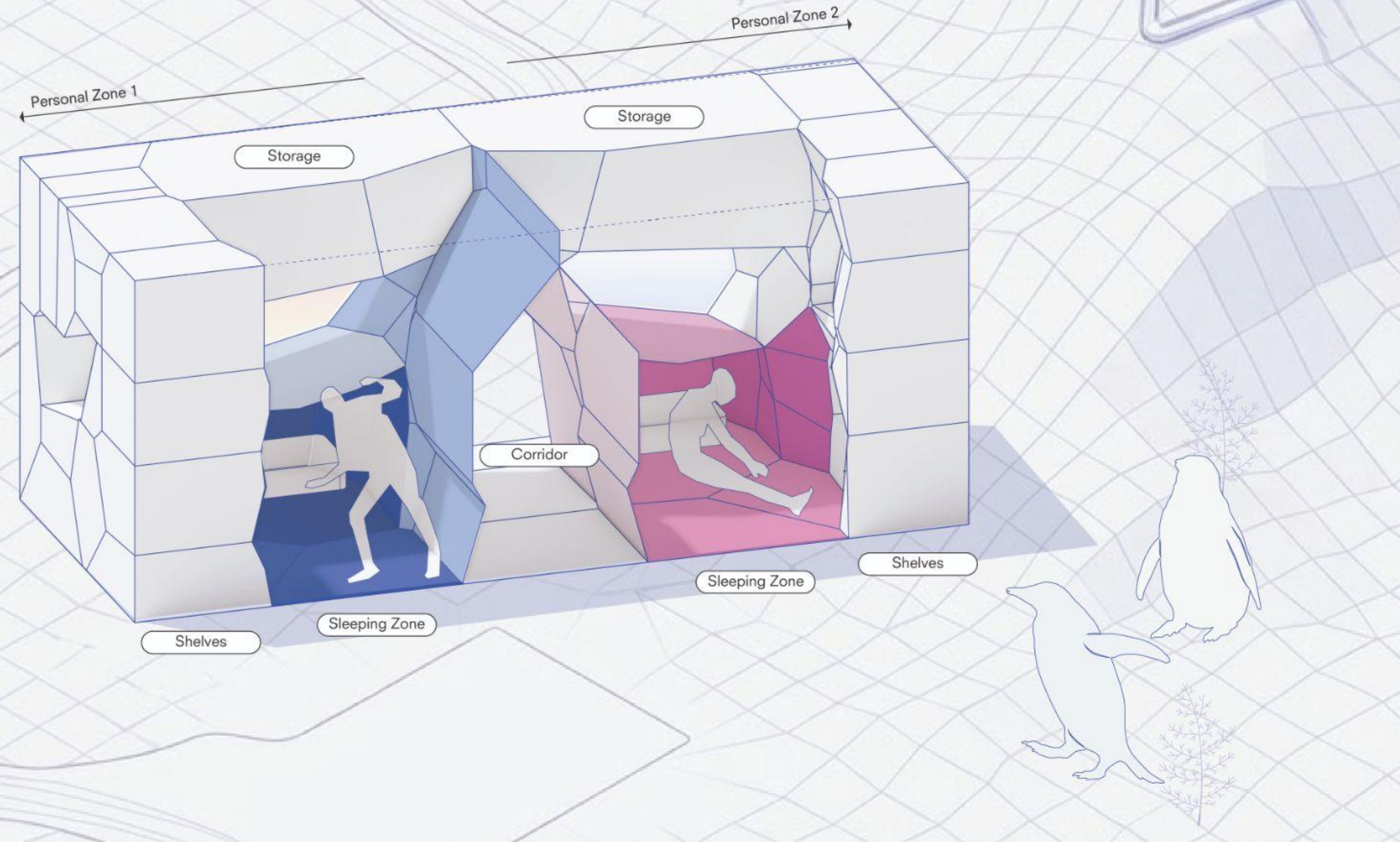
Scenario 2

No, We need Privacy!

If a more private environment is required, partitions can be installed to divide the space into two-person units. Instead of using the upper sleeping pod, the lower part can be used as a bed area.

Privacy

Interaction



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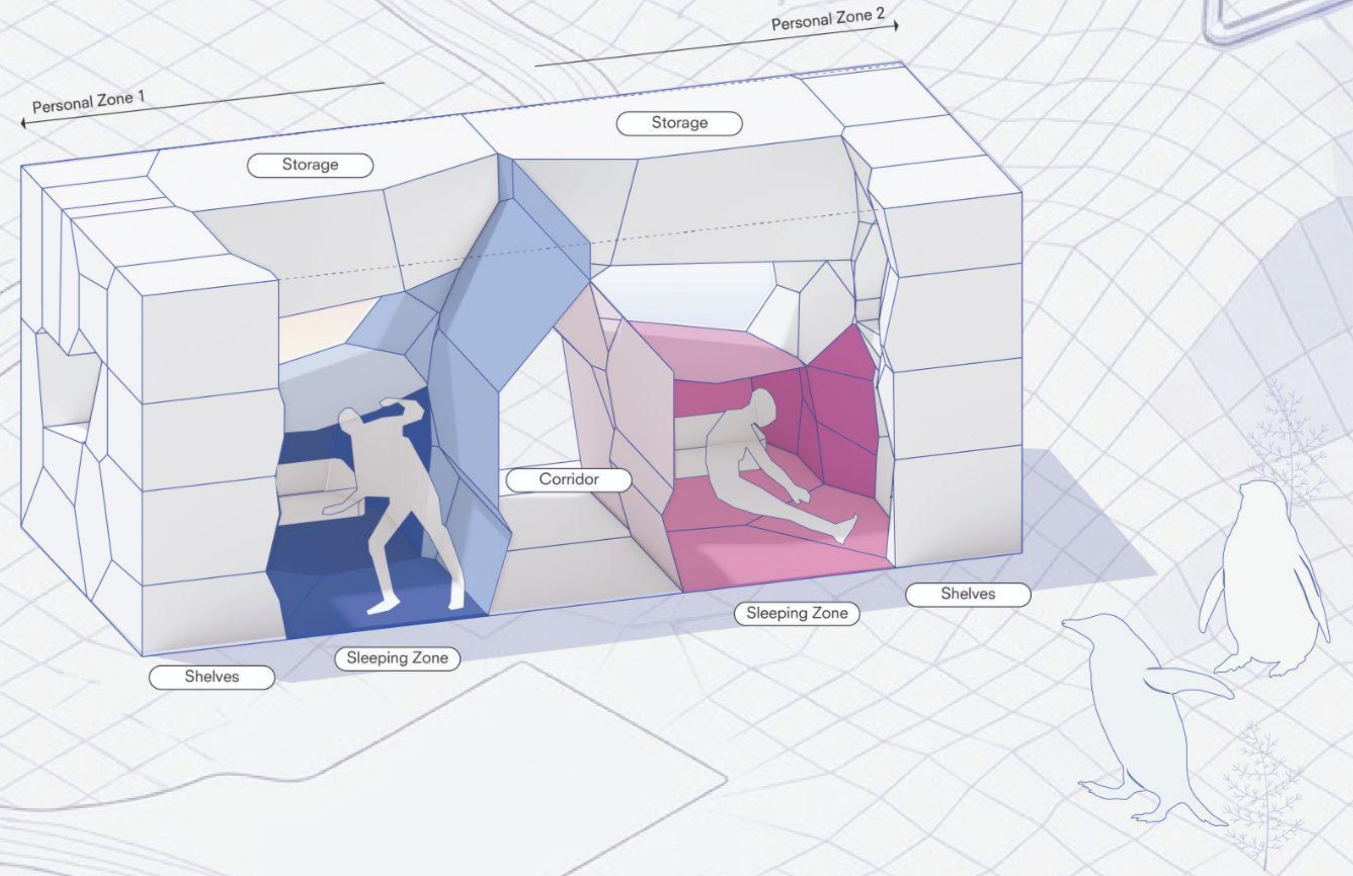
Privacy ■■■■■■■□□□

Interaction ■■□□□□□□□□



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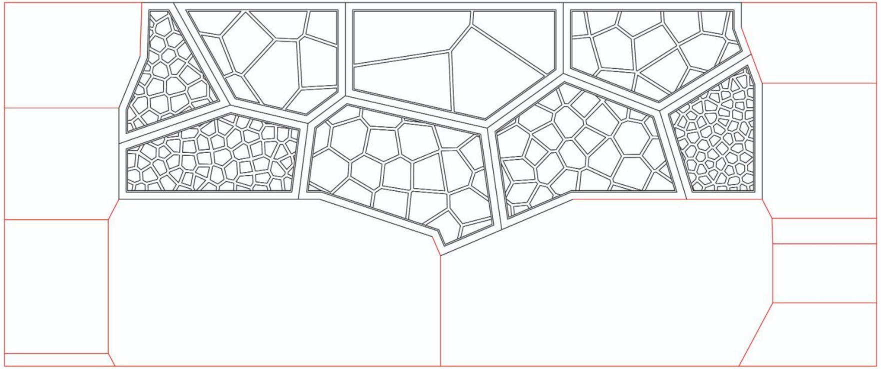
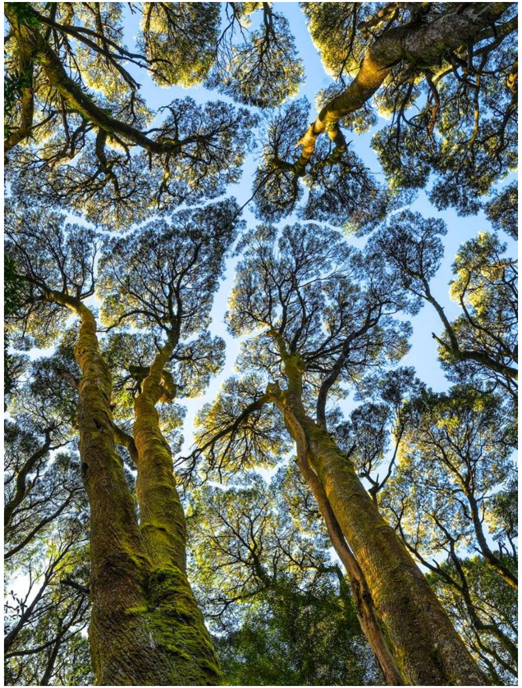
Privacy ■■■■■■■□□□

Interaction ■■□□□□□□□□

04 Design Process(skylight)

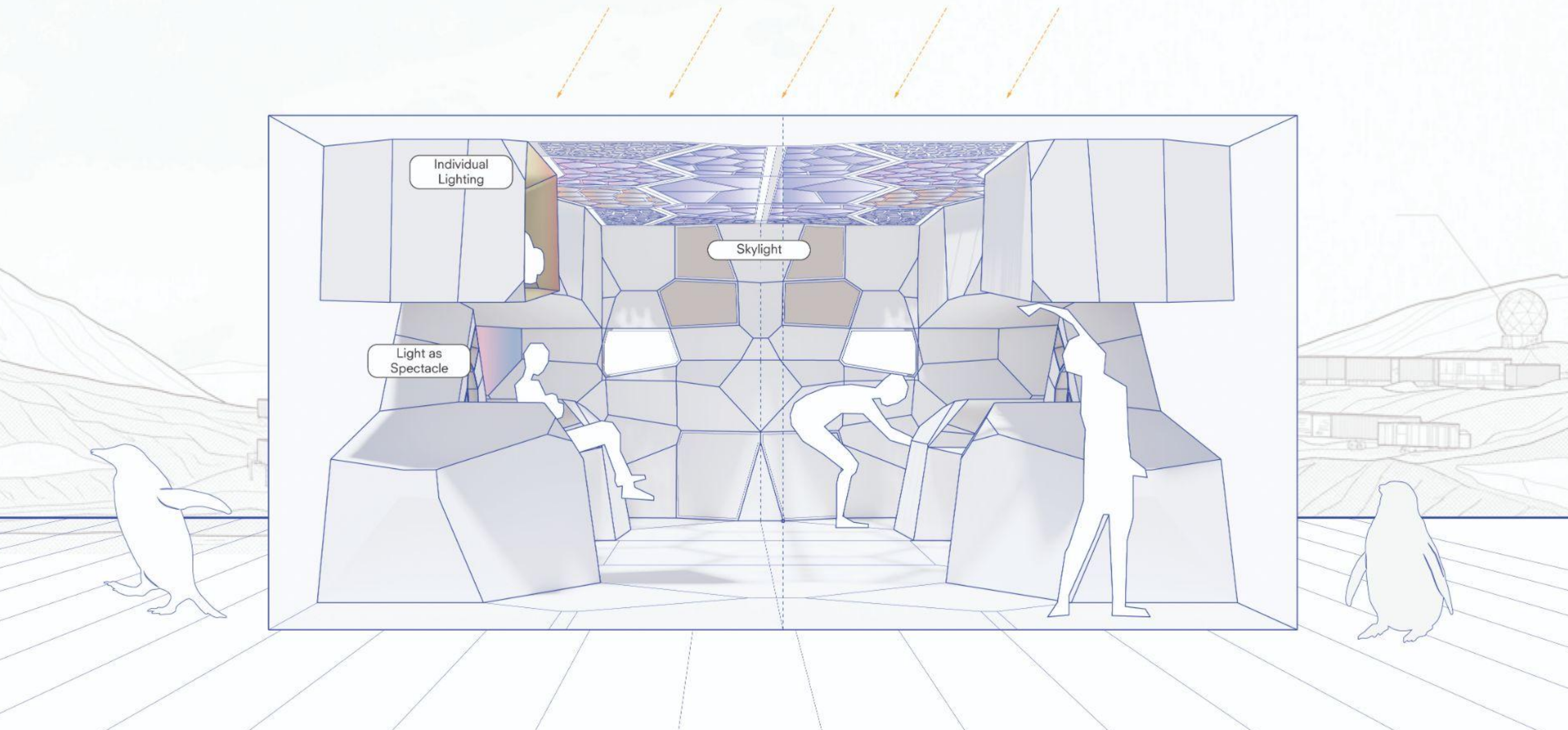


How can polar daylight
be integrated into living spaces?



Crown Shyness

04 Design Process



03 Physiological Implication: **Concept Diagram**

1. - Deep Sleep
- Wake-up - Light Shower
- Music
- Reading
- Relax

2. - Deep Focus Work
- General Work
- Reading

3. - Personal Storage

4. - Reading
- Music
- Relax (Lounge)
- Socializing

5. - Breakfast
- Lunch
- Dinner
- Debrief
- Socializing

6. - Kitchen

7. - Hygiene
- Shower
- Toilet