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GreenPatch
Architecture in sensory deprived environments

ausgeführt zum Zwecke der Erlangung des akademischen Grades einer Diplom-Ingenieurin unter der Leitung

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RESÜMEE

Nach dem Weltraumrennen sind mehrere ehrgeizige Konzepte zum Thema Bewohnbarkeit in isolierten Umgebungen entstanden. Die Bilder stellten ein ähnliches Leben wie das auf der Erde dar und waren als Ideen für zukünftige Weltraummissionen gedacht. In der Realität aber wurden die meisten Projekte durch Logistik und Kosteneffizienz stark beeinflusst und auf ein Minimum reduziert.

Die Antarktis zeigt mehrere Gemeinsamkeiten mit dem Leben im Weltraum und trägt deswegen auch den Spitznamen "Weißer Mars". Die Forscher in der Antarktis sind fast ein ganzes Jahr lang auf die Forschungsstationen beschränkt. Es gibt im Jahr nur ein kurzes Zeitfenster von fast drei Monaten, in dem frische Vorräte geliefert werden und in dem auch Notflüge stattfinden können. Die Wintermonate stellen auch ein großes Risiko aus psychologischer Sicht für das Team dar. Sowohl die Gruppe als auch das Individuum wird stark von der Isolation beeinflusst. Der ewige Winter, die ungewöhnlichen Tag- und Nachtzyklen und die einheitliche Umgebung tragen letztendlich zu Langeweile und verminderten kognitiven und motorischen Leistungen bei. Obwohl diese Auswirkung schon bekannt sind, fehlt den meisten Forschungsstationen mehrere architektonische Qualitäten.

Ziel der Masterarbeit ist es, die Probleme, die im Laufe des antarktischen Winters stattfinden, hervorzuheben und ein architektonisches Konzept für ein, mit verschiedenen Stimuli angereichertes, Modul vorzustellen. Das Modul ist für die Stationen auf dem antarktischen Plateau entworfen worden. Die Forschungsinterviews haben gezeigt, dass zusätzliche Gruppenaktivitäten und Gewächshäuser dringend benötigt werden. Das Projekt strebt an, diese beiden Bedürfnisse mit Hinblick auf die unterschiedlichen technischen Anforderungen zu vereinen. Der Fokus liegt auch auf den räumlichen Interaktionen der Mannschaft mit dem Gewächshaus.

ABSTRACT

After the space race, several ambitious concepts regarding habitability in isolated and confined environments started to emerge. Various images showing a life similar to the one we know on Earth was idealized as concepts for future space missions. In reality most of the projects were constrained by efficiency, cost and logistics and were reduced to the bare minimum.

Antarctica shares enough similarities with life in outer space to be often nicknamed “White Mars”. Re-searchers are confined to the station for most of the year, having only a small window of about 3 months when fresh supplies can be delivered and emergency flights can take place. The winter months also pose a significant psy-chological risk impacts the group dynamic as well as each individual. The lack of seasons, familiar day-and night light cycles and stimuli lead ultimately to boredom and decreased cognitive and motor skills. Even though these side effects are well known, an Antarctic station still needs to embrace a more sensory rich design.

The aim of this master thesis is to highlight the problems encountered during long stays on the Antarctic Plateau and to propose a sensory enriched add-on for these stations. The research interviews for this thesis have pointed out that greenhouses and additional space for group activities are much needed during the long winter months. The architectural project strives to incorporate these two uses with regards to the different technical re-quirements. It will emphasize on the interaction between the crew members and how an exploration greenhouse can be spatially improved.

CONTENTS

Acknowledgments

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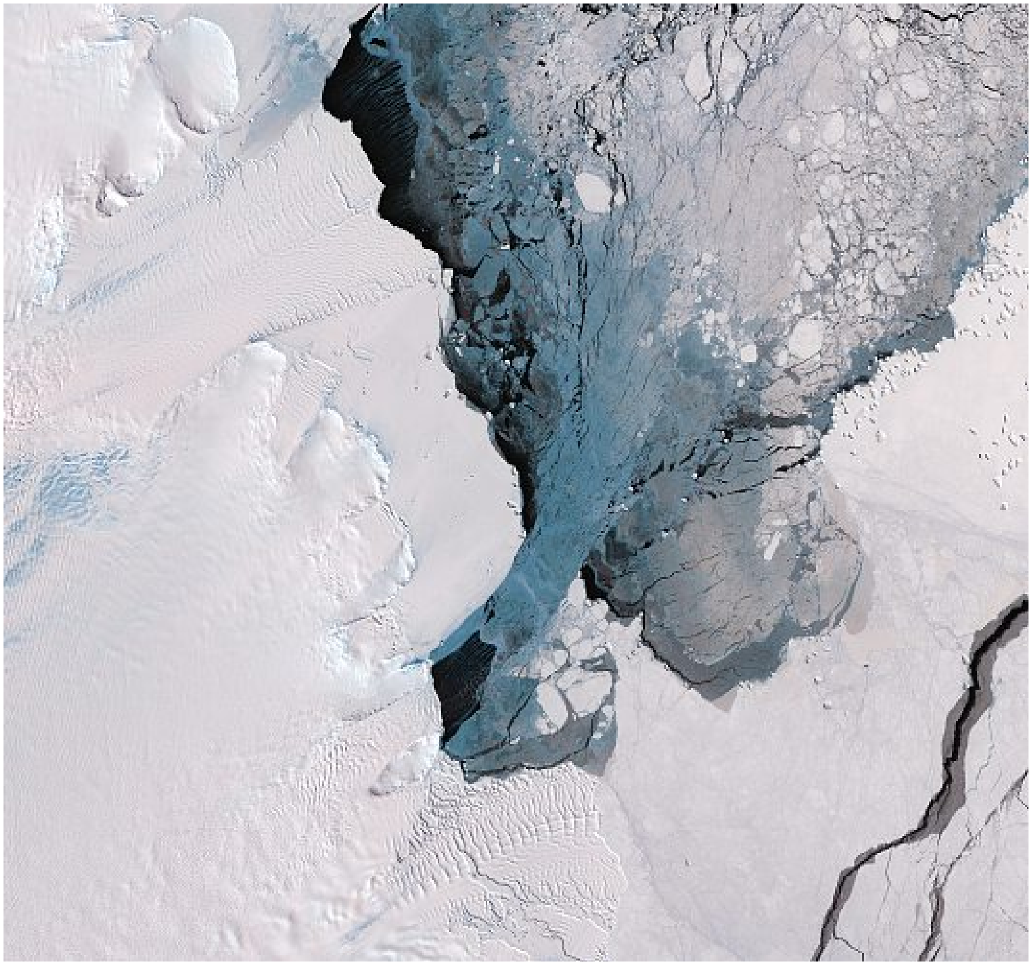


01. Satellite image of the Mertz-Ninnis Valley, Antarctica
Credit: UK-DMC2 Airbus DS 2018

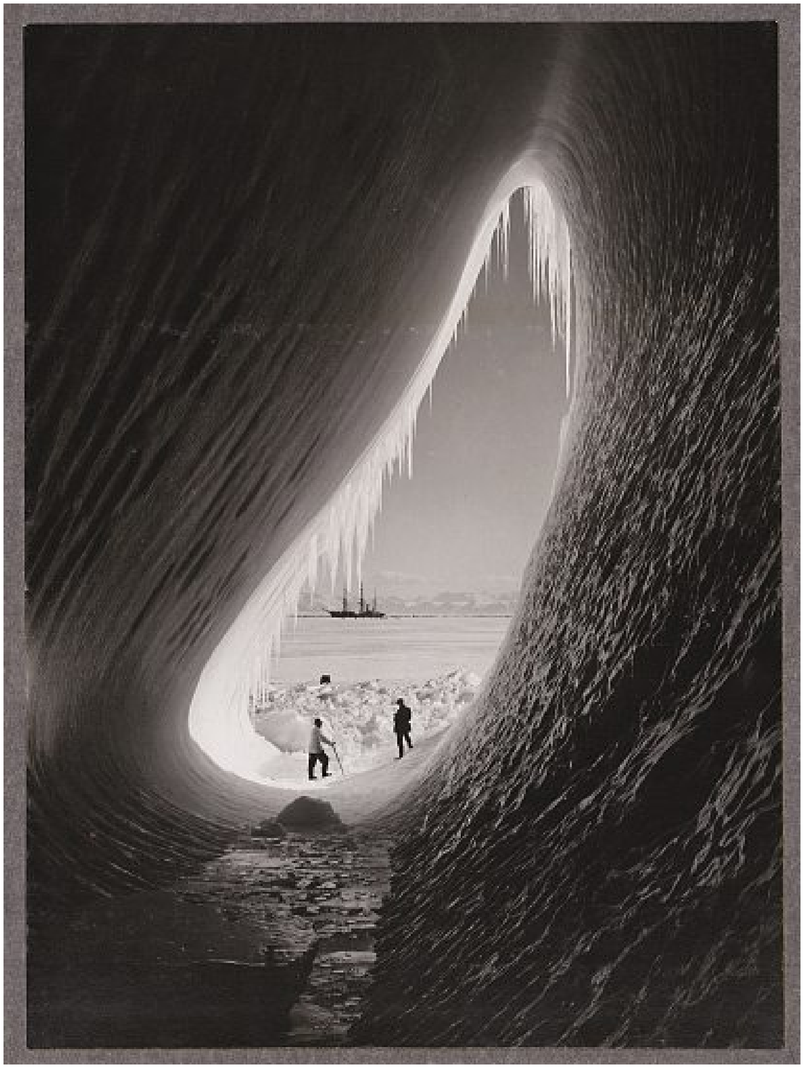
01 INTRODUCTION

As one of the harshest environments on Earth, Antarctica is habitatble for just of few species which are mostly found near the coast. The Antarctic Plateau found in the East of the continent is a vast area of about 1.000km in diameter with an average height of 3.000m. Most of the research stations are located near the coast thanks to the accessibility by ship. Stations on the coast face extreme wind speeds of over 300km/h and heavy snowfall. However, on the Plateau, the research station face very mild winds, little snowfall, but instead extreme isolation. In addition, due to the high altitudes of the Antarctic Continent, the researchers are in a constant state of chronic hypoxia.

Building a station here is a true challenge, but research done in Antarctica is very valuable. It's one of the best places on Earth to study astronomy, geology, weather, microbiology and many more. One of the most important discoveries was, in the 1980s, the Ozone hole above the frozen continent which caused huge concern. In order to get this valuble data, scientits must face many challenges. The most common problem is called the winter-over syndrome which causes different issues such as sleeping disorders, depression, anxiety and low cognitive activity. Even though the design of a station is mostly dictated by cost and logistics, adding a few design elements can help make the stay more bearable. The lack of fresh food has also a major psychological impact on the crew. A potential greenhouse on the station will have many challenges but the interaction with the plants will be beneficial for the crew. It will not only provide psychological relief but also fresh food.

02. Endurance trapped in ice during Sir Ernst Shakeltons Trans-Antarctic Expedition
Credits: National Maritime Museum

02 EXPLORATION HISTORY



03. Terra Nova Expedition 1910-1913, Antarctic Grotto in an iceberg
Credits: Herbert Ponting/ National Library of New Zeeland

02 EARLY EXPLORATION MISSIONS

- 600-300 BC - Idea of a spherical Earth with North and South Polar regions[3]
- 1772-1772 - HMS Resolution, Captain James Cook crosses the Antarctic Circle[4]
- late 18th century - whalers and sealers document sea routes and a part of the island in the sub-Antarctic for hunting reasons[5]
- 1819-1821 - Fabian Gottlieb von Bellingshausen and Mikhail Lazarev, first sight of the mainland part of the Antarctic Peninsula[6]
- 1823 - Captaim James Weddell sails furthest South ever to that day[7]
- 1839-1843 - British explorer James Clark Ross discovers the Ross Sea, Ross Ice Shelf and the Victoria Land cost[8]
- 1837-1840 - French explorer Jules-Sébastien-César Dumont d'Urville discovers the Adélie Coast and claims it in the name of France [9]
- 1838-1842 - U.S. explorer Charles Wilkes explors a vast area of the East Antarctic coast[10]
- 1872-1876 - Scottish naturalist Charles Wyville Thompson on HMS Challenger is the first to study and describe life in the ocean depths[11]

[4] British Antarctic Survey, Antarctica Timeline, n.d.
[5], [6], [8], [9], [10] Britannica, Antarctica- Early geographic discoveries, n.d.
[7] Royal Museum Greenwich, History of Antarctic explorer, n.d.
[11] Britannica, Sir C. Wyville Thomson, n.d.

02 HEROIC AGE

- 1898-1899 - the first Belgian Antarctic Expedition became trapped in pack ice and had to winter-over for the first time in Antarctica[12]

- 1899 - Norvegian explorers Carsten Borchgrevink's expedition was the first to winter-over on the mainland[13]

- 1901-1904 - British Captain Robert Falcon Scott is the first to lead an Antarctic expedition on HMS Discovery. Scott and fellow explorers Ernst Shackelton and E.A. Wilson are headed for the South Pole and travel about 650km inland before being forced to return to the ship.[14]

- 1907-1909 - second British Antarctic Expedition led by Ernst Shakelton comes within 150km of the South Pole [15]

- 1910-1912 - first to reach the South Pole was Norwegian Roald Amundsen and his crew of four men on December 12, 1911 after finding a new route of only 57days [16]

- 1910-1912 - Robert Falcon Scott departs from Cardiff on his own exploration to be the first to reach the South Pole. Scott and his crew reach the South Pole only to find that Amundsen has been there already. Due to the harsh winter Scott and his men die on their journey back[17]

[12] Britannica, The heroic era of exploration, n.d.
[13] , [14], [15]Royal Museum Greenwich, History of Antarctic explorer, n.d.
[16] British Antarctic Survey, Antarctica Timeline, n.d.
[17]Royal Museum Greenwich, History of Antarctic explorer, n.d.

- 1911 - Roald Amundsen and his crewmates are the first to reach the South Pole[17]
- 1911-1914 - first Australian Antarctic Expedition led by Douglas Mawson[18]
- 1914 -1916 - Ernst Shakelton begins his Trans-Antarctic Expedition aboard the ship Endurance aiming to become the first to cross the continent through the South Pole. His mission turns into a survival effort while the ship becomes trapped in pack ice.[19]
- 1929 - Explorer Richard Byrd, pilot Richard Byrd, co-pilot Harold June togheter with radio operator Ashley McKinley are the first to cross the South Pole by aircraft[20]
- 1935 - Caroline Mikkelsen was the first women to walk on the continent[21]
- 1943-45 - First bases were established in Antarctica during the Tabarin Operation, a mission initiated by the British Goverment in order to become a permanent presence and observe potential enemy activities.[22]
- 1947 - Americans Edith Ronne and Jennie Darlington becomes the first women to winter-over during an expedition.[23]
- 1949-1952 - the Norwegian, British and Swedish Expedition merge to the International Scientific Expedition.[24]
- 1957-1958 - International Geophysical Year. Joint undertaking of many countries to conduct various scientific projects in Antarctica[25]

[17], [18], [19], [20] Royal Museum Greenwich, History of Antarctic explorer, n.d.
[21], [22], [23], [24] British Antarctic Survey, Antarctica Timeline, n.d.

04. Roald Amundsen at the South Pole
Credits: Illustrated London News/ Getty Image

02 RACE TO THE SOUTH POLE

05. Robert Falcon Scott and crew arriving at the South Pole and finding Roald Amundsen's tent
Credits: CoolAntarctica.com

ROALD AMUNDSEN, 1909-1911

Roald Amundsen (1872-1928) was a Norwegian explorer, the first to reach the South Pole and to cross the Artic by air. [25]

During the Belgian expedition of 1897, Amundsen was part of the first crew to winter-over in Antarctica. This opened the door for future exploration attempts. However, Amundsen's initial goal was to be the first to reach the North Pole but American Robert E. Peary beat him to it. As a consequence, he changed his plans and started preparing in secrecy to venture to the South Pole instead. In the summer of 1910 he sailed towards the South and established a base in the Bay of Whales. [26] While heading towards Antarctica he sent his rival explorer Robert Falcon Scott a letter informing him of his mission. Scott was also preparing to be the first to reach the South Pole.

Amundsen had experince in polar travels. He and his men laid supplies along the first part of the route for the return journey. He had 4 men, 4 sledges and 52 dogs when he began his journey on the 19. October 1911.[27] Even though his men suffered from frostbite and some dogs had to be sacrificed along the way to provide food, Amundsen reached the South Pole on December 14.

They started their return journey on Decemeber 17 and reached the Bay of Whales on January 25, 1912. Amundsen left for his fellow rival Scott a tent with a letter. Scott would reach the South Pole just 33 days later but his mission would encounter many challenges. His achievment by being the first to reach the South Pole was overshadowed by of Scott's tragic mission ending.

[26], [27] Britannica, Roald Amundsen, n.d.

06. Terra Nova Expedition 1910-1913 led by Robert Falcon Scott, sledges hauled by ponies
Credits: CoolAntarctica.com

ROBERT FALCON SCOTT
1901-1904 and 1910-1912

Robert Falcon Scott was a British naval officer and explorer who made two attempts to reach the South Pole, his second one being the one where he reached his goal but ended in tragedy.

Scott was a lieutenant in the Royal Navy and led the Antarctic expedition on the HMS Discovery commanded by the Royal Geographical Society.[28] The exploration mission was designed to gather scientific data as well as to be an ambitous exploration journey to reach the most southern point toghether with fellow notable explorers E. Shakelton and E. Wilson They set a new record at that time for the Farthest South, at 82°17'S.[29] Even though supplies were laid in specific places by a supporting crew so that the main party will not have to carry supplies and food for the entire journey, the mission was getting harder to accomplish. The men were affected by snow blindness, frostbite and scurvy. They reached the ship on the 3rd of February 1903.[29] On the return journey, HMS Discovery became trapped in pack ice and had to be freed using manpower, two relief ships, and explosives. [30] Upon his return home, he was praised as a national hero and began raising funds for his second trip to Antarctica.

In 1910, Scott embarked on this second expedition, this time to be the first one to reach the South Pole. Aboard the ship Terra Nova and equipped with motorised vehicles, dogs, and ponies, Scott and his crew ventured to reach the geographical South Pole. The mission began to fail when the motor sledges broke down, the ponies had to be pur down while the dog party returned to the ship.[31]

[27]BBC, Scott of the Antarctic (1868-1912), n.d.
[28]CoolAntarctica, Captain Robert Falcon Scott, n.d.
[29], [30] Dundee Heritage Trust,The Story of RRS Discovery, n.d.
[31]Britannica, Robert Falcon Scott, n.d.

The sledges were being man-hauled and some men had to return back to the ship. Scott, E.A. Wilson, H.R. Bowers, L.E.G. Oates and Edgar Evand reached the Pole on the 17th of January 1912, only to find that Amundsen had already been there. On the return journey they encountered extreme bad weather and were left stranded in their tent. Fuel and food were running low and the men froze to death. Almost a year later a search party found the tragic scene of frozen bodies next to their letters, diaries and geological specimens. [32]

Scott and his men were regarded as national heroes for their courage and endurance. Scott's final diary entry notes the following:

"Every day we have been ready to start for our depot 11 miles away but outside the door of the tent it remains a scene of whirling drift.… We shall stick it out to the end, but we are getting weaker, of course, and the end cannot be far. It seems a pity, but I do not think I can write more." [33]

[32]Britannica, Robert Falcon Scott, n.d.
[33]Robert Falcon Scott Expedition Diary, 1912

ERNEST HENRY SHACKELTON 1907-1909 and 1914-1917

Ernest Henry Shackelton was an Anglo-Irish explorer. He was third liuetenant on the Discovery Expedition of 1901-1904 led by R. F. Scott and ventured togheter with Scott and Edwars Wilson to reach the Farthest South. Due to health problems he was sent back on the relief ship in 1903.[34]

In 1908 he was appointed Captain of the *Nimrod* expedition- and attempted to reach the South Pole for the first time. The party had to winter-over on Ross Island due to sea ice and continue afterwards on a sledge. The sledging crew came within 180 km of the South Pole.[35] Shakelton and this men returned to the coastal camp only to find that *Nimrod* had sailed away a few days earlier. They sent a signal by putting the camp in flames and the ship returned to retrieve them.

After Amundsen reached the South Pole in 1911, Shackelton planned a new mission to cross the continent via the South Pole. Shakelton embarked on the ship *Endurance* and sailed in 1914 towards the south. Near the Caird Coast, *Endurance* was trapped by pack ice and drifted for 10 months before being crushed by pack ice. The crew saved itself by drifting for another 5 months on a large pack of floating ice and then finally escaped in lifeboats to Elephant Island, where they survived on seal, penguin and dog meat. Shackelton and some of his men sailed for 16 days in a whaler's boat, 1.300 km to South Georgia Island. After leading four separate relief missions, Shackelton succeeded in rescuing his crew. None of his men died. In 1916 they were finally rescued and taken to Chile.[36]

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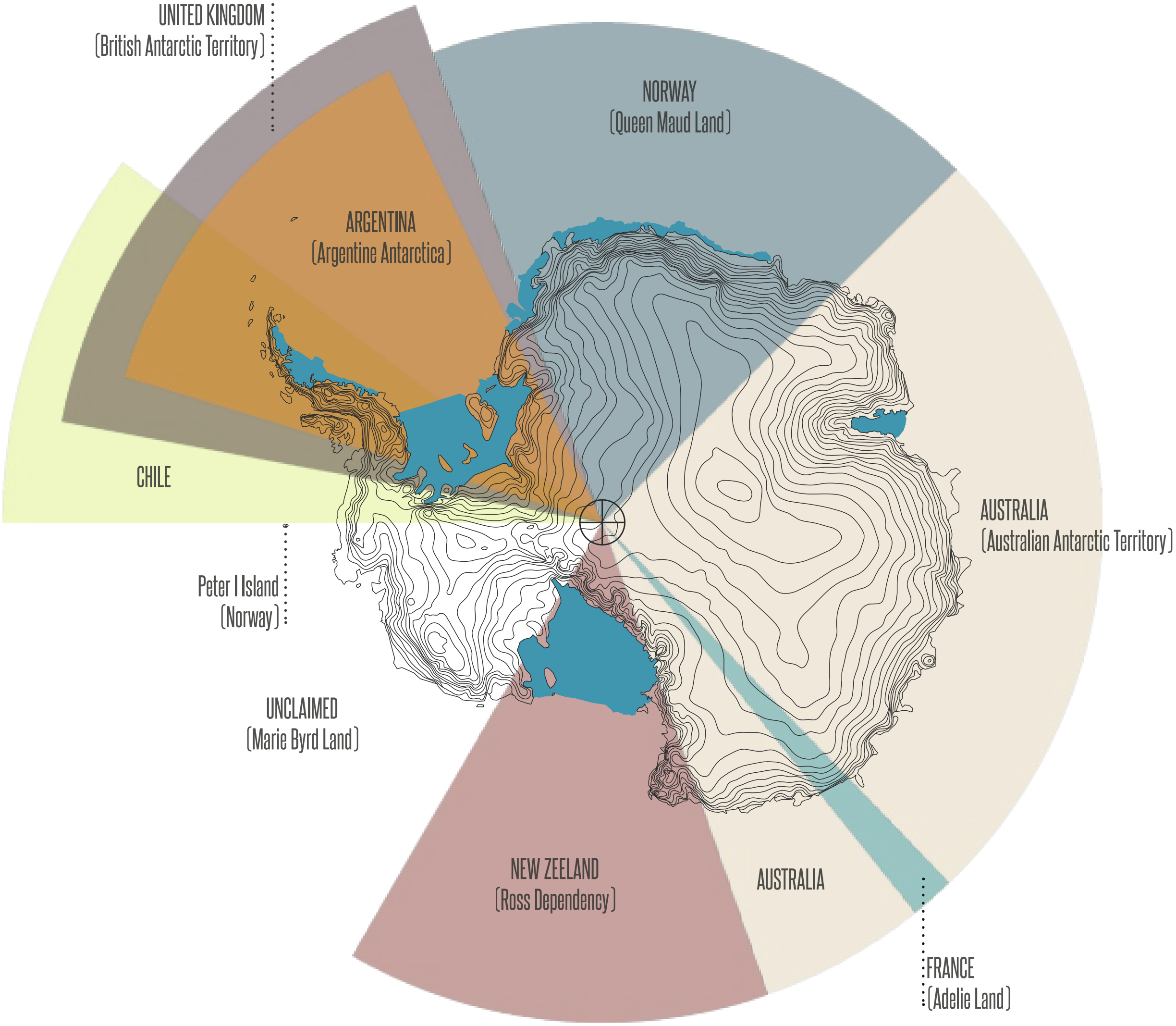
[34], [35], [36] Britannica, Ernest Shackleton, n.d.



07. Territorial claims in Antarctica, Illustration by the author

03 TERRITORIAL CLAIMS

The conquering of the Souht Pole by R. Amundsen made way for numerous Antarctic exploration missions and the first territorial claims. Since the 1950s, seven sovereign nations, Argentina, Australia, Chile, France, New Zealand, Norway, and the United Kingdom, made territorial claims in Antarctica. While some territories are overlapping, claims are recognized only by the other parties making similar claims in Antarctica.

Other parties such as the United States, Germany, Poland, Sweden, Russia, Japan and South Africa are not making territorial claims despite their exploration history on the continent.[37] 1879 in Hamburg, Germany the coordination of scientific polar efforts were being recognized in the meeting of the International Polar Commission by 11 nations. They lead to the First International Polar Year in 1882-1883 and to the decision to organize similar events every 50 years. The outcome of the Polar year had to strengthen scientific work and expeditions in the Arctic and Antarctica.[38]

Later that year in 1957-1958 the International Geophysical Year took place and concluded with the Antarctic Treaty which came in effect in 1961. The Treaty is a joint resolution to preserve Antarctica specifically for scientific purposes. The motivating factor today to claim the land is due to the oil resources which are thought to be found under the thick ice.[39]

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[37], [38] Britannica, IGY and the Antarctic Treaty , n.d.
[39] Matthew Teller, Why do so many nations want a piece of Antarctica? , 2014

08. Flags at the South Pole
Credits: Christopher Michel

03 The Antarctic Treaty

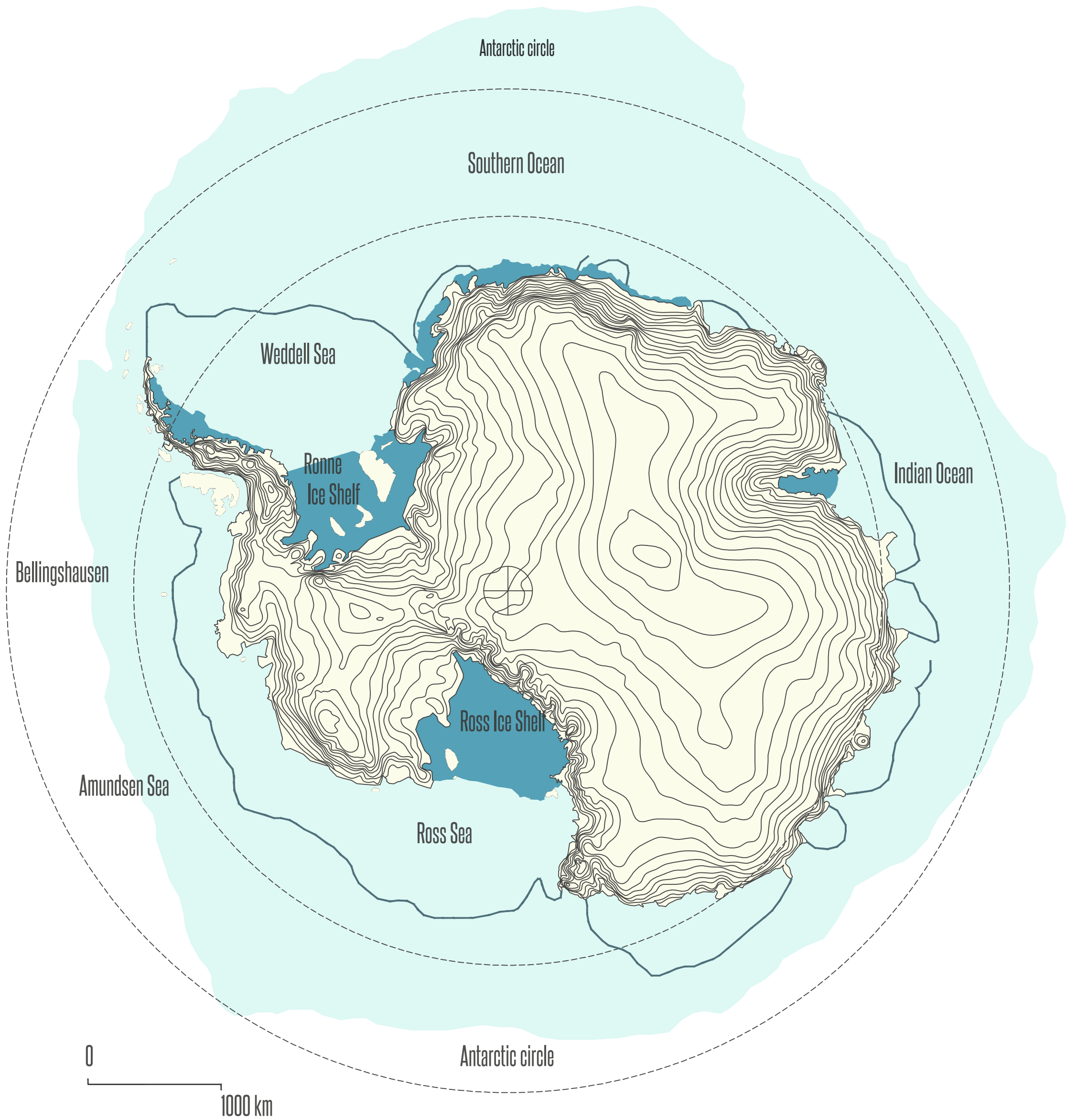
Twelve countries that were active during the IGY from 1957 until 1958 signed the Treaty in Washington on December the 1st, 1959. Until today, the Treaty has been signed by a total of 52 nations. The treaty bans military activities, nuclear weapons and military testing sites and promotes scientific cooperation and research. Findings are made accessible for interested parties and scientific personel can exchange work freely. It sets aside territorial claims and promises that research activities will neither diminish nor expand beyond already established claims. The Treaty is one of the most successful agreements worldwide and promoted decades of research and cooperation between nations while also protecting the environments by promoting conservation efforts.[40]

"Antarctica shall be used for peaceful purposes only" (Art. I)

"Freedom of scientific investigation in Antarctica and cooperation toward that end … shall continue." (Art. II).

"Scientific observations and results from Antarctica shall be exchanged and made freely available." (Art. III).

[40] British Antarctic Survey, The Antarctic Treaty Explained , n.d.



09. Antarctica topography and surrounding seas
Illustration by the author

03 ENVIRONMENT

Antarctica is an 13.000.000km^2 frozen desert. In contrast to the Arctic, Antarctica is a land mass which is covered by glacier ice. The ice sheet covers about 98% of the continent and its average thickness is 1.6km. The ice sheet can even reach a thickness of 4km in some areas. Due to the mass of the ice sheet the land has been pushed below sea levels in some areas.[1] About 90% of the entire ice present on Earth's is covering Antarctica and it also represents up to 70% of the Earth fresh water supply. The extreme low temperatures caused snow to accumulate over the years, however, due to climate change, the ice shelf started melting and could cause a significant sea level rise in the coming decades.

The average elevation is about 2.200m above sea leavel making it the highest continent on Earth,[2] with the Antarctic Plateau at an average elevation of 3.000m above sea level. Due to the elevation, the crew stationed on the Plateau are in a constant state of hypoxia. Precipitation on the continental plateau is very limited and is similar to percipitation in hot desert areas. Weather fronts usualy do not enter deep into the mainland and thus lead to a cold and dry mainland.[3] Coastal areas, on the other hand, experience heavy snowfall that can last for many hours.[4]

While the Plateau has very mild winds, the costal regions can experience up to 300km/h winds due to kabatic winds.[5] Kabatic can be described as drainage winds, which carry high-density air from higher altitudes and, due to the force of gravity, fall at lower altitudes.

[1] Antarctic Logistics, Antarctic Environment , n.d.
[2] Britannica, Antarctica, n.d.
[3], [4], [5] Antarctic Logistics, Antarctic Environment , n.d.

Kabatic winds have the power to blow away the ice sheet.[6]

Antarctica is also the coldest continent on Earth. The world's record low has been recorded at the Russian Vostok Station on the Antarctic Plateau in 1983, measuring -89,2°C.[7] Winter temperatures are on average about -60°C but can vary depending on the location. There are only a handful of stations which are also active during the winter and that record changes in temperature. Thanks to new technologies, satellites can measure temperatures even in the most isolated parts of Antarctica. A 2018 report published in the Geophysical Research Letters show that temperature drops to about -97 °C during the polar winter on the ice sheet setting a new record for the lowest temperature ever measured on Earth.[8] Summer temperatures are much milder but reach a height of 15 °C on the Peninsula.[9] Another reason contributing for the low temperature is the *high albedo* effect, meaning that solar radiation is reflected away due to the snow and not absorbed. [10]

Extreme low temperatures and light snowfall make the continent one of the driest with a relative humidity in the air of about 0,03% at the South Pole.[11] Another factor which makes it the driest place on Earth is the fact that humidity from the coastal areas cannot penetrate deep into the mainland, especially during the winter months. This phenomenon is called continentality.[12] Low humidity means low water vapour particles in the atmosphere which makes up for a very clear sky. Thanks to the preservation efforts there is also little pollution from the existing research stations, thus maintaining clear skies.

[6] Antarctic Logistics, Antarctic Environment , n.d.
[7], [9] Britannica, Antartica Climate, n.d.
[8]Alejandra Borunda, Coldest Place on Earth Found-Here's How, 2018
[10] American Museum of Natural History, Antarctica: The farthest place close to home, n.d.
[11], [12] British Antarctic Survey, Antarctica's climate: The key Factors, n.d.

The last major factor which makes Antarctica a continent of extremes is the unusual day and night cycle. The closer you are to the geographical South Pole, the longer does the darkness in winter and the daylight in summer last. While coastal stations experience only a few weeks of constant sunlight or darkness, mainland stations have prolonged periods of a few months of either complete darkenss, or constant sunglight. In between these phenomenons there are periods of twilight.[13]

Antarctica is due to this extreme conditions one of the best places on Earth for many study fields, such as astronomy, climate, maritime studies and so on. The unique environment has been often compared to climate conditions on other planets of our solar system. The continent is often nicknamed *White Mars* due to the many similarities scientists expect to find on Mars. The continent has become in the past years a study field for human group dynamics in isolated habitats. Crews that winter-over in Antarctica are isolated for many months from the world and have to face on their own extreme situations. Non-functioning groups can lead to failed mission. As well as in Antarctica as in outer space, a failed mission can have tragic outcomes.

[13] Austrialian Antarctic Program, Sunlight Hours, n.d.

10. Aerial view of Little America IV, Bay of Whales, 1946-1947
Credits: National Science Foundation/U.S. Navy

04 RESEARCH STATIONS

The Heroic Age of Antarctic Exploration was followed by a long break until the interest in the continent rose again because of strategical and military interest during and after World War 2. Thanks to the Antarctic Treaty the continent houses up to this day about 70 research stations. Most of the stations are build on the coastal areas and are only used during the Antarctic summer. Just a handful of stations are permanent, which are to be found mainly on the Antarctic Plateau. The following timeline illustrates the building process :

- 1956 - French research station Dumont d'Urville
- 1956 - British summer research station Halley I on Brunt Ice Shelf
- 1956 - U.S. Antarctic Program, McMurdo Station on Ross Island
- 1957 - U.S. Antarctic Program, Amundsen-Scott at the South Pole
- 1957 - New Zeeland Antarctic Program, Scott Base on Ross Island
- 1957 - Russian Vostok Station on the Antarctic Plateau
- 1960 - South African station SANAE I on the Fimbul Ice Shelf
- 1961 - Argentine Matienzo Station on Graham Land

11. American Amudsen-Scott South Pole Station in 2019
Credits: Mike Lucibella

- 1968 - U.S. Palmer Station on Anvers Island
- 1981 - German station Neumayer I on Princess Martha Coast
- 1992 - German station Neumayer II on Queen Maud Land
- 1995 - Japanese station Dome Fuji on Queen Maud Land
- 2005 - French-Italian Concordia Station on the Antarctic Plateau
- 2007 - Belgian station Princess Elisabeth
- 2009 - German station Neumayer III at Atka Bay
- 2012 - Indian station Bharati on Larsenmann Hills
- 2014 - South Korean station Jang Bogo on Terra Nova Bay

12. McMurdo Station, Chalet built as an administrative headquarters in the 1970s
Credits: PH 1 K.K. Thornsley

04 EARLY BASES

Ships were the first bases to arrive in Antarctica. The first explorers used to venture out on the ice shelfs or the mainland using sledges and overnight in tents. They had to take chances and face extreme temperatures and weather on the newly-discovered continent. As previously mentioned in Chapter 02, there was a huge risk that the ship could become trapped in the ice pack when winter came and as the ice packs grew, it ended up crushing the ships.

The first ships to sail to Antarctica were made using mainly wood as a contruction material. For exemple, the RRS Discovery was built for the British Antarctic Expedition led by Robert Falcon Scott in 1901 and relied on a coal powered stem engine and sail.[1] To reach its maximum of 450 horse power, stokers had to use up to 6tn of coal everyday.[2] To avoid being crushed by the pressure of the pack ice, the ship was designed without portholes.[3] The outer skin was composed of three layers leading to a thickness of 60cm which provided good insulation. Brass mushroom vents were instaled on the deck to allow light and air flow for the decks underneath.[4] Huge quantities of canned, boiled, and dried food had to be taken on board. Livestook such as donkeys and sheep was also taken on board.[5] Arriving in Antarctica, the sheep were then slaughtered and their meat was frozen. The crew also relied on fresh meat from seals and penguins. With a diet full of meat, many explorers had to stop their mission and return home after showing signs of scurvy. Huge amounts of fresh water was also stored on board, though coal was the biggest priority for the storage.

[1], [2], [3], [4], [5] Dundee Heritage Trust, RRS Discovery - The royal research ship, n.d.

13. Amundsen Scott- South Pole Station
Credits: National Science Foundation

After reaching Antarctica, snow and ice could be melted to provide additional fresh water.

On land, the first bases consisted of prefabricated wooden huts. The insulations materials improved over the first years but condensation became a problem inside the huts. Due to the lack of ventilation and the fact that the fuel was being burnt inside, cases of increased carbon monoxide levels were very common. These early stations were built for a use of about 3 years. Some were intended to be used on later missions, but returning crew found them buried in the snow and ice and could only go inside using the windows.[6]

Huts were becoming harder to access each returning season because of the snow piled around the stations by the heavy snowfall and strong winds on the coast. When the summer temperatures would go above 0°C the accumulated snow would melt, causing damage to the huts. In some cases, such as the first four British Research Stations Halley I, II, III and IV, the accumulated snow ended up crushing the wooden construction.[7] To solve these problems, stations were being built on pillars or, in more recent years on hydraulic legs, which can be adjusted to accumulated snow. Larger stations are usually divided in several buildings which are a few meters apart because of possible fire threats.[8] Many stations still consists of container-styled segments and lack any architectural quality. Thankfully, newer station focus more on the design and psychological well-being of the crew.

[6], [8] CoolAntarctica.com, Modern Antarctic bases, n.d.
[7] British Antarctic Survey.com, History of Halley

14. Belgian Princess Elisabeth Station
Credits: International Polar Foundation

04 Princess Elisabeth Station

The Princess Elisabeth Station is the first and only zero-emission research station in Antarctica which opened on 15th of February 2009. It was commisioned by the Belgian federal goverment and built by the International Polar Foundation, who also operartes the station. Belgian architect Philippe Samyn designed the underlying structure. The station is built against The Utsteinen ridge, at an altitude of 1.382m where strong winds of about 250km/h occur.[9] In order to withstand these winds, the station has an aerodynamic shap and its foundation is anchored deep in the permafrost.[10]

The station operates mainly during the austral summer, from November until February. It hosts about 25 to 40 scientiest each year. The main building has a surface of 400m2 and the technical areas to up to 1500m2. The average outside temperature ranges from -50C to -5C.[11] Out of the total of 120 mission days during the austral summer, 100 are with 24 hours of daylight. [12] The nearest station is over 400km away.

The station is designed to run on renewable energy. It is powered by several wind turbines and 380m^2 of solar panels. During the austral summer, water is heated by 22m^2 of solar thermal panels. As a back-up, the station uses two generators. 12% of its energy is generated by the thermal solar panels, 40% by the photovoltaic solar panels and 48% by the 9 wind turbines.[13]

The entire water is reused and purified by two bioreactors and filtration units similar to those used in the space sector. The station has also two shelters, mobile laboratories for field expeditions and several

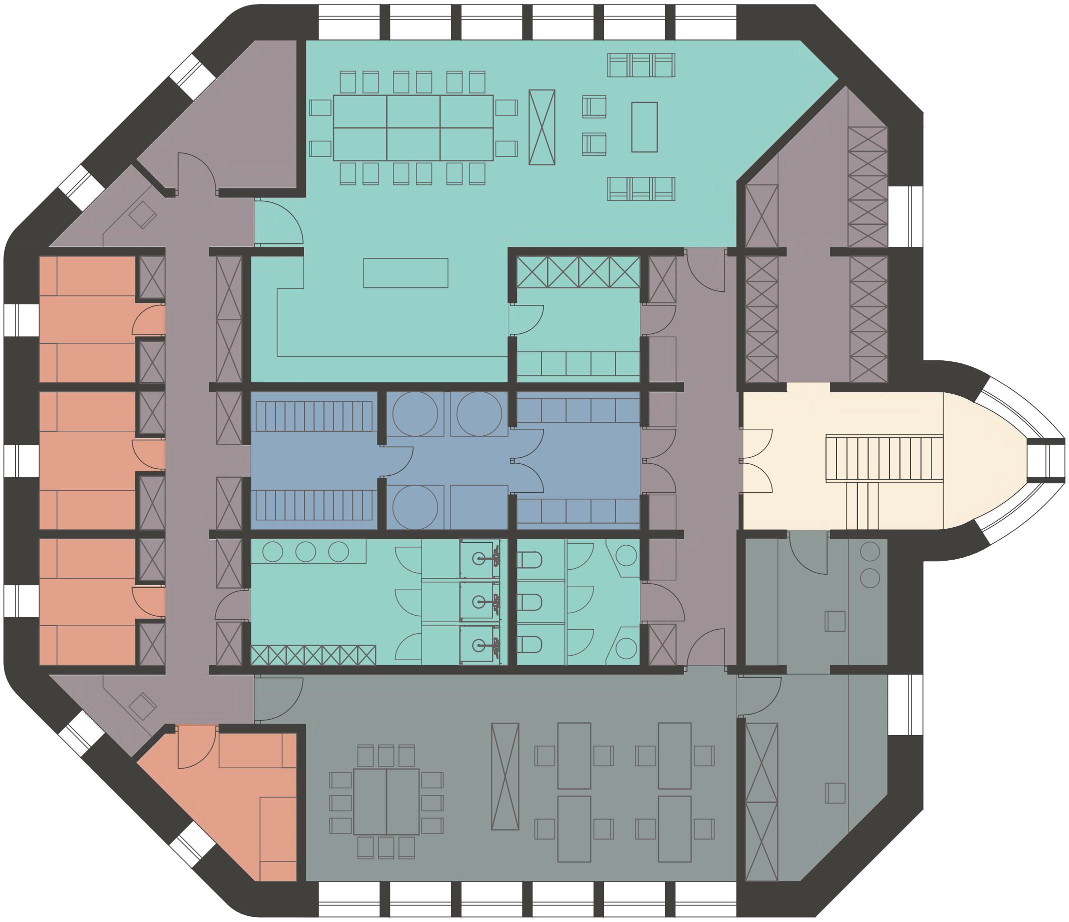
[9]AntarcticStation.org, Princess Elisabeth Antarctica Brochure, 2013
[10] Solaripedia.com, Princess Elisabeth Antarctica Polar Station, 2009
[11], [12], [13] AntarcticStation.org, Princess Elisabeth Antarctica Brochure, 2013

15. Princess Elisabeth Station in construction
Credits: International Polar Foundation

transportation and hauling vehicles. The mobile units include sleeping quarters, a kitchen and a dining room as well as offices and technical facilities.

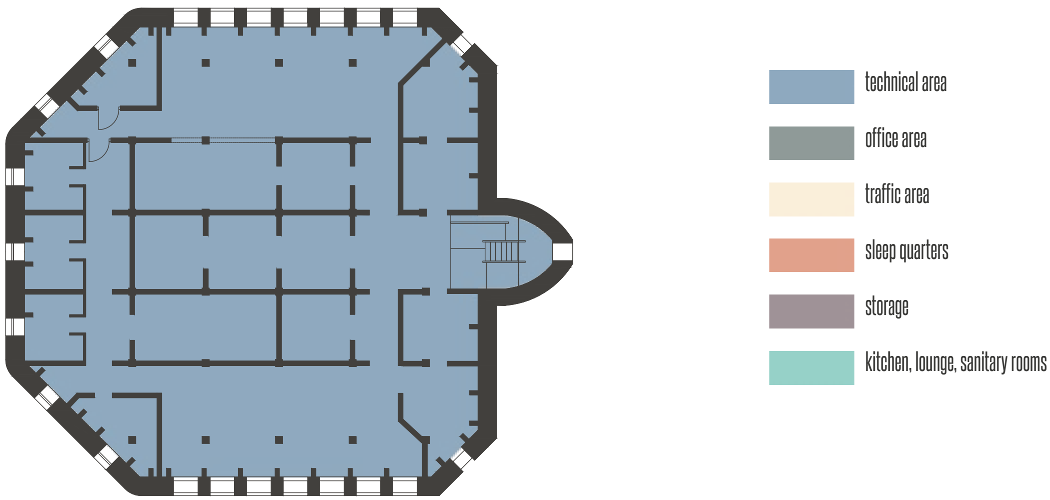
Due to the short austral summer, the station had to be constructed during multiple seasons. The designated location, which was chosen especially for the wind and solar energy production, is 200km away from the coast. Containers with building materials were shipped to Antarctica and had to be hauled to the building location. After the foundation was anchored in the rocks, the wood structure started being assembled. Wood was chosen as a material not only because of its low-carbon footprint but also because it also has smaller deformations at extreme low temperatures when compared to other construction materials. The stucture was then covered with prefabricated wall modules which also use eco-friendly materials such as wollen felt. The modules have a thickness of 60 cm to provide good thermal insulation and a minimal energy loss. [14]

[14] AntarcticStation.org, Building the station, n.d.

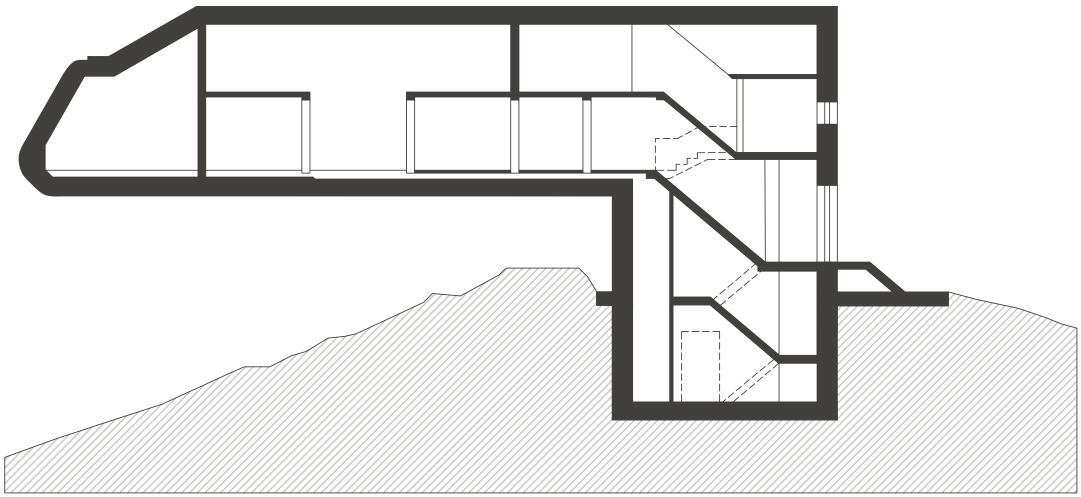


2nd floor

Floor plans and section of the Princess Elisabeth Station, Credits: the author



1st floor



section

Floor plans and section of the Princess Elisabeth Station, Credits: the author

16. Neumayer III Station on the Ekström Ice Shelf
Credits: Alfred Wegner Institute/ Thomas Steuer

04 NEUMAYER III

The German Neumayer III Station is built on the Ekström ice shelf and is the third operating station by the Aflred-Wegener-Institute. The previous two stations ended up being covered and crushed by accumulated snow. The third station has been active since 2009 and was designed with a life span of about 25 to 30 years. Neumayer III serves also as an intermidiate base for mainland expeditions. Being built on an ice shelf means that the station travels along with the ice underneath it. It is estimated that the station travels yearly 157m and in 2034 will have moved about 4km.[14]

The station sits on 16 hydraulic legs which adjust to accumulated snow and are anchored about 8m deep in the snow. Underneath the station there is a garage and a large storage space that is connected with the main building by an interior staircase. The garage is accessible by a ramp. The station has a total area of 4.890m^2 and consists of two decks: the first one houses the hospital, communication room, technical area and free time area while the second one houses the 15 sleeping rooms for 40 people, laboratories and other technical rooms.The station's research focuses mainly on meteorolgy, climate change, and geophysics has a total area of 410m^2 for laboratories. The station also provides a laundry room, a lounge, a sauna, an information technology room, showers, a dining room with kitchen, conference, and medical treatment rooms. During the austral summer the station houses a crew of 50 while during the winter months only up to 9 people live on the station [15]

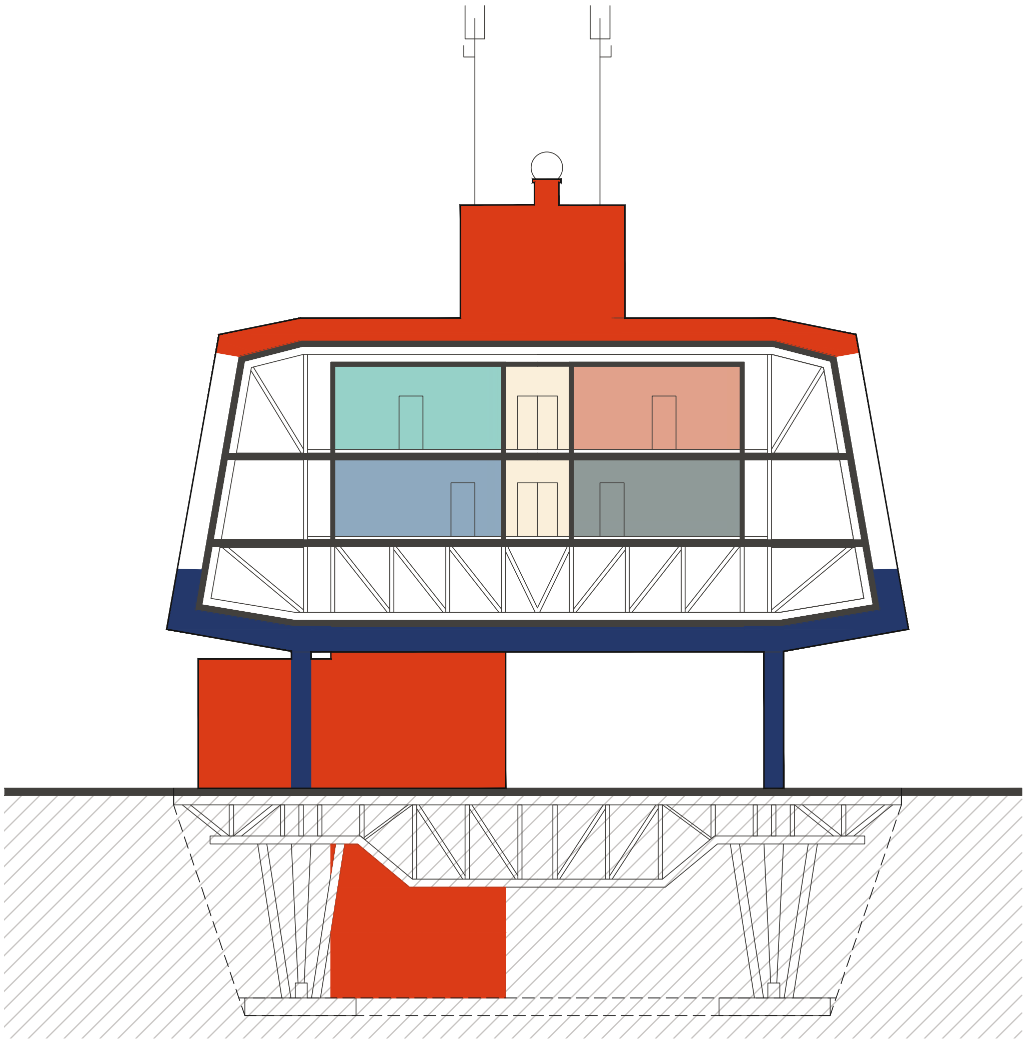
[14] AWI.de, Construction of the Neumayer Station III, 2018
[15] Council of Managers of National Antarctic Programs, Antarctic Station Catalogue, 2017

17. Neumayer III Station inside
Credits: Alfred Wegner Institute/ Stefan Christmann

All the interior compartments are made using several ship containers thar are packed in a huge steel contruction.[17] The total height of the construction is about 30m and the entire construction weights 2.300 tn. Out of the total 4.890m^2 only half is being heated.[18] Around the main building there are several container-sized field laboratories which gather various data. These smaller units are set several hundred meters apart in order for the sensitive equipment to not interfere with one another.

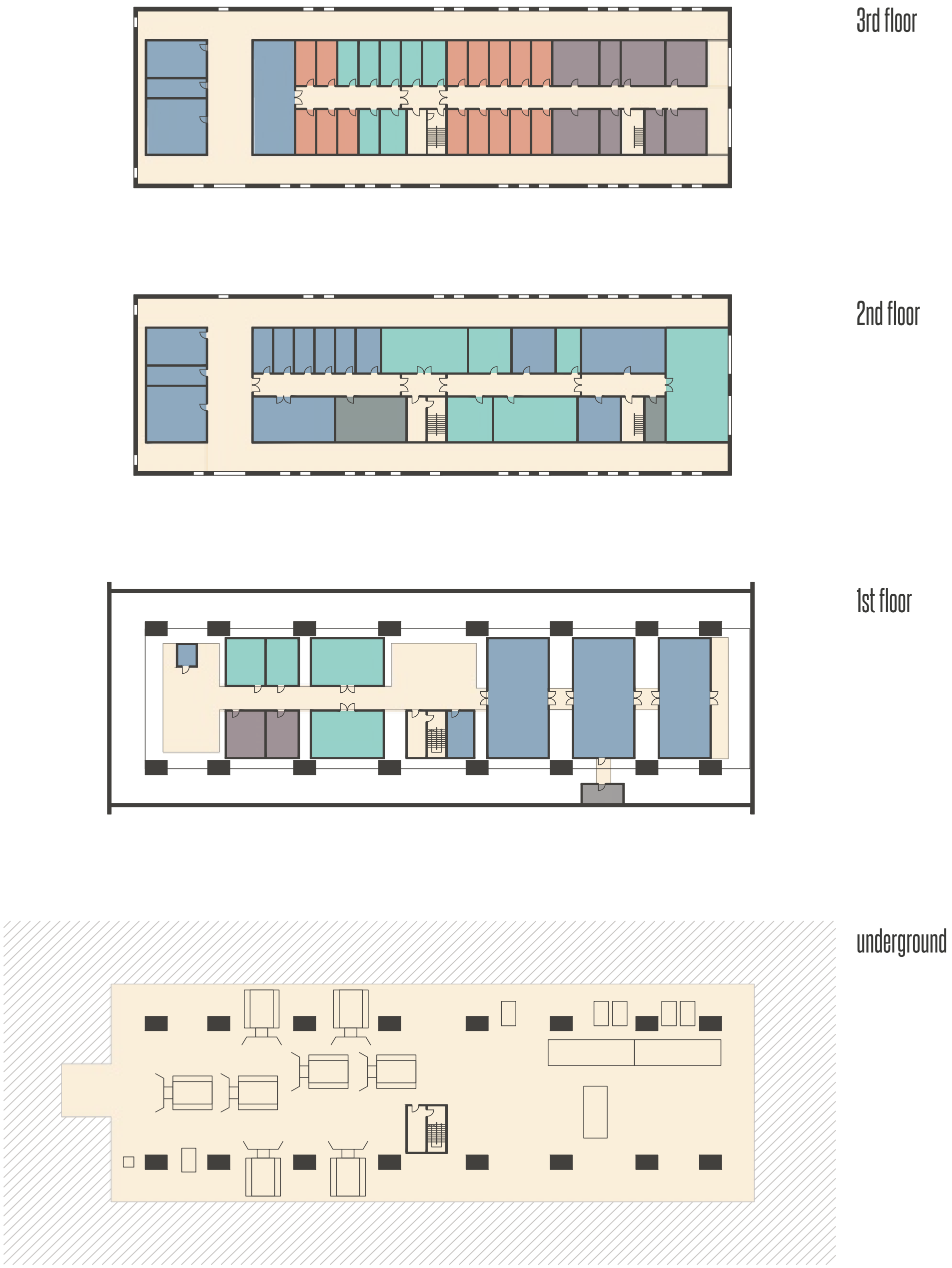
To provide fresh water all year round, snow is melted and then purified. Outside the station there is a snowmelter and snow is being shoveled by large vehicles. Electricity is being produced by diesel generators and a wind turbine.[19] To prevent energy loss, the energy is being recirculated through the entire building.[20] Harsh winter conditions make travel on the entire continent very difficult and only emergency travels are permitted. Supplies are shipped and brought to the station during the summer. The crew, together with lighter supplies travel by ski-equipped aircrafts.

[17] Welt.de, Neue deutsche Forschungsstation in der Antarktis in Betrieb, 2009
[18], [19] AWI.de, Construction of the Neumayer Station III
[20] AWI.de, Ten-year anniversary of Neumayer Station III



Neumayer III Station, section

Floor plans and section of the Neumayer III Station, Credits: the author



Neumayer III Station, floor plans
Credits: the author

Floor plans and section of the Neumayer III Station, Credits: the author

18. Concordia Research Station in the summer
Credits: IPEV/PNRA/ESA - S. Thoolen

04 CONCORDIA

The Concordia Research Station is a permanent research station since 2005 which houses up to 70 people during the austral summer and 14 during the winter and is operated by the French Polar Institute and the Italian Antarctic Program. Research areas include glaciology, astronomy, atmospheric and earth sciences, biology and human medicine. The station is built at 3.233m elevation at the Dome C on the Antarctic Plateau. The station is located less than 1.700km from the South Pole and 1.100km from coastal French station Dumont d'Uberville.[21]

The station is one of the most isolated, the nearest station is the Russian Vostok Station about 600km away. Temperatures in winter can range from -30°C to -80°C. The crew arrives at the station in November, at the beginning of the austral summer. The last airplane departs before the winter starts at the end of February. From February until November the crew has to survive on the supplies they have stored and work during the long and dark winter months.[22] Dome C was actually occupied since 1970. Between 1996 and 2004 it was the research site for the European Project for Ice Coring in Antarctica (EPICA) which collected ice from a depth of 3.270m. It's one of the most important climate records and can be dated back to 890.000 years ago.[23]

The new modern station was built during multiple seasons and opened in 2005. The previous station only consisted of tents and temporary structures for summer use only. Concordia has two main cylindrical buildings, a noisy and a quiet tower, each with a diameter of 18.5m and a height of 12m. The two cylinders are connected by a closed bridge.

[21] Concordiastation.aq, Dome C Concordia Station, n.d.
[22] ESA.int, The remotest base on Earth, 2013
[23] European Science Foundation, European Project for Ice Coring in Antarctica (EPICA), n.d.

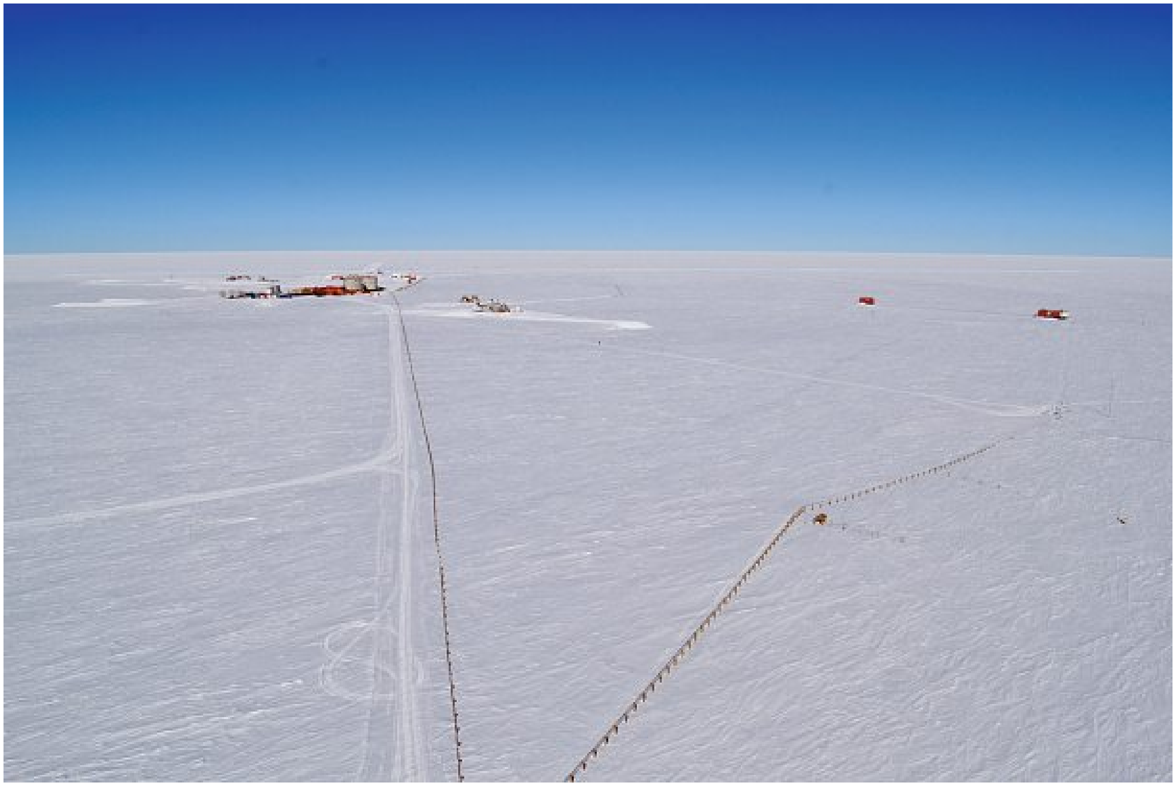
19. Scenes from Antarctica
Credits: IPEV/PNRA/ESA - S. Thoolen

The cyclinders sit on 3.5m-high hydraulic legs.[24] Since snowfall at the station is very light, about 2 to 10 centimeters every year, the hydraulic legs need to be lifted a few centimeters only when snow accumulates. The quiet tower houses on three floor the sleeping quarters, laboratories, medical and communication rooms. The noisy tower consists of the kitchen with storage and freezer rooms, library, game room, gym and workshops. In total, the station offers 1500m² for the crew.[25] Next to the noisy tower and connected with a similar enclosed bridge is the water and power station made out of several containers. It houses the power generators, a boiler room, a water treatment plant and an additional workshop.

The diesel power generators produce energy with heat as the by-product. From the three existing generators, only one is used while the others serve as back-up energy suppliers.[26] Exhaust gases are trapped and condensed to reduce the water vapour and other waste gases released outside. The cylindrical form was chosen in order to have a minimal exterior area and thus minimize heat loss. [27] The building is isolated using clads of sandwich panel of expanded polyurethane covered in glass fiber with a total thickness of only 16 centimeters.

The water treatment plant is a similar prototype to the one used on the International Space Station. All the water gets treated and is then reused for drinking water. About 85% of the water is regained water and the rest 15% is added by melting snow.[28] Snow is collected and melted outside the station with the help of heavy machinery. Afterwards it is

[24] Scienceillustrated.com, Land of science and discovery, 2012
[25] ESA.int, Concordia floor plan,2013
[26] PatricegodonPolarEngineering.eu, Concordia power station, n.d.
[27] Sciendeillustrated.com, Land of science and discovery, 2012
[28] Phy.org, The Concordia research station water recycling facility, 2018



20. Antarctic view
Credits: IPEV/PNRA/ESA - P. Robach

exposed to UV light to kill microbes and minerals are added. The quality is tested every two weeks. Water consumption is between 40 and 100L daily per crew member. [30]

Around the station there are various field laboratories and shelters. Nearby is the summer camp, the former EPICA research site, and an airstrip for planes. During the austral summer some temporary structures such as heated containers are used for extra accommodation. Waste is stored around the station and is then shipped out of Antarctica during the austral summer. There are a few snow collection spots where the area is also restricted in order to prevent pollution of the site. Other restricted areas have different measuring instruments such as the geomagnetism shelters and the seismology cave. Going outside can be very dangerous, especially during the winter. The crew has to wear multiple layers of clothing, they are allowed to go within a radius of 3km from the station during winter and only for a limited amount of time. Even a short exposure to the cold can lead to frostbite or lying in the snow can cause hypotermia. [31]

Psychological effects of life in Antarctica have been studied on many Antarctic stations, but Concordia is thought to offer a more isolated environment than that of the ISS. This isolation, together with the dangers of living in that environment, is similar to what astronauts will have to face on future space missions. Therefore, the European Space Agency sends a medical researcher yearly to study how the human body reacts during prolonged isolation and confinement.

[30] Phy.org, The Concordia research station water recycling facility, 2018
[31] European Space Agency, Living on White Mars, 2013, p.21

21. C-17 Globemaster III at the Pegasus White Ice Runway near McMurdo Station
Credits: Dominick Dirksen/ National Science Foundation

05 LOGISTICS

Antarctica is one of the most challenging places to build in. Each year there is a limited time frame of a few months to deliver the material and equipment, build or secure the structure for the next season. Storms can also happen during the austral summer and lay the construction process to rest. Due to the extreme temperatures, materials can deform and what was once carefully planned and fabricated will have difficulties fitting on site. While constructing the British Halley IV Station, the architects visiting the sites and the construction workers had diffuculties entering the station after a huge storm.

Winter stations are resupplied when the austral summer starts. Heavier supplies are shipped and then hauled using big vehicles to the station, while lighter supplies are brought in by airplane. There are no connecting roads between the station. Airplanes land on ice runways. During the summer months there are numerous field parties who study remote regions and who camp there. They are resupplied periodically by smaller aircrafts.[1]

Drastic weather and temperature changes can occur daily and impact an already planned travel. Snow storms can lay a mission to rest for many days, while white-outs conditions, caused by scattered sunlight and low cloud formation, diminish visibility. Vehicles can break down on the way and need to be repaired. Sea ice can be a quick way to travel on but cracks can be dangerous. One of the biggest issue for Antarctic mainland travels are crevasses, deep snow covered cracks which are hard to spot and can claim lives.[2]

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[1], [2] CoolAntarctica.com, Antarctic Travel-Practicalities and Modern Vehicles, n.d.

22. The last apple at the Concordia Research Station
Credits: European Space Agency

06 LIFE IN ANTARCTICA

Building in Antarctica is a big challange but living there can be an even greater one for the crew. Antarctic habitats have been referred to as *"laboratories for human behaviour"*.[1] The frozen continent is more similar to what we expect to encounter in outer space mission than what we are used to here on Earth. Similarities include dangerous environments, isolation, confinement, unusual day and night cycles and the lack of sensory stimulation. The winter isolation varies depending on the station's position. Research stations close to the coast experience a shorter winter period than those on the Antarctic Plateau.[2] The only remaining contact with the rest of the world is radio and internet communication.

When arriving in Antarctica you need to accomodate with the environment conditions, such as low humiditiy, prolonged periods of constant darkness and daylight, extreme weather conditions and low temperatures. Antarctica is a deserted, extraterrestrial-like environment with little to none sensory stimulation.[3] Natural dangers are a permanent threat to one's life, but psychological factors have a powerful impact on the well-being of the crew. Summer stations are often crowded and privacy is not always guaranteed. Beginning with March, during the winter months, the stations run with a minimal crew size but frictions between the crewmembers still occur, especially when it comes to one's role in the mission. For exemple, water consumption is regulated on the station. When more water is consumed, more snow needs to be melted and purified. Stations usually train all of their crew to be able to load snow in the melter to avoid such conflicts.[4]

[1] Albert A. Harrison, Yvonne A. Clearwater and Christopher P. McKay, 1991, p. 1
[2], [3] Patrick E. Cornelius, 1991, p 10-12
[3] Marc Levesque, 1991, p. 16
[4] Patrick E. Cornelius, 1991, p 12

STRESSORS

Venturing in a newly-discovered land can lead to many dangers and unwanted surprises. A supposed recruiting advertisment for one of Ernst Shackelton's expedition to Antarctica notted that return is uncertain.[1] Early explorers prepared for a long mission in a harsh unknown environment, where food supplies could run short and where their survivial skills were put to the test. During these missions, crewmembers also experienced no privacy, isolation, had no means to communicate with their families and no possibility to return home. They were confined in crowded ships, where boredom and interpersonal conflicts occured followed by an imense workload and emergency situations. Survival depended on the shelter, supplies and luck.[2] While other habitats in extreme environments, such as space capsules and submarines rely on sensitive life support systems, which, when broken, can end the mission very quickly, the dangers in the polar habitat represent mostly weather changes and not having enough supplies to work in safety.[3] These threats have been however rated as moderatly by Antarctic crews, leaning more on their ability to solve such problems.[4]

In an isolated and confined environment, stressors arise because one cannot freely interact with its environment. Isolation is mainly a social factor when an individual is unable to communicate with others or only with a limited number of people which contributes to a reduction of sensorial stimulation and social imput.[5] Confinement refers to a spatial restriction limited to the outside world either by natural or man-made barries.[6]

[1], [2] Peter Suedfeld, 2009, p.641
[3], [4] Burns and Sullivian, 1999 as cited by Peter Suedfeld and G. Daniel Steel, 2000, p.231
[5] Rasmussen, 1973 as cited by Sybil Carrere et al., 1991, p.230
[6] Diana Arias, Christain Otto, 2013, p. 10

Researchers summarized three factors that have a negative impact on the crewmember's well-being in such a habitat, first being the social isolation, second the confined environment and third the reduced sensorial stimulation.[7] Unfamiliar and dangerous environments produce stressors which build-up over time, sometimes without the crewmembers even noticing it.[8]

Other studies noted that winter-over crewmembers enter a state of "*psychological hibernation*" in an effort to cope with the isolation and confinement.[9] During the winter months, movements is drastically reduced to only a small radius around the station. For several months, the habitat is therefore the main work and living area, over time becoming a boring and unstimulating environment.[10] Monotonous environments become slowly an additional stressor.[11]

A recent study done at the Concordia Research station has an unusual finding, being that during midwinter there was an observable reduction in coping mechanisms. Participants in the study may have become more emotionally disengaged at that time, which consequently led to a known behavioural phenomenon named the "*Antarctic stare*", described through *"absentmindedness, wanderng off attention and deterioration in situational awareness"* (mild fugue state).[12] In a more familiar term the phenomenon is similar to the burnout experienced after a preriod of intense work.[13]

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[9], [10] Gro M. Sandal, Fons J. R. van deVijver, Nathan Smith 2018, p.1-3
[11]Peter Suedfeld and G. Daniel Steel, 200, p. 238
[12] Gro M. Sandal, Fons J. R. van deVijver, Nathan Smith 2018, p.6
[13] Maslach and Leiter 2006 as cited by Gro M. Sandal, Fons J. R. van deVijver, Nathan Smith 2018, p.6

SENSORY DEPRIVATION

The first studies on Antarctic winter-over crewmembers were conducted during the 1958 International Geophysical Year. The psychological study was conducted by a team of researchers on 85 men, 30 of whom, showed at the end of the winter-over signs of low cognitive alertness and concentration. Although short, spanning over only a few months spent there, the findings of the study had a huge impact on the international community, proving the necessity for future studies. Some cases even recorded crewmembers wandering and ending up in some places without being able to explain how they got there. These extreme exemples were seen as a case of '*fugue states*", a type of amnesia.[5] Similar to outer space, Antarctica is a sterile environment and even, although part of our planet, it is deprived of *"natural phenomena such as weather, clouds, seasons, diurnal cycles, the animated environment and natural sounds, smells and sights"*[6] A longer stay in Antarctica may result in a series of cognitive and behavioural changes which may include hallucination, decreased alertness, fugue states, daydreaming, or hypnotic susceptibility.[7],[8]

Early explorers were also confronted with the psychological effects of polar regions. During the Belgica expedition of 1898-1899, the American explorer Frederick Cook had his men sit in front of fires, in what is thought to be the first attempt to use light as a way to treat the symptoms.[9] Symptoms specific to polar regions include fatigue, boredom, impaired cognition, reduced motivation and an increased tension and irritability between crew members.[10]

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[5] Arreed F. Barabsz, 1991, p.201
[6] Wolfgang F. E. Preiser, 1991, p.155
[7] E.R. Hilgard, 1965, Weitzenhoffer and E.R. Hilgard,1962, Mullin, 1960, as cited by Arreed F. Barabsz, 1991, p.205
[8] Arreed F. Barabsz, 1991, p.205
[9], [10] Lawrence A. Palinkas, Peter Suedfeld, 2008, p.153-155

Not only the environmental stimulation but also the exposure to the dark winter months has been seen as a cause for disturbed and low quality sleep.[11] The design of Antarctica stations have and still are dictated by logistics and by cost. Containers are often used for sleeping and living quartes, as well as for storage and technical equipment. Over time, non-stimulating habitat will lead to boredom, low motivation and low work interest. [12]

The importance of design aesthetics, such as color, music, and light were first studied during the Soviet space missions Salyut 6 (1977) and Salyut 7 (1982). Color played an important role in the interior design, with specific color being assigned to various tasks and areas. The studies revealed that color, as well as lightning, had a positive impact on productivity, while monotonous spaces led to boredom, mental fatigue and physical anesthetization.[13] Outer space habitats, submarines or polar station are in great contrast with the natural environment due to the highly processed and prefabricated materials used to build them. The habitats are characterized by walls covered wih ustensils, computer screens, control panels and cables and technical shafts. The absence of natural materials lead to tactile deprivation which also contributes to the symptoms mentioned earlier. [14] Overall, sensory deprived environments, such as polar regions characterized by low diversity and phsysical stimulations[15] lead to sensory deprivation and ultimatly to a decline of task performance.[16] Sensory deprivation also leads to changes in distance and constrast perception, circadian rhythms and behavioural patterns.[17]

[11] Lawrence A. Palinkas, Peter Suedfeld, 2008, p.156
[12] Peter Suedfeld, 2009, p.23
[13] Diana Arias, Christain Otto, 2013, p. 23
[14] Diana Arias, Christain Otto, 2013, p. 34
[15] Peter Suedfeld, 1998,p.96
[16] P. Bruce Landon,Peter Suedfeld, 1997, p.137
[17] Peter Suedfeld, 1998, p.97

PRIVACY

Confined habitats usually are restriced in size and design due to logistics and costs. During the austral summer, the stations are filled with people while on the handful of station that remain opened during the winter, the crew consists of up to 90% less people.[1] Social interaction in a confined environment can turn into a stressor for the crew, as a consequence of both crowding during summer and loneliness and limited social interaction during winter.[2] Sleeping quarters are usually designed with two bunk beds, meaning that two people have to share the same room, which could lead to privacy issues and territorial conflicts. Studies noted that inhabitants tended to decorate their space with personal items like photographs or dress in special clothing for special occasions on the station.[3] The little spatial differences between workdays and weekends also contribute to spatial conflicts. Spatial parameters can help the crew with either a quiet place to retreat to, or to interact with eachother. It is a question of what the space's purpose should be. An area with different function could, over time, be a good solution considering costs. A dynamic space with places to retreat to, could avoid certain conflicts. People tend to repurpose their space in order to achieve privacy, even though it may not be beneficial for the others.[5] Territories aim at puting a social organization in place and s*moothing out* interactions between individuals. Crowded places and territories with a lack of privacy and territory can make an individual struggle with it's environment and act as an additional stressors.[6] Time spent in solitude was observed to represent 60% of the time in winter-over months.[7]

[1] Peter Suedfeld, 1998, p. 97
[2] Carrere *et al.*, 1991, p.230
[3] Carree *et al.*, 1991 as cited by eter Suedfeld, 1998, p. 97
[5], [6] Ali Namazian and Armin Mehdipour, 2013, p.110-111
[7] Carree *et al.*, 1991 as cited by eter Suedfeld, 1998, p. 97

HABITABILITY

Early exploration missions of outer space and Earth were done in confined habitats such as ships or small capsules. They focused mainly on providing a safe shelter for the inhabitants while the space was often too small for the people living there. Such shelters help explorers survive in even the harshest environments. After studies proved the importance of the design of polar, undersea, and space habitats, new ideas about how to making the interior more welcoming started to emerge. Begining with NASA's space station Skylab in the 1970's, the term habitability was new in the space station design vocabulary.[1] A stated by psychologist A.A. Harrison *"habitability serves the interest of behavioural health by minimizing environmental stressors ..."*.[2] Since stations on the Antarctic Plateau share many similarities with extraterrestrial environments, the European Space Agency had a research program called *The Aurora Exploration Program* which was ment as a Mars simulation at the Concordia station.[3] The space agency is currently sponsoring every year a medical researcher to study the effects of life in isolation and confinement.

Architects and psychologists alike can design better habitats which will provide the well-being of the crewmembers in these dangerous situations.[4] When the natural environment is harsh and provides no stimulation, architecture needs to take a step forward and compensate. Most of the habitats are inflexible, unstimulating, simple and monochromatic.[5] Ignoring these basics psychological needs creates a "false economy" because the human factor often adds to the mission costs.[6]

[1] Peter Suedfled and G. Daniel Steel, 2000, p. 229
[2] Albert A. Harrison, 2010, p. 891
[3], [4] Albert A. Harrison, 2010, p. 895
[5] Peter Suedfled and G. Daniel Steel, 2000, p. 243
[6] Albert A. Harrison, 2010, p. 895

"Functional esthetics" is another term that entered NASA's vocabulary and refers to combining science, design and engineering in the creation of a more pleasing habitat interior.[7] A study done by NASA-Ames Research Center reused a Soviet-era design strategy which implies that using photographs and artwork can combat boredom and improve living conditions.[8] The research done at NASA showed that photographs capture the attention of the inhabitants and can be a replacement for windows. In the study, images of landscapes ranked the highest by the observed Antarctic crews.[9] As well as in long term outer space missions and in Antarctica, the window view will mostly be dark and empty, with little changes. Providing imagery of Earth seems an impactful idea which can be integrated in a habitat's design.

Another proposed idea refered to creating micro-environments, a miniature representation of an natural environment.[10] Plants have been shown to improve the well-being of the inhabitant in several studies.[11] Plants have the additional advantage that they can provide fresh food for station, especially when supplies are hard to deliver. However, they need special conditions to grow in, lighting, temperature, and space which add to a mission cost. Greenhouses are not new in Antarctica, plants were brought for research and supply purposes ever since the early expeditions.[12] Today, experiemental greenhouses (EDEN ISS) for outer space mission are being tested in Antarctica at the Neumayer III research station and have been effective in providing fresh food for the crewmembers during the winter-over.

[7] Yvonne A. Clearwater and Richard G. Coss,1991 p. 331
[8] Yvonne A. Clearwater and Richard G. Coss,1991 p. 333
[9] Yvonne A. Clearwater and Richard G. Coss,1991 p. 346
[10] Paul N. Klaus,1991 p. 359
[11] Laviana *et. al.* 1983 as cited in Paul N. Klaus,1991, p.361 and Sandra Häuplik-Meusburger *et. al.*, 2013, p.142
[12] Matthew T. Bamsey *et. al.*, 2015, p. 2

GROUP DYNAMICS

Life in ICE (isolated and confined environments) poses natural and psychological dangers for the crew which thereafter can effect the crewmember's interaction with one another an can lead to a dramatic mission failure.[1] A mission's success everywhere, regardless of the environment type can by achieved by positive group dynamics. Researchers have observed the creation of micro-cultures on Antarctic stations. Crewmembers who spend several missions together grow a bond and are more hostile towards new crewmembers. Those who already experienced a winter-over also tend to differentiate themselves from the newcomers at the beginning of the austral summer.[2]

A study published in 2015 compared how groups function in confined and isolated habitats. The three habitats that were compared in the study were the Concordia Research Station on the Antarctic Plateau, the MARS 500 simulation and the Tara Arctic, an exploration mission which was meant to drift with the ice pack in the Arctic ocean.[3] The crew was monitored at meal times and then the findings were compared. Fixed meal times showed an attendence of 80%.[4] The meal duration varied from 29 minutes to 42 minutes while the setting arrangements at the table varied or were unchanged. The study concluded that the meal duration of a group as well as the setting was an indicator at the coping mechanism of the crew. Adaptation varies but a cyclicity referred more to a collective rhythm of the group over an extended period of time. The spatial organization was fixed in two parts of the habitat meaning that the group would stick to a certain group organization,

[1] Diana Arias, Christain Otto, 2013, p. 14
[2] Peter Suedfeld, 1998, p. 98-100
[3] Ocean.taraexpeditions.org, 10 years ago, Tara began her Arctic drift, n.d.
[4] Carole Tafforin, 2015, p.7

while on the Concordia Station it changed several times. This spatial change at the table was interpreted as a coping strategy. Hence, meal duration can be an indicator of a group's adaptive process to a harsh environment.[5] While all three habitats had many similarities, they are seen as an exemple for specific conditions. The Tara drift was an example for isolation, MARS-500 for confinement while the Concordia Station combined both isolation and confinement. Isolation was seen as a factor of how a group organizes itself in a space by frequent spatial changes while confinement could create stereotypes as a consequence of the fact that the placing was constant.[6]

[5], [6] Carole Tafforin, 2015, p.12-13

ADAPTATION

As stated by psychologist Peter Suedfeld, "*...the environment has no direct impact on human being*" [1] but rather how we respond to an environment mirrors our relation with that specific environment. Suedfeld further noticed that research on human behaviour should focus rather on the experience in an environment than the characteristics of one.[2] In an-alien like environment, with no palpable changing seasons, unusual day and night cycles and a confined shelter there is little interaction with the surroundings. Humans adapt quickly and without any other new stimulation, sensory deprivation sets it. Several studies showed that being deprived of simuli caused an individual to be less efficient and have as less of a stable behaviour.[3]

After adaptation, many crewmembers experience boredom and monotony. This state of mind led to "*widespread daydreaming*", absorption, increased or decreased vigilience and fugue states.[4] Similar to outer space habitats, Antarctic stations are confined spaces which act as a stressor for the crew. The impact of a stressor can be described by three factors, the first one being what kind of environment there is, the second is the type of mission that needs to take place in that environment and the third factor is how the communication functions between the rest of the world and the confined environment.[5] As mentioned before, Antarctica has the harshest conditions on Earth for life with mission there dangerous but very important for scientific research. Communication outside each station is limited and can be interrupted by the climatic conditions.

[1], [2] Peter Suedfeld, 1991, p. 138-139
[3] Gunderson, 1971, p.127
[4] Arreed F. Barabasz, 1991, p. 26-27
[5] Sidney M. Blair, 1991, p.57

23. Crewmember at Concordia Research Station
Credits: IPEV/PNRA - E. Bondoux

Even though crewmembers experience a wide rage of emotions (irritability, anxiety depression)[10] to disturbed sleeping patterns an behavioural changes, positive effects have also been noticed after the mission ended.[11] When asked to re-evaluate their stay in Antarctica for an Australian survey, crewmembers recolected more positive events than negative ones [12] and described their winter stay as a major experience in their life.[13] Thus, negative aspects do not erase positive ones.[14] Long confined and sensory deprived missions lead to many problems as previously elaborated but crewmembers also started developing hobbies and engaged in reading and games in an effort to combat the symptoms.[15] Food has also been seen as a factor against boredom and stress that can have a positive psychological impact on the well-being of the crewmembers.[16]

[10] Lawrence A. Palinkas, Peter Suedfeld, 2007, p.155
[11], [14] Lawrence A. Palinkas, Peter Suedfeld, 2007, p.158
[12], [13] Wood J. *et. al.* 2002, p. 84-110 as cited in Lawrence A. Palinkas, Peter Suedfeld, 2007, p.158
[15], [16] Peter Suedfeld and G. Daniel Steel, 2000, p.243

24. Clear nightsky over the the Concordia Research Station
Credits: European Space Agency/IPEV/PNRA - C. Possnig

07 DR. CARMEN POSSNIG

Part of the of the 14th winter-over in 2018 on the Concordia Research Station, ESA-sponsered Biomedical Researcher Dr. Carmen Possnig conducted research on human behaviour in extreme environments. The research will help to better understand how crewmembers function in extreme habitats and prepare for future long-term outerspace missions.

1. What motivated you to apply for the job sponsored by the European Space Agency and which criteria were important for the crew selection?

I'm passionate about space research, and as a medical doctor, especially space medicine. Antarctica has fascinated me ever since I read Scott's diary as a teenager, and actually spending a winter in the middle of the continent is as close as we get on earth to living on another planet.
The crew selection is done in two parts: a detailed medical checkup, to make sure there are no medical conditions that could become a problem during the isolation. Then, there are extensive psychological test, personality questionnaires, talks with psychologists and psychiatrist, to make sure that the candidates have the right kind of personality. Usually, they look for introvertive, but socially open people, who can entertain themselves, have a lot of interests and hobbies, are patient and tolerant, have effective conflict resolution skills, etc. After the individual selection, the team cohesion is evaluated, to check if everybody fits into the group.

2. Which tasks and studies were you assigned to do?

I had four different experiments in the field of space medicine to take care of, all of them focused on the adaptation of the human body and mind to extreme environments. I was mostly looking at the immune system, at the adaptation to the altitude, the microbiome (the bacteria in the gut) and at changes in cognitive and motoric skills. In addition, I was responsible for our rescue team, and expected to help our medical doctor in case of emergency.

3. How would a typical day look like on the station?

In the first two weeks of every month, I did the experiments which involved taking samples from my collegues: blood, urine, stool, saliva, hair, etc. I stood up around 7 am to prepare for that, then spent most of the day analyzing the blood. In the last two weeks of each month, I had the experiment with the Soyuz simulator, which took all morning and left the afternoon free for other tasks. In order to get outside as much as possible, I often accompanied other researchers and helped with their work. In the evening or our free time, we often went to the gym (you don't get much movement done otherwise), played music, read books, cooked together. We had fixed times for meals: lunch was at 12.30 pm, dinner at 19.30. Everybody was supposed to attend, it's a good way to make sure everybody is safely inside the station and feeling okay.

4. How did you experience the extreme cold environment, the isolation and confinement and the unusually night and day cycle during your stay at Concordia?

It was great. I quite like the cold. It is a unique experience, a lot like we imagine living as astronauts on another planet might be. I think this helped a lot: usually, the more extreme the environment is, the better some people cope with it. It gives them a boost to know that they are living an extreme experience, and they are surviving it quite well.
The long night was another thing I loved about Concordia: the sky is simply magical, nowhere else on earth you can see this abundance of stars. If there is a full moon, the landscape is often bathed in pinkish to clear blue lights, if there is no moonlight, you still don't really need a headlamp – the starlight reflecting on the snow is usually enough to guide your way.

5. During my research about sensory deprivation on Antarctica stations I often read that there is a so called winterover-syndrome. Did you or the crew experienced it?

Everybody doing a Winterover experiences it, some are more affected, some less. Some are completely unaware of it, even though severely affected. Several of my colleagues got quite aggressive or prone to sudden mood changes, others got depressive. All of us had troubles sleeping.

Then there is the famous Antarctic stare: you would often encounter someone sitting in a room, staring into the distance, completely lost and unaware of anything going on around him. Cognitive abilities are affected as well. Our ability to remember things decreased a lot, people quite often complain that they cannot remember much of their winter – which is why it is a good idea to keep a diary in situations like that. Unless, of course, you want to forget.

6. Other psychological studies refer to the need to change the environment they are living in in order to have a sense of perceived control which ultimately leads to stress relief. Were there changes the crew made to station, even minimal one like changing work schedules to moving furniture and so on?

It's not really possible to change a lot about the station. We did make some small changes. For the midwinter festival, we decorated some rooms in different themes. The living room got turned into a jungle, with lots of paper leaves we made ourselves, some trees and tropical birds, all homemade. We liked it so much that we decided to leave the decoration for the rest of the winter. Around that time, we also changed the location of our dining tables: we used to eat in the dining room, a big rather cold place next to the kitchen, which in summer is full of tables. In winter, we moved the billiard, table soccer and pingpong tables in there, and then decided to eat in the living room instead, since it was so much more comfortable and warmer. The meals were much more enjoyable in there.

We had a group project during our stay: we built our own climbing wall in the video room. It took a lot of planning because we wanted it to be permanent, so other crews could enjoy it afterwards. It was satisfying to build it with our own hands, and then see and climb the result.

7. During the winter you and the rest of the crew were isolated for about 9 months. What changes at the station would make the stay easier to cope with? A greenhouse or a bigger sport room would be a possibility?

A greenhouse would be lovely. I think plants in general would have helped a lot. Sadly, it is not allowed to bring seeds or plants to Antarctica due to the Antarctic Treaty, so as not to contaminate the continent (exceptions exist for research projects). Our sports room was quite big and well equipped, however it might be a good idea to have two treadmills for example, so that two people can run next to each other (as one of the complaints of people using it was that it was boring).
It would be an interesting experiment to try some virtual reality program there: people could experience walking on a beach or in the jungle and have a break from the usual environment.

8. At Concordia station there is a simulator for the Russian Soyuz spacecraft. I have read that you train monthly to see how the motor skills change and adapt during a prolonged isolation period. Where there any visible changes or difficulties to complete the simulation?

The data is not yet completely analyzed. I could see however that especially the cognitive abilities decreased as soon as the sun disappeared. I also had the feeling that the motor skills suffered by that time, but it might also be that my colleagues were simply losing motivation. Some of my collegues complained most about these cognition tests: at the end of each of them, the result is visible on the computer screen, along with the comparison to the previous months. I think most of them did not like this, as it gave them very explicit facts on how their performance was decreasing.

9. Another study that I read refers to the increased need of privacy for people in isolated and confined habitat. Did the station offer enough privacy especially during the summer period for the crew?

In summer, there is very little privacy. Rooms are shared between two people. At peak times there were more than 80 people in the station, since it only has 34 bedrooms some of them had to sleep in the summer camp, or heated tents. It was a relief when winter came and most people left.

10. What are the main differences between a summer stay and a winter stay?

Summer is the time from end of November to the end of January: it is a busy time. There are lots of people in the station (up to 90 at the same time), there are planes landing almost every day, it is relatively warm with a mean -30°C, the sun is shining 24 hours every day.

Winter, on the other hand, is very different: for nine months, a crew of about 13 people is completely isolated with no chance of evacuation. The crew is dependent on themselves. There is a brief twilight time in the beginning and then, in the beginning of May, the sun rises for one last time and then disappears for three and a half months. The station is in complete darkness for that time, temperatures drop to -80°C

11. During the winter could go outside the station? Under which circumstances?

Yes, some people had to go outside every day to perform experiments. It's important to take care while dressing, not leave any bare skin exposed to the cold. Even so, freezing body parts were a daily occurrence. We always had to take a radio with spare batteries when going outside, and keep regular contact with the person in the radio room.
There were days when it was too dangerous and thus forbidden to go outside, mostly during storms or whiteouts.

12. What did you miss the most during your stay?

The ability to talk to people privately without being overheard, the possibility to just being with people I like; not being constantly observed and judged.

25. Dr. Carmen Possnig during her stay at the Concordia Research Station
Credits: European Space Agency/IPEV/PNRA - C. Possnig

13. What was the best and worst part of being for one year in Antarctica?

Both the best and the worst part have been (and are) the people I spent my year with there. Another wonderful thing about being in Antarctica is, of course, Antarctica itself. It is a magical place, full of wonderful moments and experiences.

14. Were there difficulties to adjust to the normal life back home after your stay ended?

Yes, a lot. It is not easy to come back. Nobody is unchanged by a Winterover. You get to know yourself very thoroughly. The world outside has changed as well, or at least my perspective on it. In the meantime, family and friends had a "normal" year and mostly for them as well it is difficult to imagine what life is like in Concordia. So yes, coming back is difficult. Most of us found it easier make big changes rather than returning to the same life as we had before.

15. After spending 12 months in one of the most isolated places on Earth would you be interested to experience or research life in a micro-gravity environment like on the International Space Station or further?

Yes, definitely. I had a wonderful experience in Concordia and I would do it again – surely in Antarctica, but even better: on the moon or on Mars.

26. EDEN ISS, Ground Demonstration of Plant Cultivation Technologie for Safe Food Production in Space
Credits: Hanno Müller/ AWI

07 DR. PAUL ZABEL

Researcher Dr. Paul Zabel was an Antarctic gardener at the EDEN ISS greenhouse next to the Neumayer III station. Dr. Zabel successfully managed and grew crops in the experiemtal greenhouse. The project aims at testing and developing plant cultivation methods in harsh environments for use in future long duration outer space missions. [1] It is essential to understand the mechanism of crop growing in extreme environments and how design can integrate complex requirements for greenhouses in future habitats.

1. Why was Antarctica more important to test the EDEN ISS project than any other more accessible place?

Antarctica offers a lot of similarities with a typical human spaceflight mission. It is the most remote continent on Earth, the climate is very harsh, the logistics are complicated and limited, the resources (e.g. manpower, energy, data connection) are very limited. Furthermore, an Antarctic station is like a spaceship on another planet. The crew completely relies on the technology of the station to survive. The crews are typically small groups of people living and working together in isolation for more than 9 months continuously.

2. The project was approved to continue for the next two years. Are there any plans in changing or improving the current design and mission?

We have not planned major design or layout changes. Nevertheless, we have planned and already implemented a number of improvements on several subsystems to improve functionality and operations.

[1] eden-iss.net, Ground Demonstation of Plant Cultivation Technoloiges for safe food profuction in space. n.d.

3. How much time did the crew spend working inside the greenhouse?

Work on-site related to the project was around 8-10 hours per day for a single person. That includes working with plants (~1 hour), system maintenance (~1 hour), Antarctic specific and preparatory tasks (~2 hours), science (~3-4 hours) and repair work.

4. There were about 40 experiments that took place in the experimental greenhouse. What kind of experiments were in general?

The experiments conducted in 2018 encompassed the research fields of engineering, technology validation, system operations, horticulture, microbiology, food quality and safety, human factors and plant biology.

5. How is the light cycle optimized for the requirements of the plants?

We have a mixed spectrum of LED light with red and blue light being the major part. The lamps are illuminating the plants 17 hours per day. Dusk and dawn are also simulated by having the lamps going to a less light intense setting.

6. How do you choose the most important plants to study and grow in an experimental greenhouses? Which criteria is important?

There are many different criteria how to select plants and the process itself can be very complex. We decided to focus our research on fresh vegetables which need no or only little post-processing before the harvest can be eaten.

7. I read that there was a problem with plants who after pollination did not produce any fruits. What do you think could be the problem?

We are still investigating this issue and I have no final answer yet. We think it might be an issue with the environmental conditions.

8. How do you dispose of the nutrient rich water? Does it get treated?

The used nutrient solution is currently not specifically treated, but simply trashed.

9. What happens currently to the biological waste from EDEN ISS? Are there any plans and ideas to exploit the green waste?

The biological waste is treated together with the food waste from the kitchen. This waste is not exploited or recycled on-site. There are currently no plans to exploit the waste plant material, but in terms of a space life support system this would be necessary and could be tested in conjunction with the greenhouse in Antarctica.

27. EDEN ISS, inside the experimental greenhouse
Credits: Hanno Müller/ AWI

10. Which might be the most valuable crops to grow in future missions?

I don't think this question can be answered. It strongly depends on the focus of the mission and on the priorities. The focus can be on fast growing plants with a high output or on crops with a high nutritional value or on crops with a high energy density or or or…

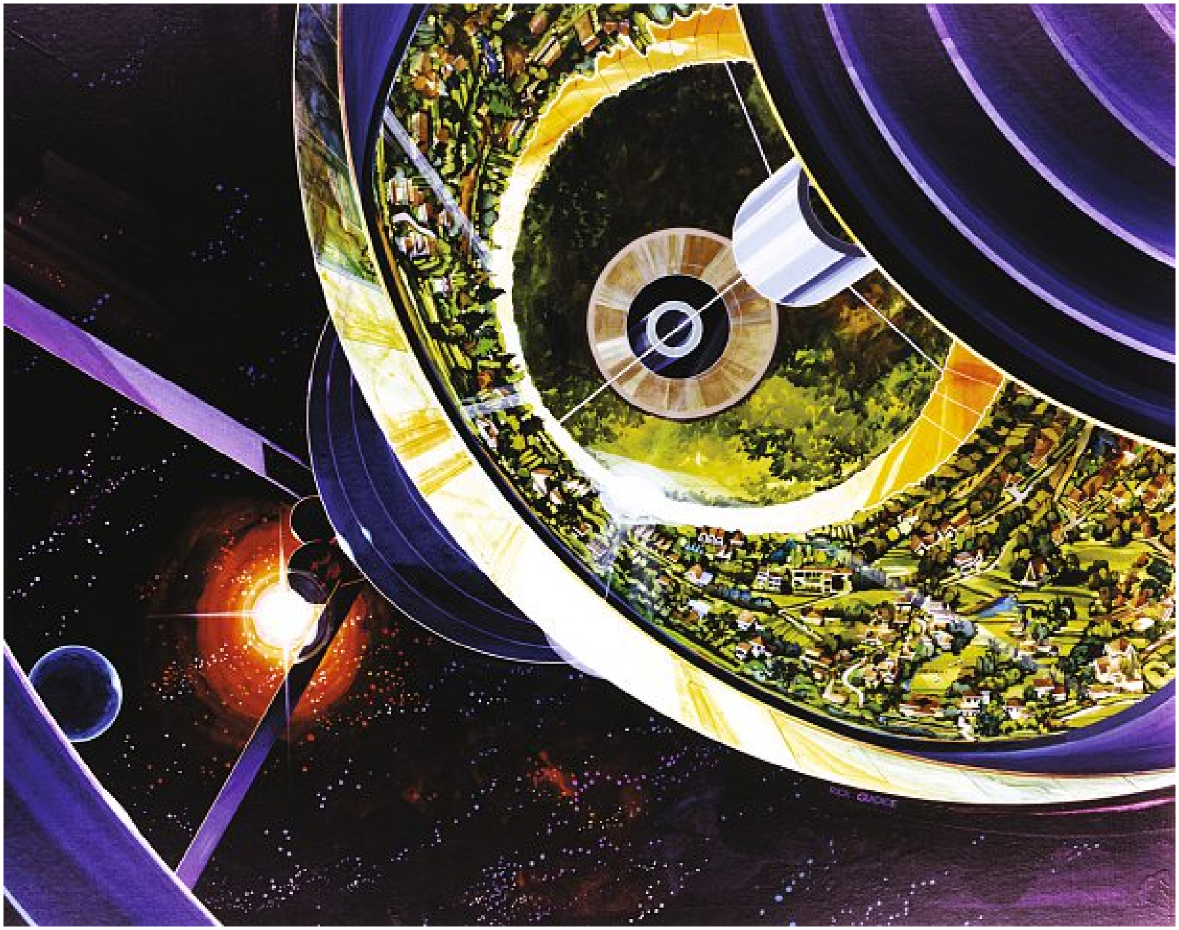
EDEN ISS is positioned about 400m away from the Neumayer III Station. During blizzards the greenhouses is operated from the command center in Bremen, Germany.[2] The greenhouse is made up out of two containers sized parts. The first part is the service section which has the support subsystems (thermal, power and ventilation controls) and the second part is the greenhouse itself.[3] The service section also serves as a working station for planting and harvesting. Both sections are separated by an airlock in order to not cross-contaminated the two parts and the outside with bateria or fungus.[4] Over the course of almost 10months the 12.5m^2 greenhouse produced 268kg of crops.[5] The fresh food feed the small winter crew and also left a "lasting impression" and a "possitive effect on the team's mood".[6]

[2] dlr.de, One year in the perpetual ice- EDEN ISS Antarctic gardener Paul Zabel returns, 2019
[3], [4] Paul Zabel et. al., 2015, p.3
[5], [6] dlr.de, EDEN ISS project presents results of a new greenhouse concept for future space missions, 2019

08 GREENPATCH

Architecture in sensory deprived environments

CASE STUDY: Concordia Research Station



28. NASA Space Colony Concept, cutaway view
Credits: NASA Ames Research Center

08 RATIONALE FOR INTERVENTION

Due to the psychological risks missions in extreme and confined environments imply, the thesis presents a theoretical architectural proposal which weighs into the possibility of providing more interactive space for the crew.

The idea of greenhouses and their many benefits to the human psychology have been addressed in many forms, from the NASA concept artwork in the 1970s, multiple research papers and science fiction movies. The proposal focuses mainly on the interaction between the greenhouse and the whole crew from an architectural point of view. Plants feed on the carbon dioxide human exhale, while humans need the oxygen produced by plants to breathe. Yet plants produce more fruits while growing under blue and red light, while humans function best in normal daylight and in the evening in warmer light to stimulate the melatonin production. However, under these light conditions plants appear to have a black color and will have a lesser visual impact on the crew.

Testing concepts in Antarctica is much easierer than in outer space. Not many Antarctic stations have greenhouses and those that have, separate the greenhouse strictly from the entire station. Providing concepts on how to combine the different functions and light conditions will provide more design opportunities.

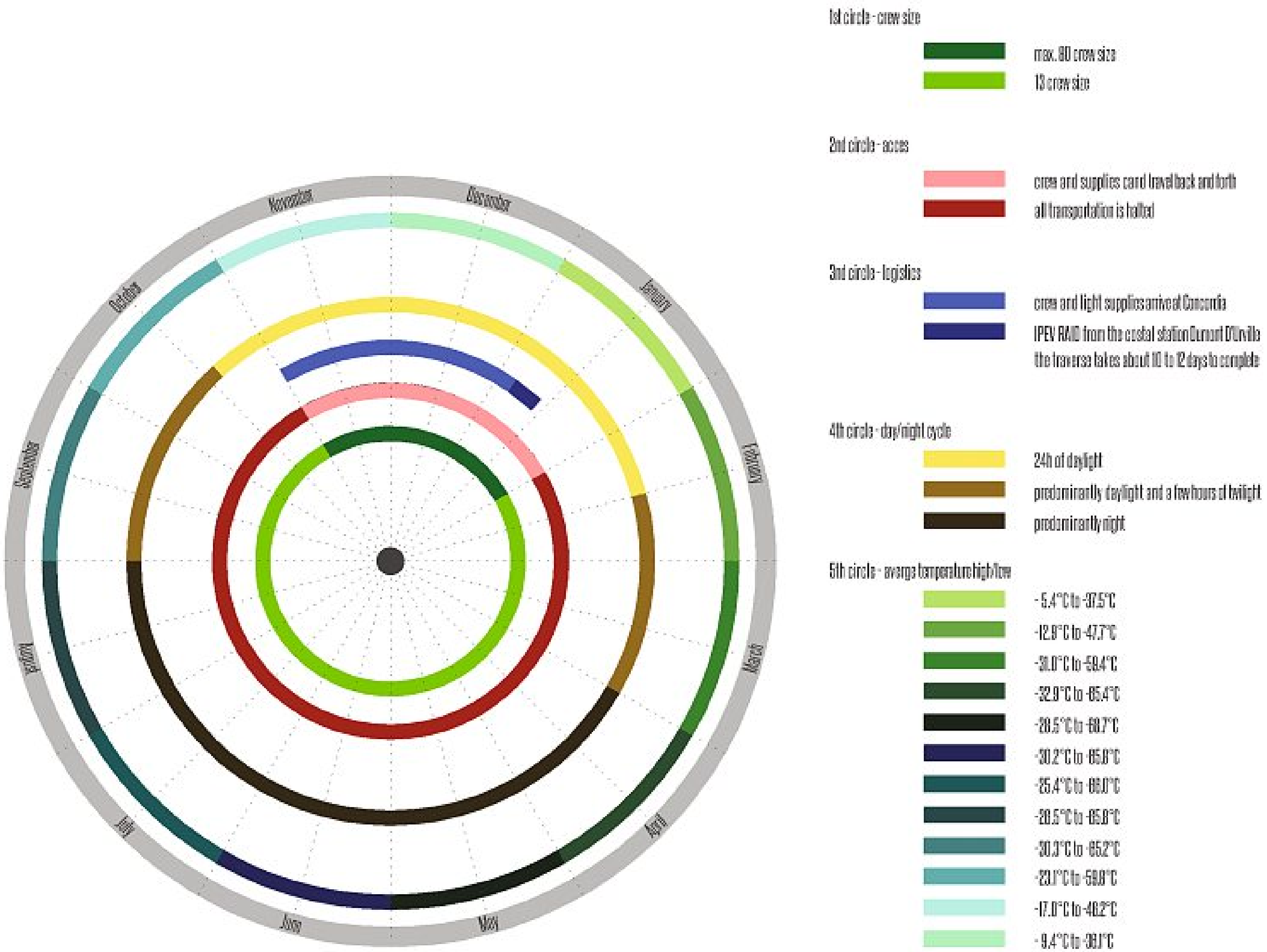


Chart illustrating common facts at the Concordia Research Station, drawn by the author

FACTS

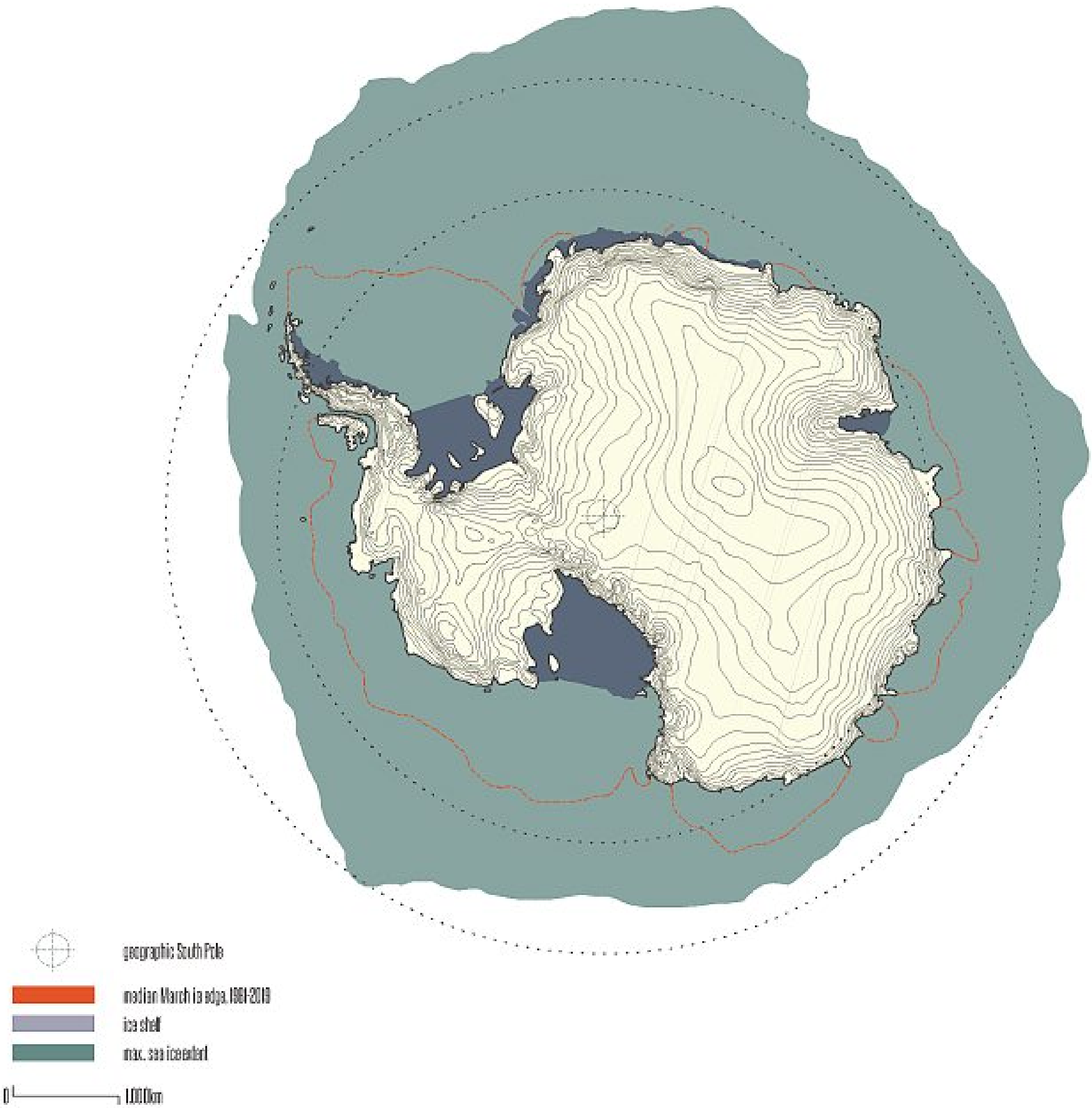
As previously mentioned, the Concordia Station is one of the most isolated and confined places in Antarctica. The chart on the left illustrates the changes in crew size, logistics, day-/night cycles and temperatures according to each month of the year. Starting with the circle closest to the center, stations and the summer camp are at its maximum capacity during the austral summer months from November until February.

The rest of the year, the continent is difficult to reach and no supplies are delivered. Crew and supplies move only during the summer months. The station that are far away from the coast are supplied with the help of traversing vehicles, which transport fuel, food and other rescources. Usually these journeys can last up to 2 weeks for just one journey.

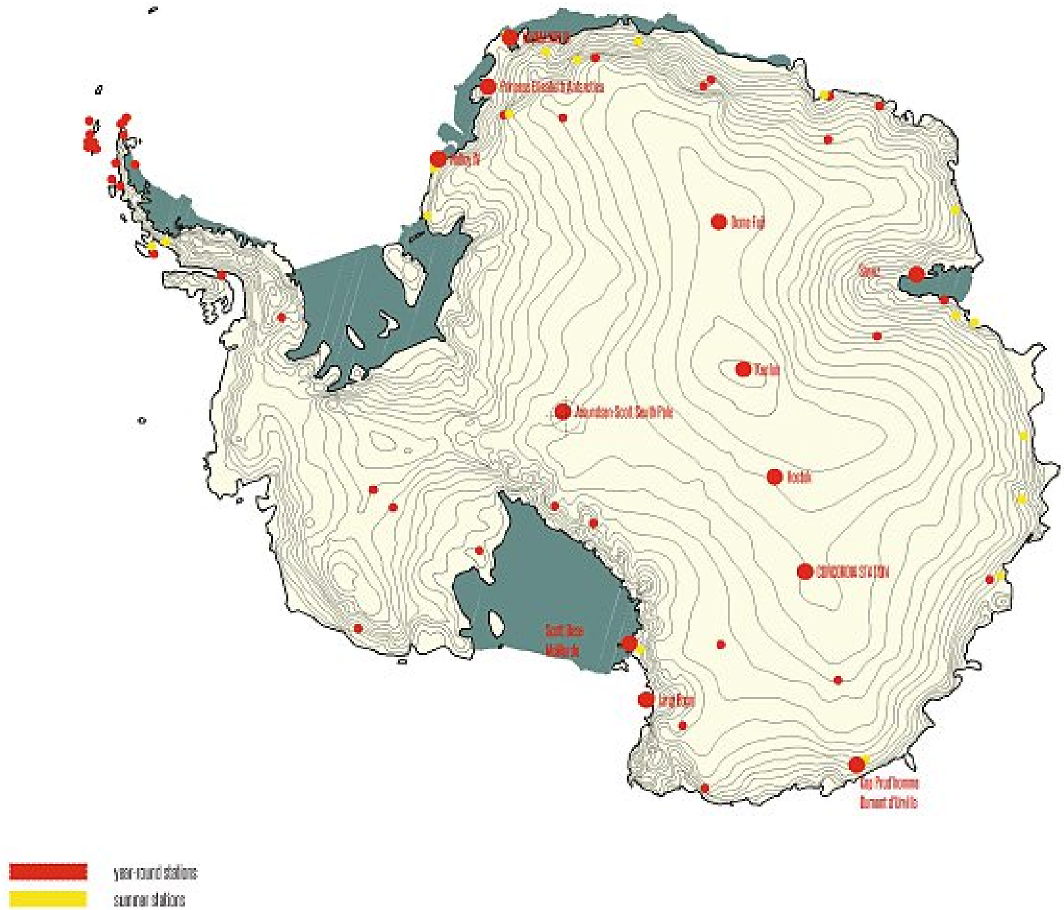
Another unique characterisctic is the unusual day and night experienced by the crew. The entire year can be split into 3 different periods each consisting of 4 months of total sunshine, twilight and darkness.

The outer circles put in context to all these monthly changes the temperatures. Austral summer months become warmer but only reach positive values at the costal stations. Winter months very cold which makes venturing outside the station also extremply dangerous. Precipitation and wind speeds were not integrated in the chart for its values are low throughout the year on the Antarctic Plateau.

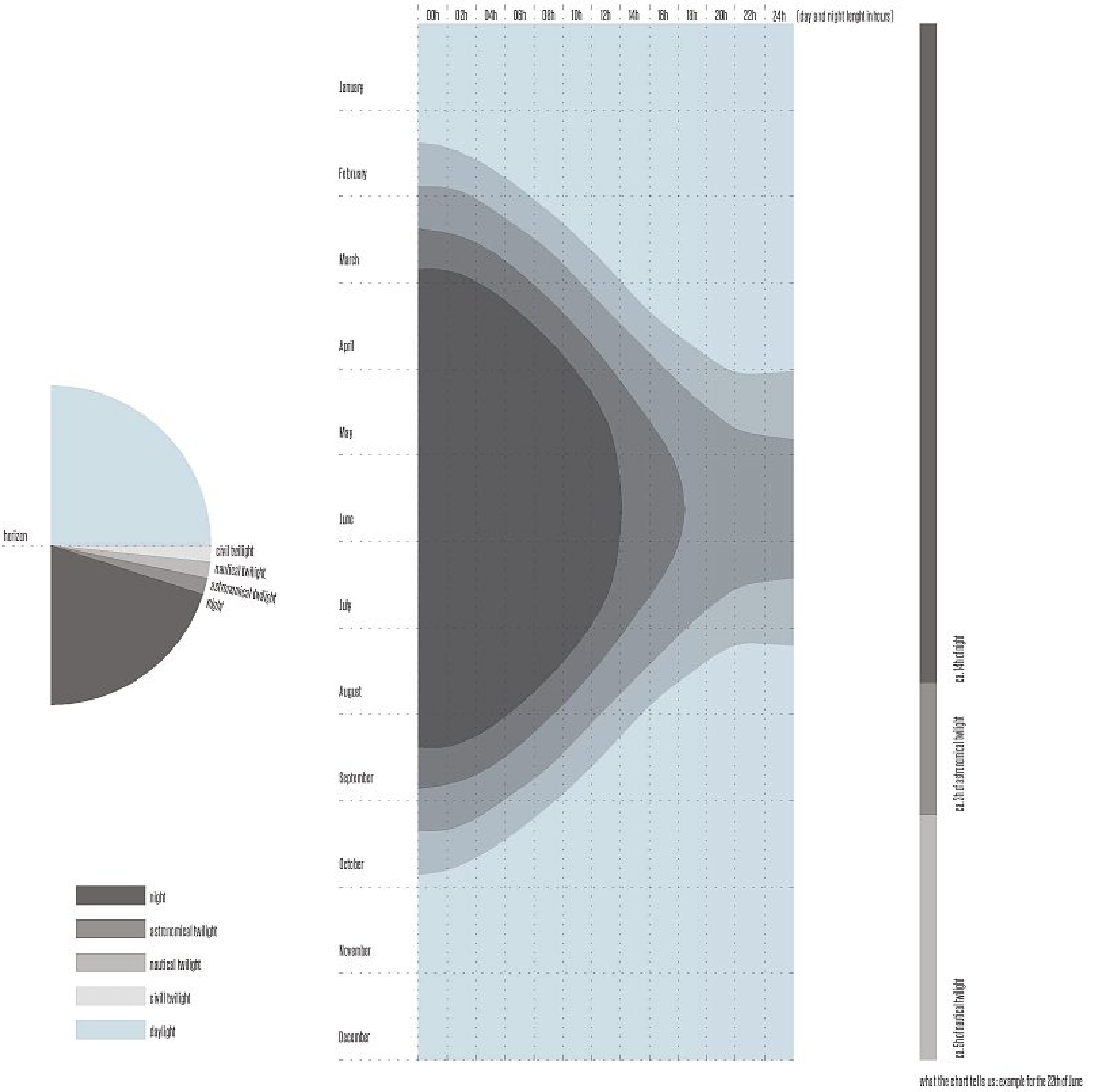
It is however important to mention that snow only accumulates and never really melts on the Plateau.



Elevation map of Antarctica, drawn by the author



Antarctica summer and winter stations. drawn by the author



Sun chart at the Concordia Research Station, drawn by the author

LIGHT CHART

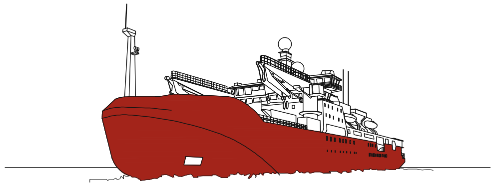
The light chart on the left illustrates with greater detail the amount of sunlight, twilight and darkness in hours which can be observed at the Concordia Research Station. Due to this unusual pattern, it is important to recreate the day and night pattern according to human circadian rhythms. Stations and modules should be able to recreate a familiar day cycle for otherwise it can cause, as previously mentionend in other chapters of this book, distrubances in the sleep patterns.

On the other hand, it provides a great opportunity to integrate an artificial light cycle in the design proposal. A greenhouse alone has special requierments and this had to be synchronised with the light cycles of the other rooms. The greenhouse needs about 16 to 17 hours of growing light per day, with sunrise and sunset integrated in the cycles. In order to produce the many fruits, the plants are fed with a mix of red and blue light. This resulting magenta light is damaging over time for humans and has to be filtered out using shutters.

During the sunset simulation, the light may turn to a more reddish color, which is more tolerable for human eyes. Since the productions of melatonin is important for a healthy sleep, the sunset color shown in the greenhouse are in accordance to the crew's needs.

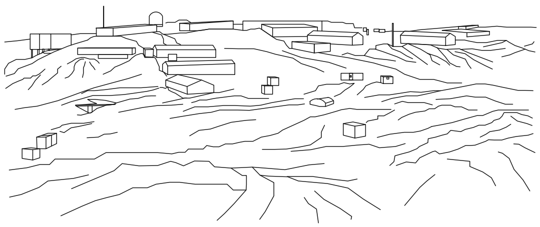
40ft container
exterior dimensions: 2.44m wide/ 2.59m height/ 12.19m lenght

1



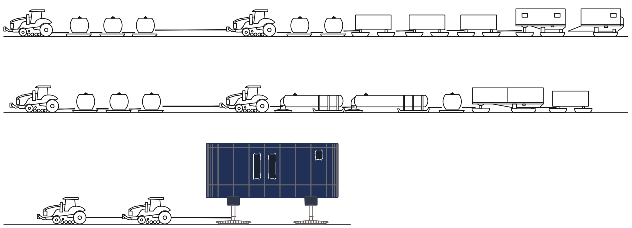
prefabricated elements shipped on ice breaker ships

2



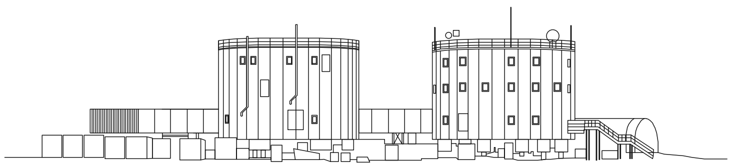
3

arrival at the French coastal station Dumont d'Urville
main part of greenhouse will be assembled here



assembled module is hauled to the main station on the Antarctic plateau during the IPEV Raid (10-12days) together with the supplies needed for the winter-over

4



at the Concordia Research Station the greenhouse is docked onto the main station
during the winter-over interior assembly can take place

5

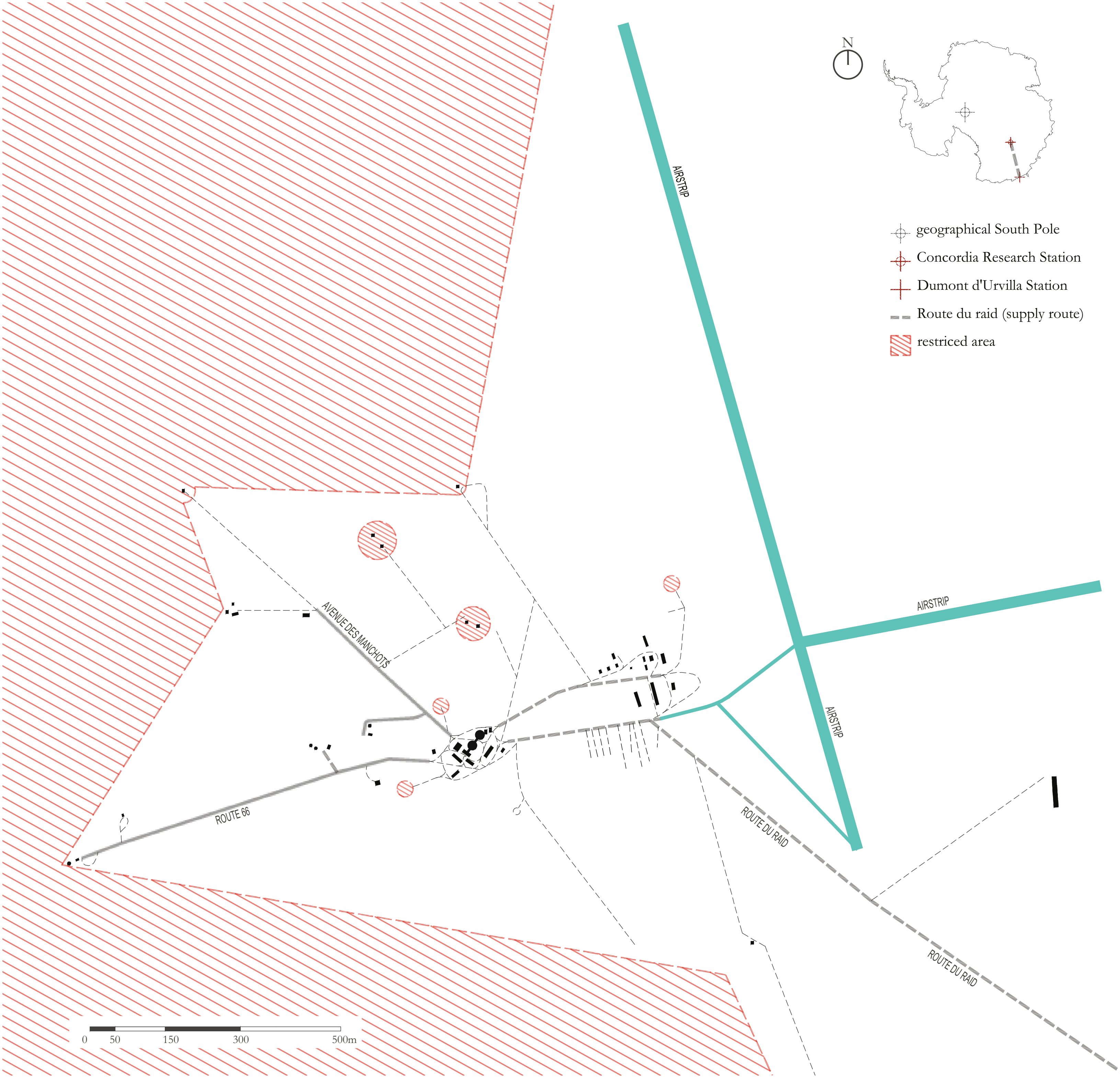
Logistics journey for the design proposal, drawn by the author

LOGISTICS

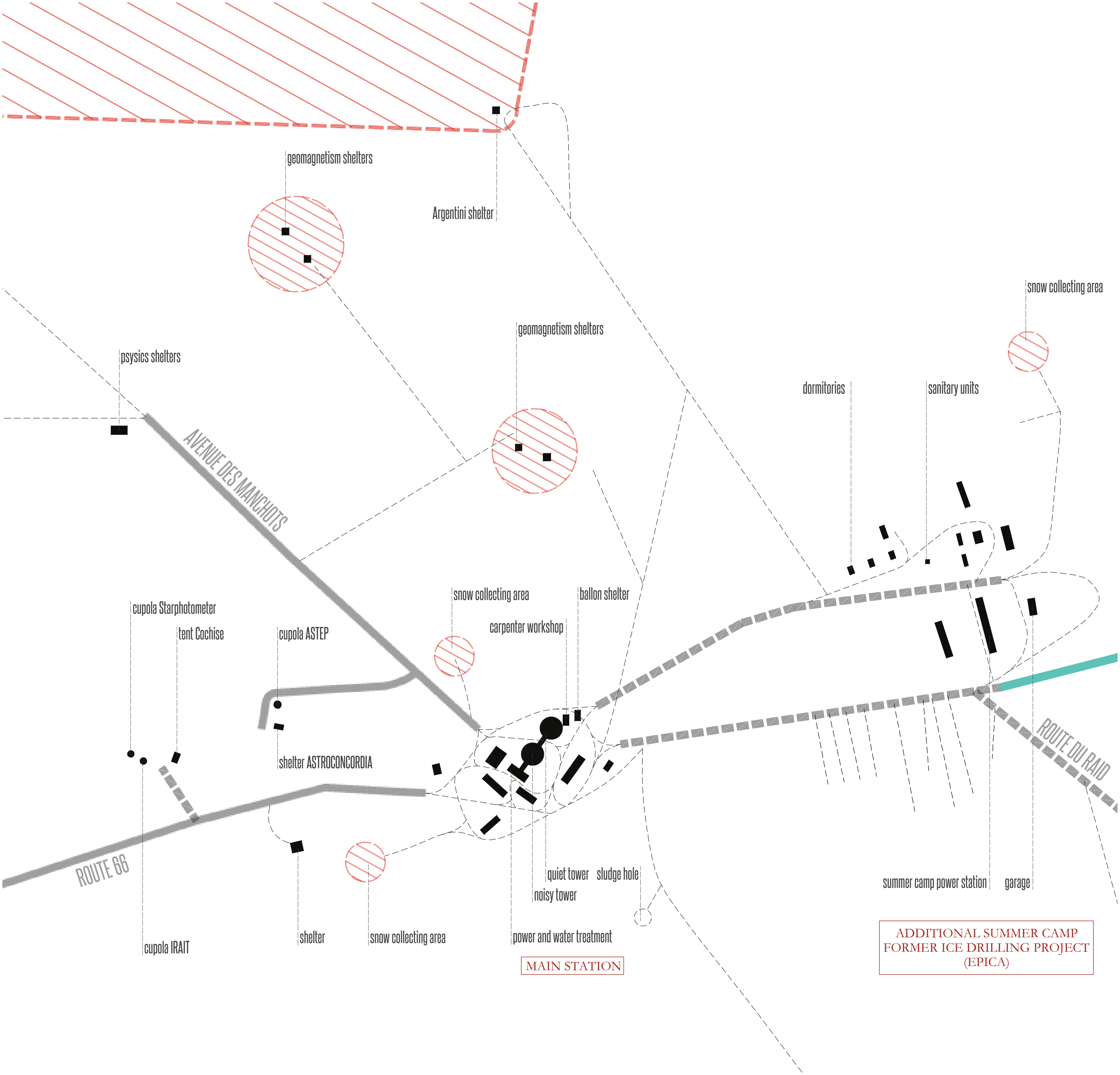
Concordia is also very interesting because of the difficulty that the logistics pose to the construction. While the lighter supplies and the crew arrives by smaller airplanes that can land on the icy airstrip near the station, heavier supplies arrive by ship at the coastal station Dumont D'Urville and are being dragged on skis during the Traverse to Concordia. The trip covers about 1.100km of land and takes about 10 to 12 days depending on the weather conditions. A smaller addition to the main station will need to be made out of prefabricated parts which should be easy and quick to assemble on site. The add-on will have to be ideally constructed after it arrives at the coast station and then be dragged together with the rest of the heavy supplies to Concordia. A similar successful attempt was done while moving the British Halley IV Research Station on the Brunt ice shelf.

The Concordia Research Station has integrated exits in the facade panelling. These openings serve as an emergency exit in case of fire and also as an opening to bring heavy supplies in each corresponding floor. One of these openings will make the connection between the main station and the new additional module.

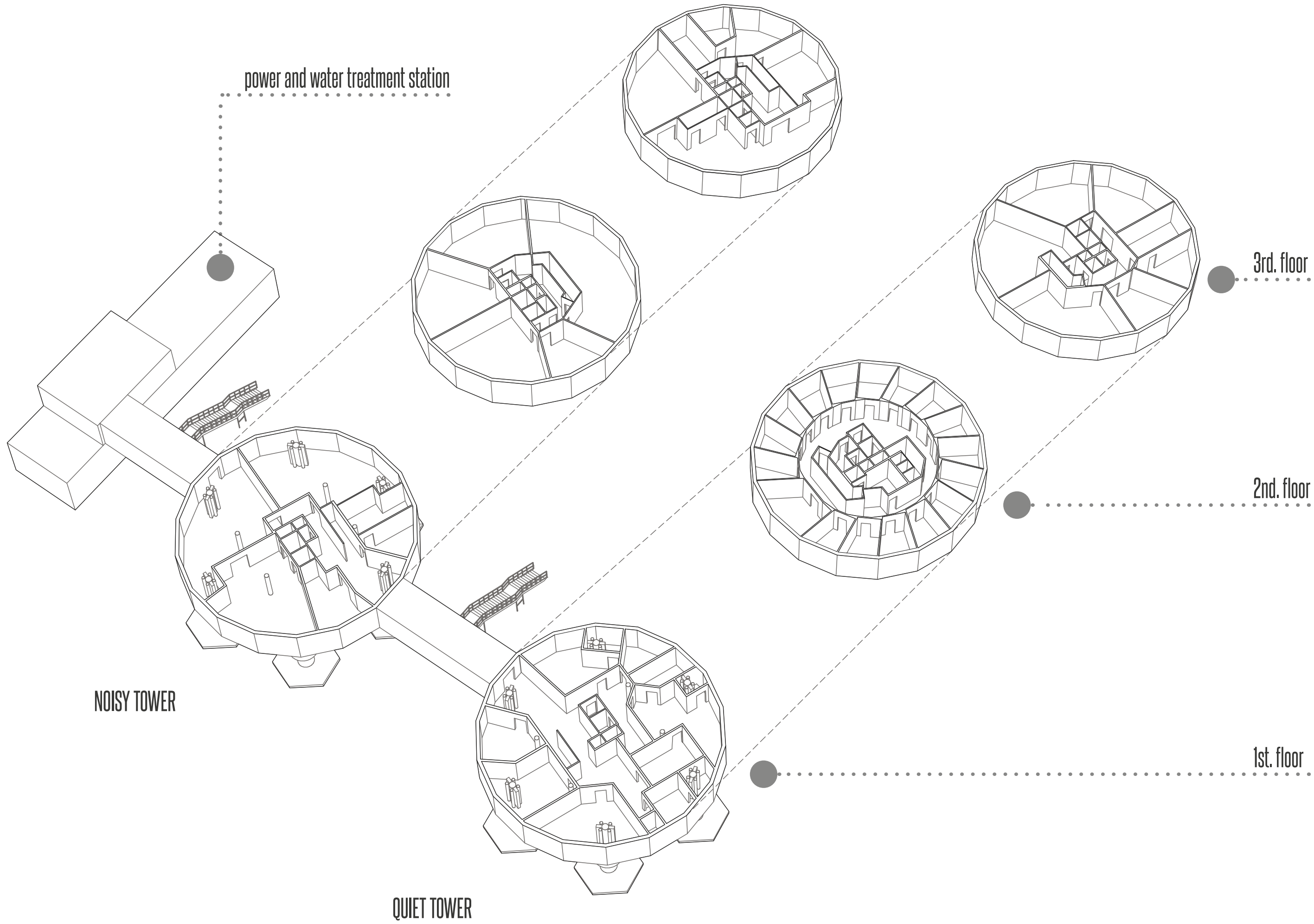
Similar to modules for outer space stations, the construction elements for an Antarctic building will be constrained by the limitation a container will impose. In Antarctica, assembly can be done more easily than in space but the construction time still needs to be limited as much as possible. The main construction materials will be prefabricated wood elements. Wood is a more sustainable material choice compared to steel and also has a much lower carbon footprint. Stations and add-ons in Antarctica are designed with a lifespan of about 25 to 30 years making wood the better choice. When stations are closed or replaced, the construction elements neeed to be disassembled and shipped out of Antarctica. Wooden elements will also improve the interior's visiual quality by adding a natural texture which is completly missing in Antarctica.



Site map/ Concordia Research Station, drawn by the author



Site map/ Concordia Research Station, drawn by the author



Axonometric diagram of the existing Concordia Research Station, drawn by the author

CURRENT STATION

The architectural proposal will be exemplified on the Concordia Research Station. This station in particular has been chosen by the author mainly because it is one of the most isolated Antarctic stations. At Concordia there is also ongoing research conducted by the European Space Agency on human behaviour and group interactions. This facts support the main focus point of the architectural design which is to provide sensory enrichment especially for the winter-over crews.

The add-on has been design also with the possbilitiy of being attached to other stations on the Antarctic Plateau who house winter-over crews. However, the connection between the add-on and the existing station will need to be accordingly to each station.

The Concordia Station has almost on every floor additional openings which can be used as emergency escapes and for bringing in heavy supplies. However, openings can only be used though during the summer times when the temperatures are milder and the weather is friendlier.

One of these openings on the second floor in the *Noisy Tower* will serve as a docking point for the new add-on to the station. Using one of the openings allows a quick access from inside the station and it is positioned near other rooms which are used during free time, such as the cinema or sports room.

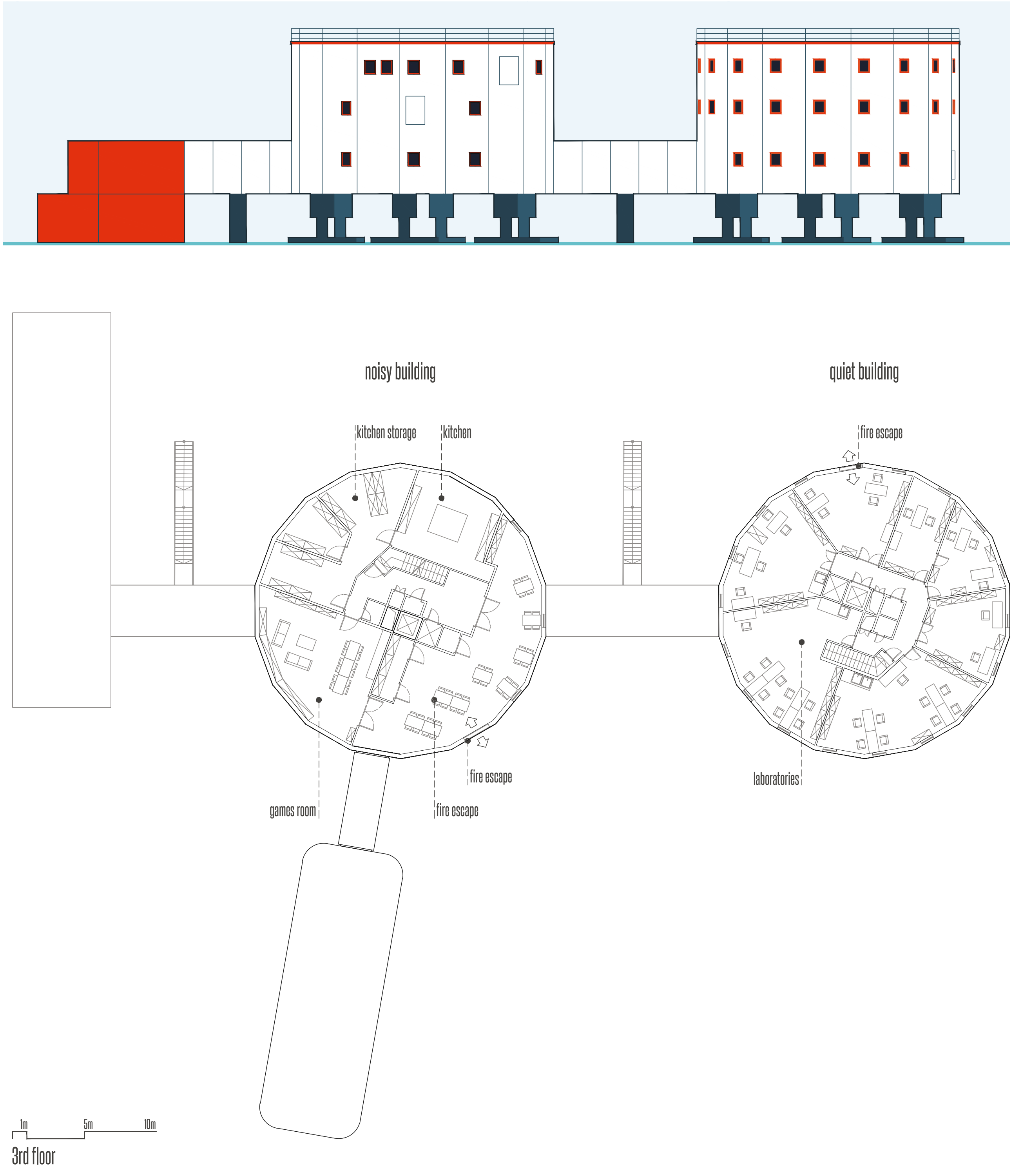
GreenPatch is also designed to work as an add-on on other stations but the connection to the existing station has to be customized according to each situation.

DESIGN PROPOSAL

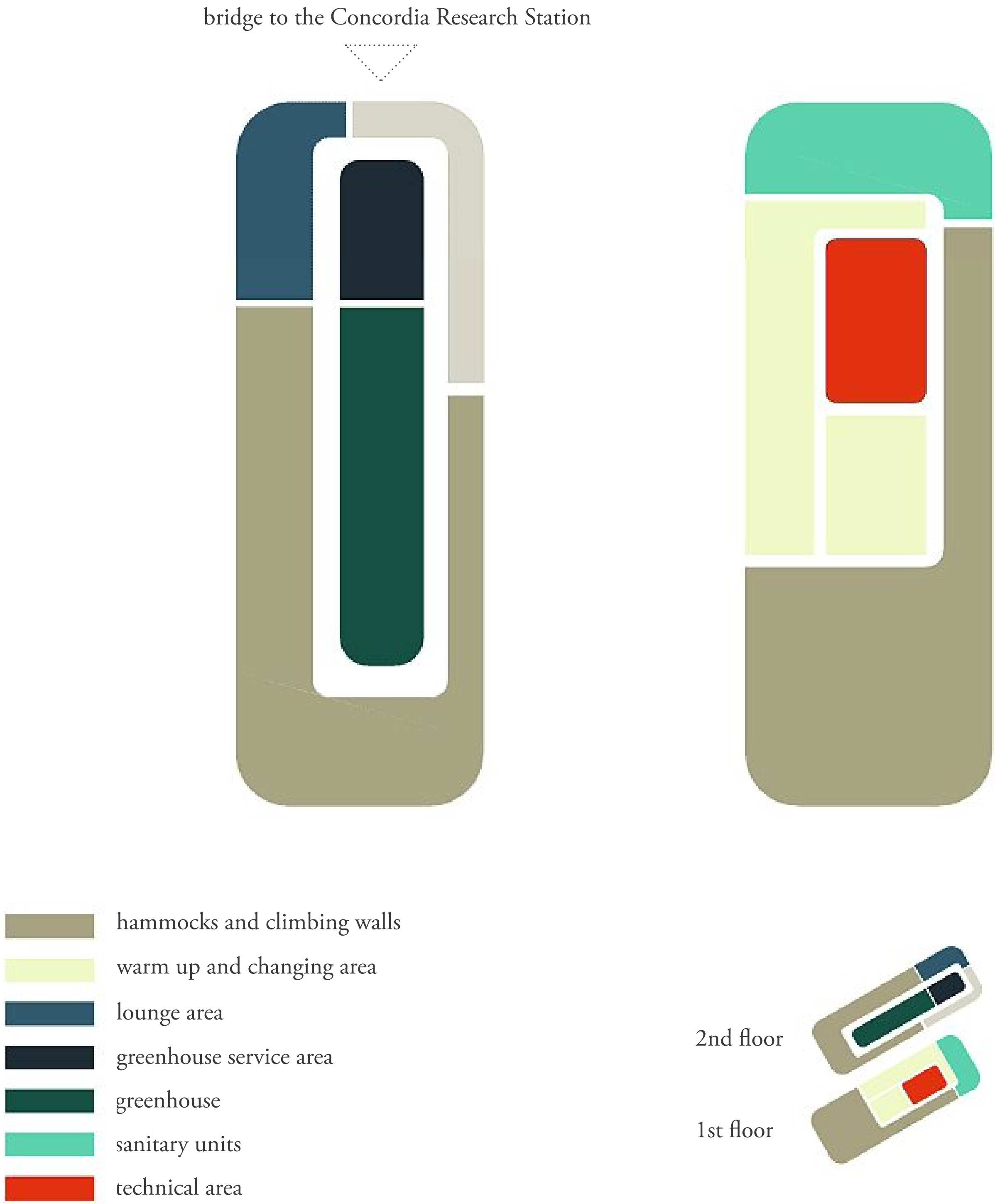
The design proposal consists of an add-on to the already existing Concordia Research Station situated on the Antarctic Plateau.

GreenPatch is ment to be able to be intagrated also on other stations in Antarctica. Concordia has been chosen as a case study for its ongoing studies on human habitability in extreme environments performed by the European Space Agency and unique isolation and confinement conditions. GreenPatch provides 20m^2 of greenhouse growth area and a service and monitoring area of 9m^2. Around these rooms is an additional work/lounge area and a sports area. The tehnical and equipment storage rooms are on the lower level, beneath the actual greenhouse. The two storey-high module provides enough room height for a climbing wall and hanging mats. A previous crew built themselves a climbing wall inside the main station due to it's strict construction design, the main station did not provide enough space for such a group activity. Due to the splitting of the greenhouse in two levels, a 6m high climibing wall resulted, which leads to hanging mats from where the greenhouse and its plants are perfectly visible.

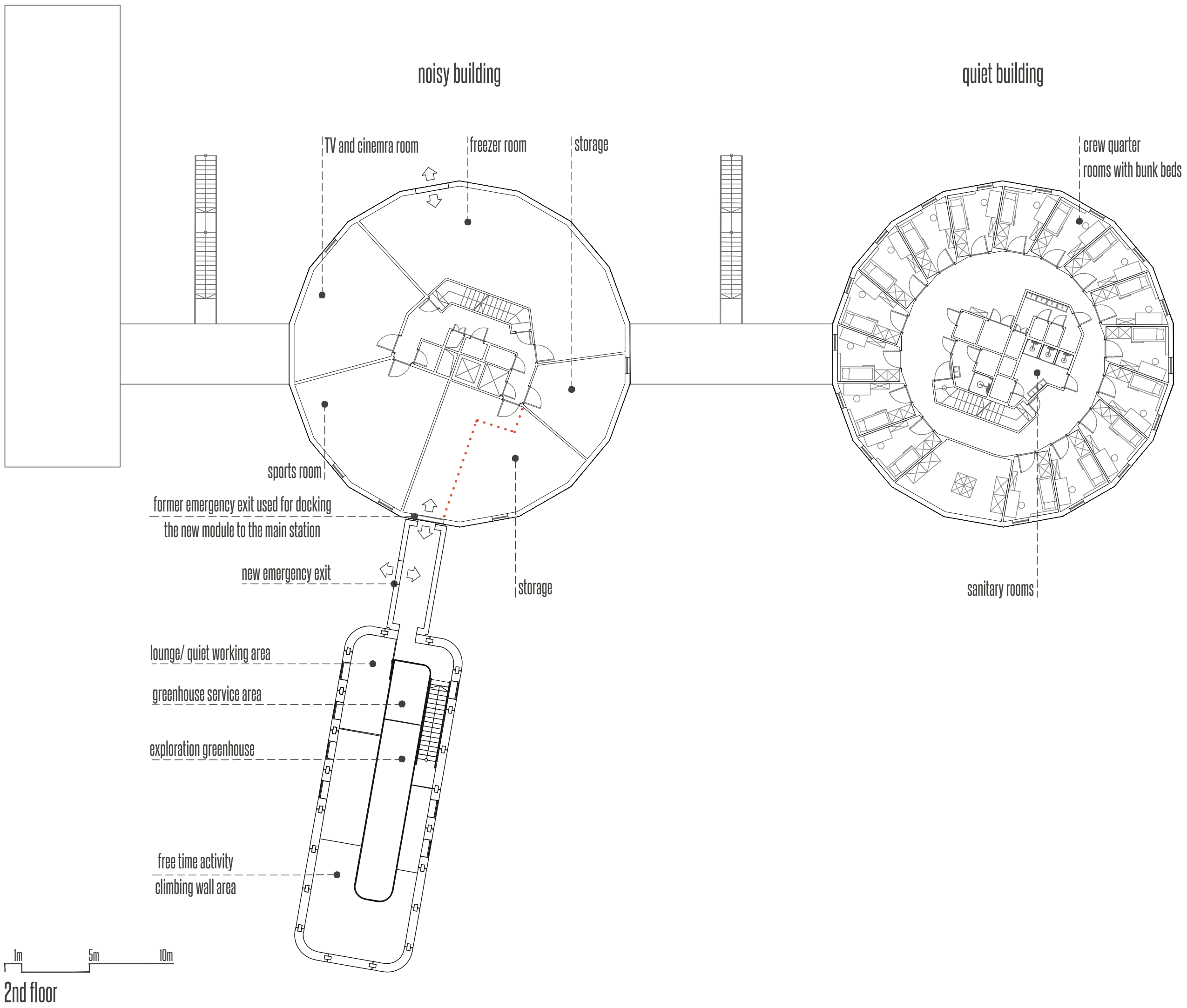
While there is a pretty strict work and leisure program on Antarctic stations, with fixed meal times, GreenPatch will provide work space and also leisure space after the working hours. During the day, also when the greenhouse light is the least bearable, onlylthe lounge and monitoring areas will be occupied for the working crew. After dinner, when the crew has free time, GreenPatch offers the climbing walls for group sport, hammocks for smaller groups and the lounge area for personal quiet time.



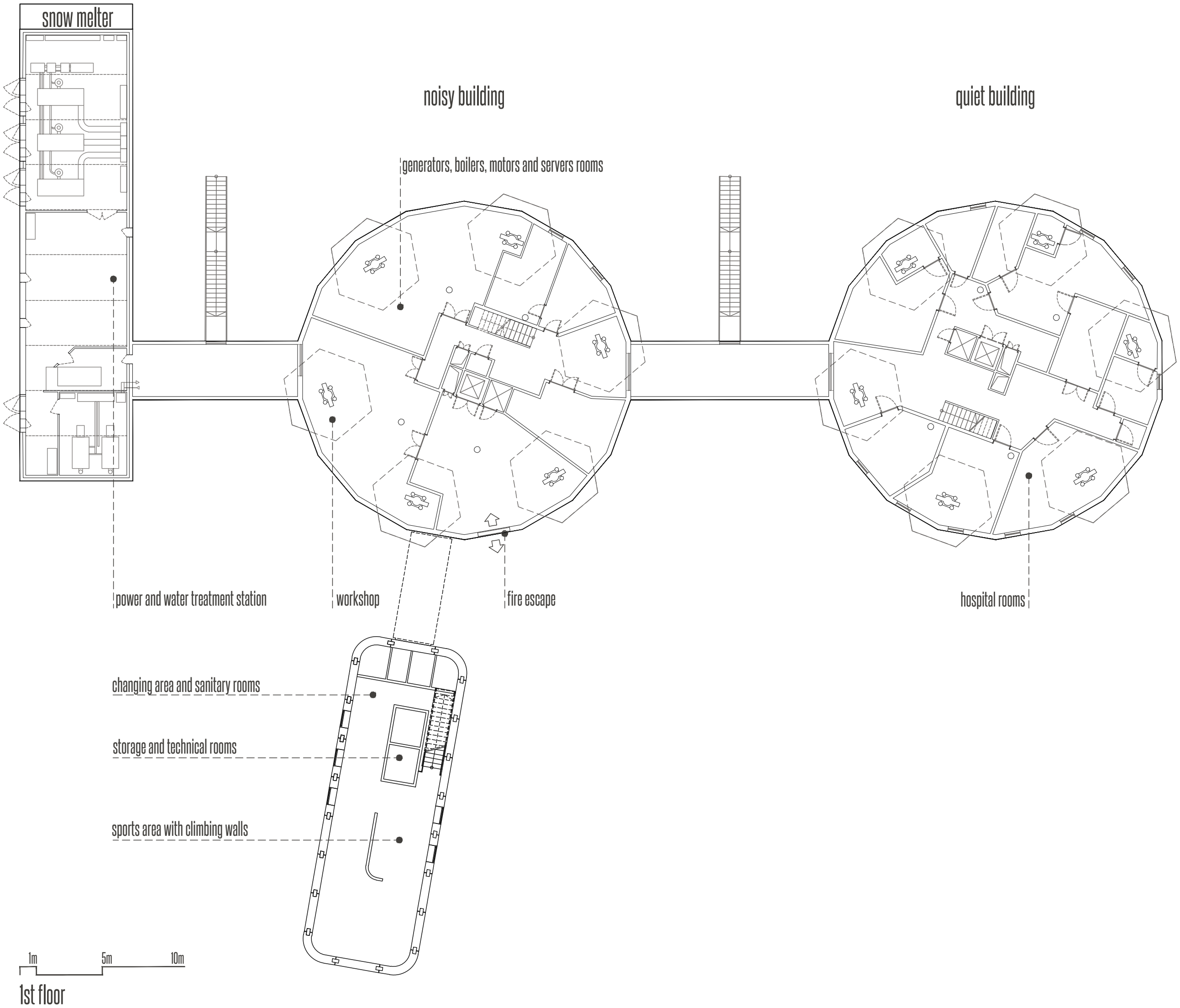
3rd floor of the Concordia Research Station with attached exploration greenhouse, drawn by the author



Mind map, upper floor



2nd floor of the Concordia Research Station with attached exploration greenhouse, drawn by the author



1st floor of the Concordia Research Station with attached exploration greenhouse, drawn by the author

29. EDEN ISS, inside the experimental greenhouse
Credits: EDEN ISS Consortium Porject/DLR/ESA.

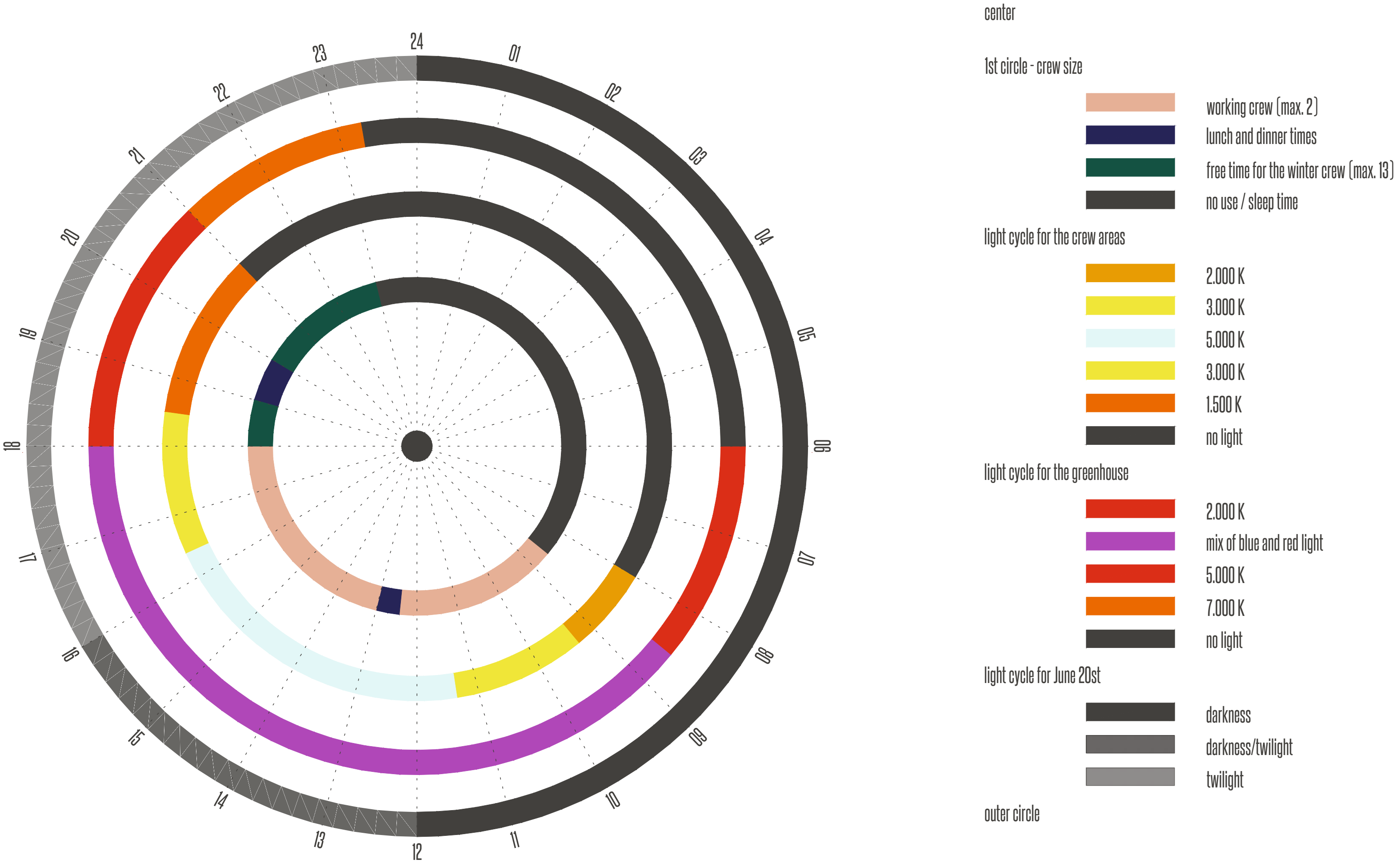
LIGHT SIMULATION

Due to the unsual day- and night cycles on the Antarctic Plateau the light cylce inside plays a major role. While the plants are fed up to 17 hours of red and blue light a day, the crew will use GreenPatch during certain times.

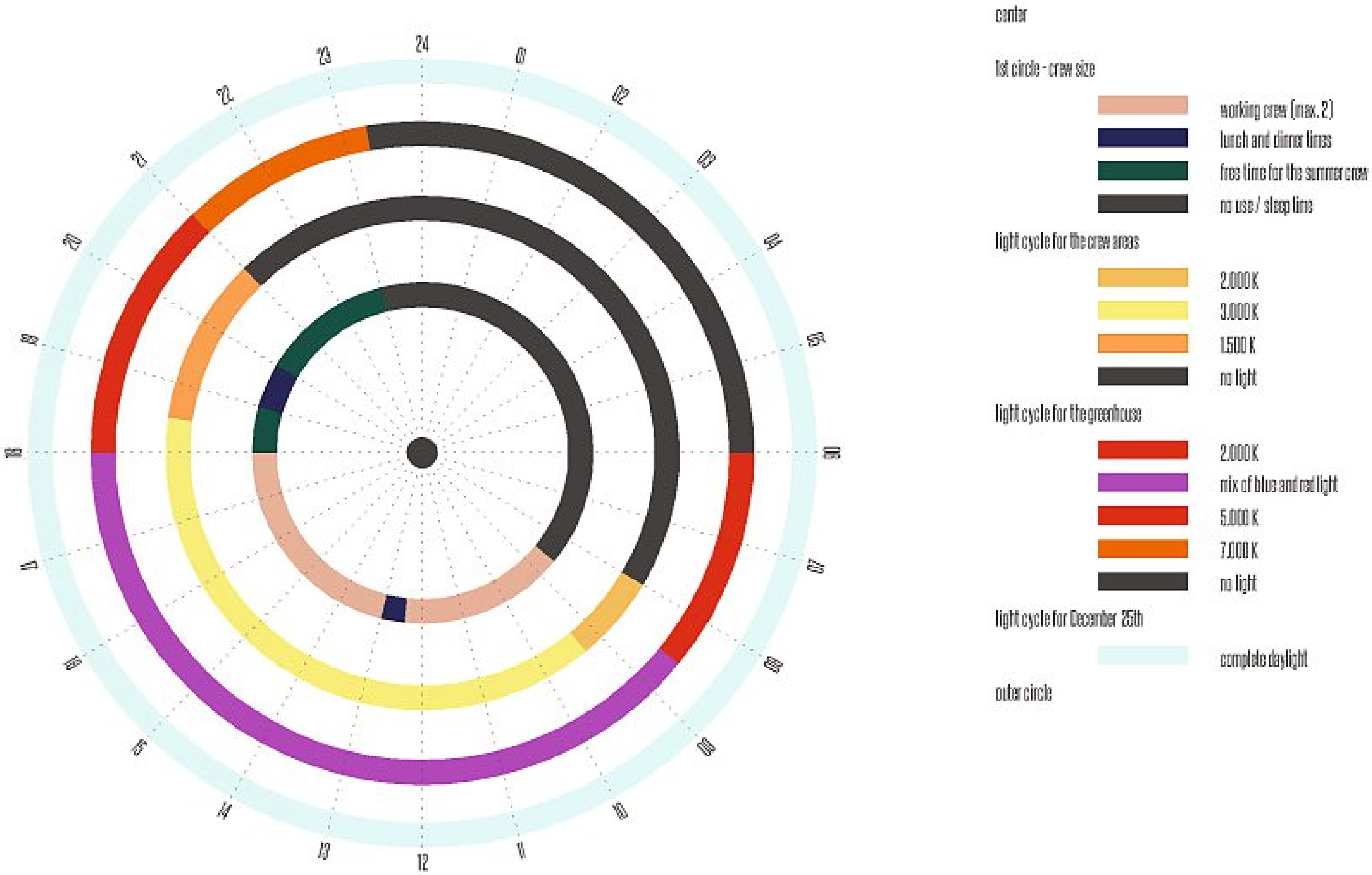
It is important for the crew to maintain the cicardian rhythms humans are used to as previous noted in the research. The unusual Antarctic light cycle can be a good factor for allowing an independent light cycle inside, regardless of the light condition outside.

The greenhouse will simulate sunrise early in the morning and sunset late in the evening. During the day, the red and blue light not only lets the plants appear black but can also become, over time, harmful to the human eye. At it highest peak, the greenhouse light can be visually separated from the service and lounge area in order to allow the crew to work in optimal conditions. In the evening, the greenhouse light will switch to a more red-orange tone similar to evening colors. Warmer colors are also good for the crew when they are enjoing free time in GreenPatch for they increase melatonin production and help with the sleep disturbance that occurs often on Antarctic stations.

During the austral summer months, when there is daylight for almost 24h, shutters block the outside light from entering the station and allow the simulation of sunset and night.



Light chart for the 21st of June



Light chart for the 25th of November

06:00-08:00 a.m.

08:00-11:30 a.m.

12:00-04:00 p.m.

04:00-06:00 p.m.

06:00-09:00 p.m.

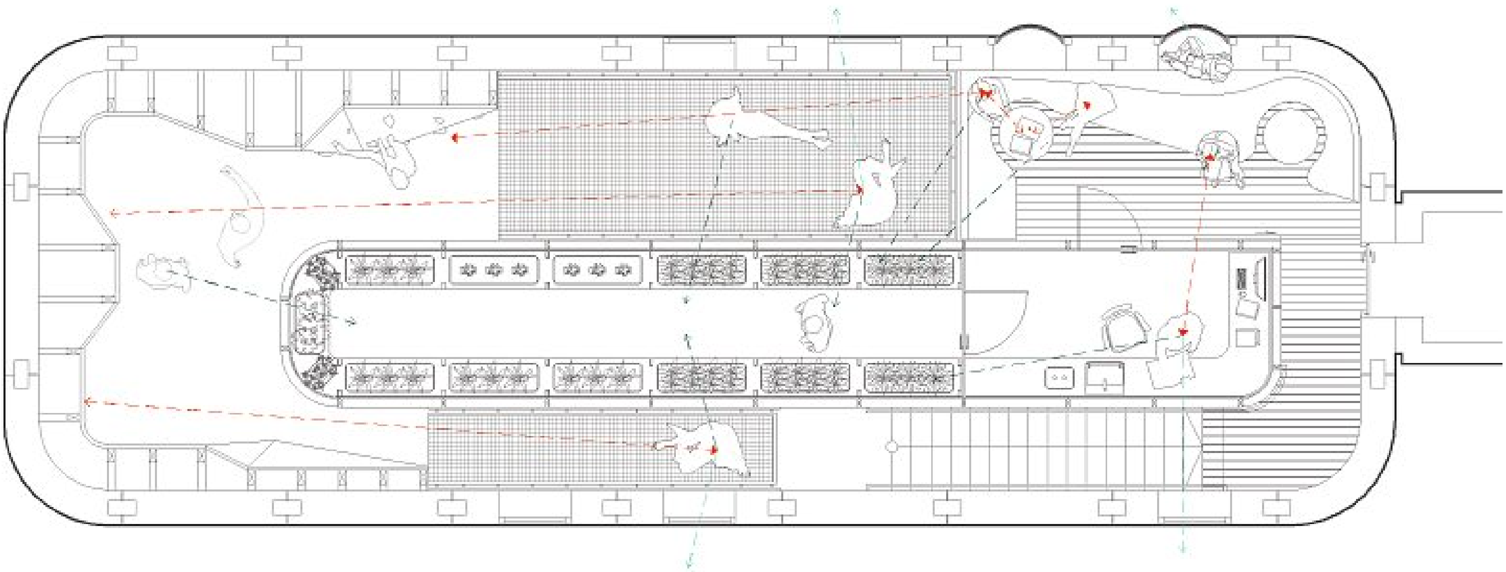
09:00-11:00 p.m.

Light simulation inside the final presentation model

INTERIOR CYCLE

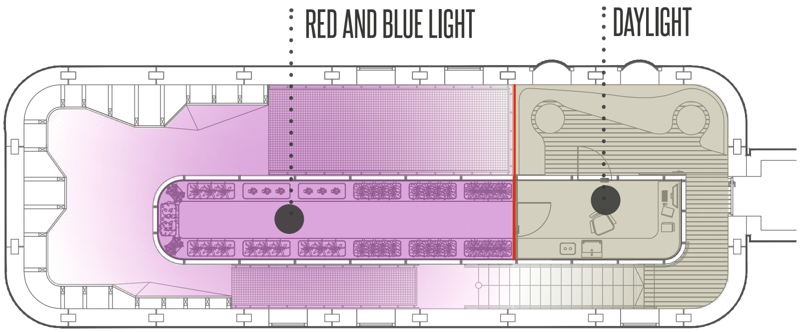
The greenhouse has been spatially positioned to be the center of the module, making it visible, as illustrated in the next diagram, from all the corners of the module, visual interaction between the greenhouse and the crew being the main design factor. The interior provides three different types of spaces for free time activities such as the climbing area for a more larger group, the hanging mats for smaller groups and the lounge for more quiet and private interaction. The lounge is also acoustically seperated from the first two activites.

As shown in the images on the left, especially during the long and dark winter days there will be a need for an interior lighting simulation. Early in the day the lights in the greenhouse will start and simulate a sunrise. When the workday starts, the greenhouse lights shine red and blue light on the plants. The working area will need to simulate a normal day cycle. Both light cycles will work independently from one another with shutters a possible solution to block the inconvenient red and blue light . In the afternoon, the greenhouse lights will slowly start to simulate dawn and sunset, changing to a more reddish color. In the meantime, after the workday, the crew has time to engage in group activities in the module. The orange-red light in the greenhouse will allow for such free time activities to take place and also make the plants visually more engaging.



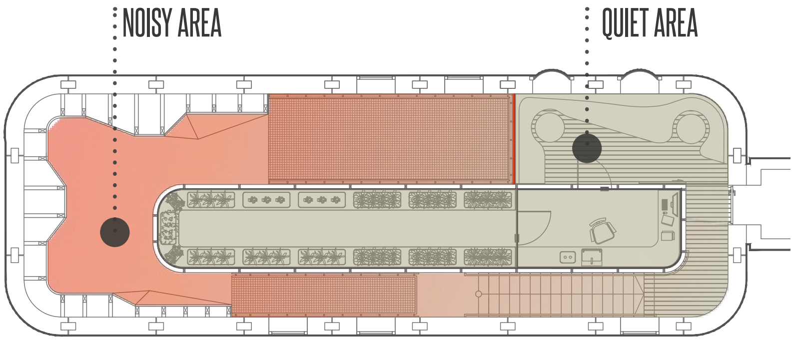
VISUAL INTERACTIONS

greenhouse
outside environment
crew



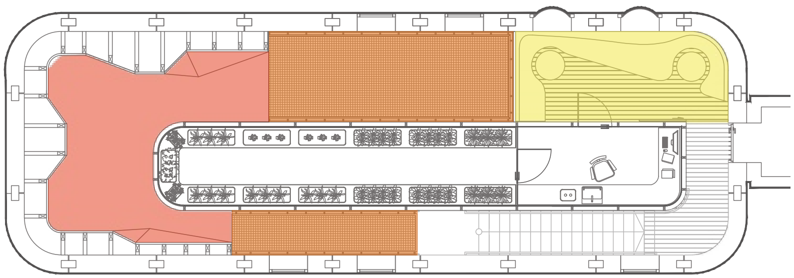
LIGHT

shutter can filtrare the unpleasant red and blue light coming in the working area



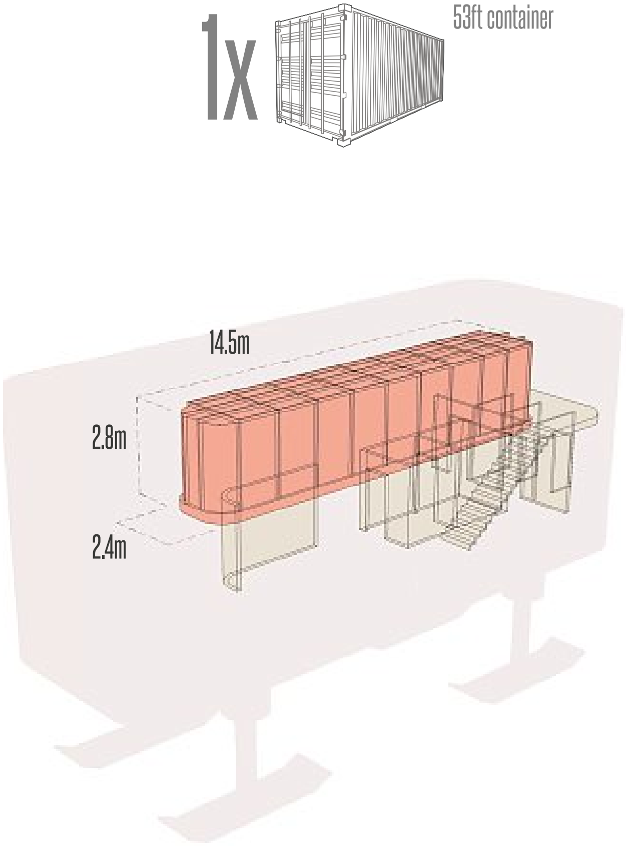
ACOUSTICS

glas partition wall providing sound insulation

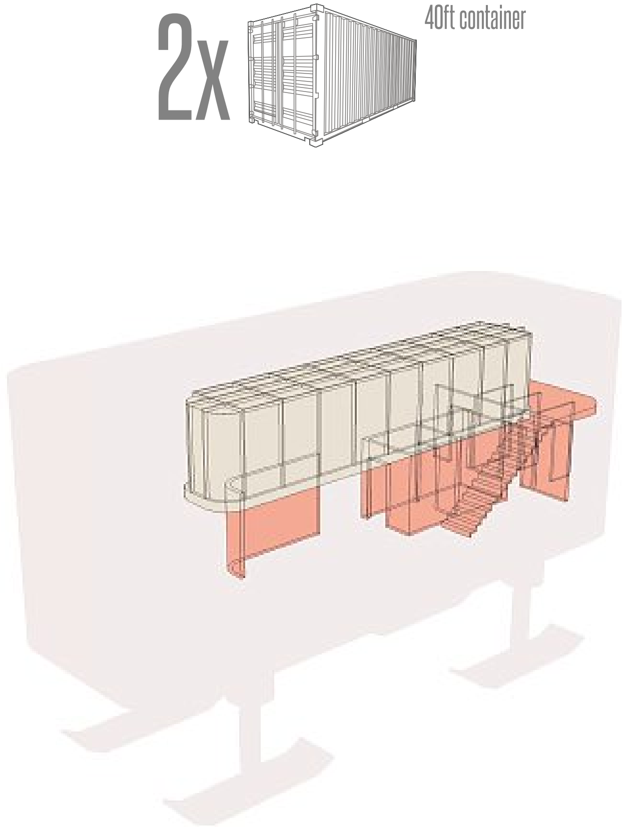


PRIVACY

the interiors offers space with more and less privacy, the red area is designed for goup activities, orange area for smaller groups and the yelloe area for up to two people and individual activities



greenhouse module

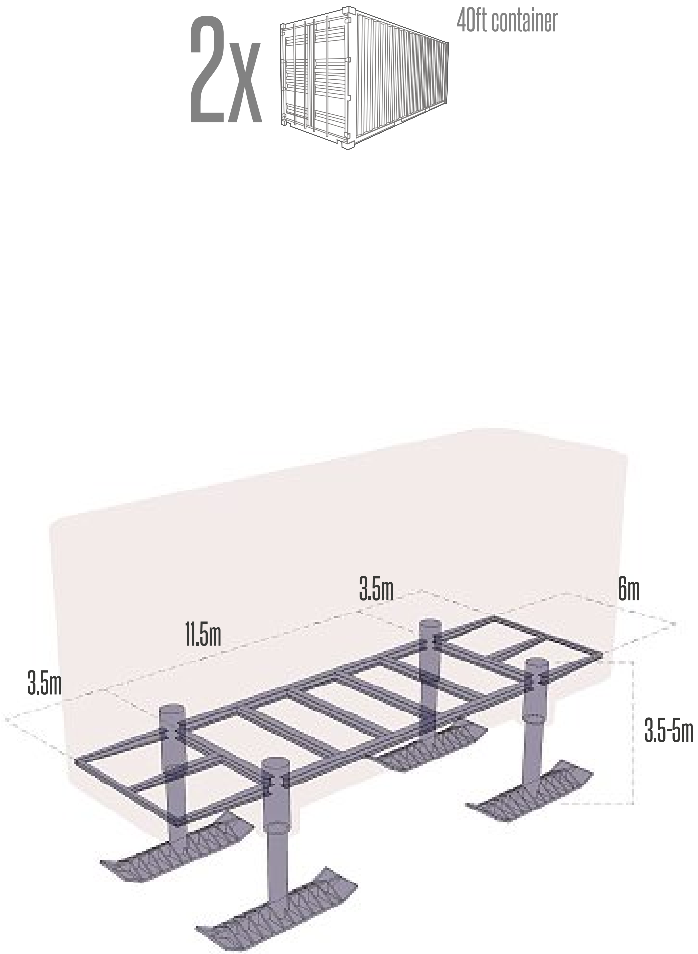


interior wall panels made out of cross laminated timber

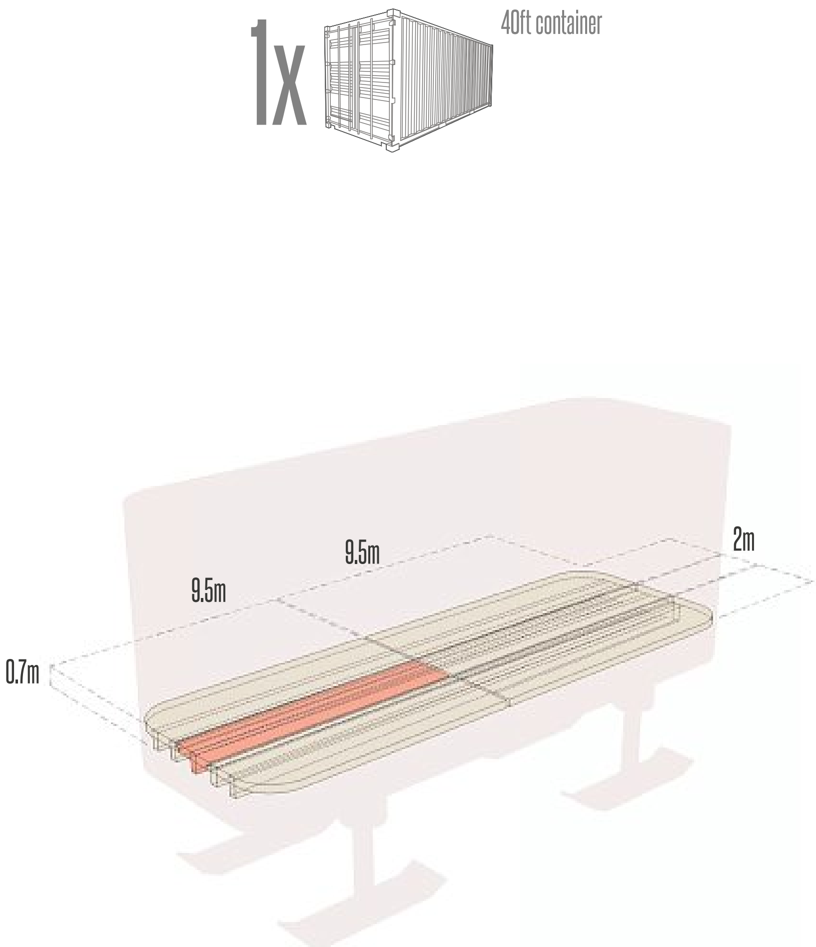
ELEMENTS OVERVIEW

Most of the materials used for GreenPatch are prefabricated elements out of wood, designed to fit in the usual shipment containers. Wood has been chosen as the main construction material for its sustainable qualities and for the low material deformation at low temperatures compared to steel. Weather and temperature can change very quickly in Antarctica and prolong construction time. Using materials and prefabricated modules that have low deformation points and are quick to build are desired in these extreme conditions.

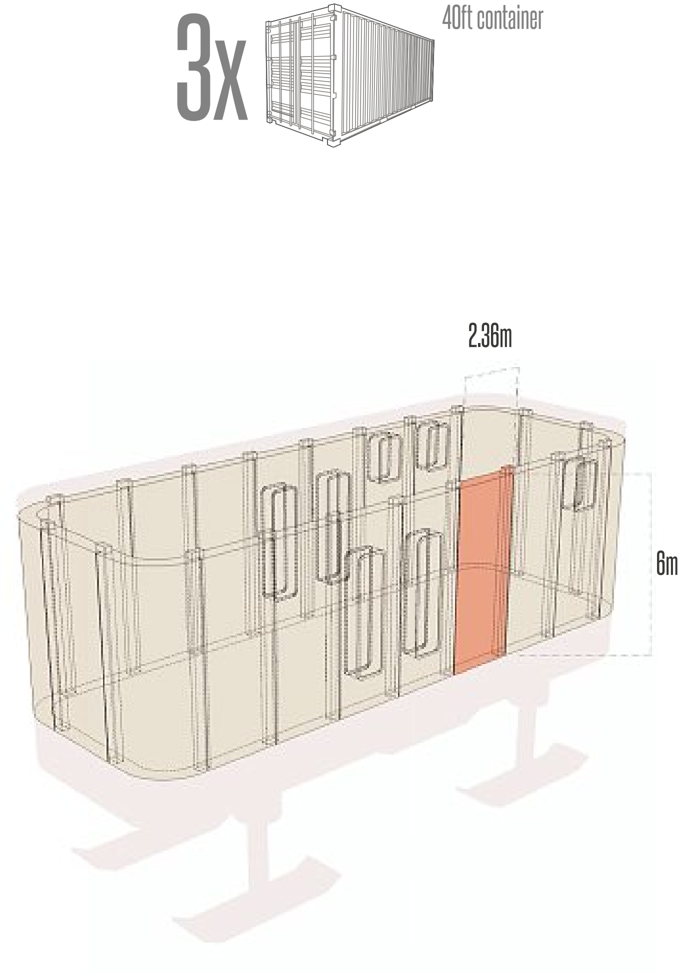
The greenhouse module has been designed to fit as a whole in a larger 53ft container in order to avoid prolonged exposure to the elements. The interior wall consists out of cross laminated timber which will be assembled at the site. After the placements of the greenhouse and the completion of the upper floor, the roof can be completed. After the add-on is completely closed, work inside such as the shelved assembly of the greenhouse and technical installations can continue regardless of the weather outside.

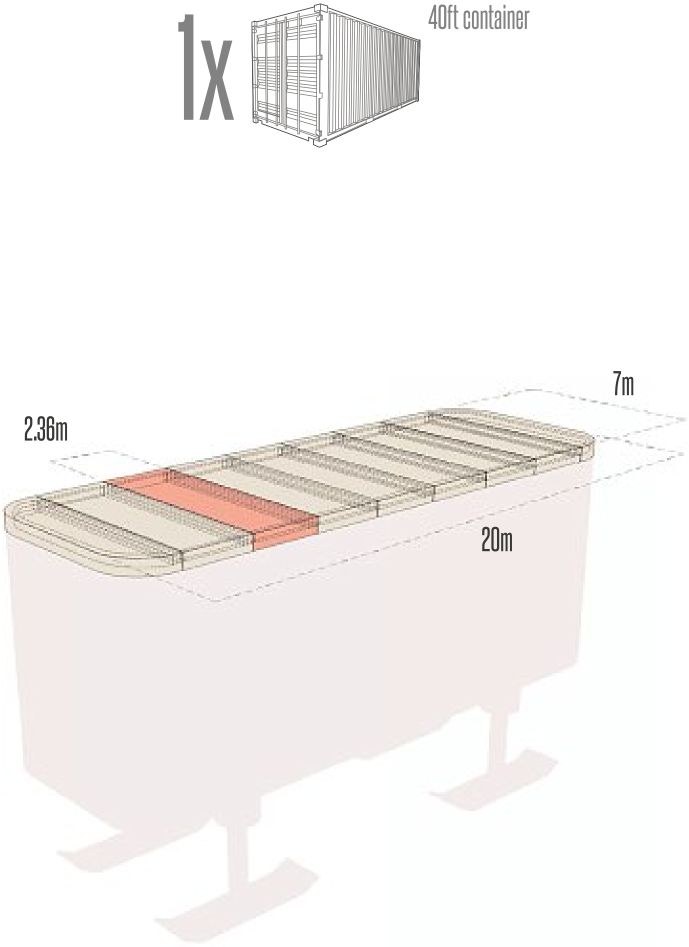


hydraulic legs and supporting steel structure



prefabricated wooden-beam subfloor





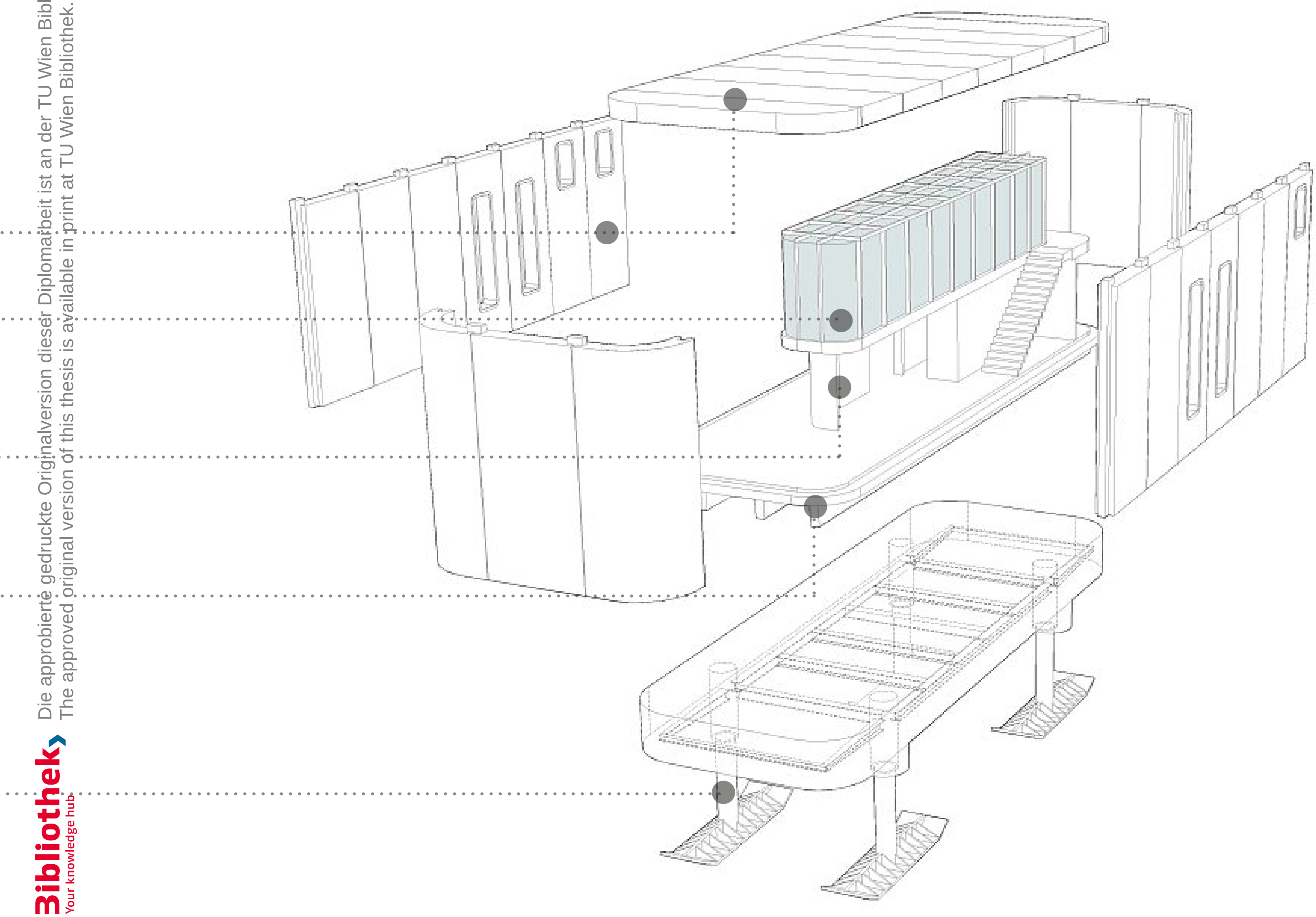
outer layer consisting of prefabricated wood panels with insulation outer layer consisting of prefabricated insulated wood panels

greenhouse - wooden frame construction and glass
the entire greenhouse can be fitting in a single 53ft container

interior wall panels made out of cross laminated timber

prefabricated wooden-beam subfloor
elements are dimensioned in order to fit in 40ft containers and designed
to be assembled quickly on site

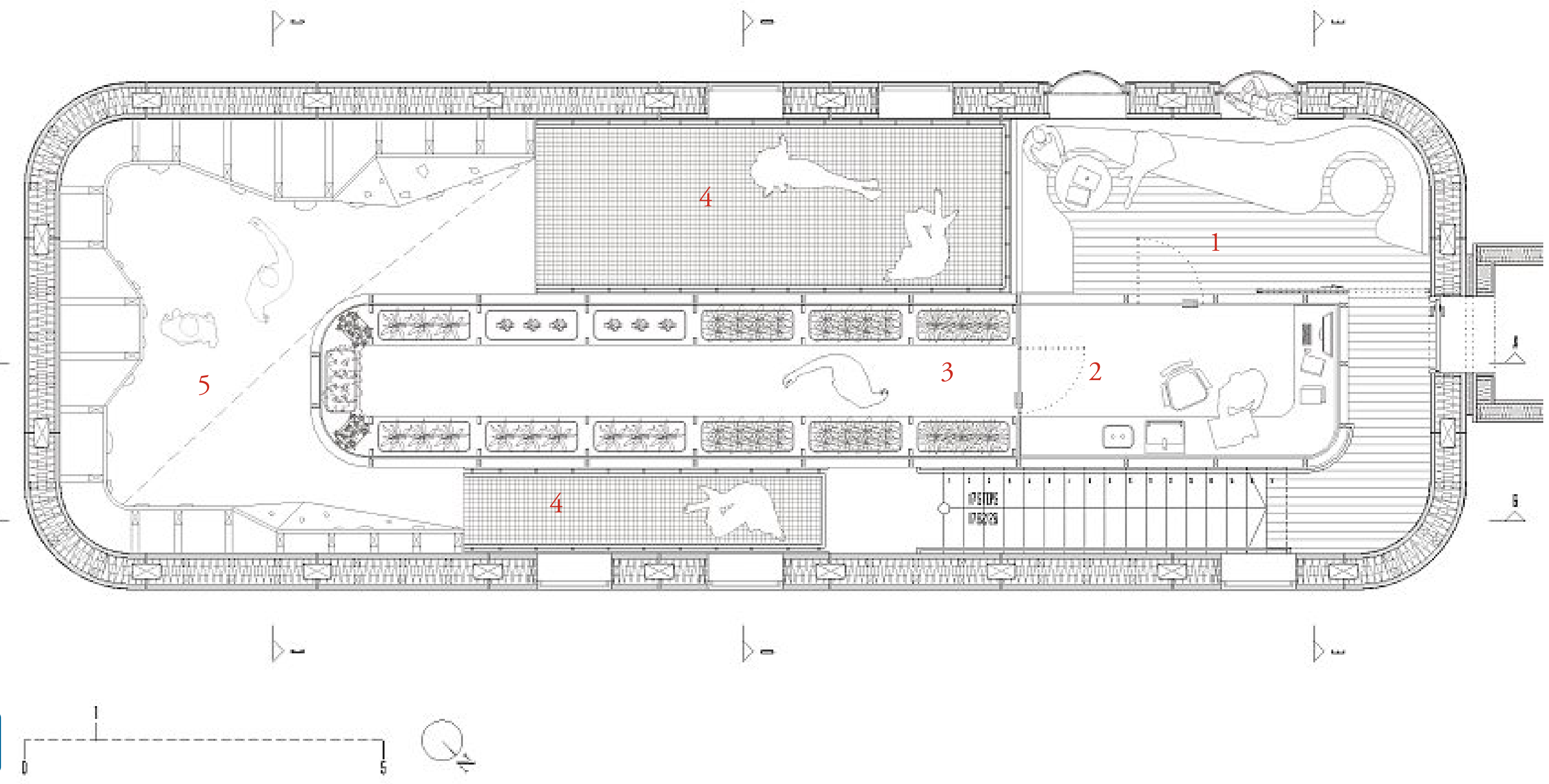
hydraulic legs with supporting steel structure



FLOOR PLANS

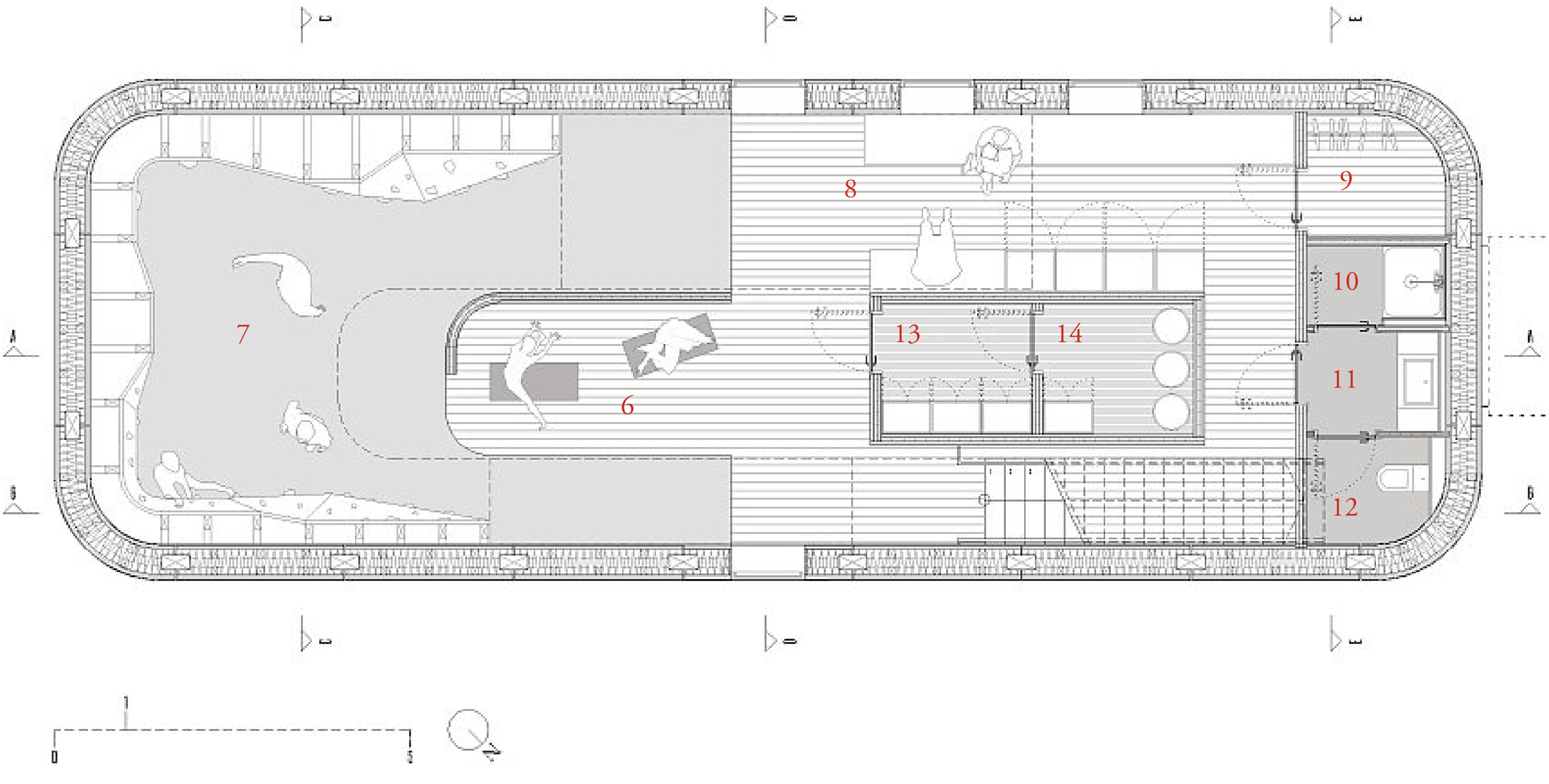
upper level

0 bridge from the main station to the greenhouse
1 quiet room/ lounge, 19.04m²
21°C - 40% relative humidity
2 service room, 9.33m²
21°C - 40% relative humidity
3 greenhouse, 20.33m²
21-23°C - 65% relative humidity
4 hammock accesible over the climbing wall
5 airspace

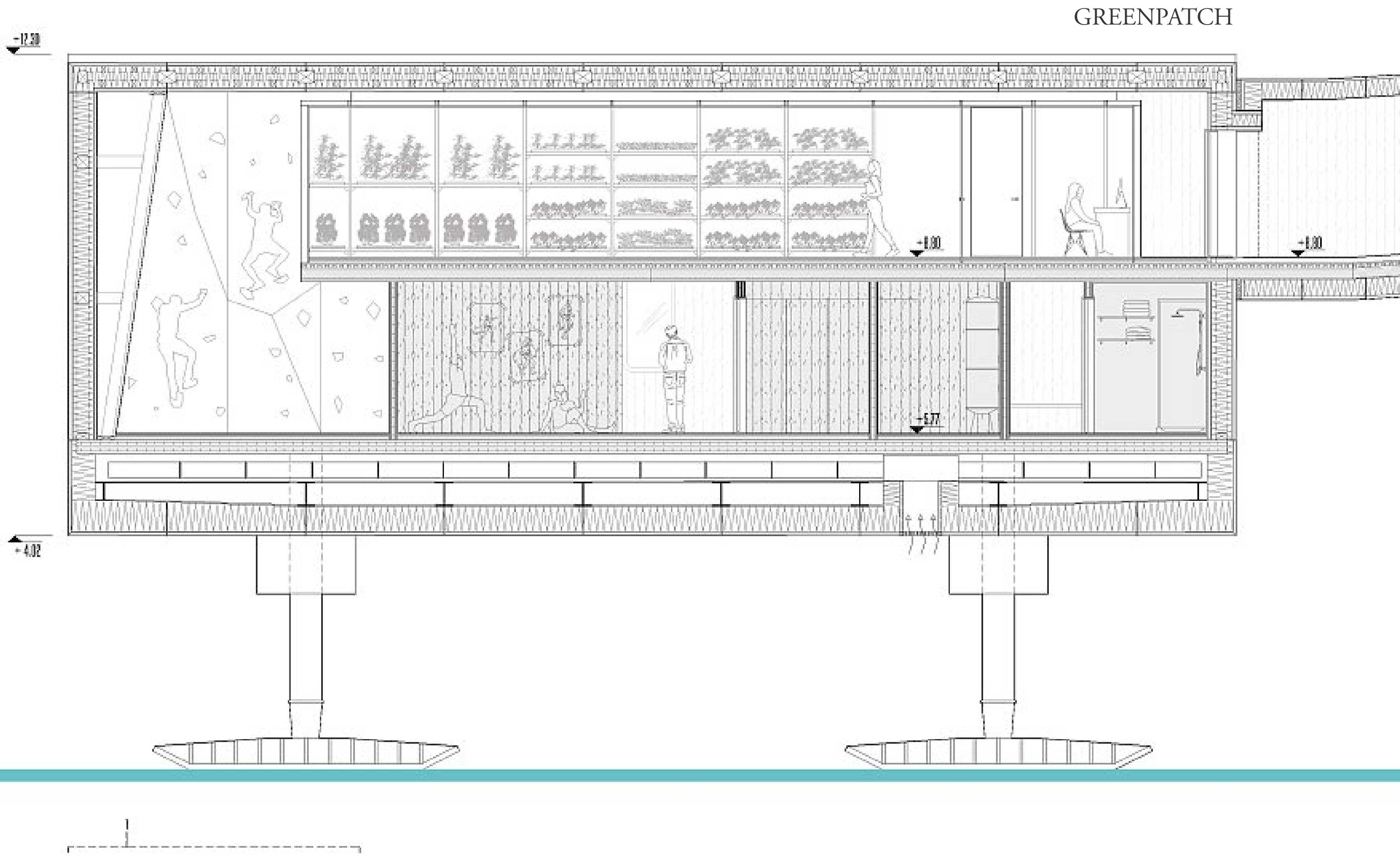


lower level

6	warm up area, 8.30m²
7	climbing walls, 32.63m²
8	changing area, 14.02m²
9	changing room, 3.16m²
10	shower, 2.1m²
11	washroom, 2.56m²
12	toilet, 2.50m²
13	storage room for greenhouse equipment, 3.93m²
14	storage room for water and CO_2 tanks, 3.93m²

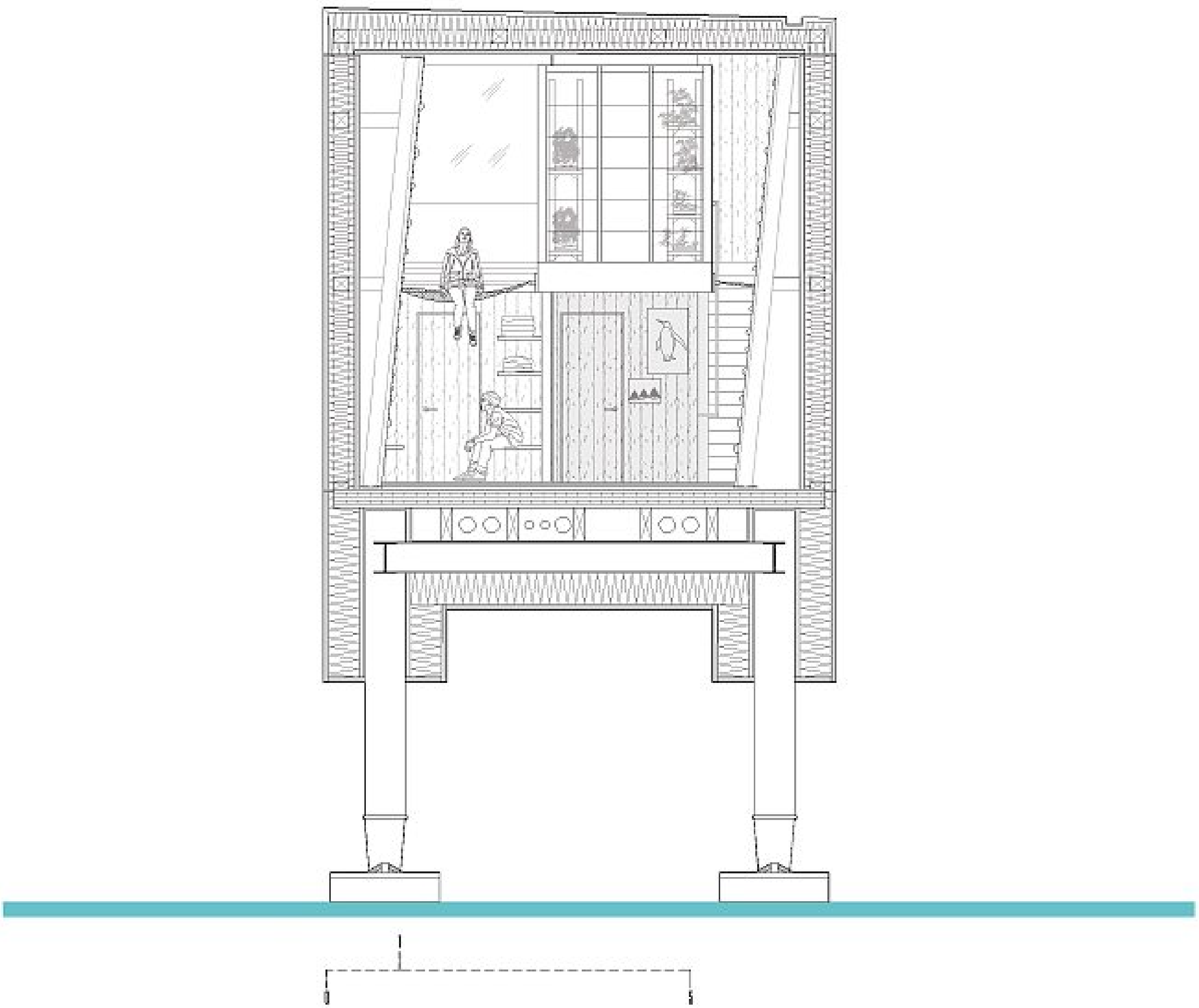


SECTIONS

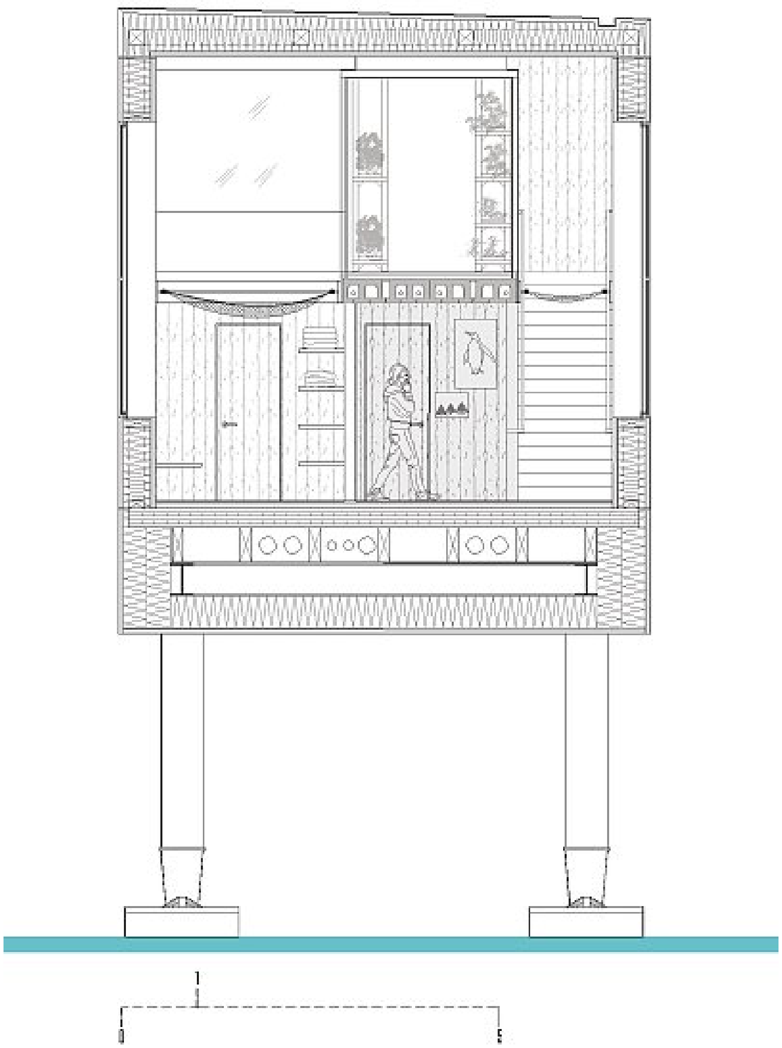


section A-A, 1:100

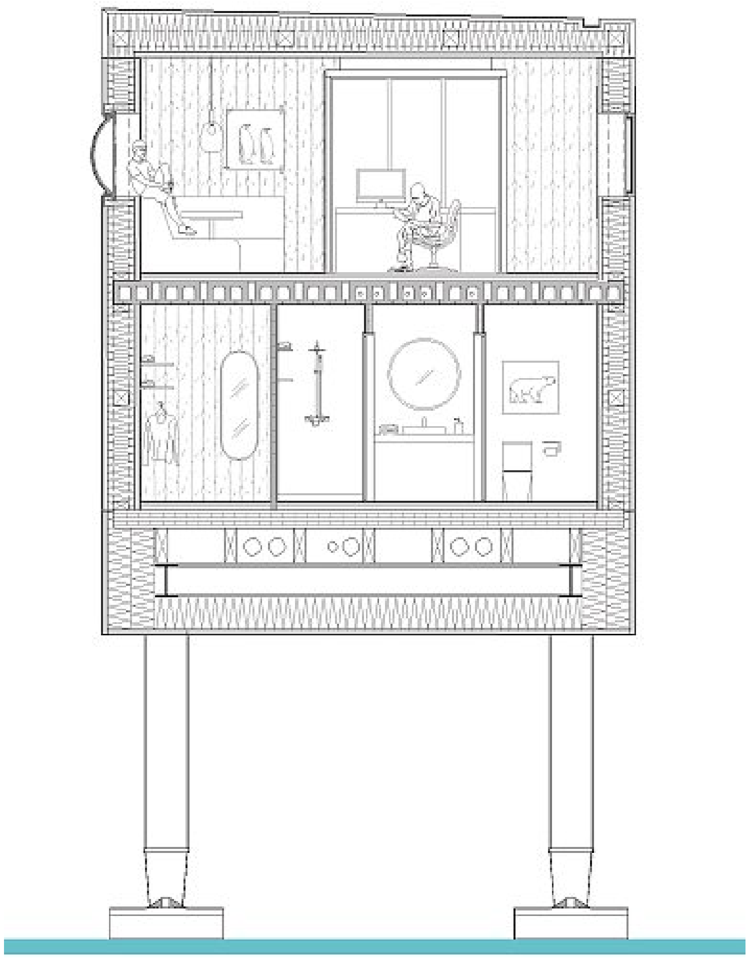
Concordia Research Station



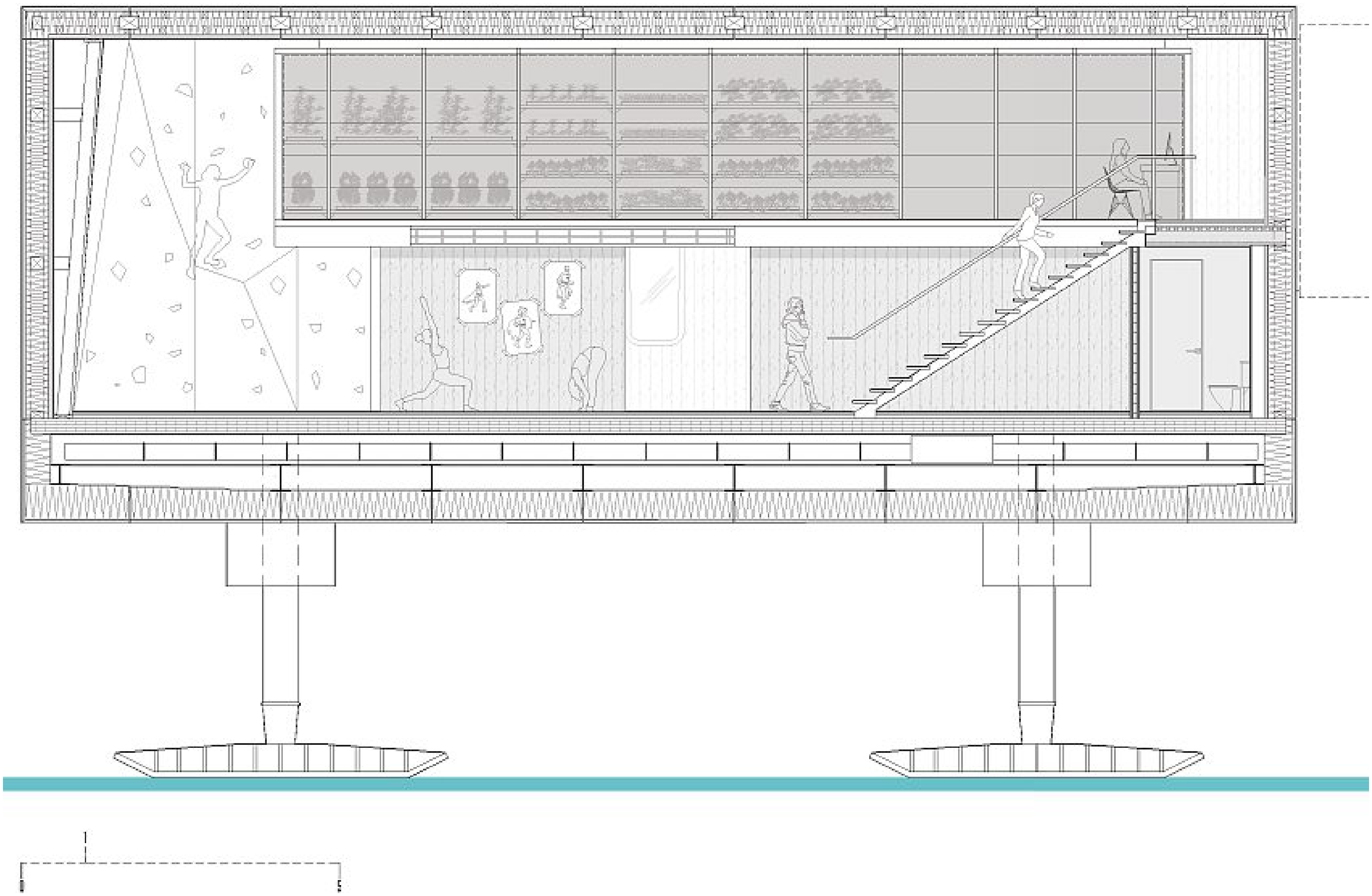
section C-C, 1:100



section D-D, 1:100

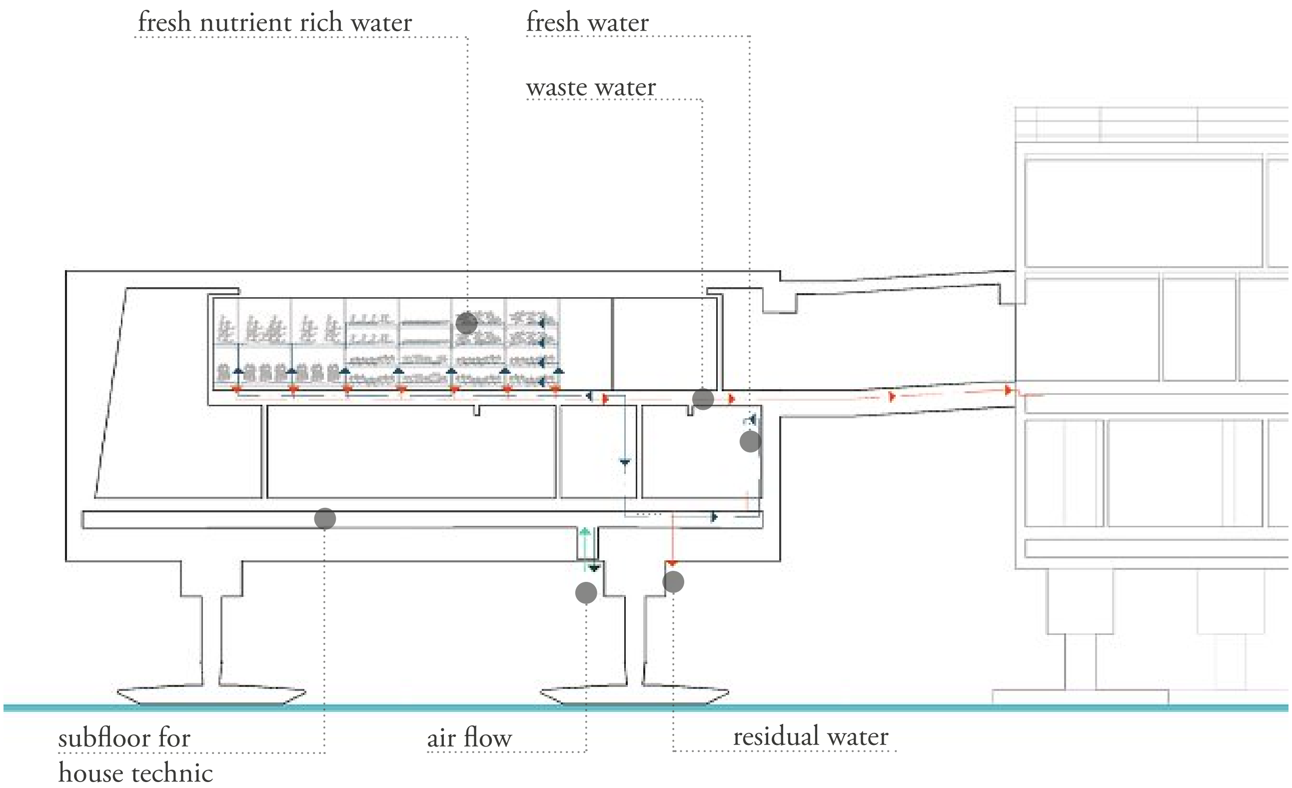


section E-E, 1:100

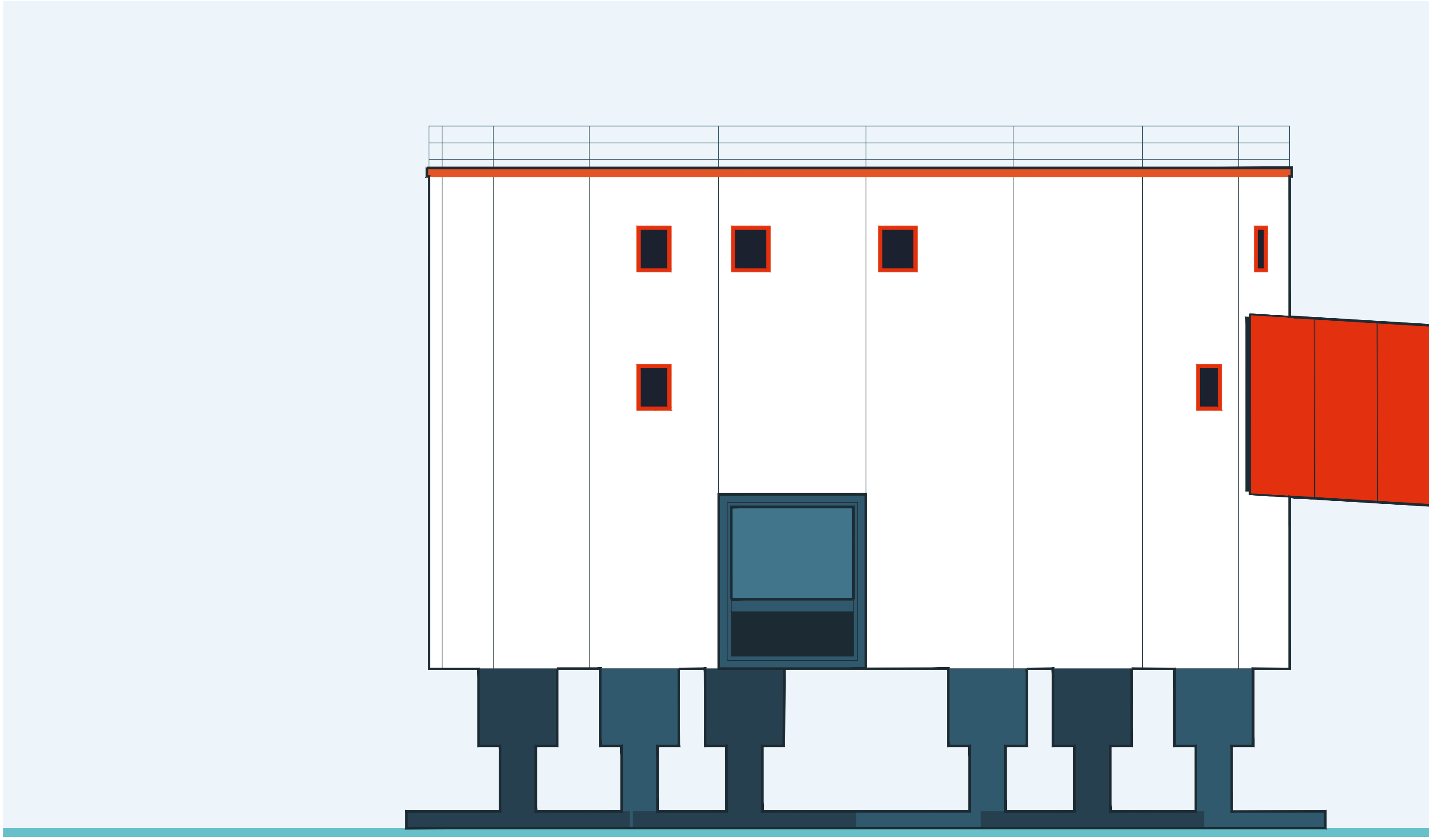


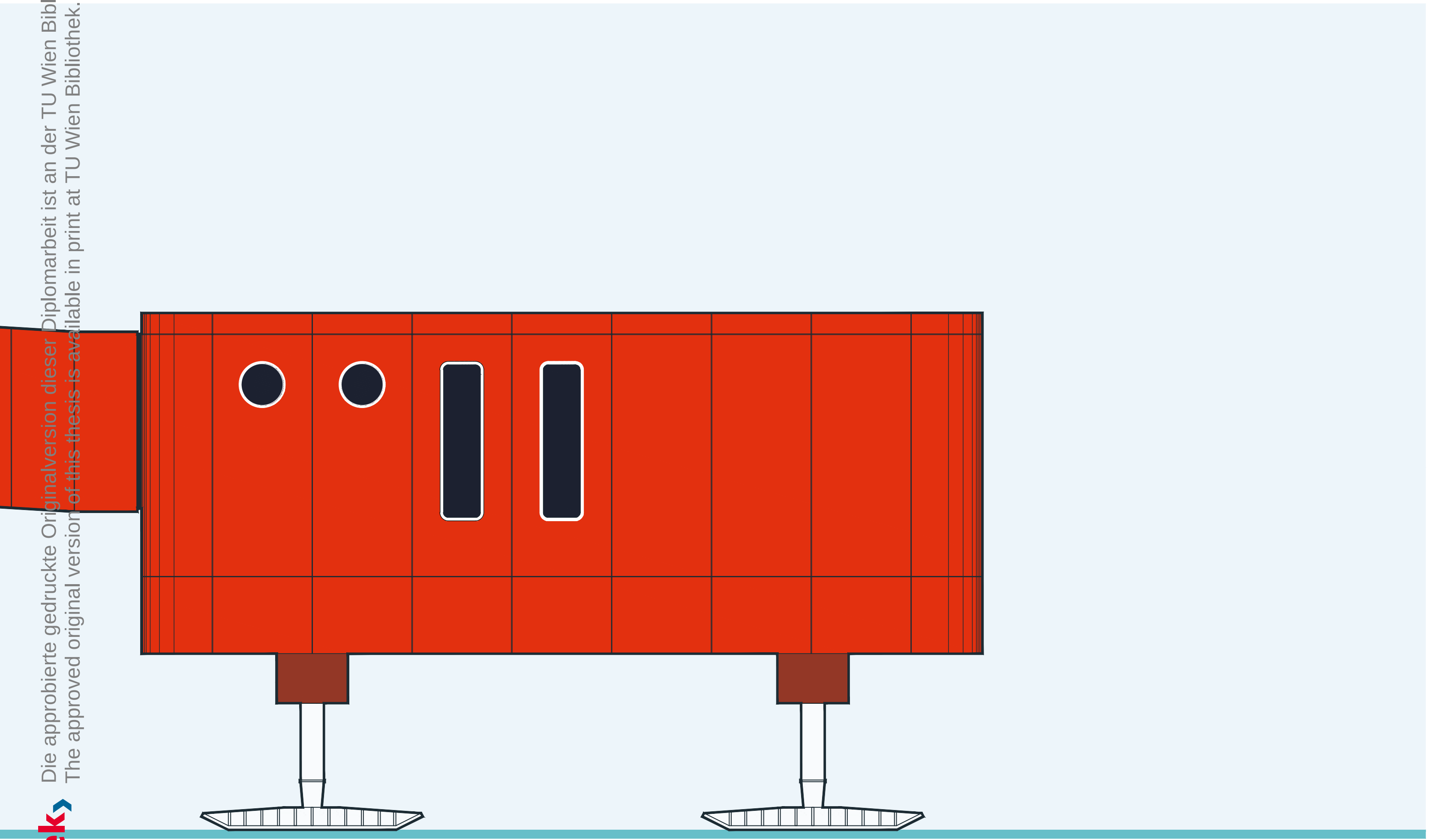
section B-B, 1:100

In order to improve to have a high-yiels whilst reducing reducing water consumpation the exploration greenhouse uses a hydroponic system, where the plants roots lay in nutrient rich water. This system completly emilinates soil and reduces logistics. The used water from the greenhouse is then transfered to the main water treatment system of the main station. Residual water from the sanitary units is collected in the technical subfloor and then transfered to the main sludge holes arouns the station. Currently this is the main solution also for the Concordia Stations sanitary units.

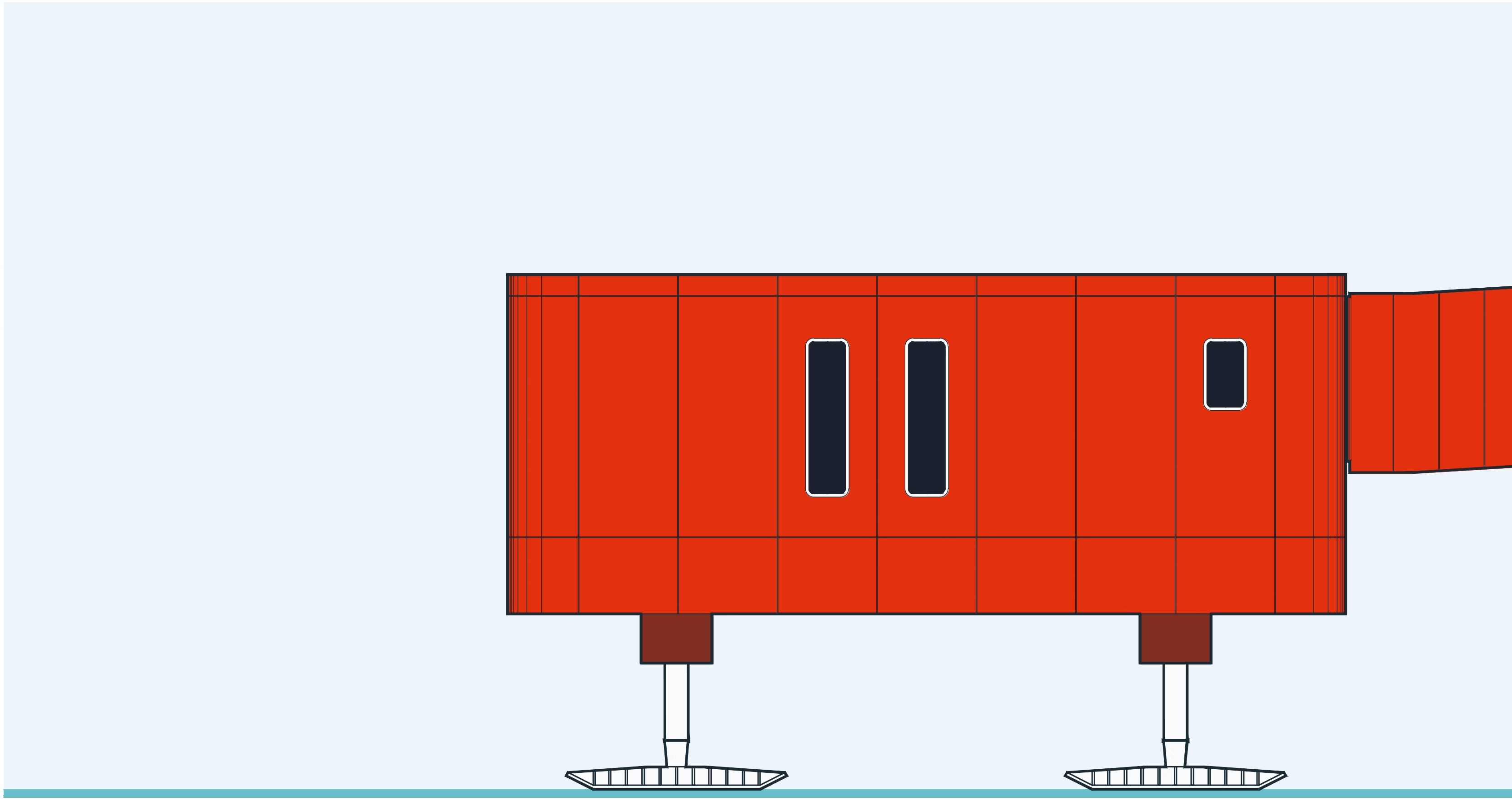


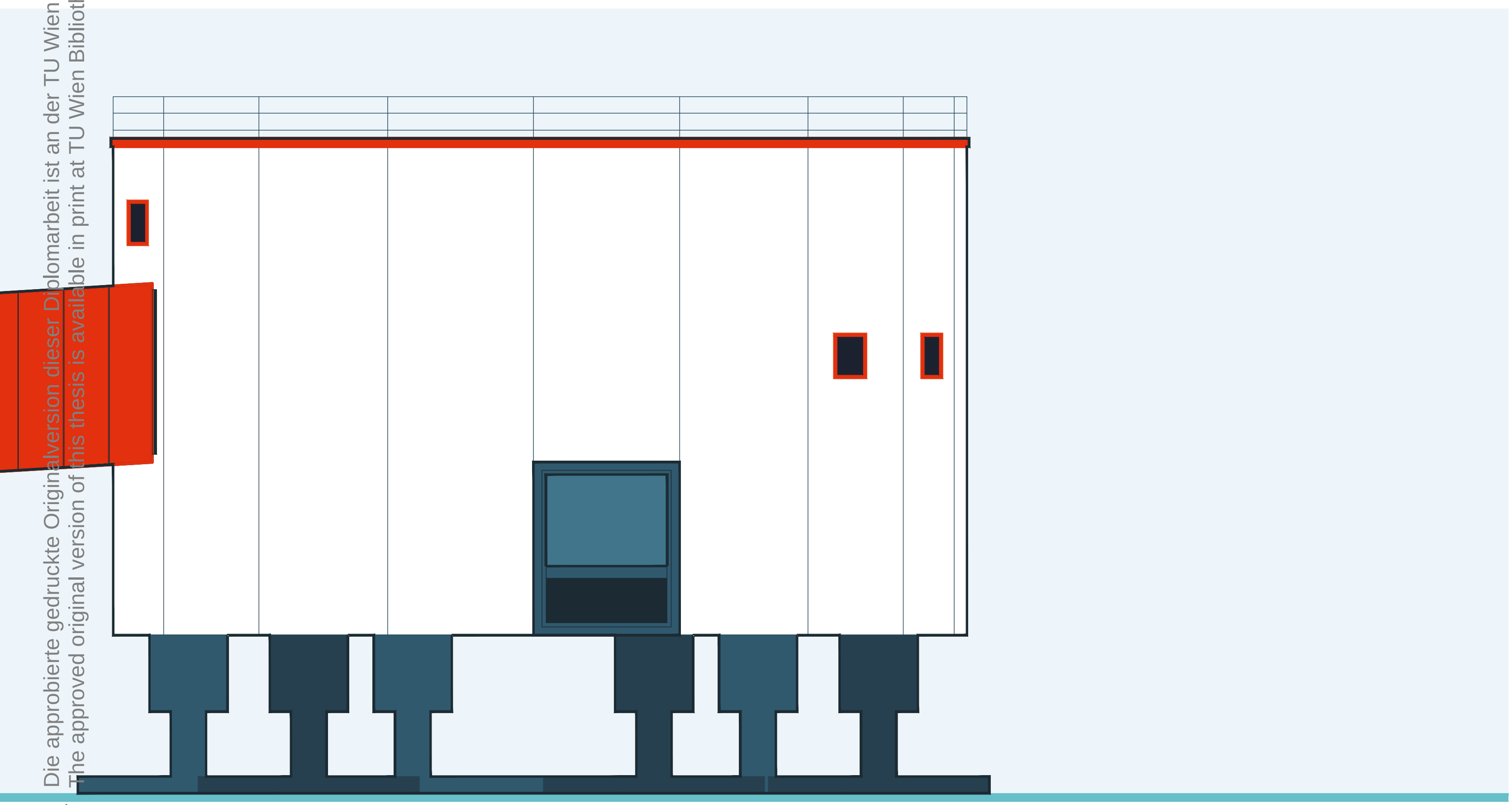
EAST-VIEW

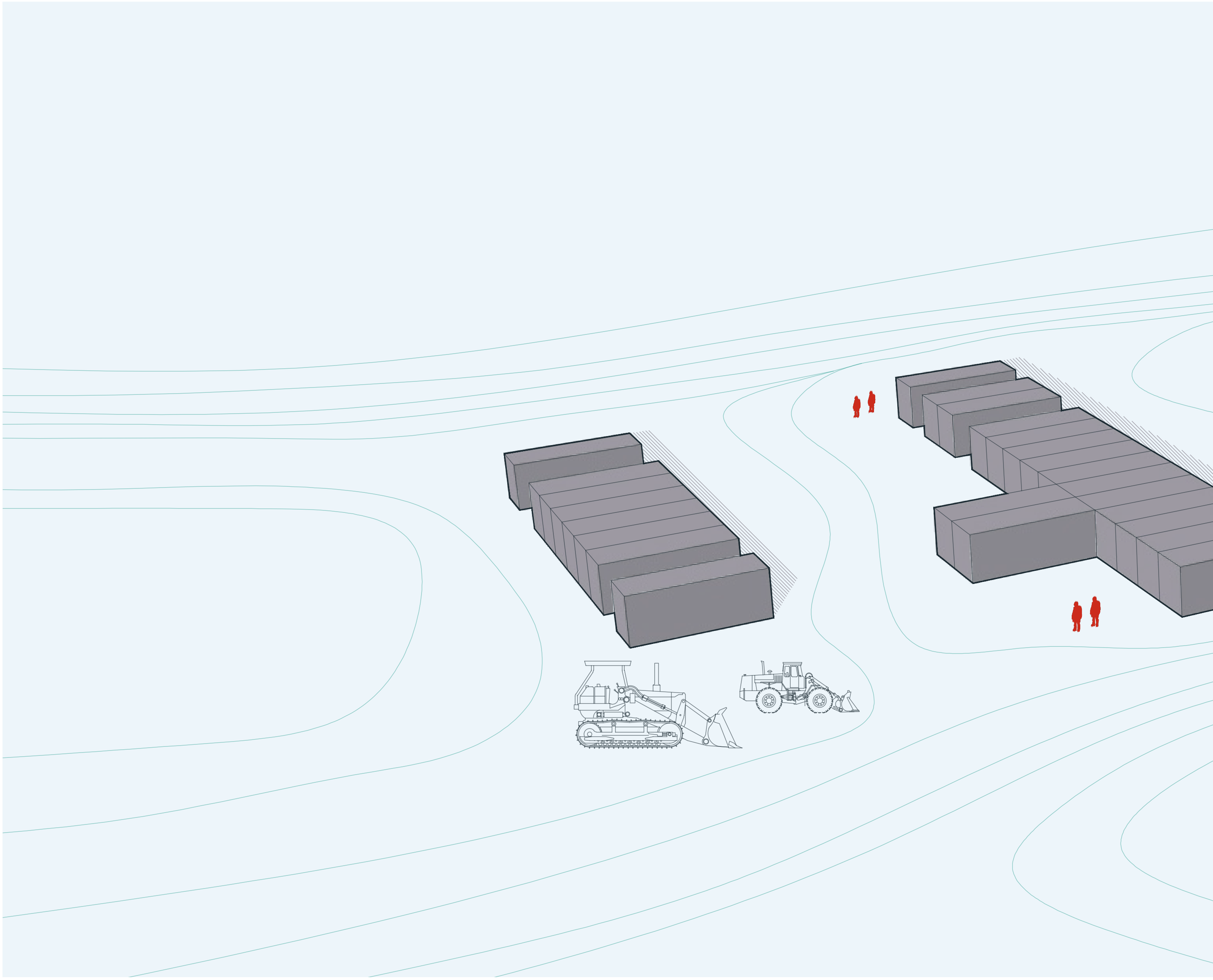


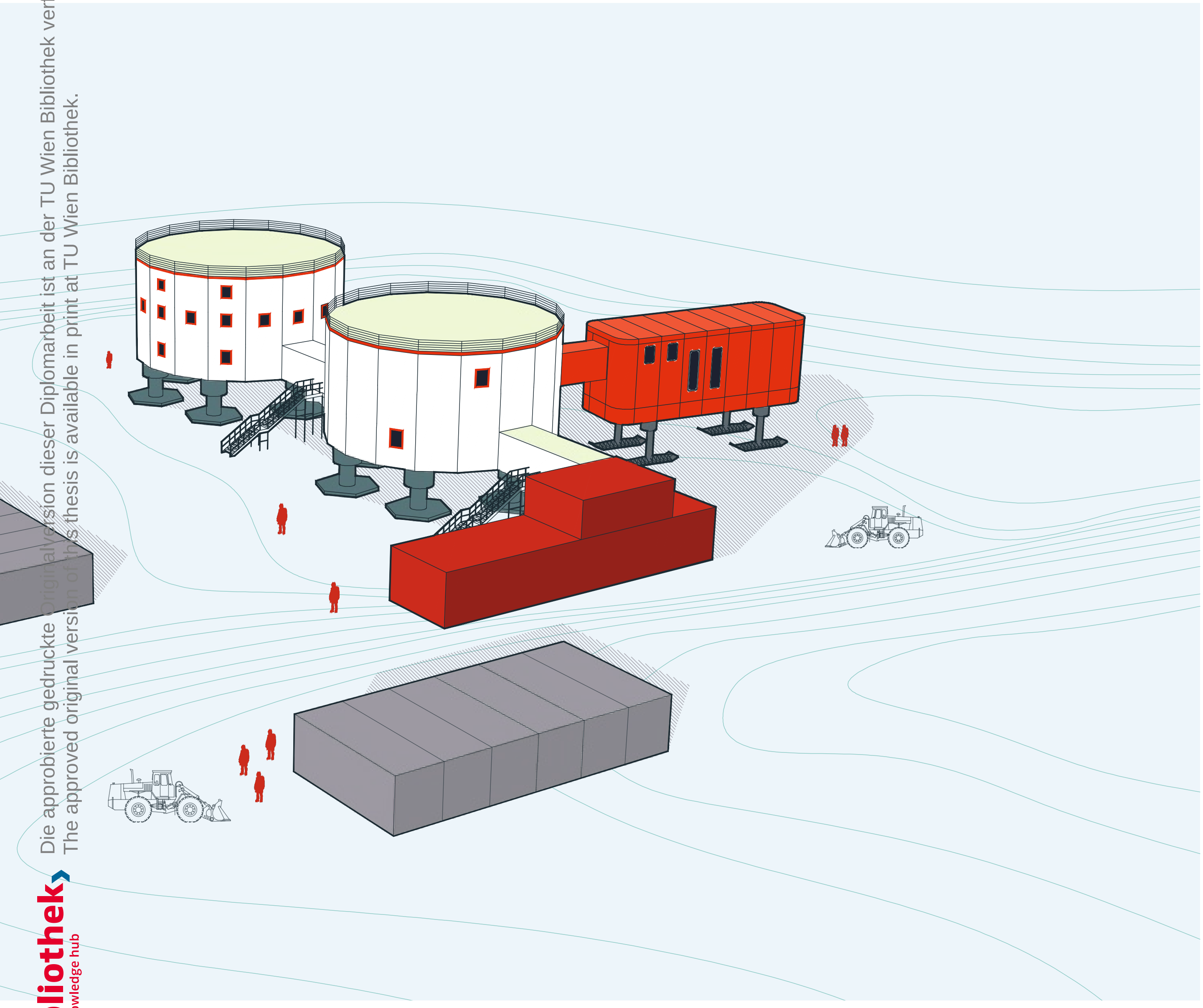


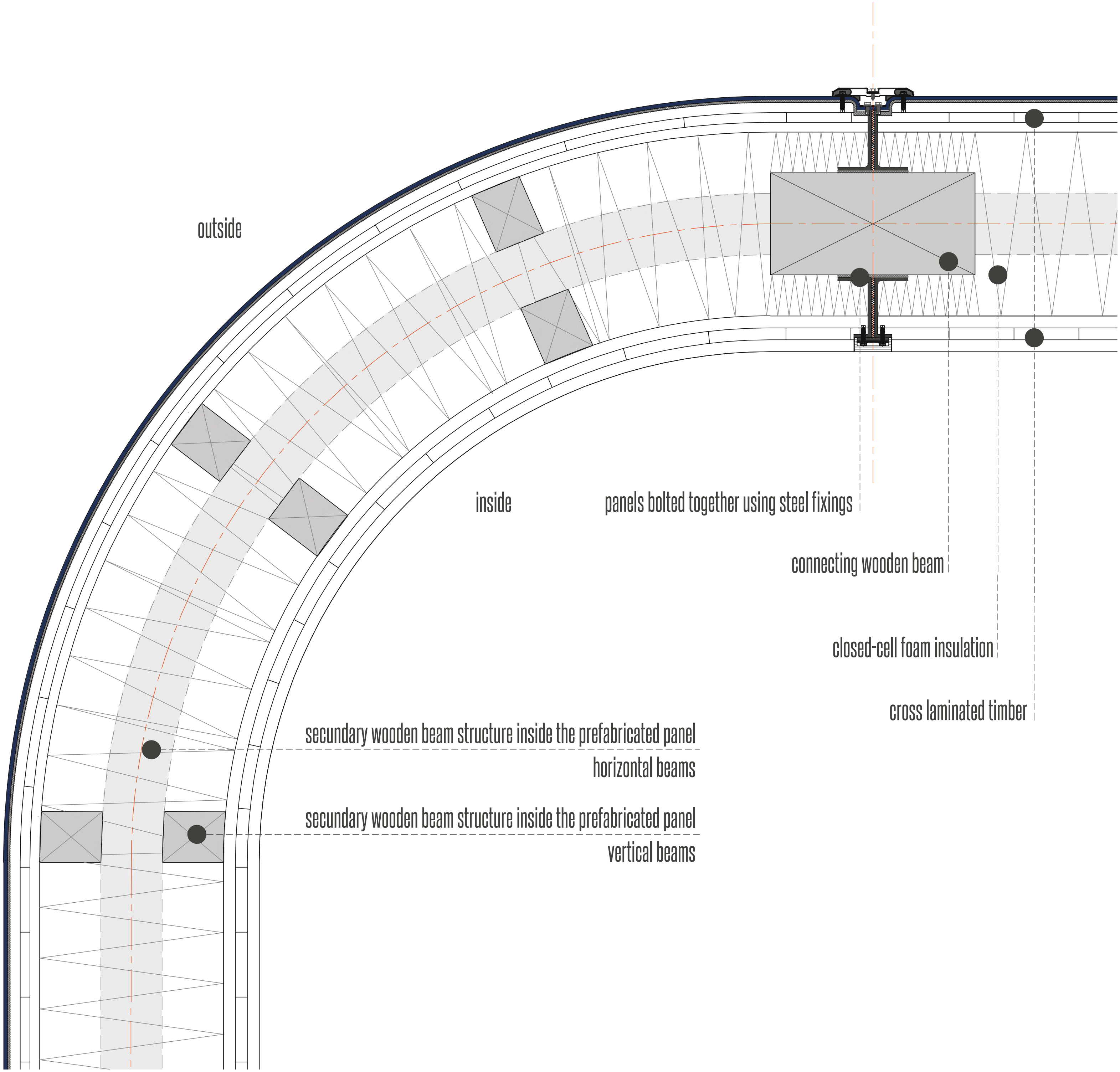
WEST-VIEW





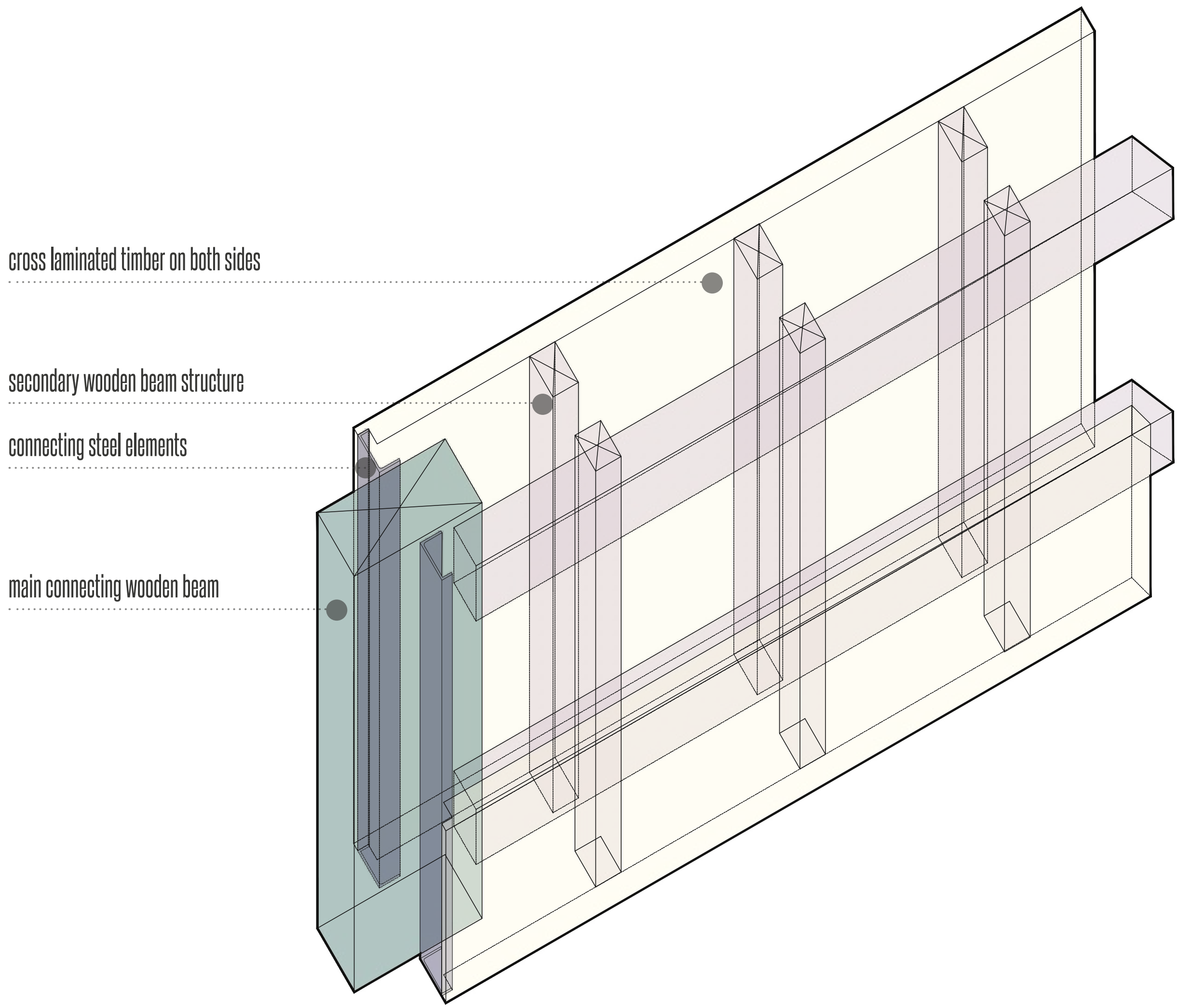


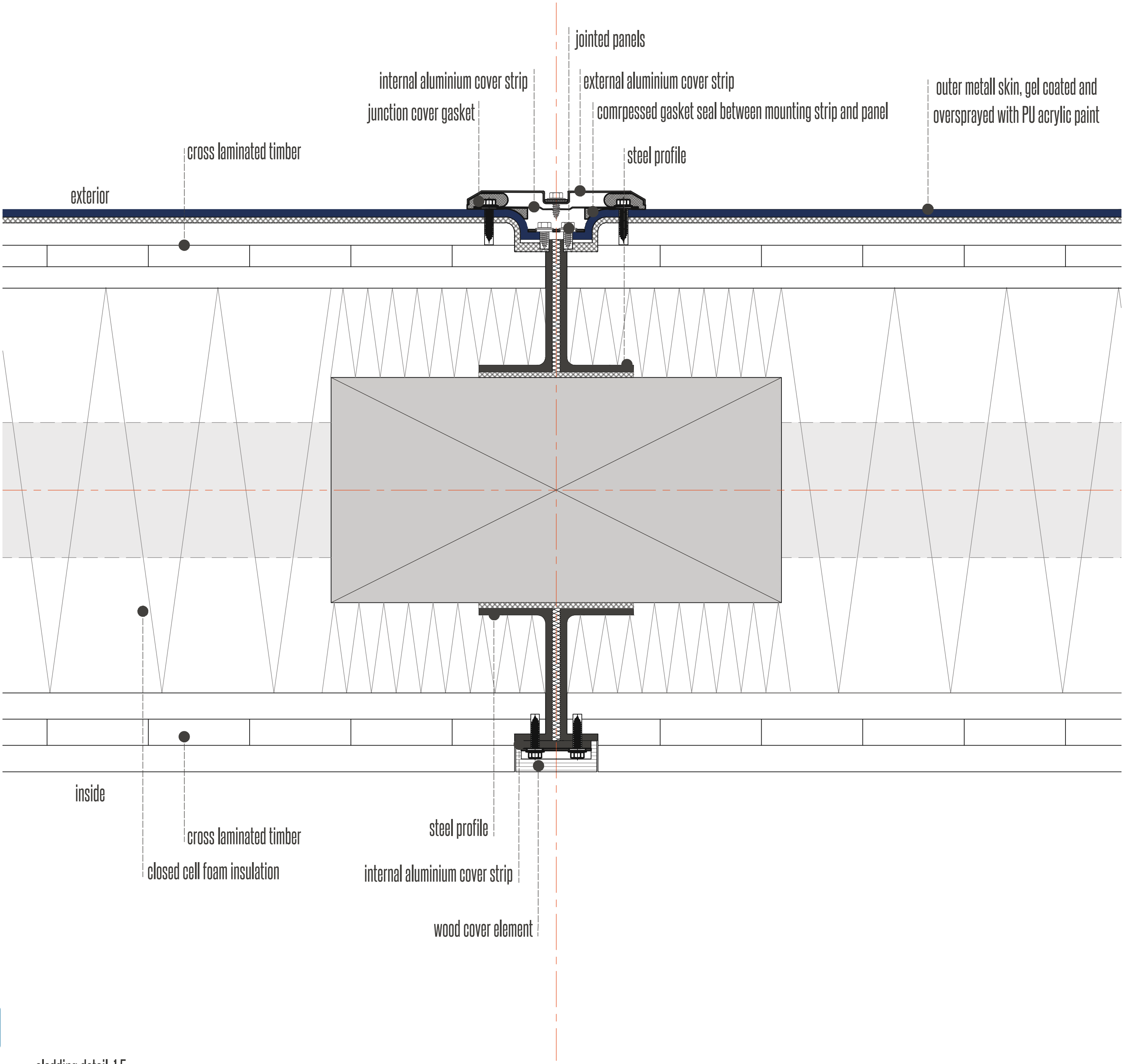




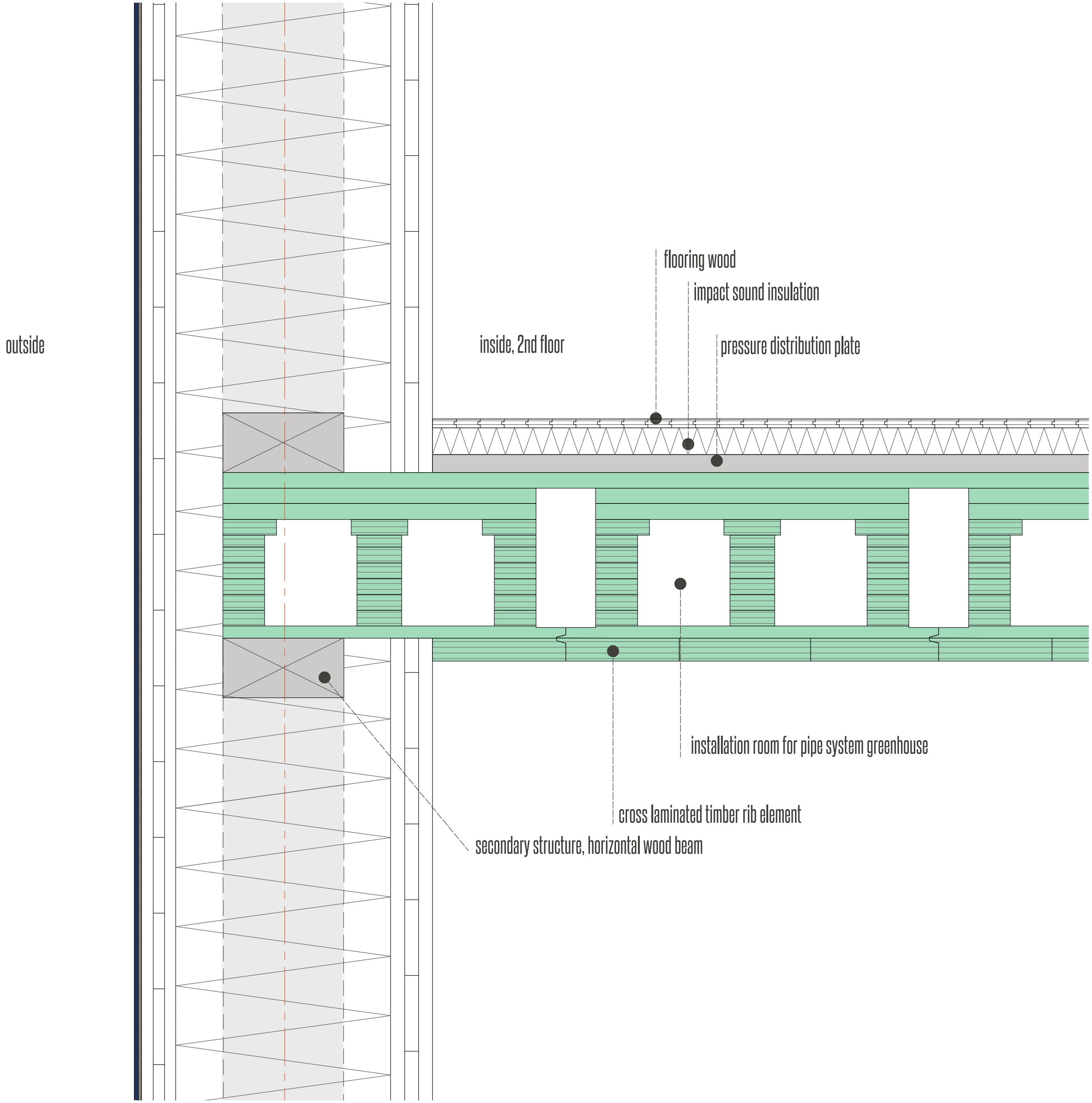
outer wall detail , 1:10

CONSTRUCTION DETAILS

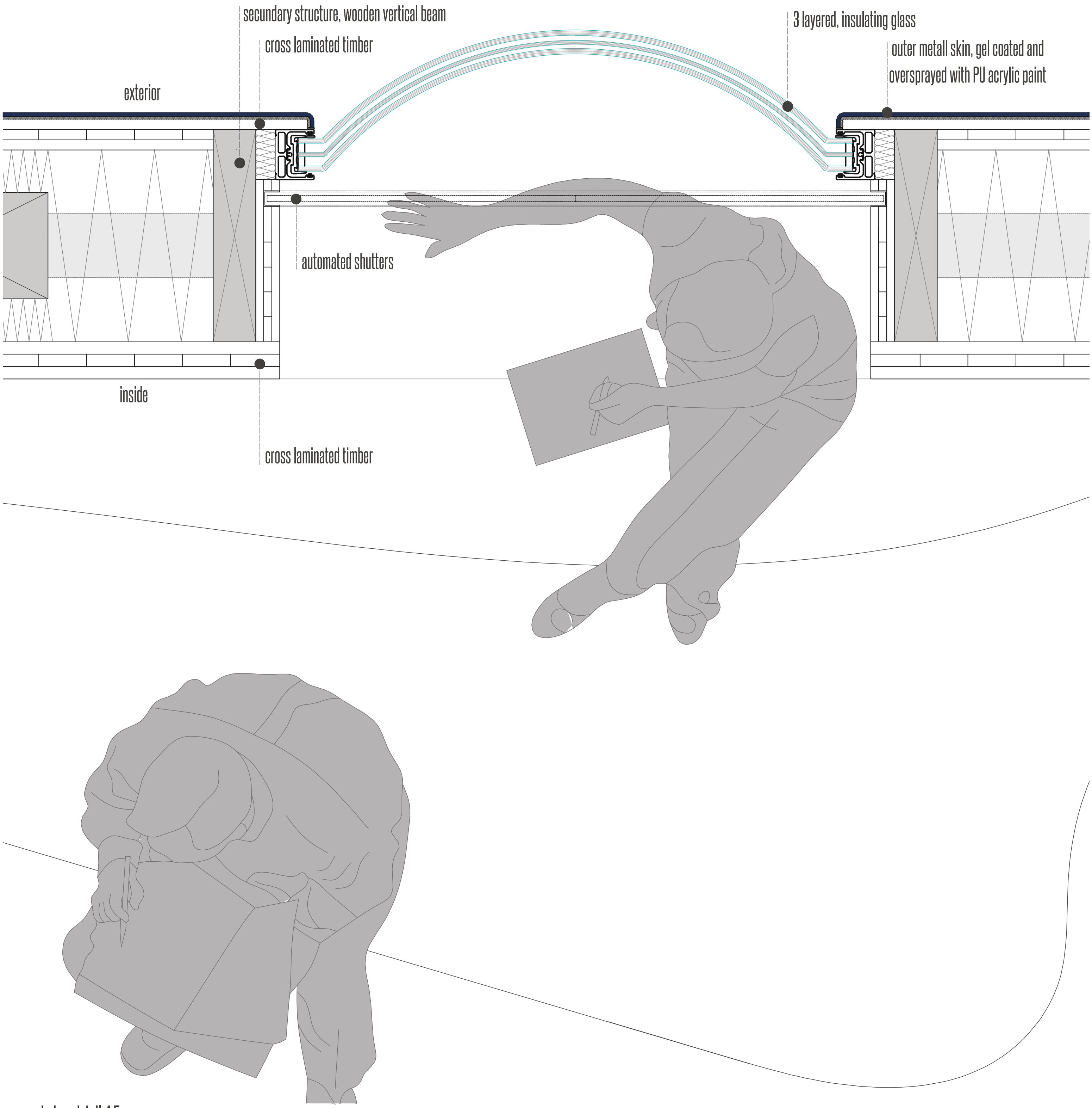




cladding detail, 1:5



2nd loor detail, 1:10



window detail, 1:5

interior view

CONCLUSION

While it is known for a fact that stress and other factors mentioned in the paper will have a negative impact on the crew's well-being and ultimately on the success of the mission, more studies and proposals are important in order to explore the possibilities that lie ahead. While every human reacts different to it's environment, a longer space mission on a Moon or Mars settlement will certainly encounter new and difficult situations for the crew. Irritability, stress and the desire to become more separated from the group are common on insolated habitat here on Earth and will only increase in amplitude?

When human are far away from home and in a completely new environment. Mission designers will need to anticipate these kind of reactions of the inhabitants and design habitat that will allow the crew to have their own personal space while also not isolate them from the rest of the crew. The cost reductions and minimalist policies are understandable but allowing more unconventional/untraditional design elements will be beneficial for the overall success of a mission. Designing flexible habitats with at least two different purposes, work and the possibility for leisure activities, might have a smaller impact on a mission budget. A greenhouse is a perfect example for the two purpose essential for a long duration mission. There are many benefits for a greenhouse as previously mentioned and reducing it so a growth and service area will not use all of its potential. Designer will need to experiment more with habitats especially taking into account the psychological issues the crew will encounter, while also meeting the logistical and technical requirements.

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