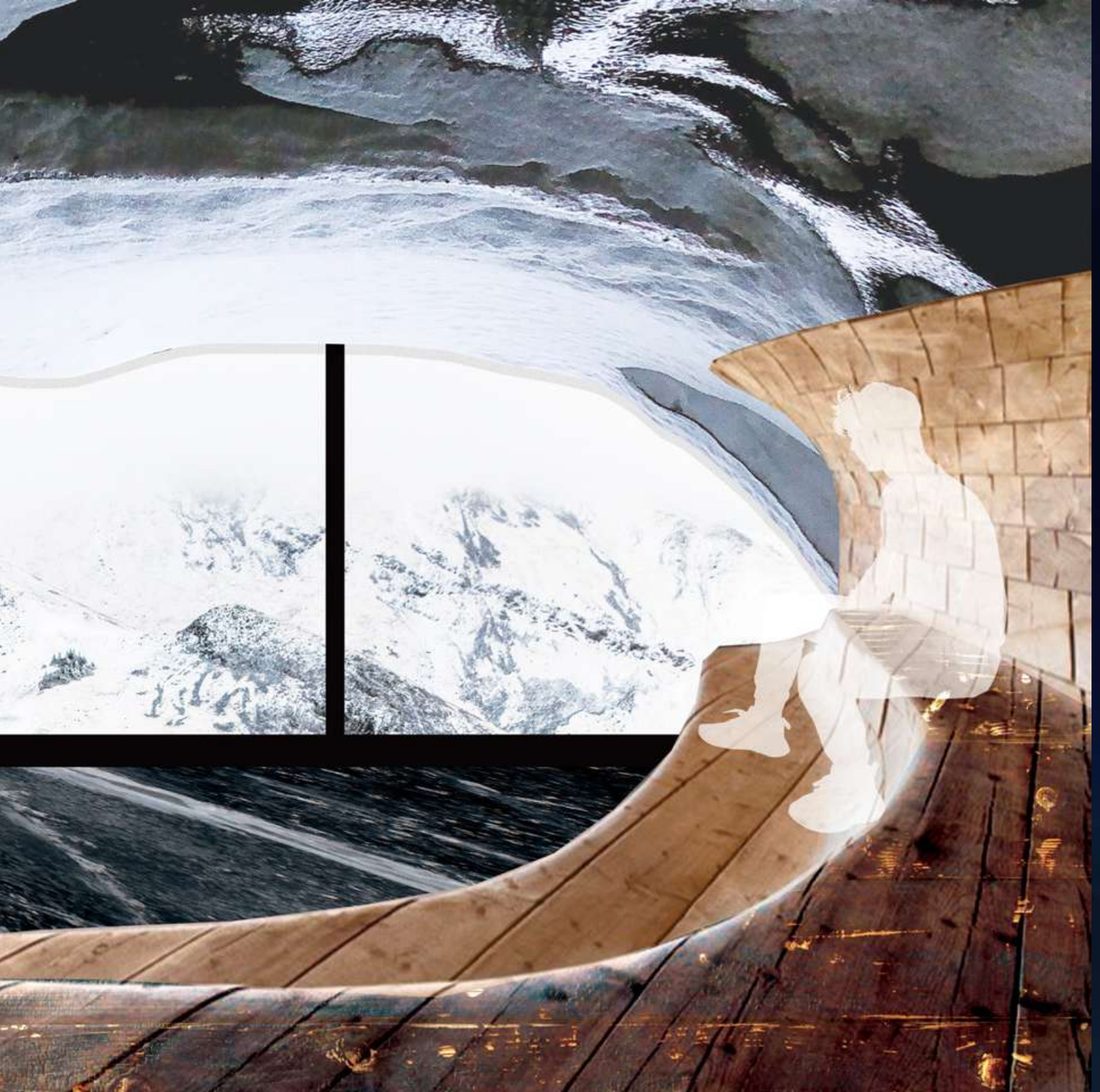
DESIGNING FOR COGNITIVE FUNCTION IN EXTREME ENVIRONMENTS

ICECUBE ANTARCTIC RESEARCH CENTER

LAUREN LEWIS | THESIS 2023

/ contents



01 / THESIS STATEMENT

01 / THESIS TOPIC

THESIS STATEMENT

DESIGNING FOR COGNITIVE FUNCTION IN EXTREME ENVIRONMENTS

The environments we exist within affect our ability to function on a cognitive level. From sensory stimulation to light levels to a space's ability to support a sense of community, our physical environment can either support our cognitive wellness or cause it to deteriorate. Through research, we understand that physical environment affects the overall health and wellbeing of human beings, but what happens when a person is in a place so severe that it actively fights against everything they require to mentally and physically function?

Through my research it is evident that the severe environmental factors experienced in these environments directly combat against all the requirements needed to maintain cognitive function at a normal level. As we continue to scientifically advance as a species, or face more challenges of severe climate change, the rate at which we explore and encounter these extreme environments will continue to increase. This increase highlights the importance of understanding how to build and design environments, cities, and communities that support people at the highest possible level. Whether it be space, the ocean floor, severely changed climates across the globe, or in the case of my thesis, the Antarctic, I believe designers have a unique opportunity to create spaces that allow people to not just simply survive, but to thrive. My thesis will explore how design can create physical habitations that support cognitive function in the extreme environments of today and the extreme environments we may face in our future.

EXTERIOR PERSPECTIVE

02 / LITERATURE REVIEW

02 / LITERATURE REVIEW

DESIGNING FOR COGNITIVE FUNCTION IN EXTREME FROZEN ENVIRONMENTS

Introduction

Extreme environments, specifically extreme frozen environments, have unique conditions that create challenging living conditions. The challenges faced in these places have the ability to effect habitants on a deep cognitive level. In this literature review, I will present information supporting that cognitive function is the key to overall wellness, and how physical environment can affect a person's overall cognitive function and health. Through drawing parallels between our cognitive needs and the cognitive related challenges of extreme frozen environments, the importance of designing for these environments will be made clear.

Cognitive Function as Wellness

In 1964, The World Health Organization (WHO) defined health as a state of physical, mental, and social well-being, not merely the absence of disease. These categories can be extended to include diet, exercise, sleep, social engagement, emotional balance, and cognitive health, though the exact criteria lacks consistency amongst the medical community (Bart et al., 2018). While cognitive health has often been included as a dimension of health and wellbeing, its study as a singular focus is a more recent development (Aidman, 2020).

The American Heart Association and the American Stroke Association defines cognitive health or "optimal brain health" as an optimal capacity to function adaptively. Categorically this could be summed up with thinking, moving, and feeling, and encompasses abilities such as the capacity to "pay attention, perceive, and recognize sensory input; to learn and remember; to communicate; to problem solve and make decisions; to have mobility; and to regulate emotional status (Gorelick, et al., 2017)." When looking at "cognitive fitness", which is often seen as an even higher level of cognitive health necessary for high-risk environments and tasks, a study by Cognitive Fitness Framework showed the links between cognitive function/fitness and other categories of human health such as physical health and social health (See Figure 1) (Aidman, 2020). Similarly, the NIH Research Domain Criteria (RDoC) for cognitive functioning, outlined below, highlights similar links between cognitive function and overall health.

1. Negative Valence Systems (fear, anxiety, sustained threat, loss, frustration).
2. Positive Valence Systems (approach motivation, initial and sustained responsiveness to reward, reward learning, and habit).
3. Cognitive Systems (attention, perception, working and declarative memory, language, and cognitive control).
4. Social Processing Systems (affiliation/attachment, communication, self/other-perception).
5. Regulatory Systems (arousal, circadian rhythms, sleep and wakefulness).
6. Sensorimotor Systems (motor actions, agency and ownership, sensorimotor habit, innate motor patterns).

Phase	The domain of cognitive functioning	Target constructs	Examples of training/development objectives[a]
Cognitive gym: Foundational training	Cognitive fitness:	Self-awareness	Stress symptoms detection
	Trainable cognitive primaries	Attention	Focus endurance
		Task switching	Dual-tasking
		Impulse control	Response override
		Co-action	Action mirroring
			Handover execution
Advanced cognitive training	Cognitive skills	Controlled response	Effortless concentration
		Energy management	Arousal regulation
			Progressive muscle relaxation
			Resonant frequency breathing
		Situation awareness	Perceptual acuity (detection)
			Sense-making (interpretation)
			Anticipatory skills (prediction)
		Decision making	Pattern recognition
			Bias detection and mitigation
			Confidence calibration
		Adaptability	Change detection
			Cognitive flexibility
		Teamwork	Shared mental models
			Non-verbal communication
Mission-ready training	Tolerance and resistance	Tolerances	Generalized discomfort tolerance
			Pain tolerance
			Alertness upregulation (drowsiness tolerance)
			Mental effort tolerance
			Monotony tolerance
			Frustration tolerance
			Ambiguity tolerance
			Startle/surprise tolerance
		Resistances	Distractor resistance
			Susceptibility to deception
			Resistanceto manipulation
		Task resilience	Error detection
			Performance recovery
Operational augmentation	Operational task performance	Cognitive state	Alertness monitoring[b]
		Cognitive workload	Fatigue countermeasures[b]
		Decision making	Adaptive decision aids[b]
		Equipment use	Operator state-aware autonomy[b]
Recovery	Cognitive recovery	Sleep recovery	Sleep/wake cycle management
		Reflexive practices	Mindfulness and meditation
		Nutrition	Healthy eating habits[c]
			Hydration[c]
		Connectedness	Interactional competence
			Social support[c]

Notes: [a]The list is not exhaustive and is subject to validation through expert consensus. These training objectives are not directly linked to operational task performance. Similar to strength and conditioning in physical training, the products of CF training feed into the subsequent cognitive skills training, and only through this skill training—into operational performance. [b]Given the nature of the Operational Augmentation phase, performance augmentation tools are listed here instead of training objectives. [c]The recovery phase is focused on the development of habits and practices that promote cognitive fitness and, as such, they are applicable to all other phases of the Cognitive Fitness Cycle.

Figure 1

Cognitive Function and Physical Environment

According to research by the American Hearth Association and American Stroke Association, there is a direct connection between our brain health/cognitive function and our environment (see Figure 2).

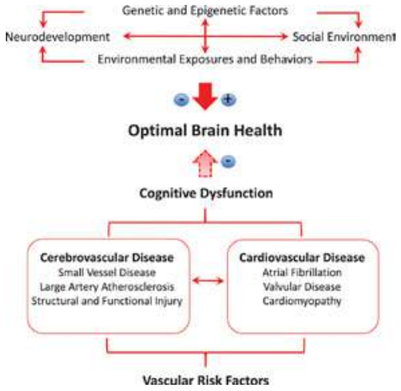


Figure 2

Sensory Stimulation

Our senses are consistently seen as the following: seeing, hearing, tasting, smelling, and touching. Our senses are translated through our brains and that interpretation produces our perception of the world around us (DeSalle et al., 2018). Our perception of our world and environment is rarely, or possibly never, shaped solely by one sense, and no sense ever works completely independently (DeSalle et al., 2018).

While sensory stimulation tends to be considered unanimously important and valuable to human experience, it's impact on cognitive function is still somewhat debated, often based on length of deprivation. A research study on short-term sensory deprivation completed by Peter Suedfeld in the 1960's presents data that suggests sensory deprivation could actually improve an individual's ability to complete simple tasks. Alternatively, for complex tasks, sensory deprivations worsens their ability to complete the task (Suedfeld, 1986). A more recent study that focused on those with more long-term sensory deprivation, due to congenital or acquired sensory impairments, resulted in data showing a higher prevalence of anxiety, depression, dementia, suicidality, and psychosis than people in the "general population" (Sahoo, 2021), all of which ultimately negatively impact cognitive function.

In "An Architecture of the Seven Senses" Juhani Pallasmaa explores the impact of the senses and sensory stimulation in a physical environment. A person's perception of an environment is dictated by their sensory response to that location. This can vary from how sound reverberates around a room to the materiality, to the perceived and actual memory it holds. These physical attributes all impact how someone's senses are stimulated within that space, and ultimately how they perceive that space. Pallasmaa argues the importance of avoiding design and architecture that becomes "flat, sharp-edged, immaterial, and unreal" which push our society more towards a "chilling, de-sensualization" caused by the lack of stimulation and lack of sensory experience in design decisions.

In Jun'ichiro Tanizak's "In Praise of Shadows" he highlights not only the beauty of shadow, contrast, and stimulating multiple senses with design, but he also emphasizes the benefits. In contrast to highly lit interiors, Japanese interiors casted in varying light and shadow provoke an experience that consists of multiple senses actively working together. This use of shadow has been used in Japanese design for centuries, and while Westerners often are amazed at their simplicity, their use of shadow and light create depth, contrast, mystery, and more moments of sensorial stimulation than many Western buildings built around bright light and visibility (Tanizacki, 1977).

Light

While Jun'ichiro Tanizak's "In Praise of Shadows" highlights the importance of sensory stimulation, it focuses on the stimulation provided by light and lack of light in a physical environment. Through adding moments of shadows and darkness, Tanizak suggests that a space is more stimulating and interesting. The benefits of varying light levels in a space for cognitive function is supported by research completed by the Frontiers of Neurology.

The research from Frontiers of Neurology highlights the important of different light levels throughout our days. In modern times, people tend to occupy environments that do not follow the natural Light-Dark schedule in duration, wavelength, light intensity, and this impacts and challenges our circadian rhythm. In particular, people are often over exposed to blue-enriched light. This light is often expelled by LED lights, computer/phone screens, and is similar to the daylight one would experience outside mid-day which provides higher levels of energy and alertness. Dim-light is more beneficial in the evenings as it allows one's body to rest and get ready for sleep. Exposing oneself to blue-enriched light at night "can suppress melatonin concentrations, delay the onset of sleep by increasing alertness, decreases the efficiency of sleep at night and can reduce cognitive performance the next morning" (Gonzalez, 2018).

Further research by the same group has proven that disruptions in our circadian rhythm negatively impact people on a cognitive level and a multitude of other health problems including: metabolism, cardiovascular function, mental health, memory impairment, higher cancer risk, poor performance, insomnia, emotional disturbances, and gastrointestinal issues. Circadian rhythm disruption has been tested on rodents, and these issues tend to be consistent regardless of how it is disrupted, whether all dark, all bright light, or all dim-light (Fisk, 2018).

Isolation

Physical isolation and social isolation is proven to negatively impact cognitive function (Terelak, 2021) so much so that data shows people seeking out additional social interaction when they face more extreme levels of isolation (Terelak, 2021). In "An Architecture of the Seven Senses" Juhani Pallasmaa speaks about the importance of seeing the memory imprinted upon a space (Pallasmaa, 1994). Signs of patina and ware show how a space was occupied and carry a sense of comfort that is different than a space that doesn't do these things. Knowing that people crave community and socialization for their cognitive health (Terelak, 2021), we can determine that spaces with characteristics outlined by Pallasmaa could positively impact cognitive function, particularly more than a space that does not have similar details (Pallasmaa, 1994).

The severity of our need for socialization can also be linked back to the benefits of place-identity. In Harold Proshansky's Place Identity, he describes the link between spaces and their importance to a person's self identity. The strong link between place-identity and self-identity showcases the importance that place-identity and connection have to space, and to a person's psychological and cognitive health (Proshans-

ky, 1983). The severity of this link can be seen in the data regarding suicide rates in Arctic regions. While many believed the high suicide rates may be linked to light levels, such as polar night, the reality seems to point towards the indigenous community and the negative impacts colonialism and global warming have had on their home and culture (Barrett, 2019).

Extreme Cold Environments

Extreme frozen environments come with unique environmental challenges. In Antarctica, temperatures drop below 60 degrees Fahrenheit, winds reaching 100 mph, and snow accumulation that often blocks doors, windows, and paths in, and, to the outdoors. While most years of Antarctic exploration consisted of shelters simply aimed at keeping the elements and cold out, now there is a shift in thinking to the value of human comfort (Gendall, 2020). In addition, light conditions in these environments are challenging. Polar night, a time where the sun does not rise, lasts between 2-6 months, and polar day, a time where the sun does not set, lasts between 2-6 months (Terelak, 2021). These environmental challenges all have the power to unbalance the internal environment of the human system, and thus their cognitive function (Terelak, 2021).

Sensory Deprivation

The extreme conditions in these frozen environments also comes with negative sensory impact. An often overlooked impact of these polar regions is the high altitude. It often disrupts human senses like balance and breathing problems. It also can cause nausea and light headedness. This leads to a need to acclimatize to the environment's altitude on top of the other challenges presented in these places (Terelak, 2021).

Light variation and effects on circadian rhythm, both discussed more in detail below, also have huge impacts on the senses. The light-dark levels in these regions, such as all light or all dark, affect humans on a deep cognitive and ultimately hinder their cognitive function (Terelak, 2021).

An additional impact to be considered in these polar climates is the boredom and monotony that is often associated with them. Due to the lack of variation in spaces, the isolation they endure, and the minimal visual contrast, days can feel more monotonous and therefore less mentally stimulating (Terelak, 2021).

The severe lack of sensory stimulation in these environments results in lower sensitivity thresholds (increased sensory sensitivity). Data collected by a study from Terelak, 2021 describes the facts of decreased auditory and olfactory sensitivity during Antarctic winters. Other data cited by C.S. Mullin in 1960 indicates that around 40% of American polar explorers exhibit symptoms of intellectual retardation, impaired memory and focus. These symptoms consistently appear in data collected during the winter months, which are also the months that are the least stimulating to our senses (Terelak, 2021). While most task and mental related activities decline during these periods of severe lack of sensory stimulation, there is data that shows and increase in social interactions and so called "positive contemplation" like dreaming, memories, fantasizing, and even hallucinations. From this we can deduce that occupants are seeking cognitive stimulation during the most extreme conditions (Terelak, 2021). These correlations between time of year and cognitive impact can be seen in Figure 3 (Terelak, 2021).

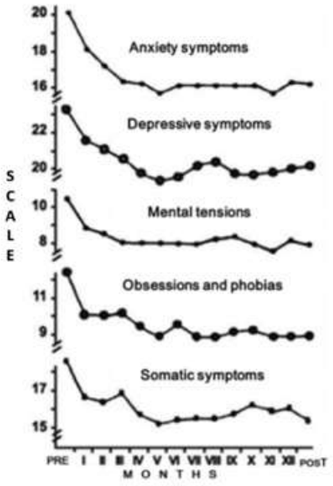


Fig. 3. Clinical distribution of the level of anxiety and its attributes in the annual isolation of wintering-over at the Arctowski Station

Source: own elaboration.

Legend: Pretest. – initial tests; XII, I, II…, – monthly tests; Posttest – tests on the ship on the way back to the country; all differences between Pretest and subsequent tests are significant at $p < 0{,}01$ and $p < 0{,}05$.

Figure 3

Light

The severity in changes in light in polar environments is a unique challenge. Polar night and polar day periods expose people to prolonged periods of darkness or lightness. Research confirms that disruption to our light-dark schedule in duration, wavelength, and light intensity, impacts and challenges our circadian rhythm (Gonzalez, 2018). A disrupted circadian rhythm negatively impacts cognitive function and overall health (Fisk, 2018). The lack of contrast during these times are particularly unique in that during polar night only the immediately surroundings are illuminated, or everything is completely dark. Whereas, during polar day there is undifferentiated whiteness and lack of contrast creating "white darkness". The lack of contrast in these visual environments make the eye and brain function as if they are operating in complete darkness (Terelak, 2021).

Isolation

Due to the extreme remoteness in polar regions, isolation is a huge concern in regards to its negative impacts on cognitive health. Data suggests that isolation has negative impacts on a person's cognitive abilities, and also points to the acute importance of community in these regions. The need to belong to a group and successfully integrate, is correlated with stronger cognitive function and satisfaction (Terelak, 2021).

The feeling of isolation can also be expanded to a challenge in forming place-identity with these extreme environments. Expressing a lack of belonging, Antarctic explorer Jean McNeil wrote in her diary "After that one day at base, I knew we were in a different dimension, that Antarctica is like an extraterrestrial civilization that knows nothing about humanity. People have never lived here, so the land does not know us (Terelak, 2021)." In addition to feeling a lack of belonging with the environment itself, these habitats are often called "micro-climates" on an interpersonal level. Due to the intellectual and cultural demands of living in these small and specifically focused communities, such as research centers, the formation of interpersonal relationships is hindered. This further creates a feeling of isolation in addition to the separation from one's loved ones and other social groups, restriction of living space to an enclosed area, and restriction of external stimulation (perceptual deprivation). All of these factors contribute to isolation and cognitive impairment. Research by R.E. Strange and

W.J. Klein conducted on social and emotional adaptation to Antarctic isolation further proves the negative cognitive implications of isolation. They describe the negative impact of isolation as "winter-over" syndrome characterized by depression, hostility, irritability, sleep disturbances, and reduced mental performance (Terelak, 2021).

Designing for Extreme Arctic Environments

In the past, designing for polar/frozen regions was focused on keeping the elements out, rather than the interior and human experience within them (Gendall, 2020). The United Kingdom's Halley VI was one of the first projects to start thinking of habitation in these environments differently. Sensory stimulation was considered through the use of bright color choices and by adding olfactory stimulating materials such as cedar. Bedrooms were designed to be comfortable, but not so comfortable that people would isolate themselves, and would be encouraged to embrace community. Raising the architecture on stilted platforms/legs also allows the research center to avoid snow built up and thus creates more opportunities for natural light in windows during seasons with daylight (Gendall, 2020). While progress has been made, materiality of these newer research centers are still harder and cooler, versus materials that can hold and communicate memory and connection (Gendall, 2020).

In contrast to Antarctica, the Arctic environment has faced a more colonized approach to architecture and design. Often referred to as "empty" space, indigenous communities are often disregarded and their architectural practiced looked down on. While the renowned "Arctic Architect" Ralph Erskine has been criticized for his colonized approach to the Arctic, he has been appreciated for recognizing the uniqueness of the Arctic and how it cannot be treated similarly to other habitations in more populated areas of the world. Due to the extreme environment, it is important to understand architecture and interiors need to be approached differently. It's also important to understanding the role of indigenous communities and the impact of new architecture and communities built within their space (Hemmersam, 2016).

Regarding aesthetic design decisions, light considerations, due to light's impact on circadian rhythm, are vital to ensuring high cognitive function in interior environments. Allowing natural light and using appropriate artificial light in interiors are design choices that can support this data (Fisk, 2018). Areas that limit isolation are also incredibly important due to our awareness around negative cognitive impact of isolation (Terelak, 2021). In addition, adding in materiality that can increase place-identity and support self-identity within these new extreme spaces also can assist in creating a design that cognitively supports inhabitants (Pallasmaa, 1994). Lastly, incorporating sensory stimulation into design is vital to creating a space that supports cognitive function and health (Terelak, 2021). Using shadows and reflective materials to create levels of depth and visual interest can create a more dynamic and emotive space (Tanizacki, 1977). Adding materiality that can stimulate and evoke memory, emotion, and connection can also add to a stimulating space that supports healthy cognitive function (Pallasmaa, 1994). There is also benefit to designing a space that embraces the surroundings in a positive way to allow for positive and appropriate connection to the environment itself (Zumthor, 2006). This technique can be supported by data that shows habitants in these areas who embrace environmental events like the polar night tend to have lower rates of Season Depression Disorder (SAD) than those who do not (Leibowitz). While it is important to create an environment that is supportive of comfort and feels like an escape from the elements (Terelak, 2021), it also seems to be important to find ways to embrace the existing beauty of the extreme qualities in the environment itself and fit within that world (Zumthor, 2006).

Conclusion

The existing approach to designing for extreme Arctic and Antarctic environments is often limited to old ways of thinking, or to prioritizing keeping out the elements. While the approach to design in these areas has started to improve regarding the quality of life of inhabitants, there are still many design techniques that can be implemented to specifically benefit cognitive function. This is particularly true in environments occupied by "transplants" or people not originally from these types of environments, such as those occupying research centers or visiting the area on a long-term but temporary basis. Using existing scientifically supported data on obtaining and sustaining cognitive function, researched design choices can elevate the lives of those living in extremes. Paring this scientific data with design choices that embrace and appreciate the environment itself, allows for a space that heightens the overall experience and wellbeing for inhabitants, and allows them to not just survive, but to thrive.

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The six senses are linked to all of our experiences. The sensory input we get from our environments forms our memories, experiences, bonds, and overall personality. Without sensory stimulation, our cognitive health declines.

03 / RESEARCH

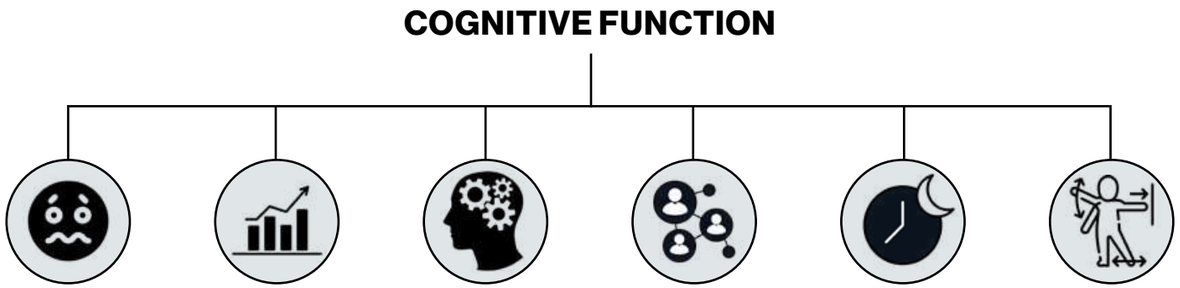
COGNITIVE HEALTH

Cognitive Wellness = Overall Better Health

The National Institute of Health (NIH) outlines six systems responsible for our cogntive wellness which includes: Negative Valence systems, Positive Valence systems, cognitive systems, social processing systems, regulatory systems, and sensorimotor systems.

When any of these 6 symptoms is negatively impacted congitive wellness declines. It is common to encounter some negative impact to these systems in “normal” daily life, but human resiliency allows people to handle minor impacts fairly well. This is particularly true when the impacts occure over shorter periods of time or are less severe. The true negative cognitive impact tends to occur when people are being impacted in multiple categories and/or are being consistently impacted over a long period of time. The severity of the challenge is also relevant to the level of cognitive impact.

Extreme environments are fundamentally challenging. As they are, they challenge all of these cognitive systems necessary for opitmal health.



NEGATIVE VALENCE SYSTEMS

fear, anxiety, sustained threat, loss, frustration

SOCIAL PROCESSING SYTEMS

affiliation/attachment, communication self/other-perception

POSITIVE VALENCE SYSTEMS

approach motivation, reward learning, habit

REGULATORY SYSTEMS

arousal, circadian rythyms, sleep & wakefulness

COGNITIVE SYSTEMS

attention, perception, working memory, language, cognitive control

SENSORIMOTO SYSTEMS

motor actions, agency & ownership, sensorimotor habit, innate motor patterns

EXTREME ENVIRONMENT CHALLENGES

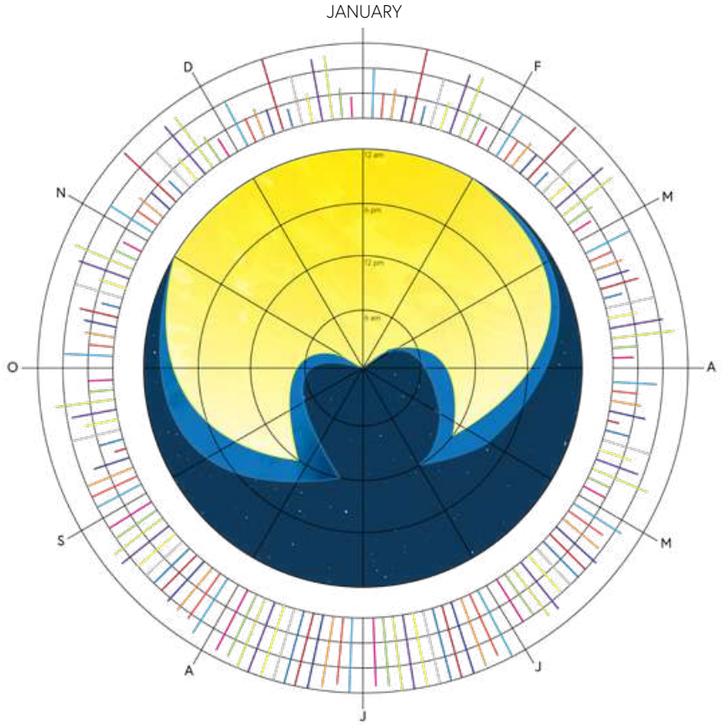
The chart below outlines the multitude of “extreme environments” and the challenges one may face when inhabiting them. While there are a multitude of environments that could be categorized as “extreme” they all face the same types of challenges related to survival.

These challenges each impact multiple systems required to maintain high cognitive health. The multitude and severity of these challenges highlights the severe cogntive impact caused by living in extreme environments.

ANTARCTICA - ANNUAL SUN STUDY & CHALLENGES

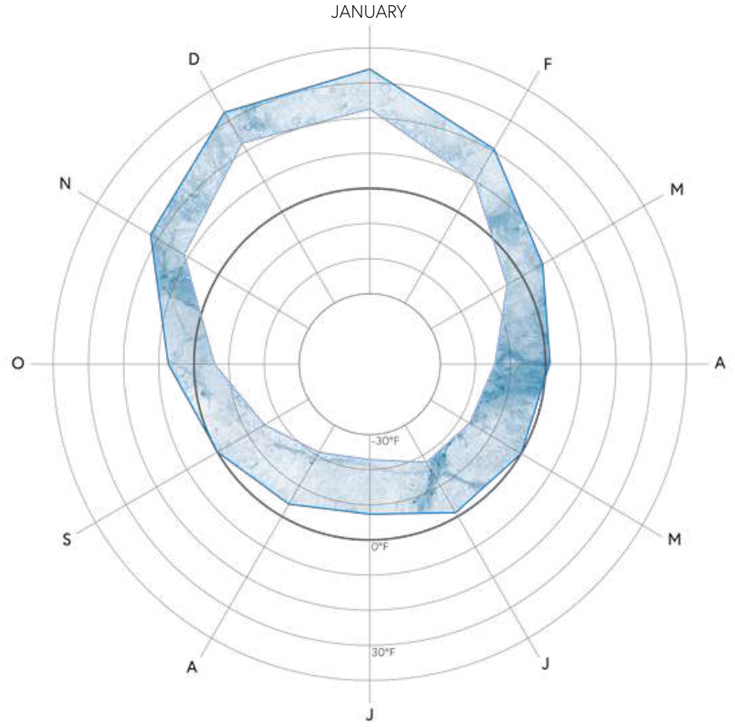
The visualization below outlines the different light levels experienced in Antarctica over a year. A significant challenge experienced in this region is the severe sunlight. Depending on the proximity to the South Pole, there can be 3-5 months of constant light and 3-5 months of constant darkness. Only 2-6 months of the year experience any level of sunrise or sunset.

The outer rim of this visulation shows the accompanying challenges (see chart on previous page) and their severity over the year.



ANTARCTICA - ANNUAL TEMPERATURES

This visualization outlines the annual temperature variations over the year in Antarctica. The average high and low temperature is highlighted for each month. This particular chart is focused on the coastal region near McMurdo Station and the Ross Bay. Temperatures range from -23 to 35 degrees Fahrenheit over the year.



CIRCADIAN RYTHYM

Circadian rythym can be seen as an internal clock in humans. Our natural daily “schedule” of wakefulness is linked to our circadian rythym.

In most areas of the world, over the course of a day, we experience different lighting from the sun and our overall environment. We slowly wake with warmer light from sunrises, become more alert with the cooler lights of mid-day, and slowly tire and get ready to sleep as the light warms again and then dissipates into night.

Science shows these light shifts impact how awake, alert, productive, etc we feel. Without this natural cycle of light, our bodies struggle to regulate and keep a healthy schedule.

In many extreme environments, the sun cycle is severely abnormal resulting in days of constant light and/or darkness. This disruption leads to a multitude negative cognitive impacts.

SUN CYCLE - ROSS SEA, ANTARCTICA

The photos below illustrate the severe light levels experienced at the selected site for my thesis (near the Ross Sea) over a calendar year. This severity creates dramatic impact to one’s circadian rythym and cognitive function.

MARKET RESEARCH - SURVEY

An informal survey was conducted with 60 participants. Participants were required to have spent at least 2 consecutive months in the Arctic or Antarctic. All participants had experienced polar day (24 hours of sunlight), polar night (24 hours of no sunlight), or both.

The insight from this survey supported the scientific research on extreme environments negative impact on cognitive function. It also provided design insight regarding programmatic requirements, needs, and dislikes of this market. In addition, this survey highlighted the different mindsets to these extreme environments when comparing Arctic vs Antarctic and resident vs foreign (those who grew up in this environment vs those new to this environment - Arctic only).

SURVEY QUESTIONS

1. Why did you/do you live in Antarctica or within the Arctic Circle?
2. How did/do you feel about living in an environment experiencing POLAR DAY (periods of time with only daylight - sun remains above horizon all 24 hours)?
3. How did/do you feel about living in an environment experiencing POLAR NIGHT (periods of time with no sunlight - sun does not rise above horizon for all 24 hours)?
4. While living in these environments, did you ever experience an onset or increase of any of the following challenges? Note: If you have lived in this climate your whole life, please mark only the challenges that seem to increase during polar day and/or polar night
5. What do you ENJOY about living in this environment (Arctic and/or Antarctic)?
6. What do you DISLIKE about living in this environment (Arctic and/or Antarctic)?
7. What helps you cope with and/or enjoy the winter time and cold weather?
8. What is your FAVORITE part about living in this environment?
9. What do you like LEAST about living in this environment?
10. What are your favorite interior places to spend time in this environment and why? (ex. your home, bedroom, coffee shop, etc)
11. If money was no object, what improvements would you want to be made to the interior or architectural spaces where you live/lived?
12. (ex. More facilities, better furniture, community spaces, etc)
13. Is there any advice you would give a designer/architect designing a space for people living in these extreme environments?

Cognitive Impact Question

While living in these environments, did you ever experience an onset or increase of any of the following challenges?

Note: If you have lived in this climate your whole life, please mark only the challenges that seem to increase during polar day and/or polar night

04 / PRECEDENTS

04 / PRECEDENTS

HALLEY VI - U.K. RESEARCH CENTER

Name
Halley VI Antarctica Research Center

Location
Brunt Ice Shelf, Antarctica

Operated by
British Antarctic Survey (BAS)

Users
United Kingdom Researchers and
52 in summer | 16 in winter

Architects
Hugh Broughton Architects

Years Built
2005-2013

Budget
£25.8 million

Accolades
Won design competition held by BAS

Published in Dezeen, The Architectural Review, Architizer, DesignBoom, and multiple Antarctica focused websites.

Environment
Temperatures drop to -56°C

Winds blow in excess of 160 kph

105 days/year there is no sun

Challenges
Snow accumulation 1m a year

Possible shifting/breaking in ice

3 months a year for building

3 months total darkness

Sustainability & 20 year life

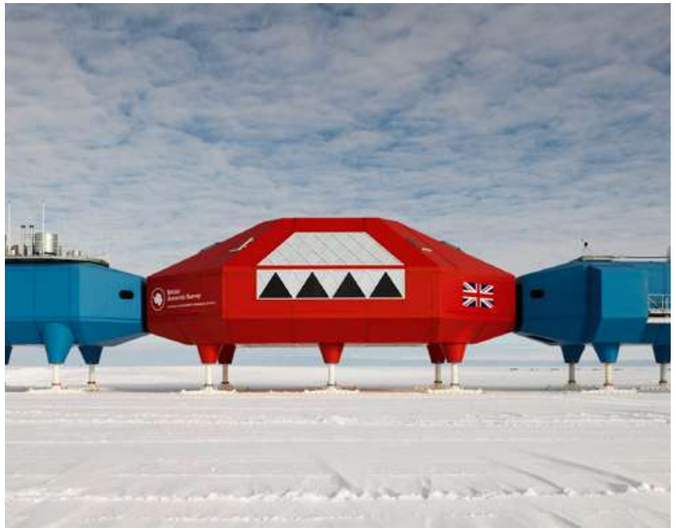
Most design decisions were made around requirements and/or benefits for the extreme environment and client's requirements.

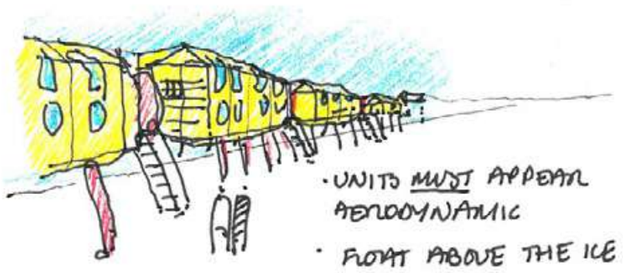
ARCHITECTURE

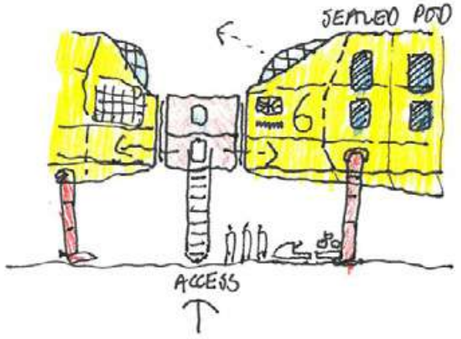
- Modular design
- Ski legs - easier to pull and move
- Hydraulic legs - "climb" out of the snow
- Raised datum - my aerodynamic and helps with snow accumulation
- Aerodynamic shape (each segment and as a whole)

INTERIOR

- Lighting to simulate circadium rythym - lights above bunks to simulate sunrise and light all around that simulates natural lights
- Red and blue - Psychologist recommended to avoid seasonal affective disorder (SAD).
- Cedar planks in center module to bring smell to design (no smell in this type of freezing environment)
- Windows allow natural light in when daylight is available including a skylight in the center module
- Game room, gym, kitchen, dining area, and quiet room to allow for a multiude of options







PUBLIC, SEMI-PUBLIC, PRIVATE

Very little private space besides bedrooms, and bedrooms are often shared.

Public space varies between public and semi-public based on what activity is being done in that room - Not everyone needs access to the same rooms.

All rooms are segmented off as separate spaces with little obvious connection besides doors - private but closed off

MATERIALS

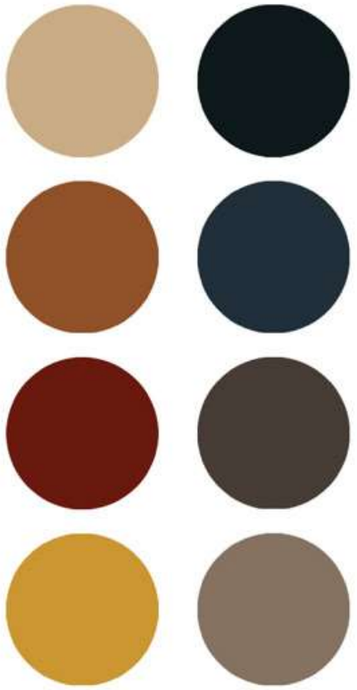
- Chosen to withstand the elements of the harsh climate
- Color choices used to assist in creating spaces that support mental health
- High quality construction and craftsmanship done out of necessity (windows, walls, joinery all NEED to be of the highest quality
- Some unique choices like cedar wall cladding adding in olfactory sense

CONSTRUCTION

- Hydraulic legs used to "climb" out of snow and prolong life of building
- Modular structure & ski legs to allow for relocation of modules
- Meant to resist environment vs age with it

REINDEER PAVILION - NORWAY

This pavilion designed by Snohetta, embraces the natural environment. Colors and materials are reflected by the natural landscape's flora and fauna. The shapes are inspired by ice formations and erosion in the surrounding mountains. While located in an extreme environment, the designers embraced the beauties of the extremes. This results in a beautifully balanced and evocative space that allows a visitor to feel connected to the environment in a deeper and complex way.



DOVREFJELL NATIONAL PARK

05 / SITE & PROGRAM

05 / SITE & PROGRAM

ANTARCTICA

ZUCCHELLI STATION

The site chosen for this thesis is the current site of the Italian research center, Zucchelli Station. For the sake of this thesis, this base is to be a more remote extension of the close by U.S. Research Station, McMurdo Station.

This station is positioned by the Ross Sea and in close proximity to the TransAtlantic Mountains.

WHY?

Proximity to McMurdo Station

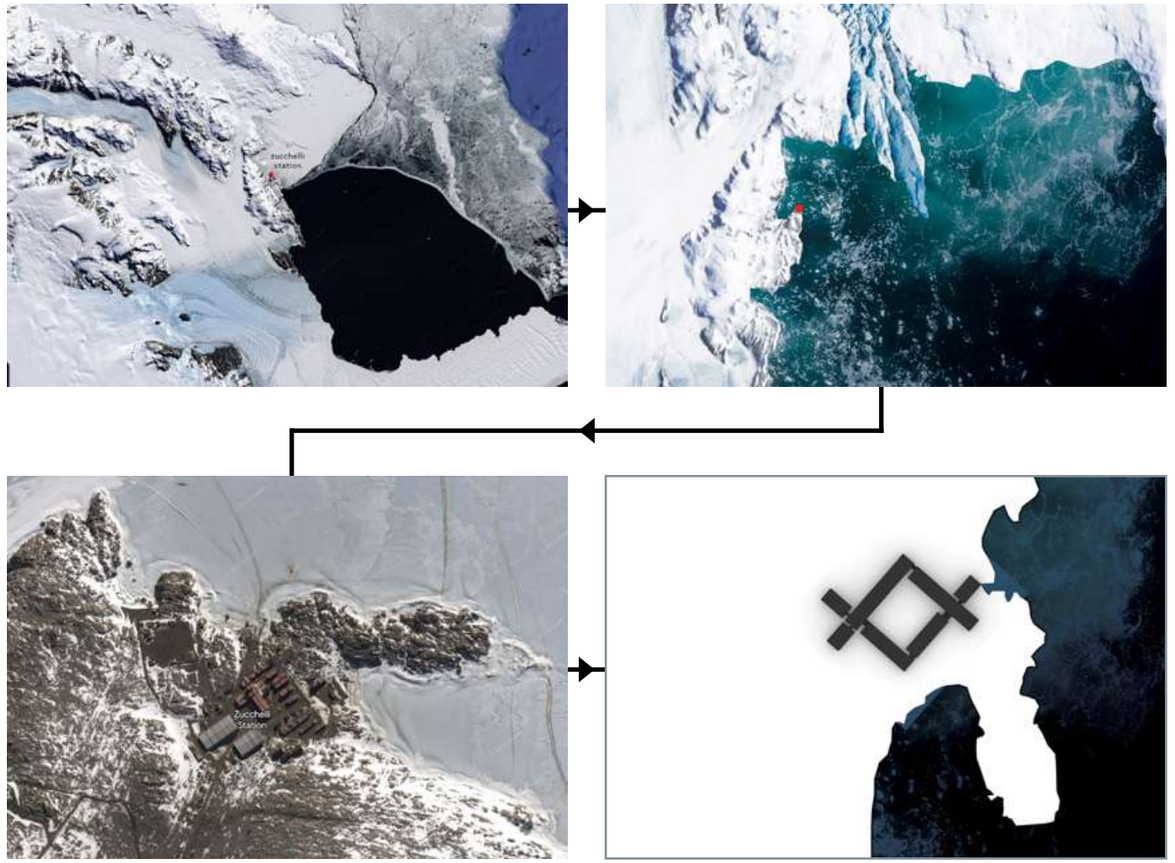
This proximity creates more accessibility and more availability of necessary resources and transport.

Proximity to different environments

This station is located on the coast, which allows for better accessibility and more research opportunities for geology, biology, and zoology.

Proximity to the TransAtlantic Mountains and nearby volcanoes puts this station in a great location to study climate change and geological studies.

Diverse viewpoints to increase visual stimulation for cognitive support.



ARCHITECTURE

COMANDANTE FERRAZ ANTARCTIC STATION

The architecture used in this project is based on the current Brazilian Antarctic Station located on King George Island, Antarctica.

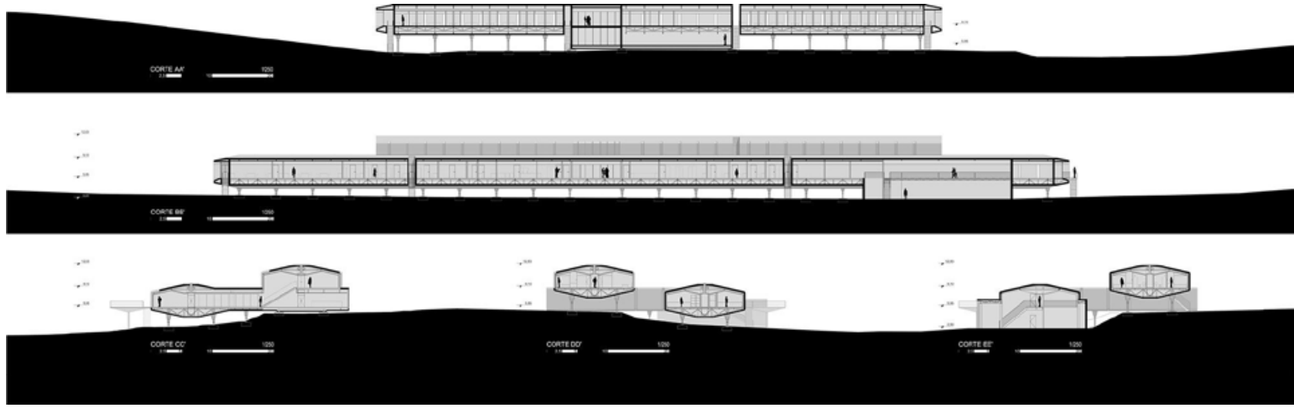
Due to the lack in quality and design consideration, the existing structures aren't able to meet the complex needs of this environment. A new building is necessary to ensure the design supports the physical and mental needs of the occupants.

WHY?

Modular "pods" or units allows for flexibility in design

Designed for similar extreme environments

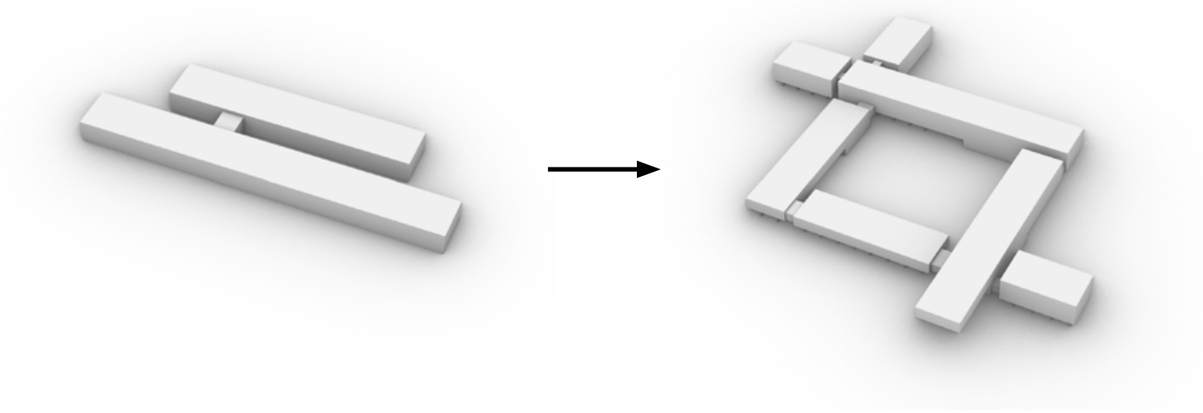
More modern and recent design supports higher end interior



NEW CONFIGURATION

Using the existing units, the composition of the building was changed for the new site. The original architectural layout was not condusive to supporting the needs of the research center. The long linear and parallel forms creates monotonous walking patterns. Monotonomy and lack of complexity is already a significant challenge in extreme environments.

The new layout of the units allows for cyclical circulation and distinct new viewpoints. This not only encourages more movement from occupants, but it also allows for occupants to be "placed" in new environments with new views while they are still in the same building. This allows for more cognitive stimulation.

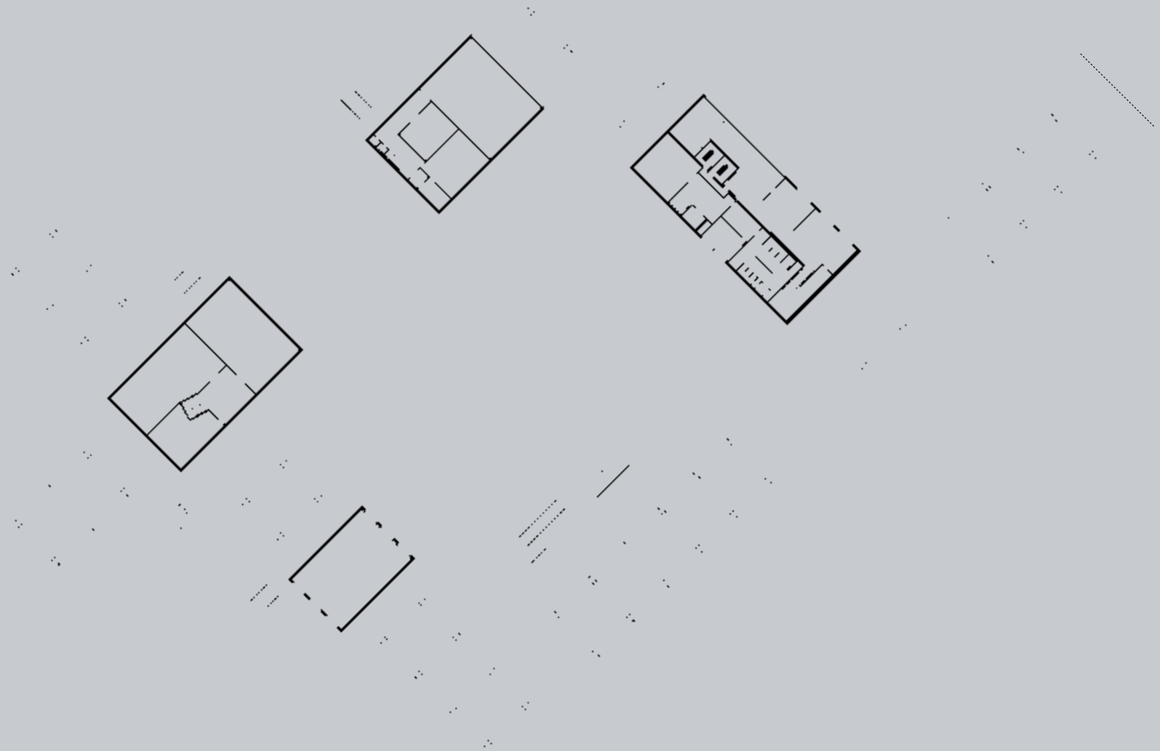


PROGRAM

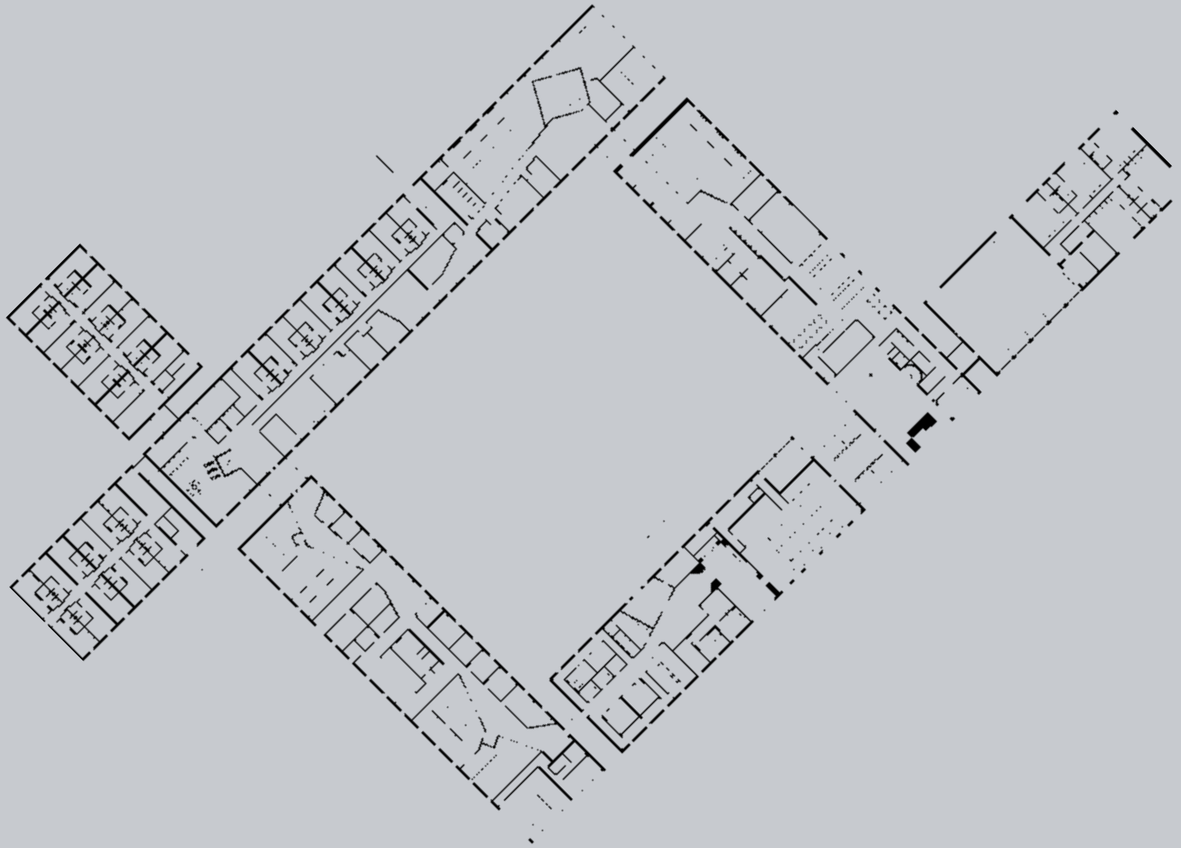
ANTARCTIC RESEARCH CENTER & LUXURY LODGE

ICECUBE
RESEARCH CENTER

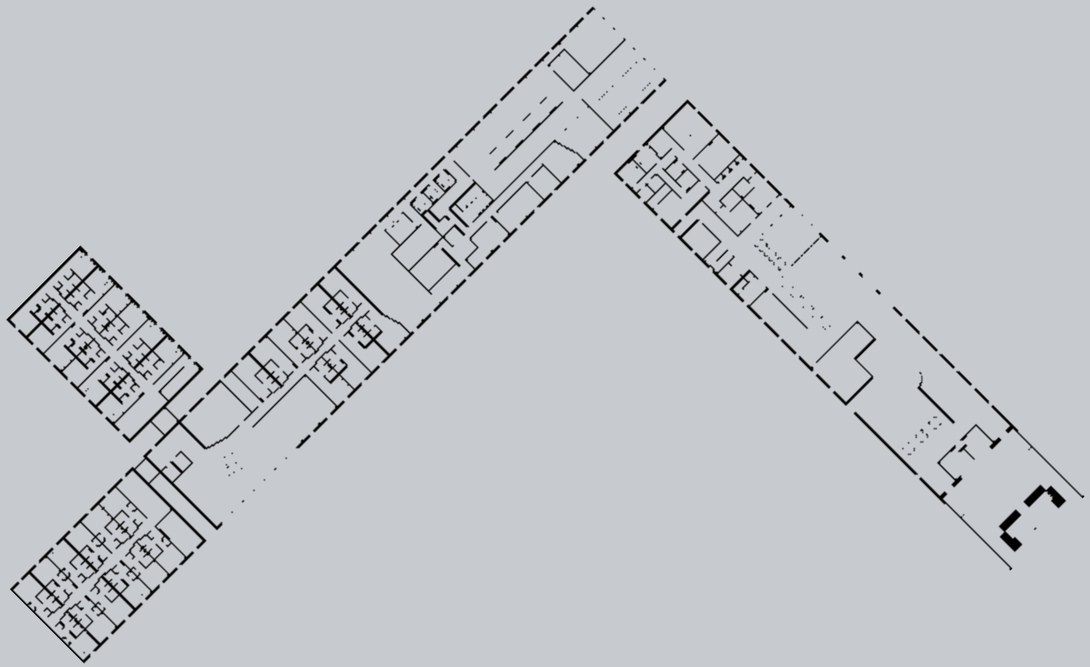
RESEARCH	COMMUNITY	LODGE
Laboratories	Common areas	Suites
Storage	Bar	Common area
Garage	Cafe	Dining area
Data center	Laundry	Bar
Offices	Salon	Storage
Meeting areas	Sauna/Spa	Bath
Reception	Cafeteria	
Bedrooms	Greenhouse	
Medical	Gym / Rec area	



GROUND FLOOR PLAN
not to scale

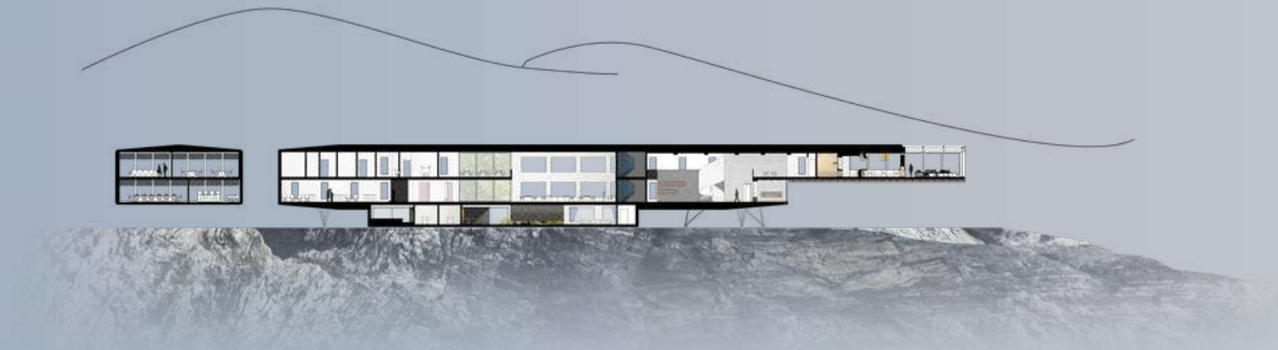


FIRST FLOOR PLAN
not to scale



SECOND FLOOR PLAN

not to scale



SHORT SECTION

not to scale

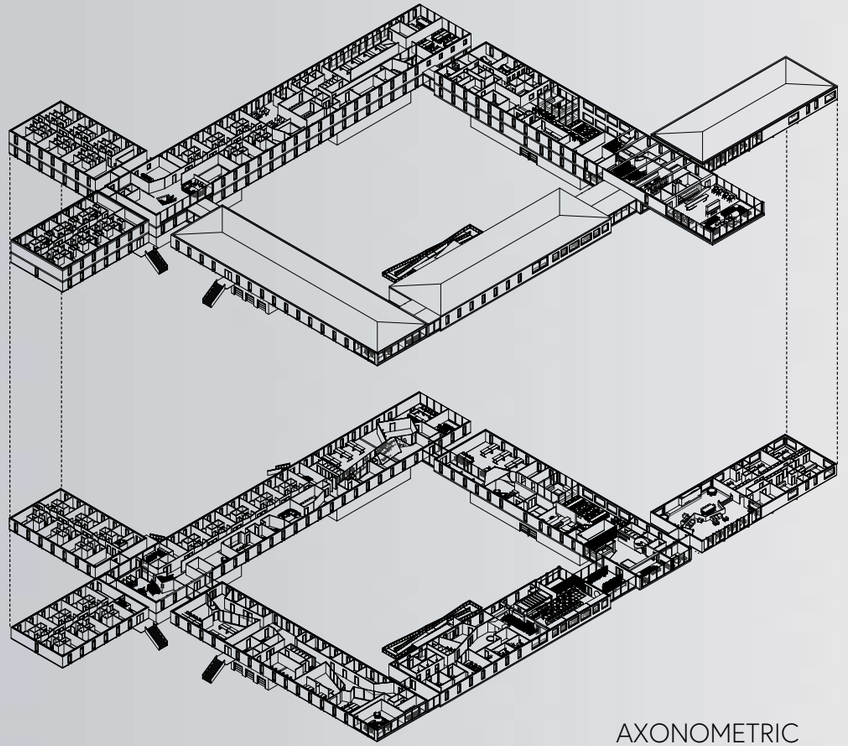
LONG SECTION

not to scale

CIRCULATION

Architectural shape and layout focuses on lateral and longitudinal circulation. Due to the reality where occupants are often stuck inside and have limited outdoor access, it's important to encourage physical movement. The layout highlights different views on each side of the building allowing occupants to feel as if they are in new environments while remaining in the same building.

This circulation breaks up monotony and adds cognitive stimulation, both of which assist in maintaining cognitive wellness.



AXONOMETRIC

not to scale

06 / DESIGN

TRACES OF HISTORY

Those who participate in programs in Antarctica tend to feel **deeply connected to the history** of the continent and the explorers who came before them. They are part of a very small “club” of people. This connection should and can be embraced through design choices.

Design decisions help highlights these moments of history. Recreations of fossils discovered on the continent are shown as art.

The **flag ceiling installation** is created by each research team adding their flag with their signatures. Over time, the ceiling will become more full and the age difference of the fabric will be visually evident. This visual reminder of history and contribution to the cause of the research center assists in creating connection to place.

WELCOME AREA - FIRST VIEW

MATERIALITY & MEMORY

Brass | Leather | Wood | Light Fabrics

Materials like these naturally change with their history and **hold memory**. Traces of activity can be visually seen and felt and builds deeper connection.

CONNECTION

These types of materials create connection. Seeing the actual trace of human history brings comfort to occupants in a space. This is especially important in an extreme environment since signs of life are unusually minimal. Seeing a real connection to the past can bring comfort and a sense of safety.

Connection & Artifacts

Cast recreations and original fossils found on Antarctica are highlighted as art work. Artifacts are respectfully displayed. These design choices not only show a respect and celebration for the work conducted on this continent, but also **highlights the life** that has been on this land over history.

In the bar, a vertebrae of a local whale species is hung. This is a reminder of the life present in this location and brings a museum quality to the space.

RESPONSIVE TECHNOLOGY

CAPTURING HEAT WASTE

Sustainability is vital in extreme environments. Due to limited resources and the limited accessibility to and from the location, all resouces should be used as much as possible.

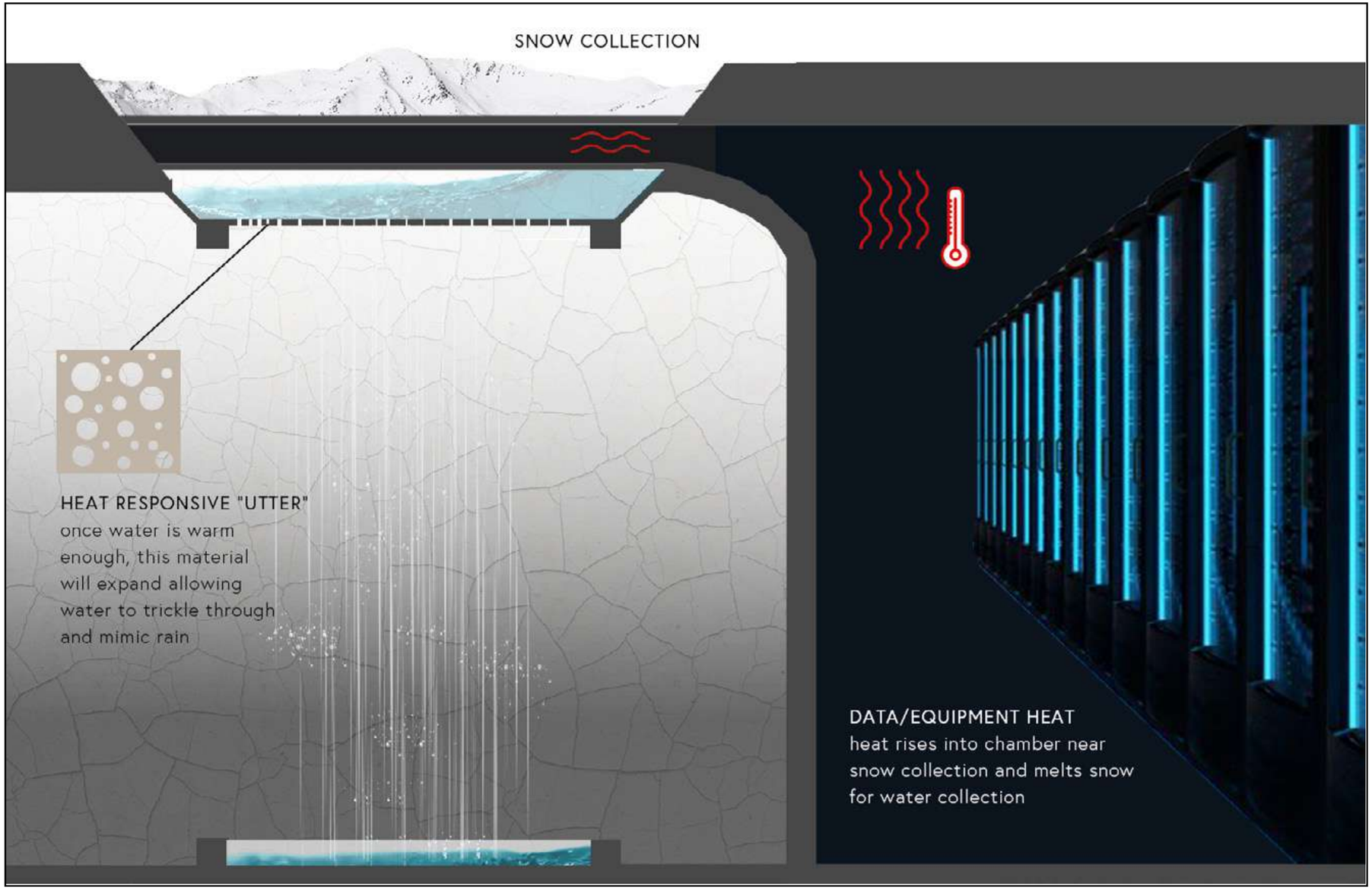
“Heat waste” is created from running equipment and from data centers. This heat is often released from the building, but this building captures that heat and utilizes it.

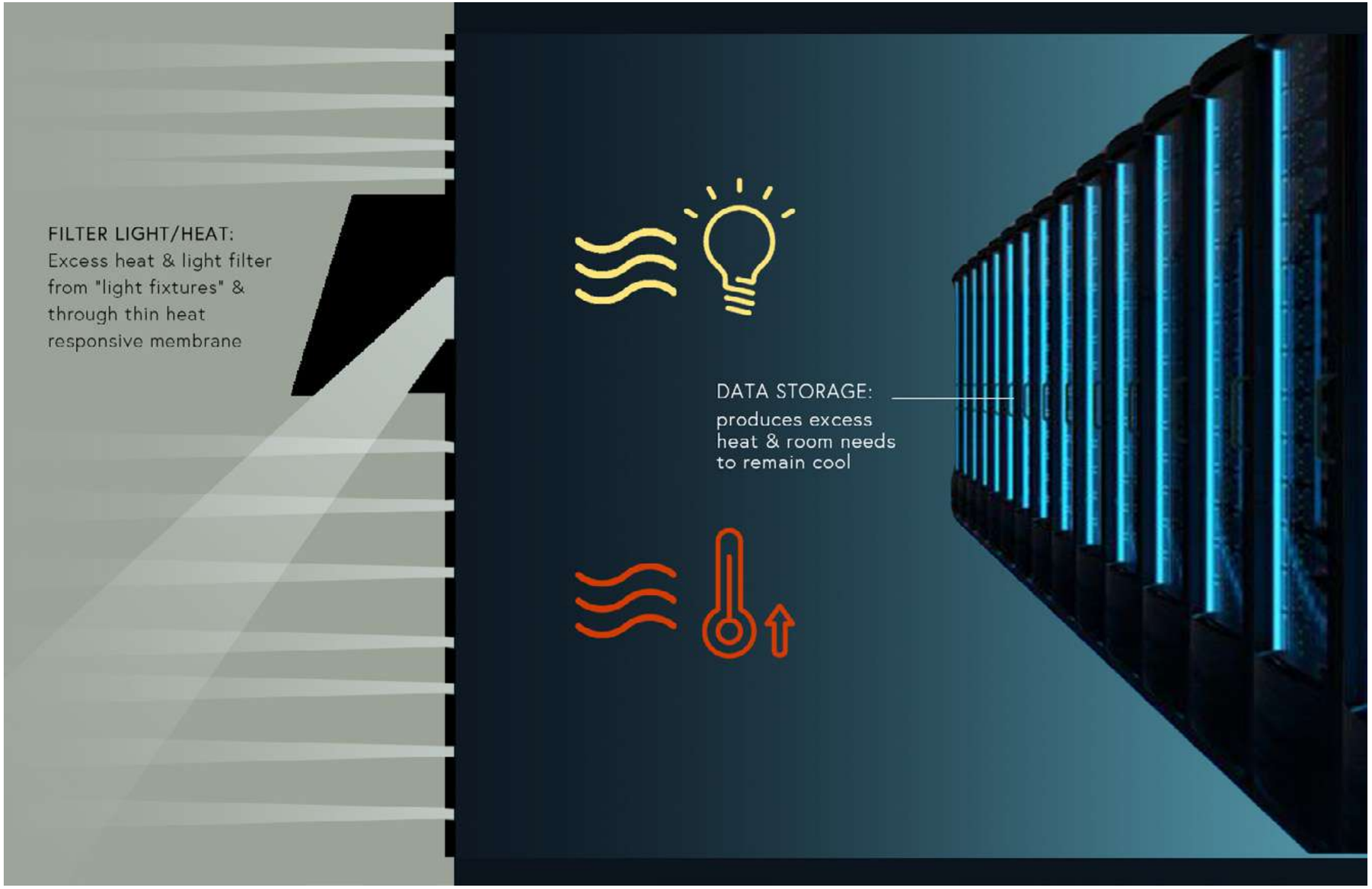
SNOW & WATER COLLECTION

Antarctica experiences large levels of snow fall all year long. This diagram shows the collection of snow through the architecture itself. This collected snow is then heated by heat waste and melted. As the snow melts and warms a heat responsive membrane expands and releases the water.

This membrane acts similar to an utter and releases a rain like pattern of water that creates a unique water features that also mimics nature. This water is then collected and put into the buildings filtration system to be used.

This water feature is not only stimulates visual and auditory senses but the mimic of natural rain can increase mental and cognitive wellness.





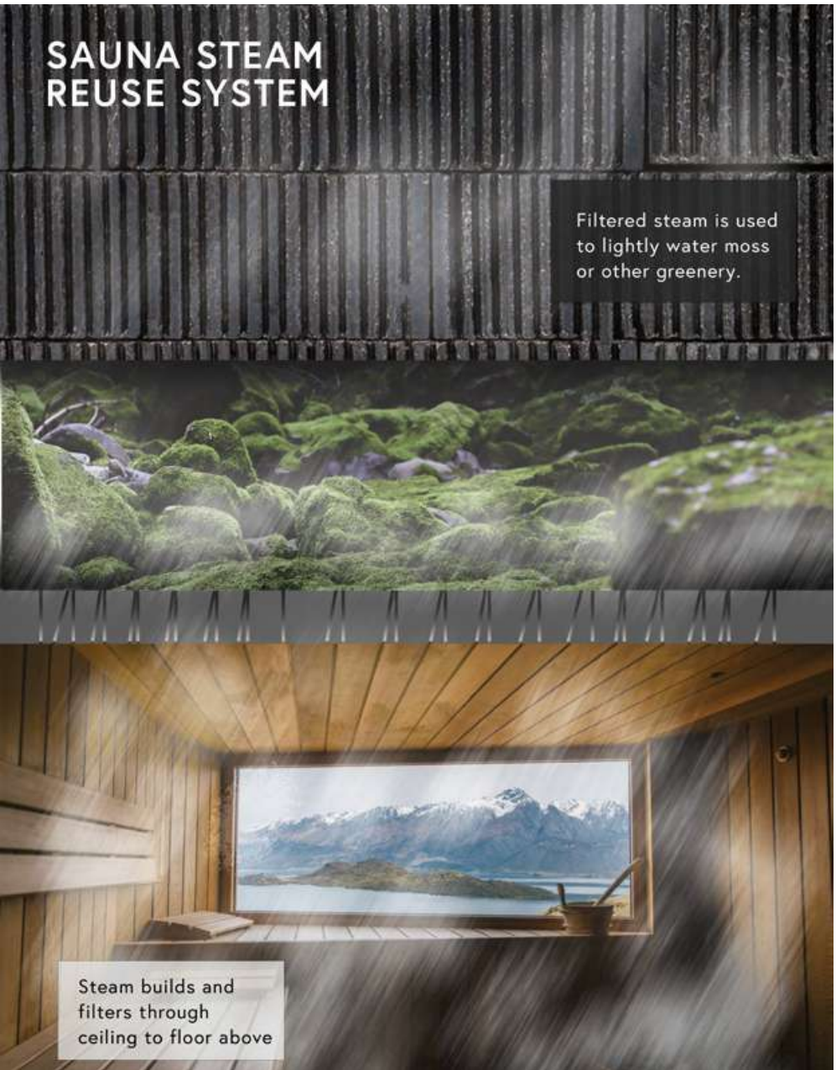
HEAT & LIGHT WALL

This diagram highlights to use of heat and light waste created by data centers. The “light fixtures” on the wall are actually openings in the wall. These openings are covered in a double laminated metal that “curls” and opens at a certain heat level. When the data center gets too warm, this metal opens and releases the heat.

These openning allows for a dynamic wall feature that not only cools the data center of excess heat, but the heat and light coming from this room heats and lights the adjacent room in a sustainable way.

Water feature and light feature wall can be seen on the following pages.

This system takes steam from the sauna on the ground floor and reuses it to stabilize humidity in the greenhouse. In the cooridor, the steam lightly waters the mossy rocks and also creates spontaneous stimulating moments.



CIRCULATION - ARTIFACTS & GREENHOUSE

CIRCADIAN RYTHYM

Three to six months of the year (depending on proximity to the South Pole), the sun either always stays above the horizon or never rises above the horizon. This results in 3-6 months of constant light or constant darkness. This makes circadian rhythm a vital interior consideration for the environment.

Human beings have what can be compared to an “internal clock”. This internal clocks signals our brain and body so that it responds appropriately to the time of day.

Warm light from sunrise slowly wakes us up, brighter bluer light keeps us alert in the middle of the day and allows for higher productivity, warmer light as the sun goes down signals our brain that is almost time for bed, and darkness signals that it is time for sleep.

When our circadian rythym is disrupted, especially this severely, there are drastic negative cognitive impacts. It leads to deterioration of cognitive and physical health and wellness, and often causes cognitive decline, depression, feelings of isolation and distress.

With technology, light temperatures can be programme to change over the day to mimic the natural light pattern of which our body’s are accustomed.

<2000K 3500-4500K 5500-6500K 3500-4500K <2000K

MAIN CIRCULATION AREA

This area is the main area of circulation in the building. It is easily accessed from all large public areas.

A reflection pool was placed in the center to evoke a sense of natural immersion. The large rock placed in the pool makes it feel as if the exterior environment is merging with the interior environment. This assists in building connection to place. Due to the natural conflict occupants have with extreme environments, it's important that occupants don't become to disconnected as this can create cognitive disruption and unrest.

CIRCADIAN RYTHYM

Extreme light levels (3-6 months of constant darkness or sunlight) makes circadian rhythm a vital interior consideration.

Light temperatures change over the day to mimic the natural light pattern of which our body's are accustomed.

LAB SPACE

Lab spaces spaces are differentiated through the use of materiality, cooler light to support productivity, and sharper angles.

This differentiation allows residents to easily separate their work space from their living spaces. Since residents live in the same place they work, it is important to give them a way to “escape” work and enjoy work/life balance.

MATERIALITY

All labs areas are visually “labelled” by the black perforated metal. The angled application draws people into the new type of space and differentiates living spaces vs working spaces.

Research being completed by each lab is also highlighted in the hallways through monitors. Teams can share infographics, live models, trackers, or photos/videos of their progress and findings. This creates opportunity for labs and employees to have their work seen and recognized by others while also making others feel more connected to the building and the work being completed there.

07 / FINAL RENDERS

EXTERIOR - SUMMER

EXTERIOR - WINTER

ENTRY AREA

ENTRY SEATING

BAR

BAR - ICE EXPERIENCE INSTALLATION

MAIN LOUNGE

MAIN CIRCULATION HUB

CAFE

COORIDOR - GREENHOUSE

LAB WORK AREA

EXTERIOR - SUNSET


LAUREN LEWIS | THESIS 2023