HOW DOES EXTREME CLIMATE CONDITIONS IMPACT BUILDING ENVELOPE DESIGN?

INTRODUCTION

MOTIVATION

An interest in space exploration.

Pushing the limits of architectural technology to the cutting edge of designing buildings for the most extreme environments on Earth and beyond.

To learn how to design for the most extreme environments outside of Ireland.

Climate change may result in us adapting our approach to designing buildings in Ireland.

AIMS

Understand what design considerations are made when designing a building and external envelope for Earth's most extreme climatic conditions.

Show how designing a building on Mars compares to the extremes on Earth.

OBJECTIVES

Produce an analytical esquisse exploring how two case study buildings are designed for the most extreme climate conditions on Earth.

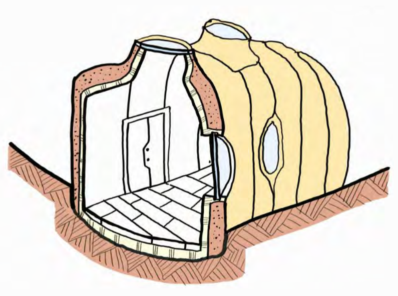
Compare the two case studies on Earth to a case study concept building designed for Mars.

Carry out a thermal analysis of each case studies external envelope.

Carry out interviews with experts in designing buildings for extreme climate conditions.

SCOPE

The research acknowledges the many design considerations faced with designing a building for Mars but focuses on the external envelope design and boundary conditions.

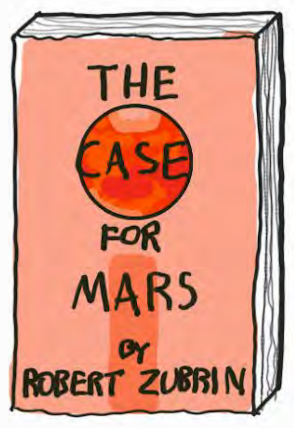


RESEARCHERS IN THIS SPACE

Elon Musk claims SpaceX will begin building a base on Mars from 2028.

NASA has held three 3D-Printed Habitat Challenges. The competition aims is to advance the construction technology needed to create sustainable housing solutions for Earth and beyond.

TIMELINE OF RESEARCH KEY EVENTS



25/01 — Ted Talks

Watched Ted Talks by Bjarke Ingels and Stephen Petranek, who are experts on all things Mars. The talks were focused on how homes on Mars could be constructed. The challenges faced with designing homes on Mars was noted, indicating that high levels of radiation and delivery of materials to the site were key issues.

30/01 — Hugh Broughton Webinar

Attended a webinar hosted by Shackleton, featuring Hugh Broughton talking about the Halley VI project and future construction projects they are undertaking in Antarctica. Took notes and asked Hugh Broughton how Halley could be improved in a next-generation design and what he had learned in designing for Antarctica that he will apply to his Mars house design.

03/02 — Esquisse

Began an exploratory esquisse analyzing how two case study buildings are designed to withstand extreme environmental conditions. These case studies will be compared to a concept design of a house on Mars.

04/02 — The Case For Mars book

Read a chapter from a book titled “The Case For Mars” by Robert Zubrin. The chapter focused on how a base could be built on Mars using on-site materials to create bricks to create large pressurised vaults.

17/02 — Ice Station book

Read about the design and construction process behind Halley VI which is well documented in the book “Ice Station” by Ruth Slavid.

25/02 — Macro Presentation

Presented five A1 sheets of macro-level overlook of the research topic. This included an introduction to the Halley VI case study, how Halley VI was designed to combat the harsh environmental conditions, a Mars vs Earth comparison and Hugh Broughton's concept Mars house design.

05/03 — Contacted Hugh Broughton Architects

Contacted Hugh Broughton to enquire about the possibility of organising an interview. Unfortunately, Hugh Broughton could not attend due to a busy schedule. However a student information pack was received including drawings, photographs, renders and a project description of Halley VI.

10/03 — Documentaries

Began watching a series by National Geographic titled “Mars”. The show documented how people like Elon Musk are developing technologies to be used on Mars and how they will be used there.

26/03 — Micro Presentation

Presented six A1 sheets of a micro-level investigation of the research topic. This included a comparison of all the case study climates, how a panel joint defect on Halley VI was amended, heat loss calculations and proposals for how Hugh Broughtons Martian house could be constructed on Mars.

27/03 — Listened to Podcast on building a Martian House

Listened to a podcast titled “Building a Martian House” by The Interplanetary Podcast. The podcast discussed Hugh Broughton's Mars house design which featured Architects who have worked on proposals for Mars architectural designs and Architects working on the Hugh Broughton project.

28/03 — Contacted Rob Annable

Contacted one of the Architects who featured on the podcast asking their opinions on the thesis.

02/04 — Thermal Analysis

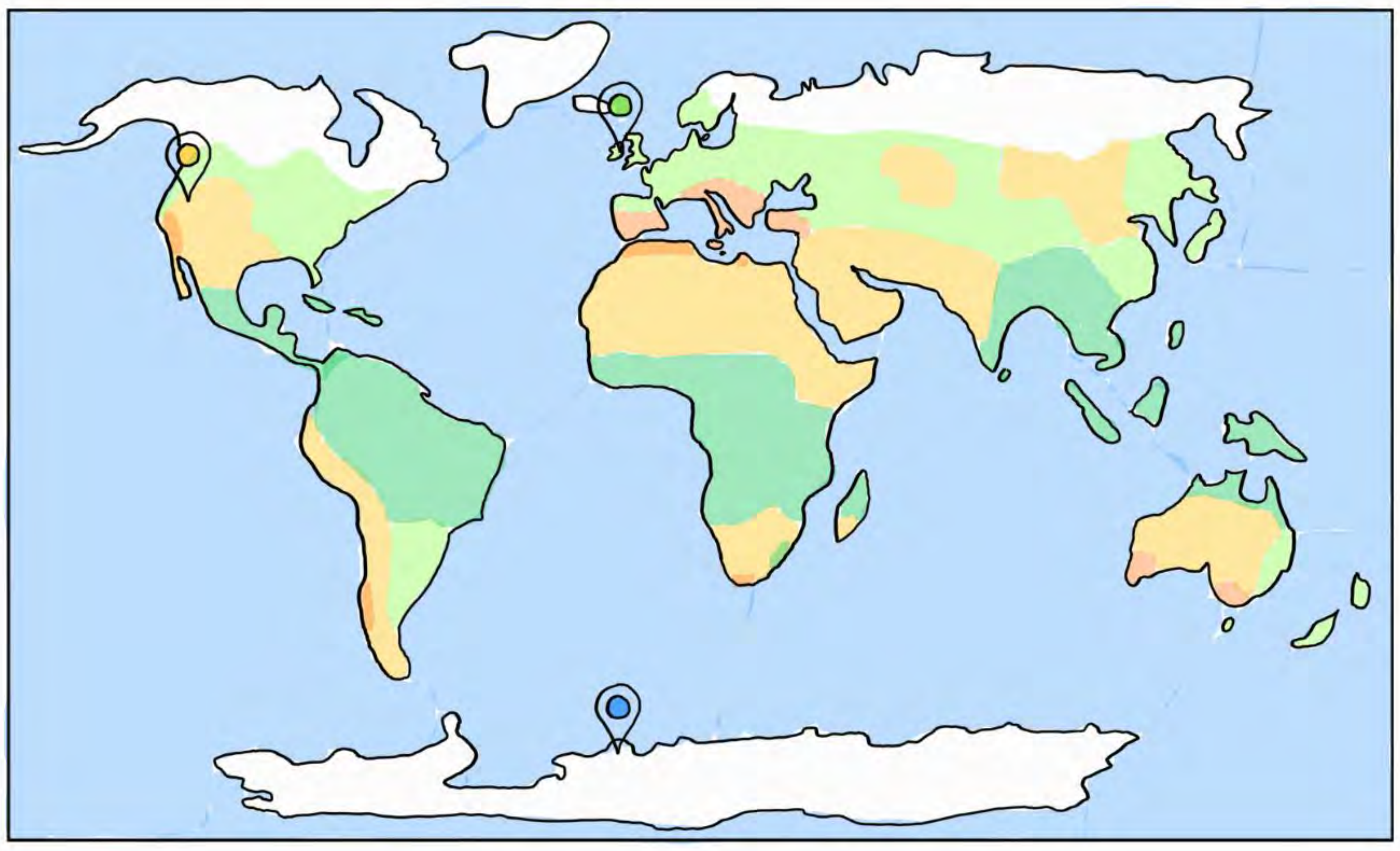
Created a Revit model of Halley VI, the Osoyoos desert centre and Martian house case studies. A section drawing was created from these models and analysed by the Numfem thermal analysis software. Numfem output the U-Values, phi values and fRsi values for each of the case studies external envelopes.

09/05 — Final Presentation

HOW DOES EXTREME CLIMATE CONDITIONS IMPACT BUILDING ENVELOPE DESIGN?

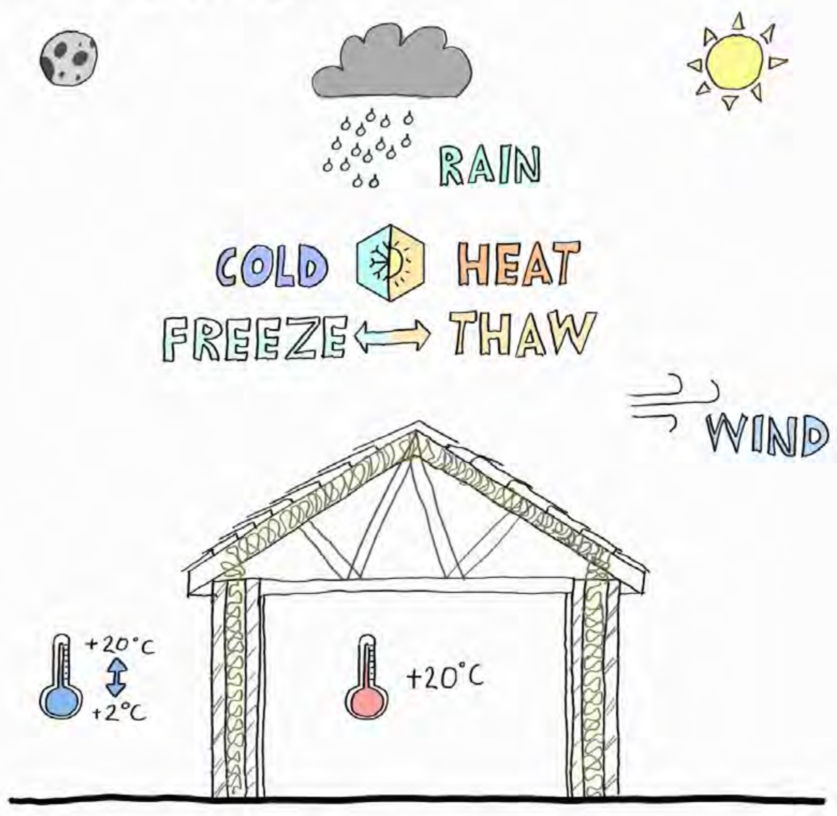
CLIMATE COMPARISON

- Polar
- Tropical
- Temperate
- Mediterranean
- Arid



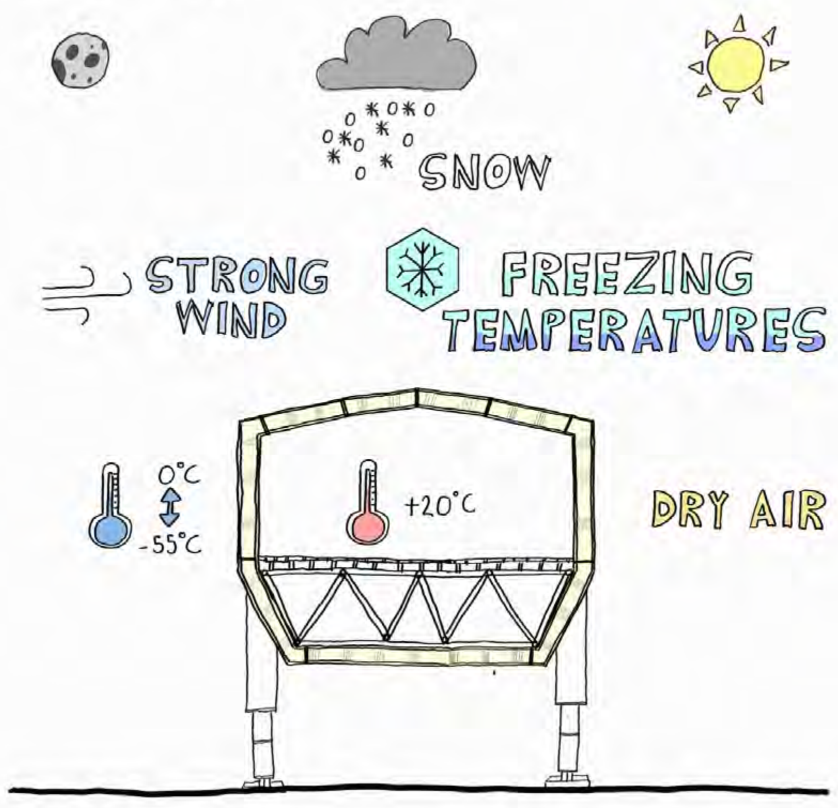
- Halley VI, Antarctica
- Nk'Mip desert cultural centre, Osoyoos, Canada
- Dublin, Ireland

DUBLIN, IRELAND



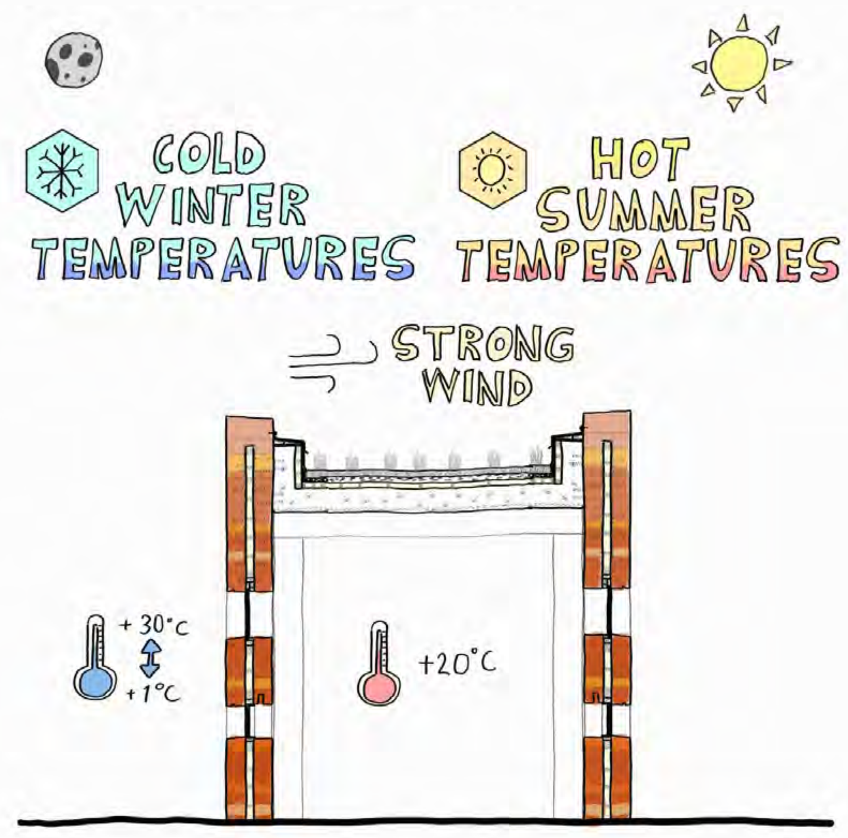
- Temperate temperatures all year round.
- External materials endure freeze-thaw action from absorbing rainwater and freezing during cold nights - expanding the materials.
- The building drains rainfall appropriately reducing the risk of water ingress.
- Winds can exceed 150 km/h during occasional winter storms.

HALLEY VI, ANTARCTICA



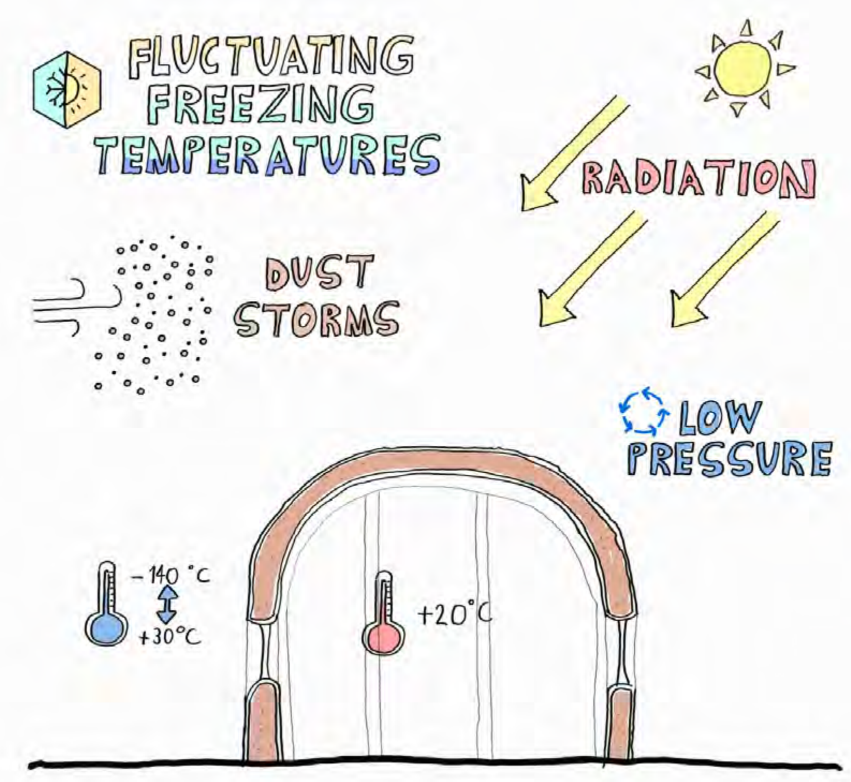
- The building endures freezing temperatures all year round.
- Antarctica accumulates 1.2 m of snowfall every year. The building raises itself above the snowdrift once a year to avoid getting buried, unlike the previous Halley research stations which were abandoned.
- The building is oriented perpendicular to the strong winds. The aerodynamic form of the building allows the winds to blow over and under the modules.
- The air is dry in Antarctica because of the freezing temperatures. This means no water can get into the panel joints and expand into ice.

DESERT CENTRE, OSOYOOS



- The building endures extreme heat during the summer and freezing temperatures in the winter.
- An occasional heavy downpour of rain is absorbed by the green roof.
- Occasional windstorms can sweep across the building that are powerful enough to uproot trees.
- Snow blizzards can occur during the winter, which the roof accommodates the load of.

MARTIAN HOUSE, MARS



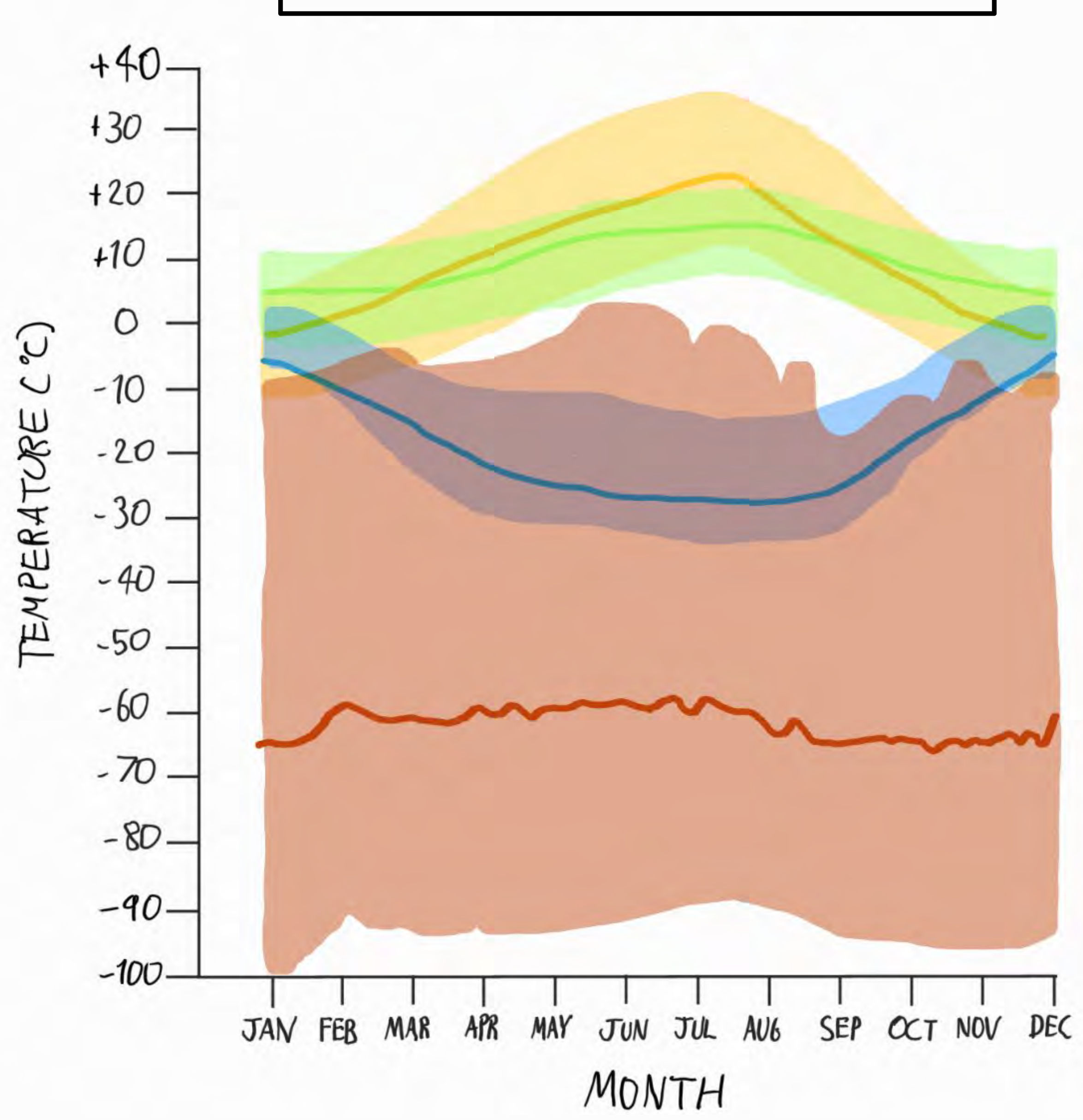
- The building will endure daily fluctuating freezing temperatures all year round whilst maintaining a constant indoor temperature of 20 degrees.
- Dust storm winds will batter the external surface of the building with fine Martian dust and build up around the building.
- The external fabric of the building must protect the inhabitants from the deadly high levels of radiation from the sun due to the lack of magnetic field around the planet.
- The buildings fabric will need to be able to "flex" because of the dramatic pressure difference between the inside and the outside of the building.

WEATHER DATA (27/02/2021)

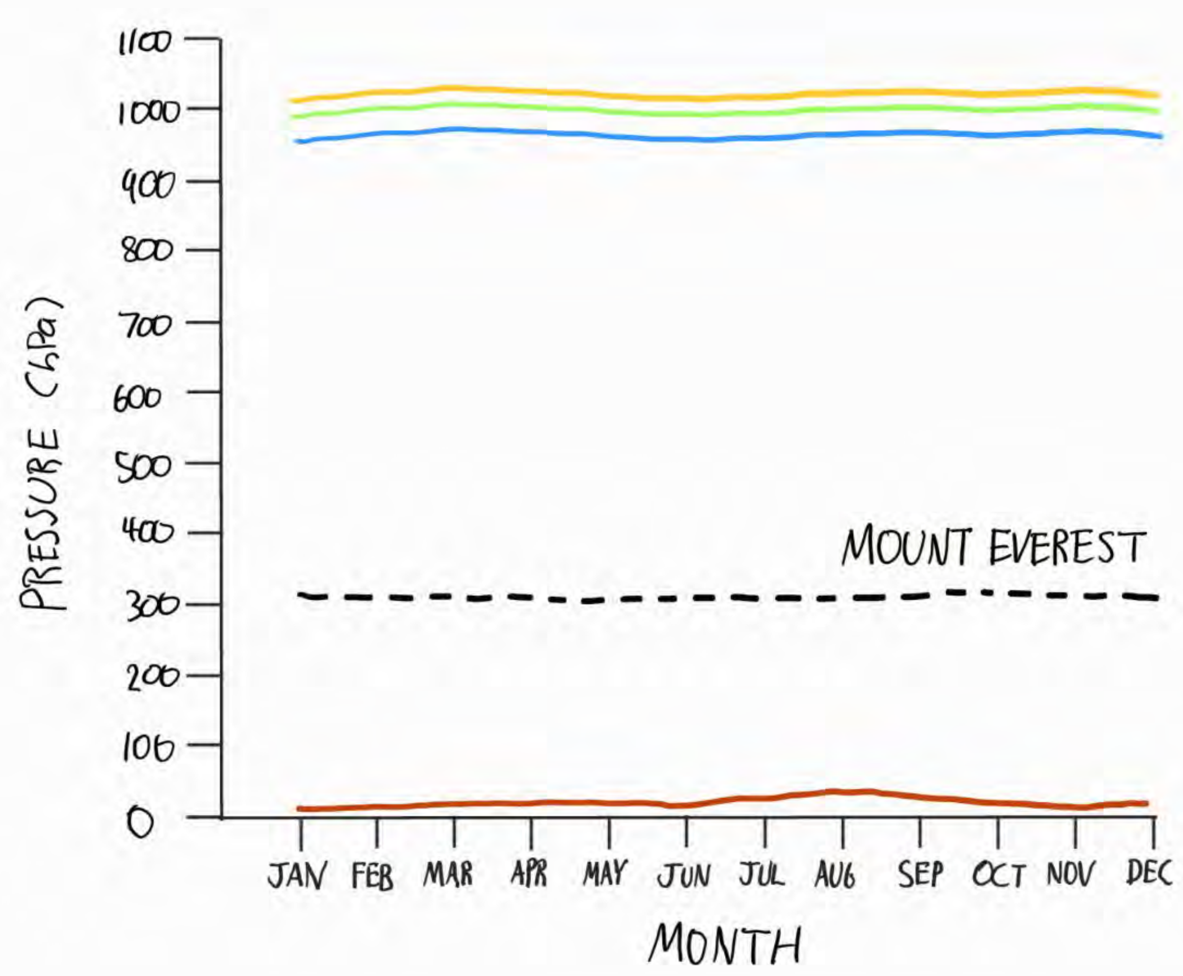
	Dublin	Antarctica	Osoyoos	Mars (NASA InSight probe, Elysium Planitia)
Temperature (°C)	11	-7	7	(-13) - (-73)
Pressure (hPa)	1041	981	1010	8
Wind Speed (kph)	6	14	4	14
Wind Direction	SW	E	NW	-
Maximum Gust (kph)	-	16	-	-
Humidity (%)	64	95	88	-

ANNUAL TEMPERATURE GRAPH

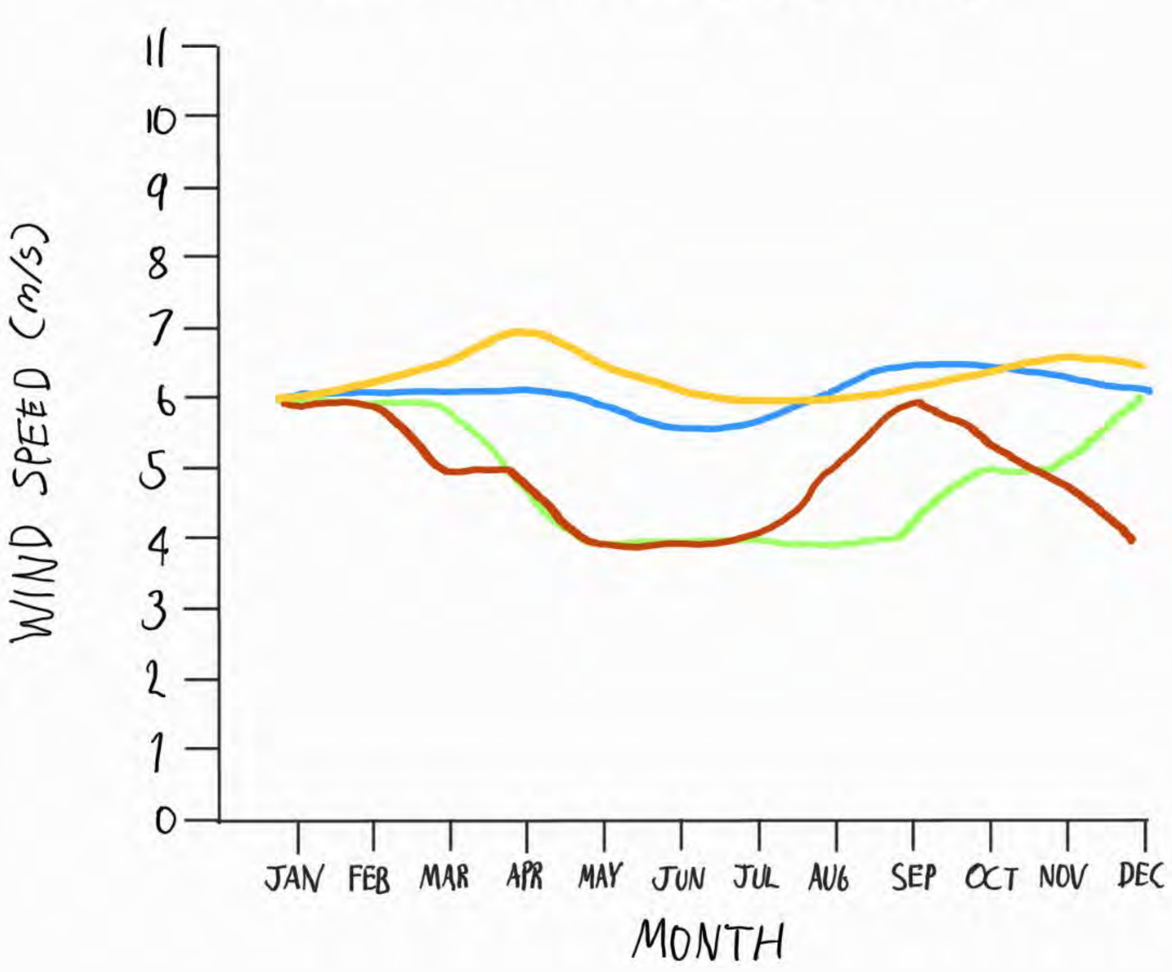
DUBLIN ANTARCTICA OSOYOOS DESERT MARS



ANNUAL AIR PRESSURE GRAPH



ANNUAL WIND SPEED GRAPH



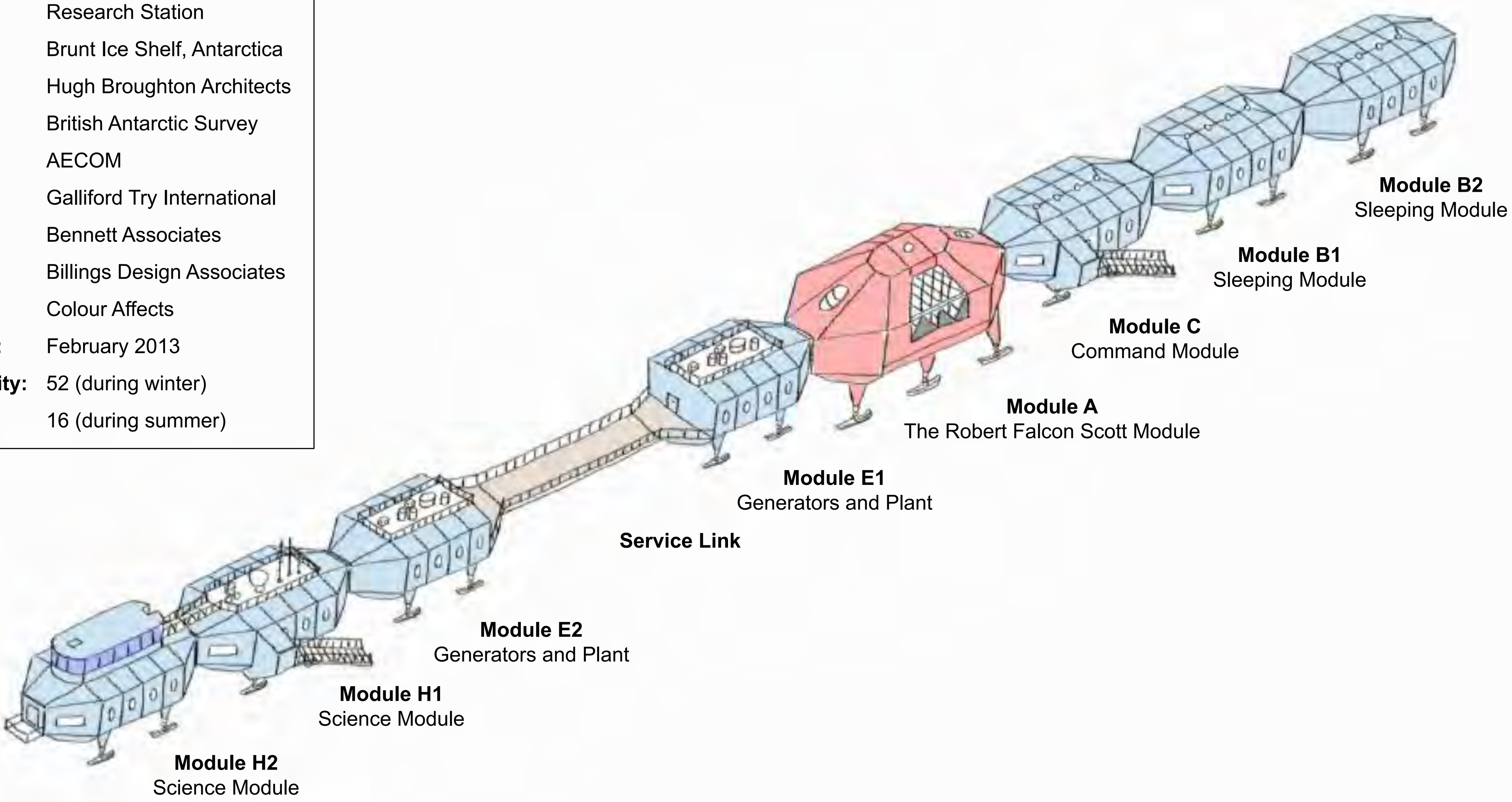
Ref. 1

HOW DOES EXTREME CLIMATE CONDITIONS IMPACT BUILDING ENVELOPE DESIGN?

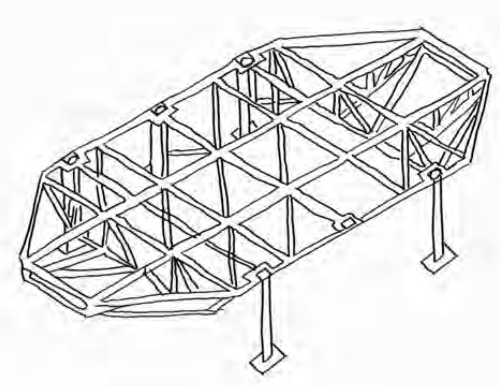
CASE STUDY 1: HALLEY VI, BRITISH ANTARCTIC RESEARCH STATION

PROJECT INFORMATION

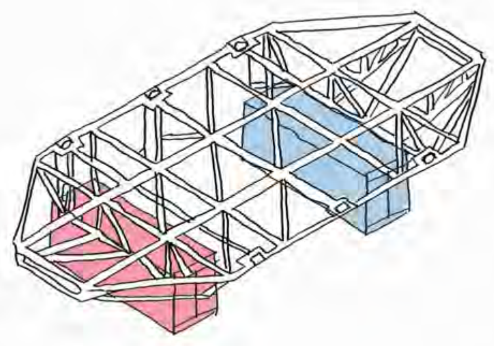
Name:	Halley VI, British Antarctic Research Station
Location:	Brunt Ice Shelf, Antarctica
Architect:	Hugh Broughton Architects
Client:	British Antarctic Survey
Engineer:	AECOM
Contractor:	Galliford Try International
Subcontractors:	Bennett Associates Billings Design Associates Colour Affects
Completion date:	February 2013
Occupant Capacity:	52 (during winter) 16 (during summer)



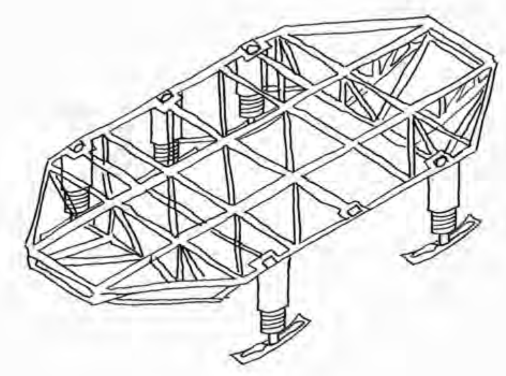
CONSTRUCTION SEQUENCE



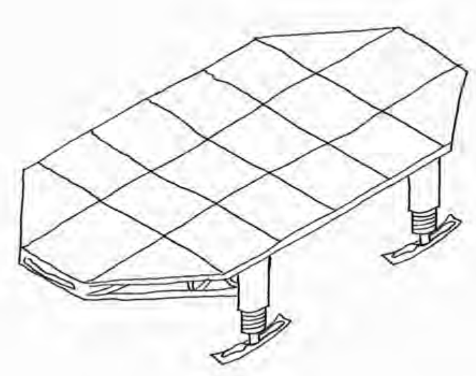
Stage 1: The space frame of a standard module supported on its transit skis, having just arrived at the Halley V site.



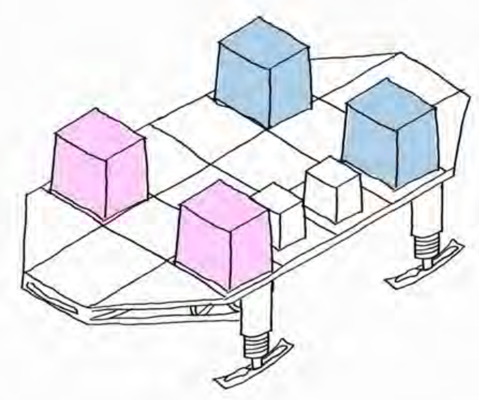
Stage 2: The module is raised on shipping containers to allow the hydraulic legs and Lehmann skis to be installed.



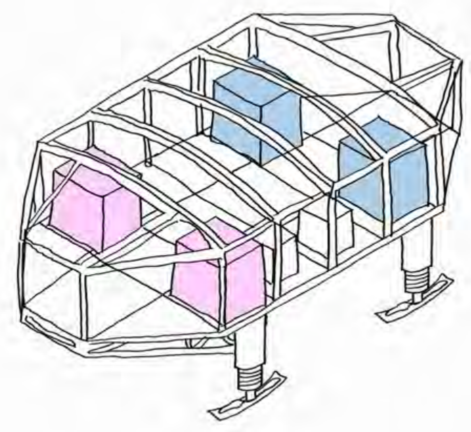
Stage 3: Hydraulic legs and Lehmann skis are installed, holding up the steel frame.



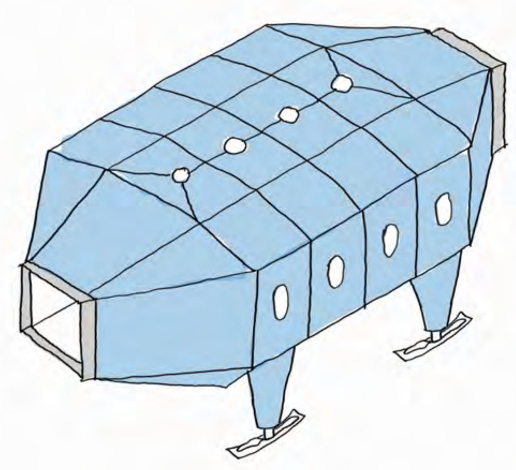
Stage 4: Prefabricated timber floor cassettes are installed onto the space frame, creating both a working platform and the floor of the module.



Stage 5: Prefabricated pods are installed onto the floors of the module. The pods installed include fuel tanks, generators, bedrooms. bathrooms, etc.



Stage 6: Steel superstructure is fitted over the pods, ready to receive the cladding.

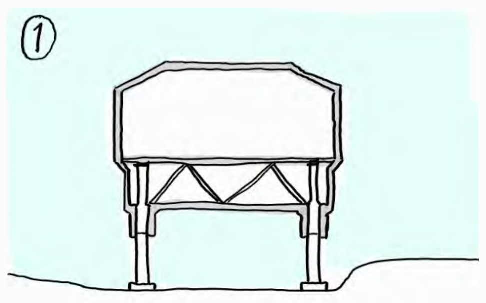


Stage 7: Glass-reinforced plastic pre-glazed cladding panels are lifted into position and fixed to the steel frame.

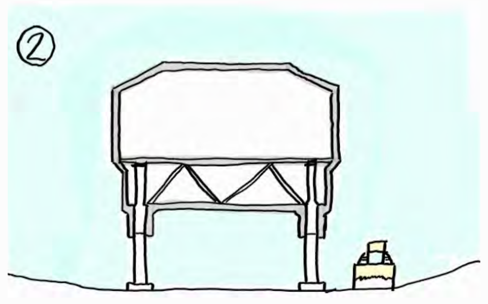
The cladding design maximised the size of the panels to minimise the erection time. The nose cones were made from a series of flat panels bonded together in the factory to create complex geometric forms, which could be bolted into position as fast as possible.

Ref. 3

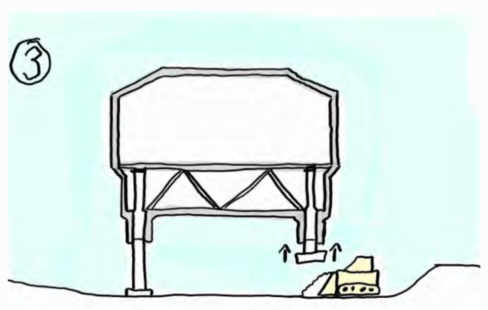
COMBATING THE EXTREME ENVIRONMENT



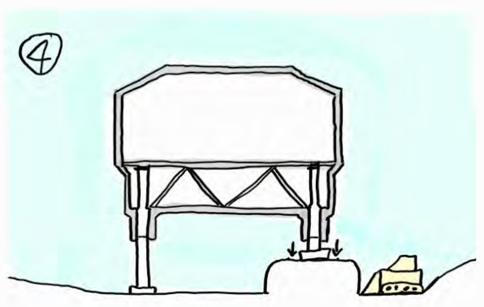
Snow builds up on the side of the module.



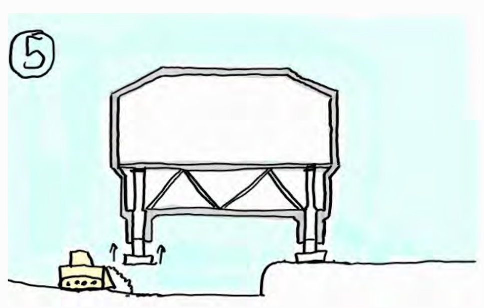
A bulldozer clears the snow build up.



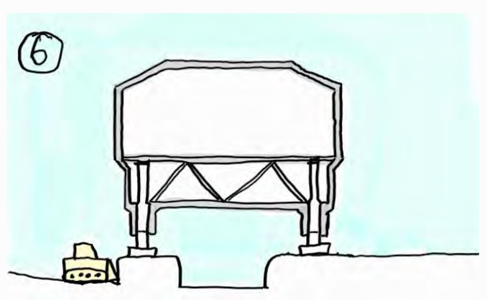
A hydraulic leg is lifted on one side of the module.



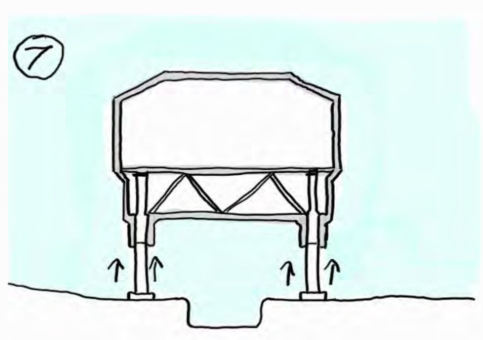
The bulldozer piles up snow under the lifted leg.



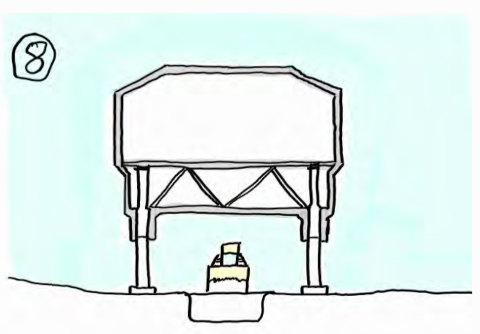
The hydraulic leg is lifted on other side of the module.



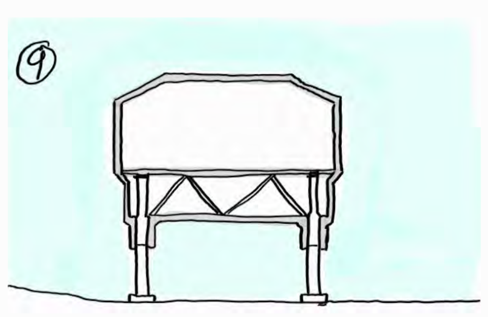
The bulldozer piles up snow under the other leg.



Once each leg is under a pile of snow, the module is raised by the hydraulic legs.



The bulldozer fills the gaps between the snow piles with snow.



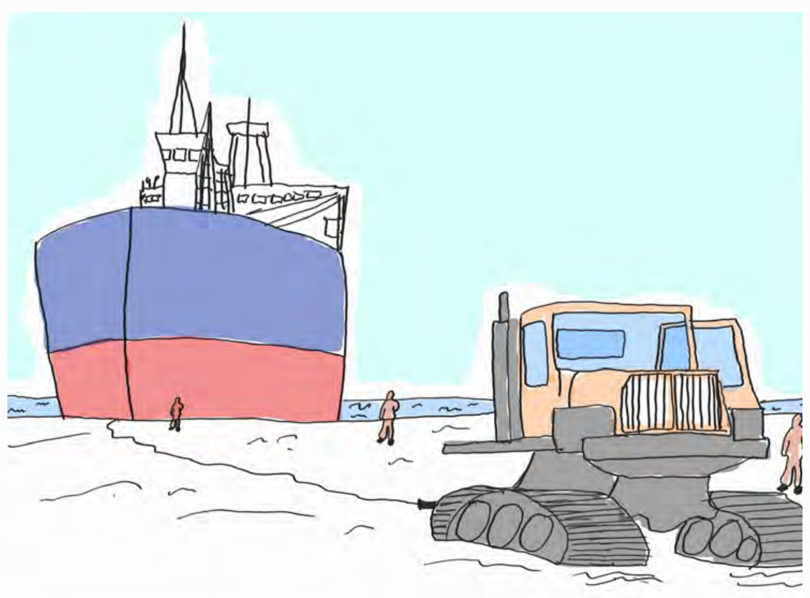
The module is now above the snow drift.

Halley's five predecessors were abandoned when they got buried or crushed by a buildup of snow. There is snowfall of around 1.2m a year. In the winter the temperature can drop to -50°C. The snow never melts, therefore, and blown by the prevailing wind, it builds up against buildings and obstacles.

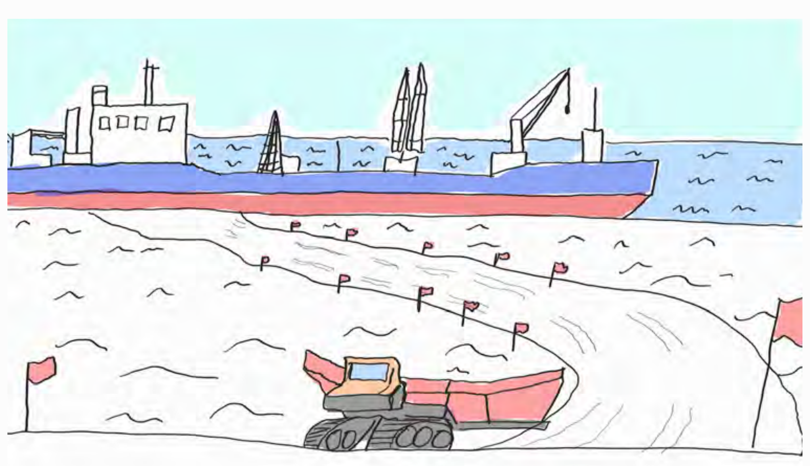
Ref. 2

LOCATION

DELIVERY TO SITE



The components of construction were delivered to Antarctica in a giant ice-strengthened Russian cargo vessel - the Anderma. Bow and stern lines were moored in the sea ice. Mooring points had to be prepared in advance of the ship's arrival. These entailed excavating 2 m deep holes into the ice and setting timbers into the excavation with anchor ropes extending to the surface. The holes were refilled with compacted snow which then refroze, providing secure mooring points.



As the sea ice is rarely more than 2-3 meters thick and can be very fragile, the British Antarctic Survey stipulated that the largest load which could be unloaded could not weigh more than 9 tonnes, including the sledge. The station, therefore, had to be constructed as a series of pre-fabricated components, which could be towed up onto the ice shelf and onto Halley V where they could be fitted together. The largest component was the steel space frame substructure of a standard module. Once on the ice shelf, loads were consolidated for onward transport to the construction site.

Ref. 3

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CASE STUDY 1: HALLEY VI - EXTERNAL ENVELOPE ANALYSIS

Legend

1 GRP outer skin to panels finished with gel coat and oversprayed with polyurethane acrylic automotive paint to ensure UV stability. Filled polyester resin used to achieve 30-minute fire resistance.

2 190mm polyisocyanurate (PIR) closed-cell foam insulation to achieve a U-Value of 0.113 Wm^2K.

3 Resin-infused cross-fibres prevent delamination under wind load.

4 Flexible elastic-silicone cladding mounting screwed into GRP "hardpoints" cast into panels

5 Steel cladding brackets welded to the primary steel superstructure.

6 Steel superstructure finished in intumescent coating to achieve one-hour fire resistance. Steel grade selected for performance at extremely low temperatures.

7 Steel structure to prefabricated room pods (bedrooms, bathrooms, offices, etc)

8 Panels bolted together through GRP flanges using stainless-steel fixings.

9 Continuous compressible neoprene insulation maintains thermal performance at joints, finished with PTFE to reduce friction during installation.

10 GRP inner skin to panels finished with intumescent paint to achieve Cs3d2 (Class 0) surface spread of flame characteristics.

11 Panels jointed with GRP jointing strip fixed with countersunk M0 stainless-steel cap screws through compressed foam neoprene gasket.

12 Extruded aluminium internal cover mounting strip.

13 Aluminium mounting strip fixed with coach screws. Foamed EPDM compressed gasket seal between mounting strip and panel.

14 Extruded aluminium external cover strip finished with polyurethane acrylic automotive paint to match panel finish, fixed to internal aluminium mounting strip with self-drilling stainless-steel fasteners.

15 Junction cover gasket formed in foamed EPDM.

16 Pods lined in 2 layers of Fermacell plasterboard selected for rigidity and acoustic performance.

17 Silicone rubber sealing gasket.

18 Lip in the panel to receive the gasket.

19 Gasket lips machined off to create a smooth corner detail.

Legend

1 Triple glazed window unit.

2 Blind.

3 Window trim.

4 1 layers of Fermacell plasterboard selected for rigidity and acoustic performance.

5 External wedge gasket.

6 Chamfer to exterior of window reveal in panel.

7 GRP outer skin to panels finished with gel coat and oversprayed with polyurethane acrylic automotive paint to ensure UV stability. Filled polyester resin used to achieve 30 minute fire resistance.

8 Resin-infused cross-fibres prevent delamination under wind load.

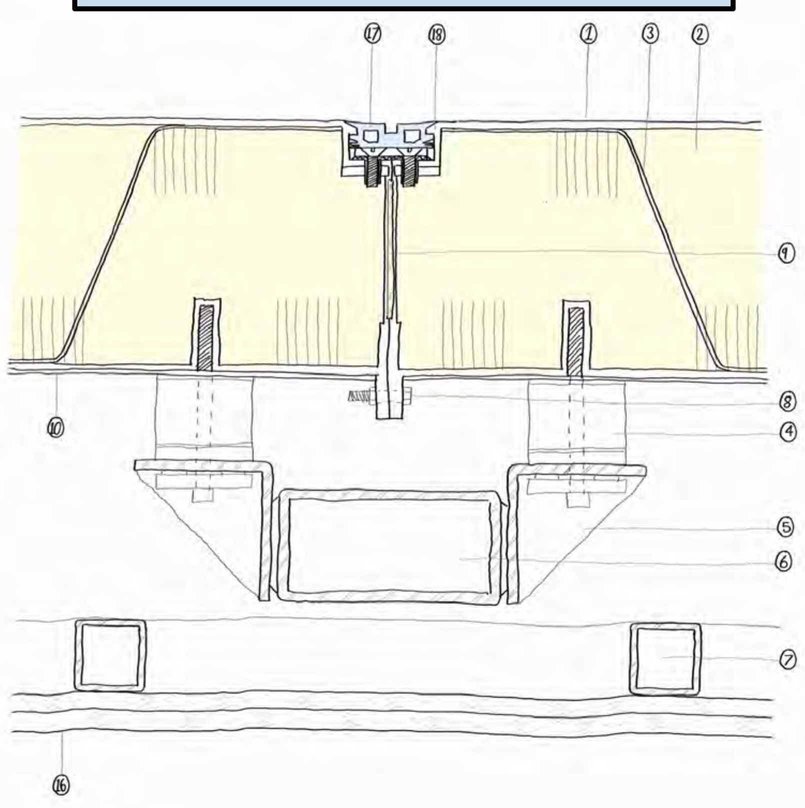
9 Intermediate window glazing spacers.

10 190mm polyisocyanurate (PIR) closed-cell foam insulation to achieve U-Value of 0.113Wm^2K.

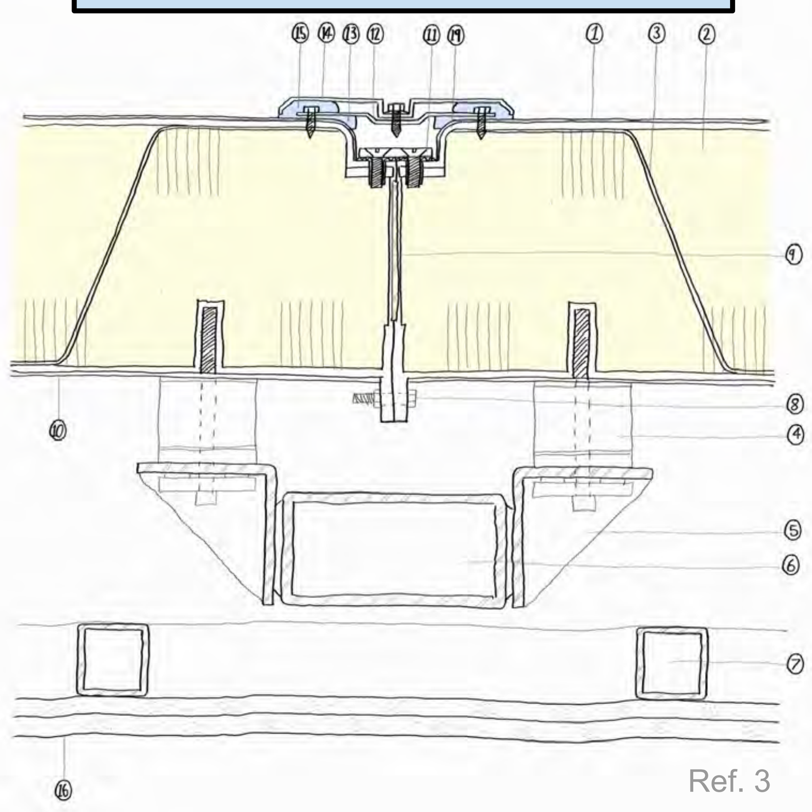
11 Steel studwork.

Ref. 4

DEFECTIVE PANEL JOINT DETAIL (2D) - 1:5

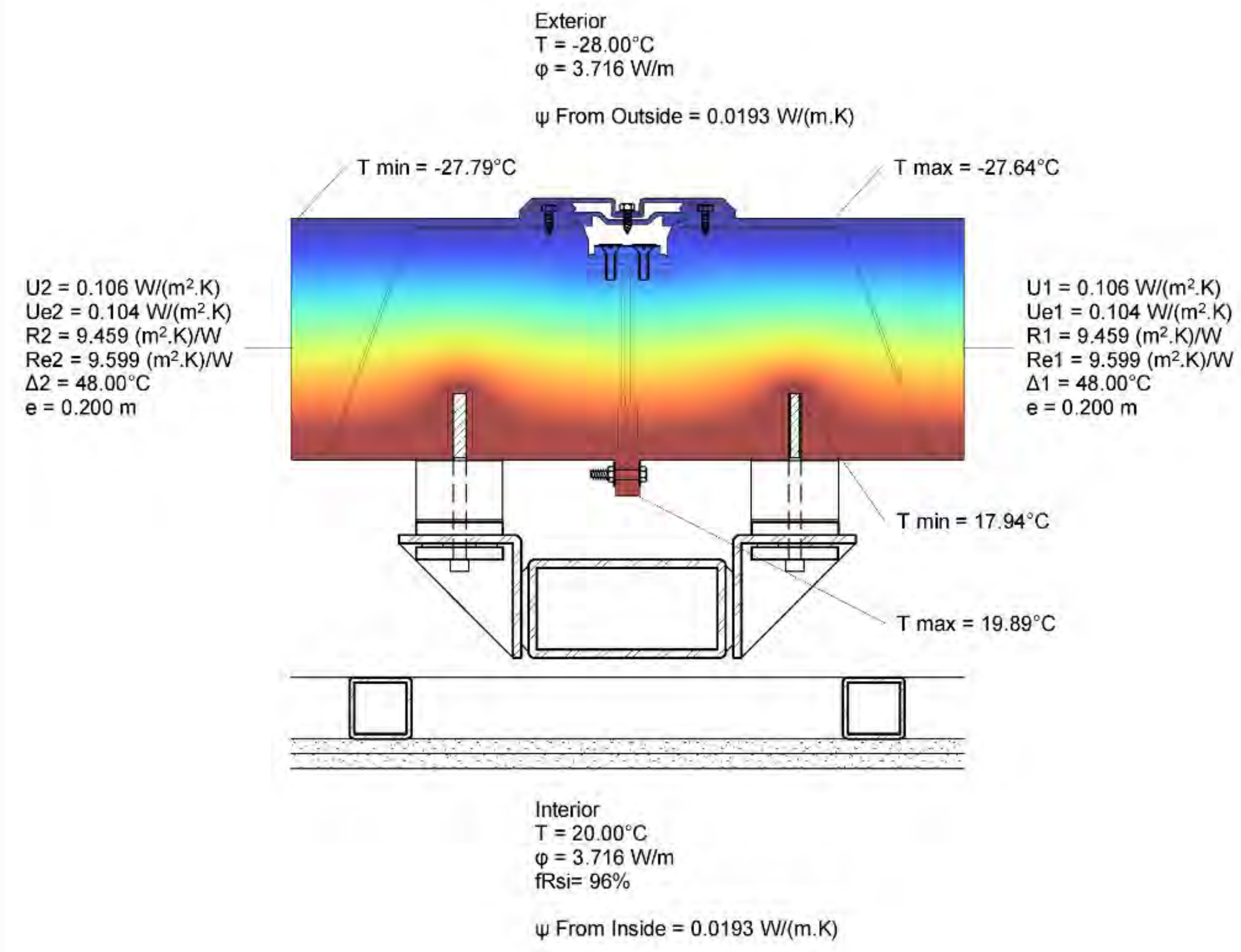


AMENDED PANEL JOINT DETAIL (2D) - 1:5

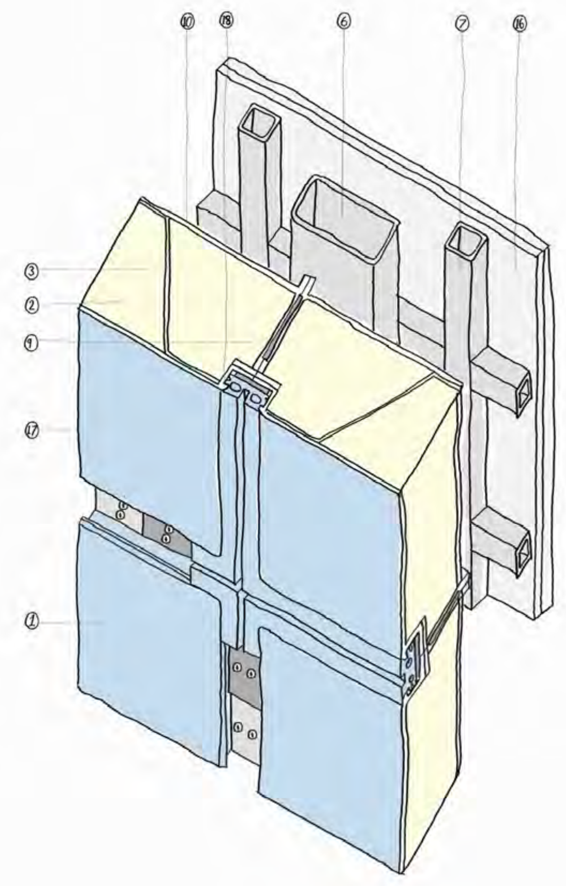


Ref. 3

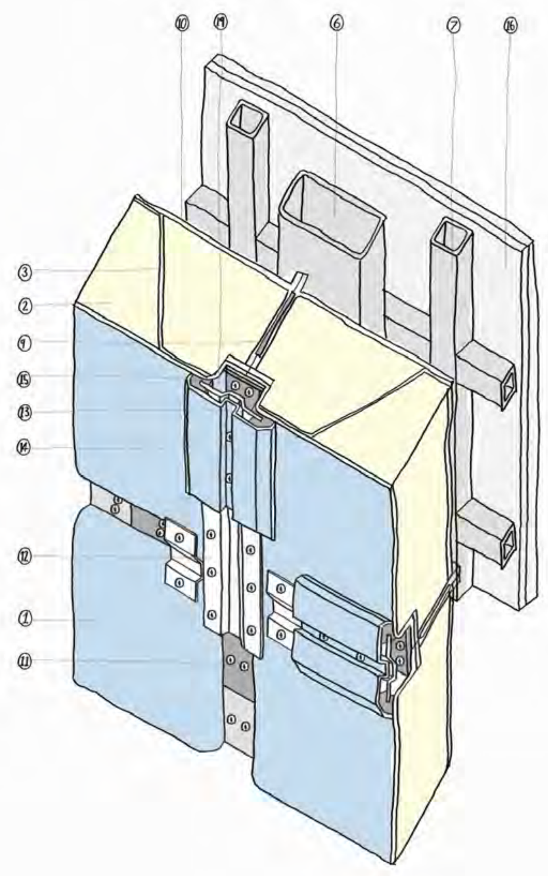
AMENDED PANEL JOINT DETAIL THERMAL ANALYSIS



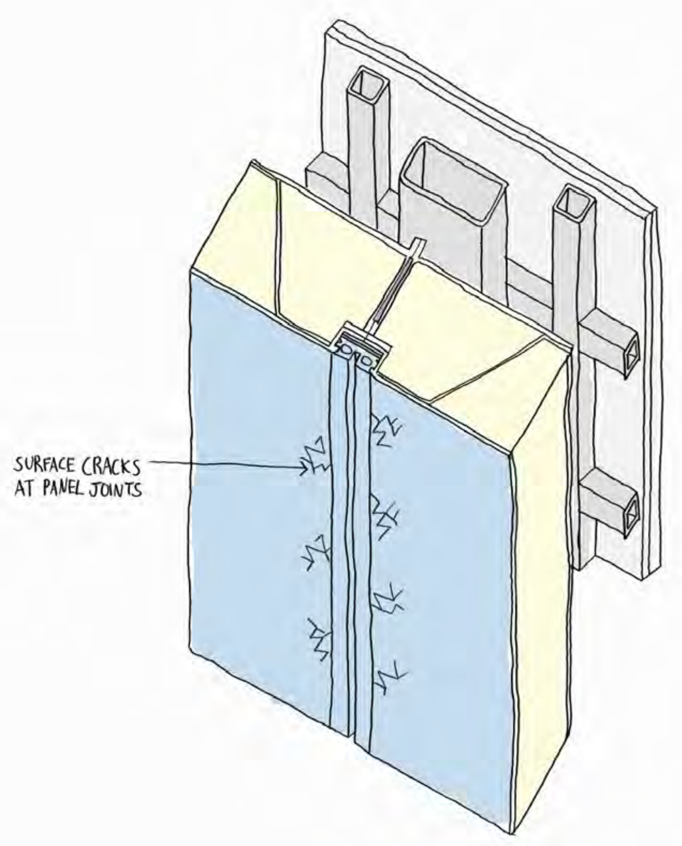
DEFECTIVE PANEL JOINT DETAIL (3D) - 1:10



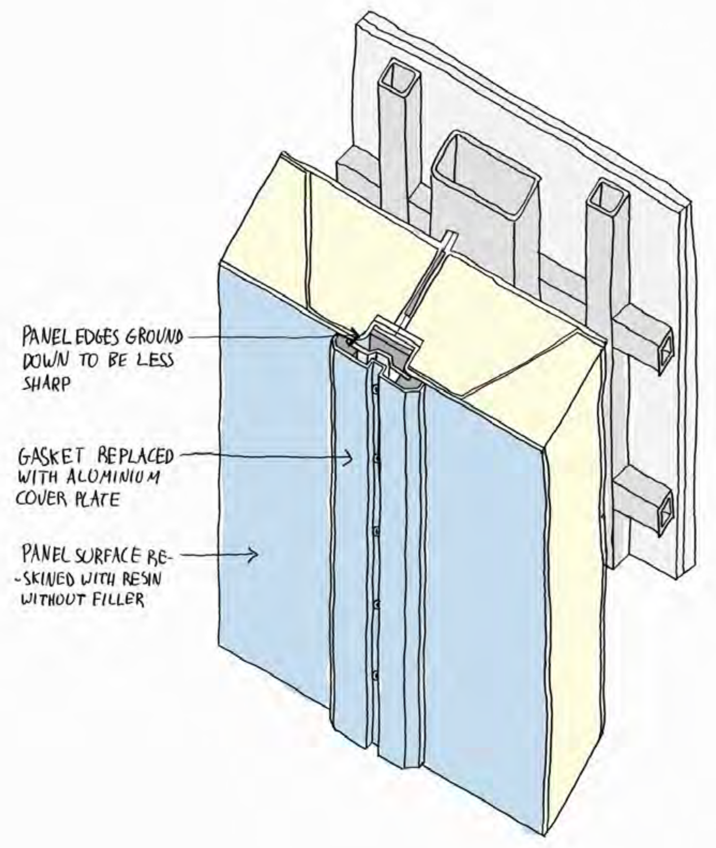
AMENDED PANEL JOINT DETAIL (3D) - 1:10



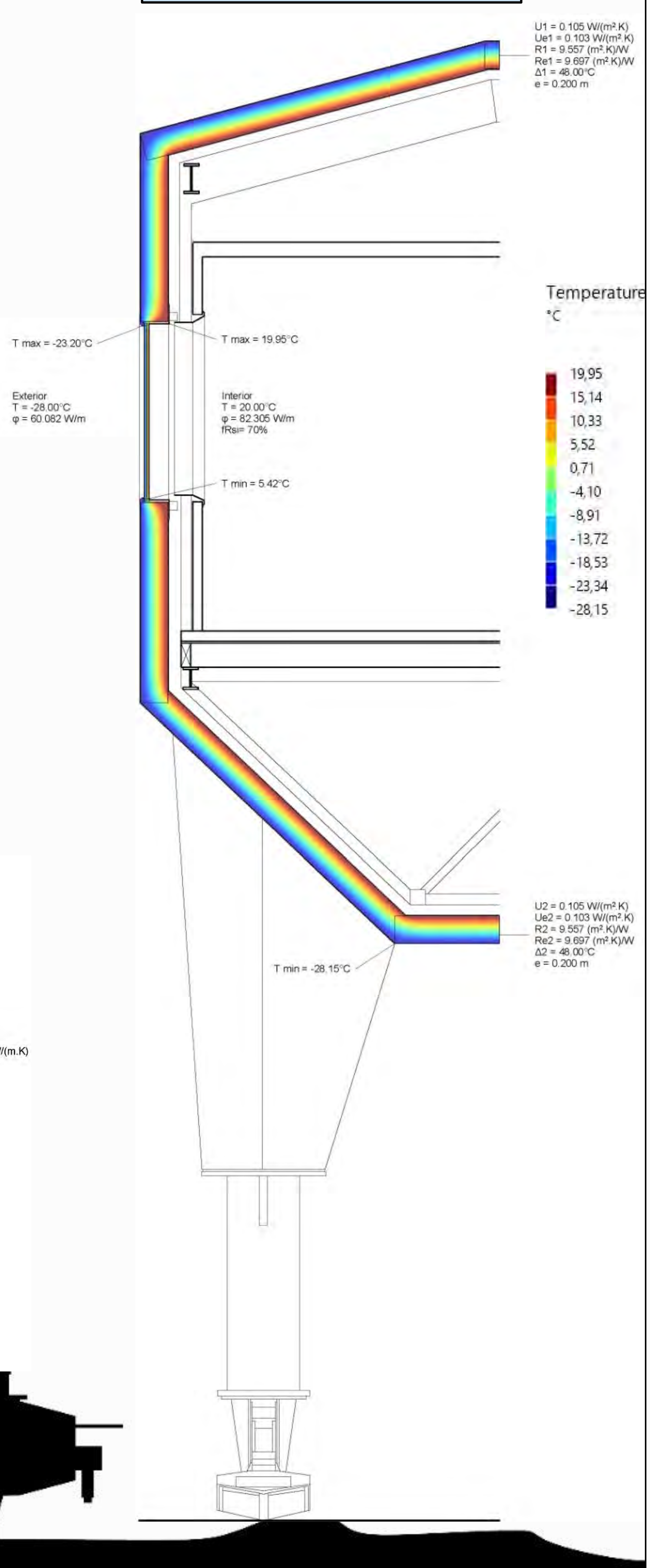
CLADDING JOINT DEFECTS



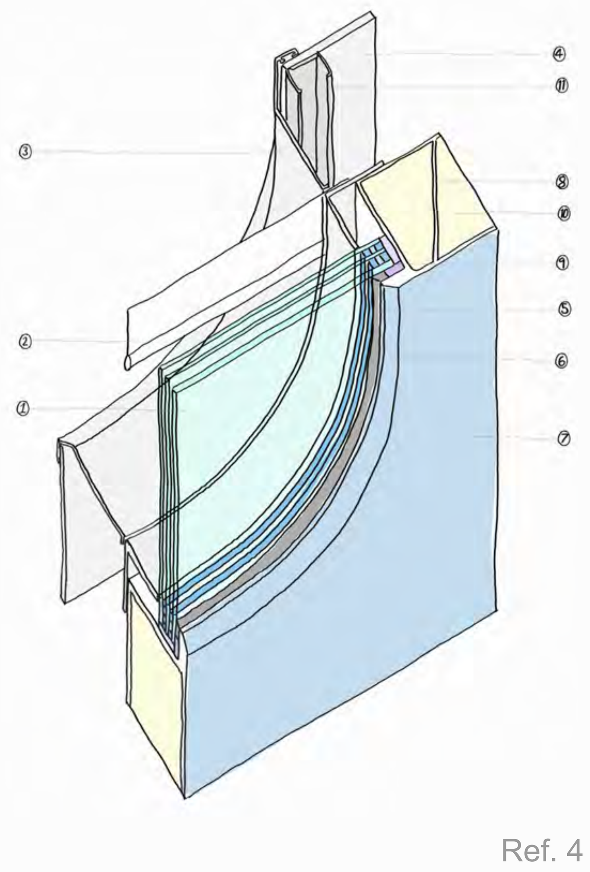
AMENDING THE DEFECTS



SECTION - 1:20 THERMAL ANALYSIS



WINDOW DETAIL (3D) - 1:10



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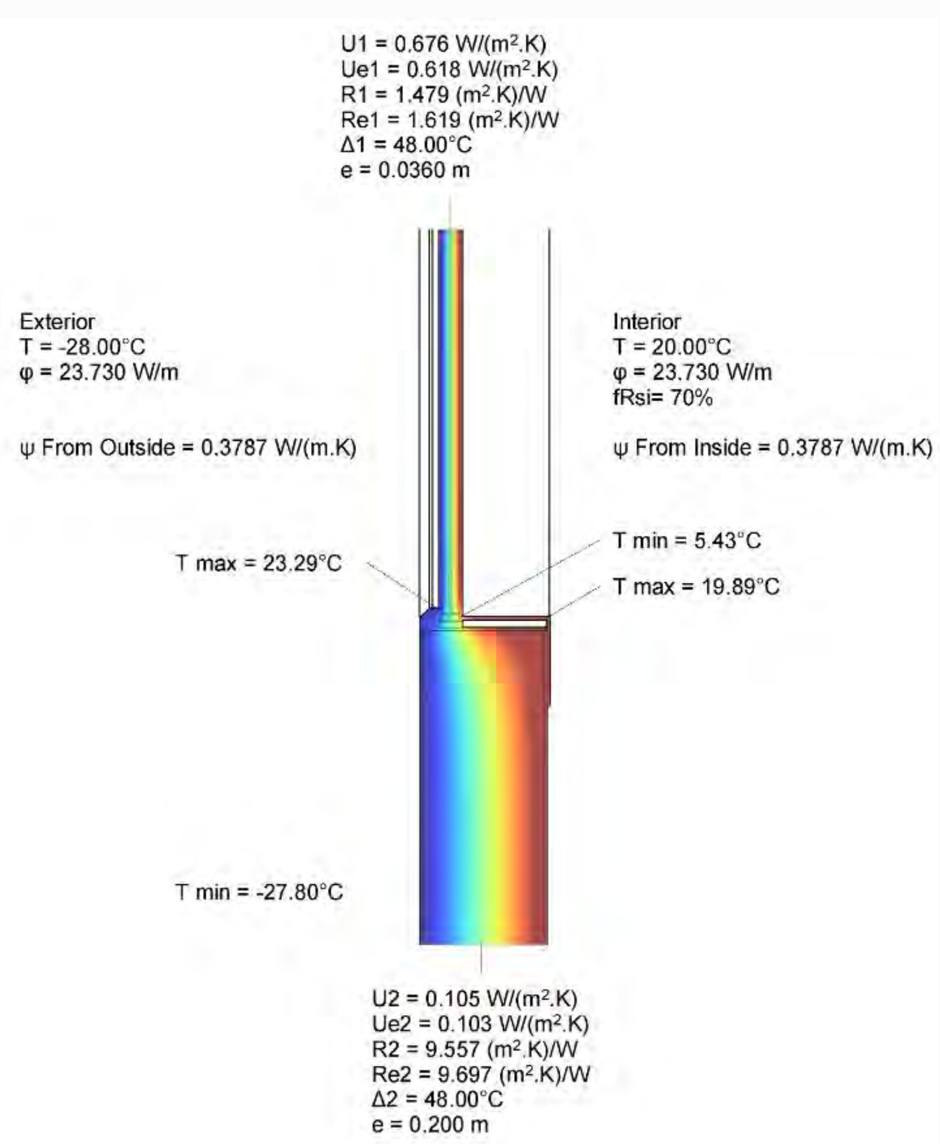
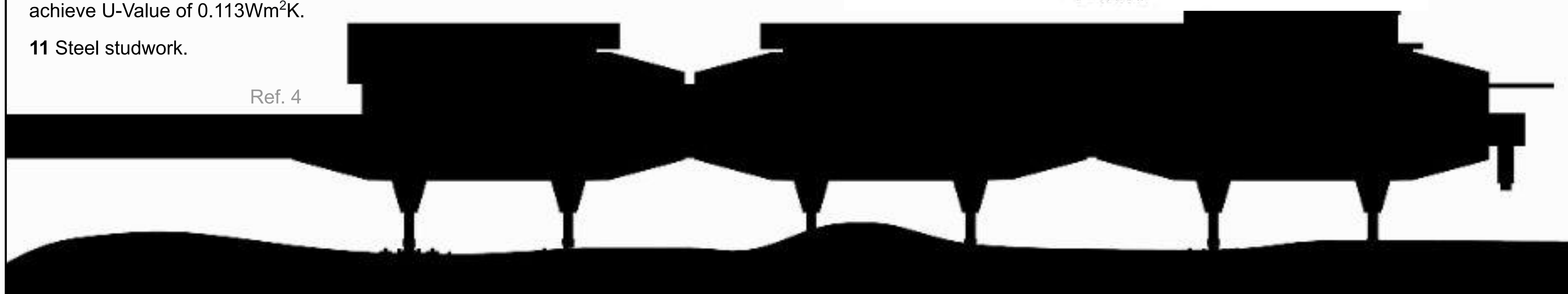
WINDOW DETAIL (2D) - 1:10 THERMAL ANALYSIS





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CASE STUDY 2: NK'MIP DESERT CULTURAL CENTRE, OSOYOOS, CANADA

PROJECT INFORMATION

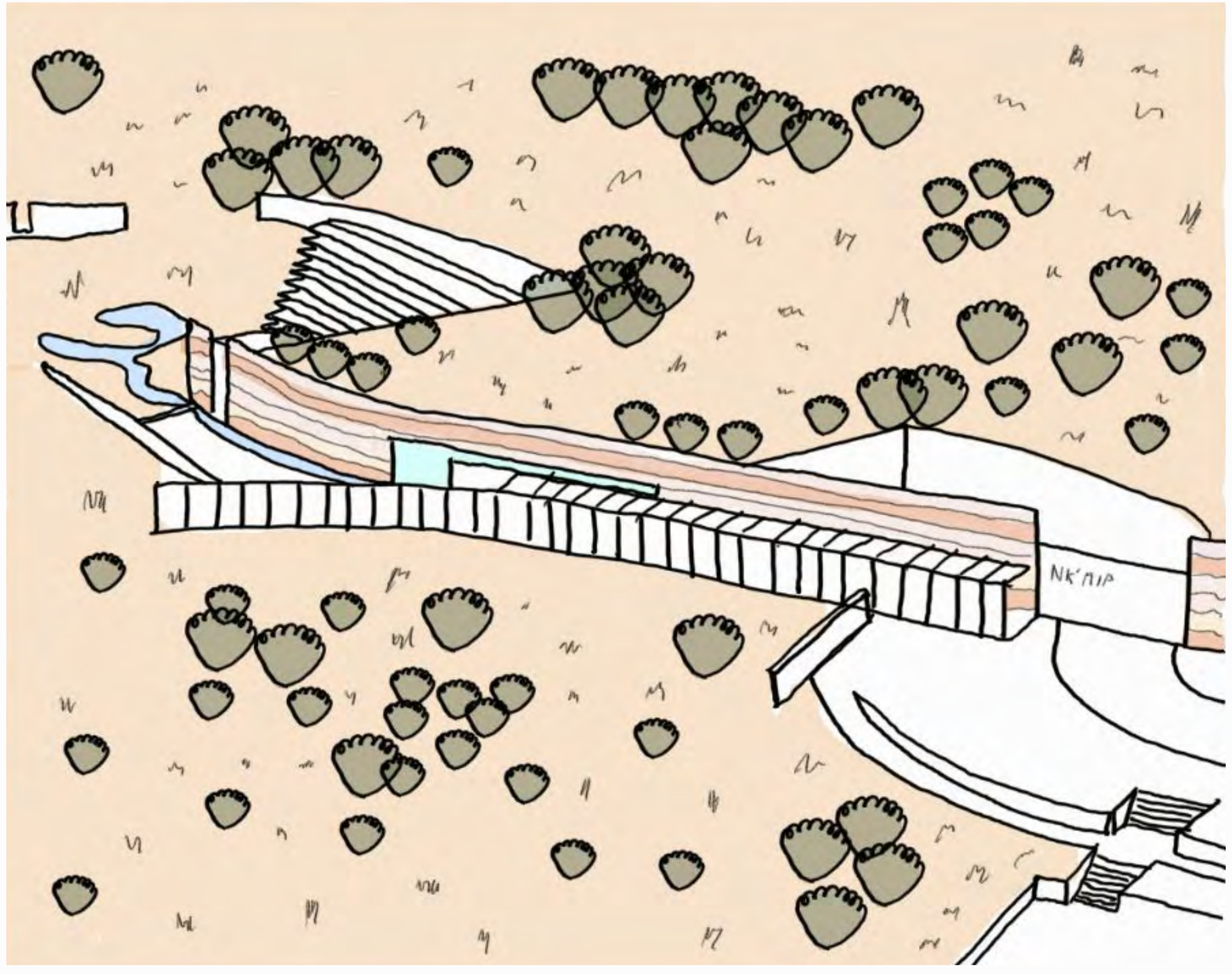
Name:	Nk'Mip Desert Culture Centre
Location:	Osoyoos, Canada
Architect:	DIALOG
Client:	Osoyoos Indian Band
Contractor:	Greyback Construction
Engineers:	Cobalt Engineering
	Equilibrium Consulting
	MCL Engineering
Completion date:	2006
Size (area):	775m²

Ref. 5

Ref. 5

The rammed earth wall consists of local dirt, with organic matter filtered out, combined in a mix of 10% concrete and colour additives. Contractors from British Columbia's Terra Firma Rammed Earth Builders laid down each strip and then mechanically tamped it down to 50% of its original height.

Ref. 5



PROJECT DESCRIPTION

The Nk'Mip Desert Cultural Centre is located in one of the most spectacular and endangered landscapes in Canada. Its rare desert condition is the northernmost tip of the Great American Desert, which extends southward as far as the Sonoran Desert in Mexico. This parcel of land is the largest intact remnant of this unique habitat in Canada. It is part of the land of the Osoyoos Indian Band. This band also belongs to the larger Okanagan Nation which extends down into the US (the Okanagan represents a broader geographic area of bands sharing a common language with separate constituent bands).

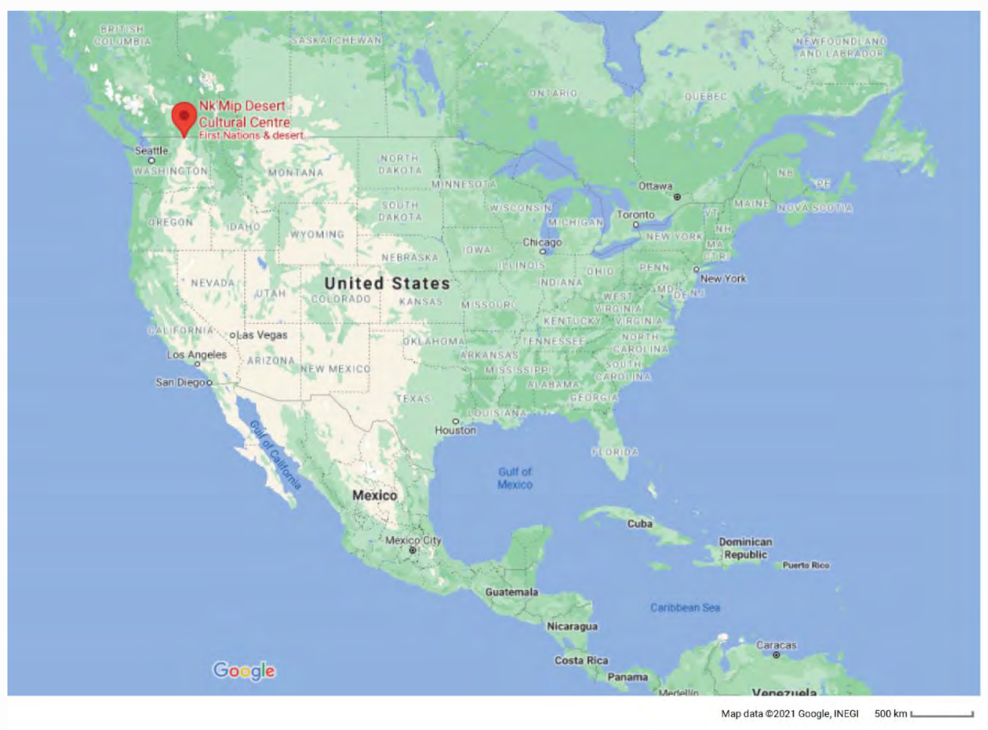
The building features indoor and outdoor exhibits that celebrate the culture and the history of the band, and is designed to be an extension of the remarkable site, and reflects the band's role as stewards of the land. The desert landscape flows over the building's green roof, held back by a rammed earth wall. The partially submerged building is sited very specifically to focus the visitor's eye away from the encroaching development of Osoyoos to the west, with the height of the wall set to create a layered view of the desert rising up in the middle ground, receding to the riparian landscape adjacent, and the mountains in the distance.

Ref. 5

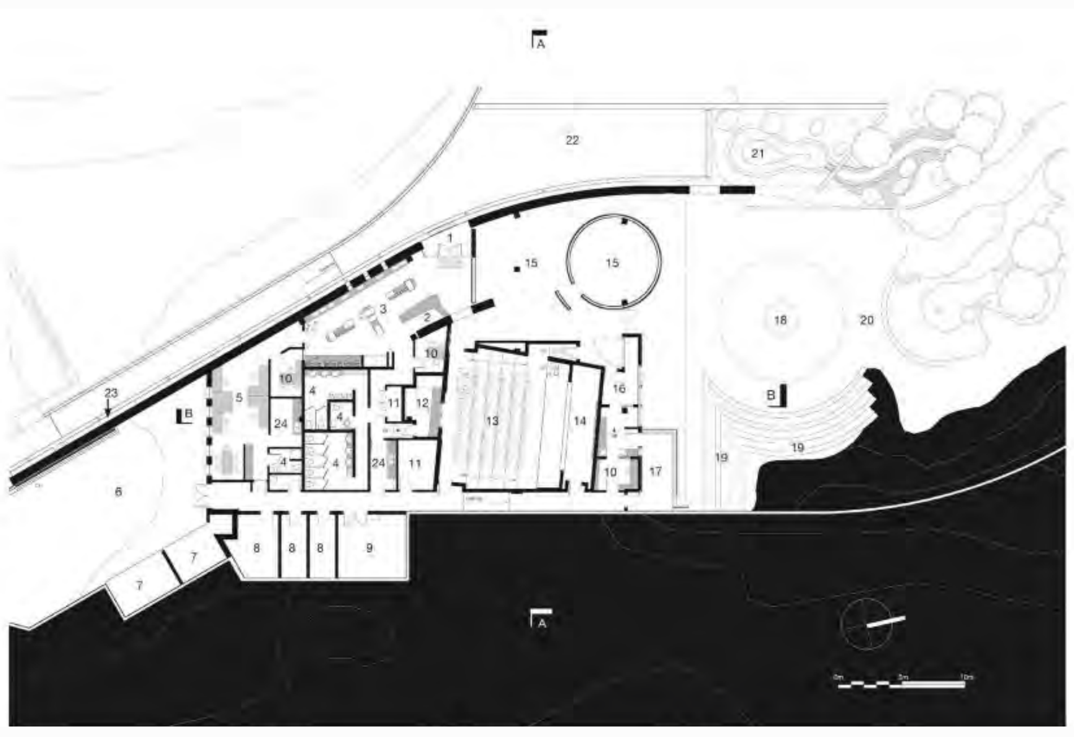
Formwork for the rammed earth wall construction.

Ref. 6

LOCATION



GROUND FLOOR PLAN - 1:500



Ref. 5

On-site testing of the rammed earth wall. The wall was able to withstand a 3,500-psi water stream.

Ref. 6

RULES OF THUMB FOR DESIGNING BUILDINGS FOR A HOT-DRY CLIMATE WITH COLD WINTERS

1. The key is to slow the rate of indoor heating on summer days using thermal mass and shading.
2. Adopt shaded courtyards for cooling.
3. Use natural cooling in summer, with water if available.
4. A heating system is required to provide heat during the cold winter.

Ref. 7

Legend

1 Entry	**12** AV Control Room
2 Reception	**13** Lecture/Performance Theatre
3 Gift Shop	**14** Stage
4 Washroom	**15** Exhibit Gallery
5 Administration	**16** Animal Habitat Display
6 Service Yard	**17** Demonstration Area
7 Garbage/Recycling	**18** Outdoor Amphitheatre
8 Service Room	**19** Seating
9 Workshop	**20** Outdoor Intererative Area
10 Office	**21** Retention Pond/Animal Habitat
11 Storage	**22** Terrace
	23 Desert Stream

Steel rebar installation between the formwork for the concrete walls.

Ref. 6

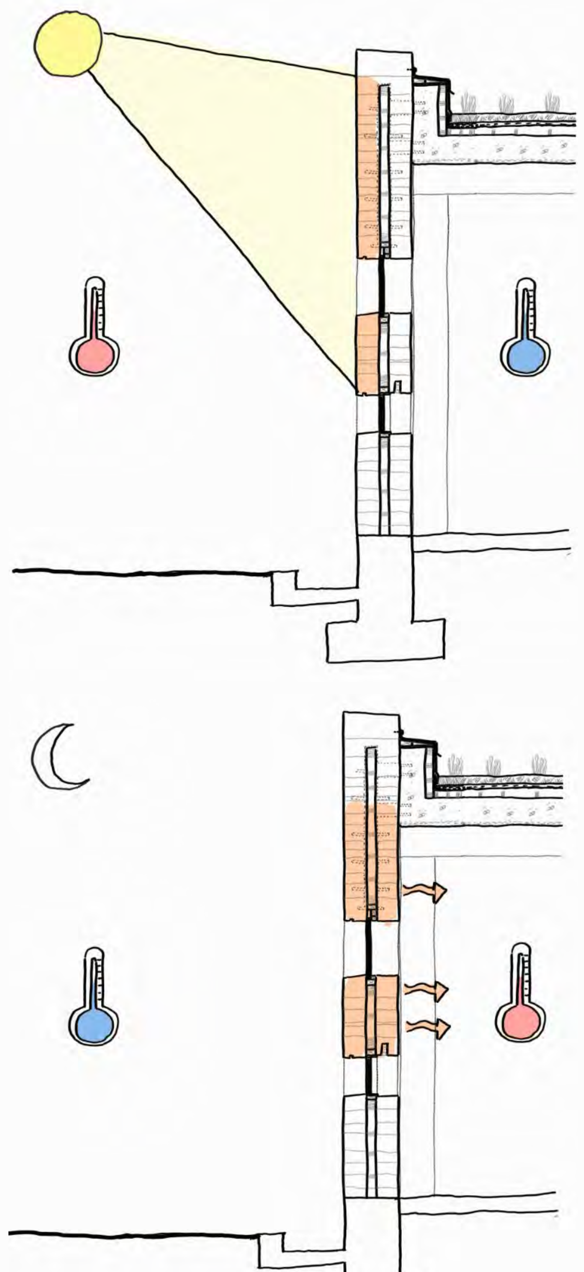
WEST ELEVATION - 1:500

Ref. 5

HOW DOES EXTREME CLIMATE CONDITIONS IMPACT BUILDING ENVELOPE DESIGN?

CASE STUDY 2: NK'MIP DESERT CULTURAL CENTRE - EXTERNAL ENVELOPE ANALYSIS

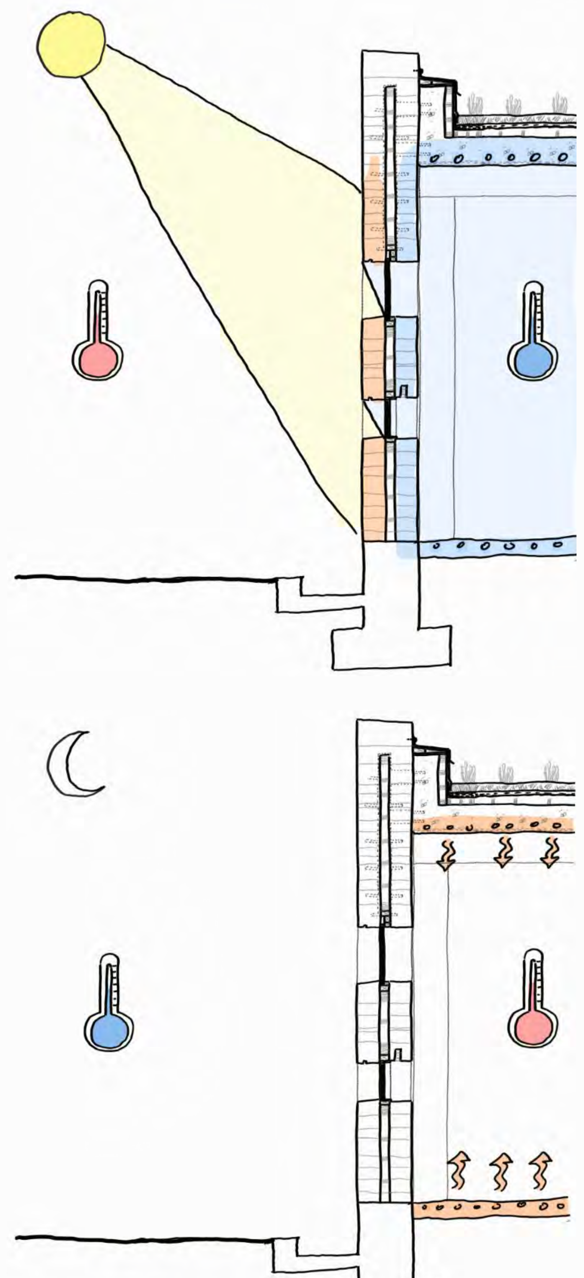
COMBATING THE EXTREME CLIMATE



The extreme climate made design a very particular challenge. Hot, dry summers and cool, dry winters see average temperatures ranging from –18 degrees to +33 degrees and often reaching +40 on summer days. The building's siting and orientation are the first strategic moves toward sustainability: the partially buried structure mitigates the extremes in temperature, and its orientation optimizes passive solar performance, with glazing minimized on the south and west sides. The project's ambitious approach towards sustainable design also includes the following features: The largest rammed earth wall in North America. At 80m long, 5.5m high, and 600mm thick, this insulated wall (R33) stabilizes temperature variations. Constructed from local soils mixed with concrete and colour additives, it retains warmth in the winter, its substantial thermal mass cooling the building in the summer - much like the effect the surrounding earth has on a basement.

Ref. 5

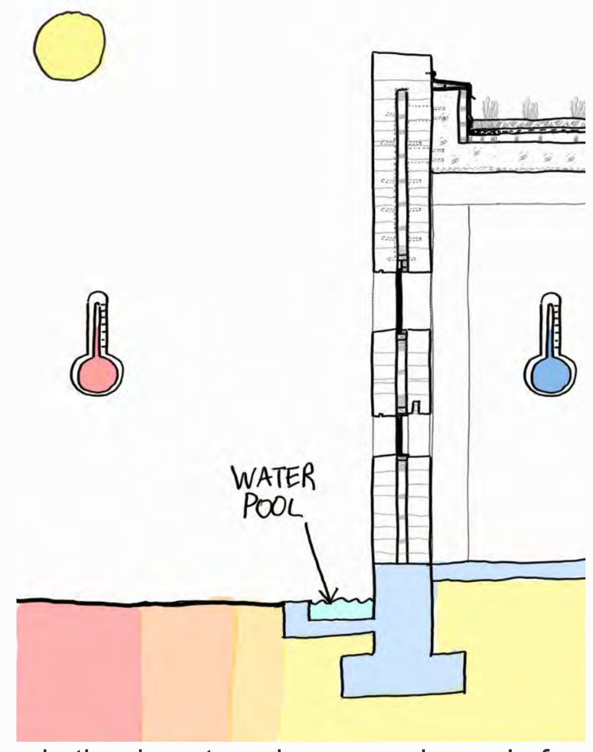
HEATING AND COOLING



In-slab radiant cooling and heating in both ceiling and floor slabs create an even, comfortable environment that avoids blasts of air, noise and dust. Coupled with 100% outdoor air displacement ventilation, the system will result in savings of 30 to 50% over a forced-air system.

Ref. 5

WATER USE MANAGEMENT

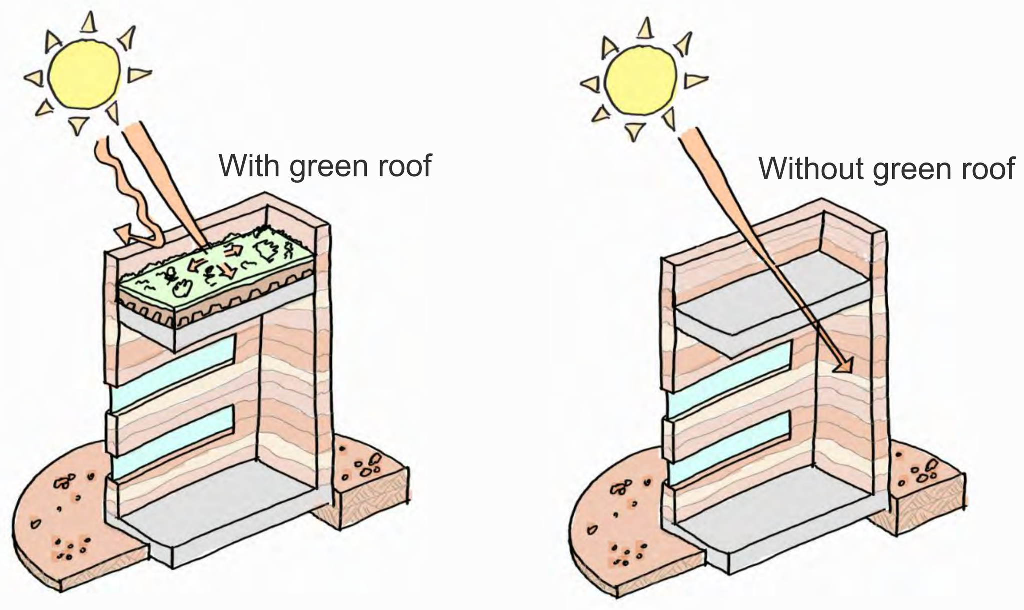


Water is precious in the desert, and a spare channel of water at the entrance along the rammed earth wall introduces this theme. The water also acts as an evaporative cooling device.

Less visibly, demand on the site fed well is reduced by 40% by incorporating low-flow faucets, waterless urinals, and dual flush toilets.

Ref. 5

GREEN ROOF



The habitable landscaped roof reduces the building's visual imprint on the landscape and allows a greater percentage of the desert landscape habitat to be re-established on the site (replanting uses indigenous species). The roof also provides further temperature stabilization and insulation.

Ref. 5

Legend

1 Topcoat - cementitious water stop seal to top of the parapet.

2 Puddled earth top lift

3 Saw kerf reglet for continuous membrane flashing and pressure bar - caulk.

4 Prefinished metal flashing.

5 Green roof construction (inverted torch on 2 ply SBS membrane):

- Native plants on
- 230 native soil growing medium on
- Root resistant membrane on
- Drainage panel & filter fabric on
- 100mm rigid insulation (RSI 3.5) on
- Cap sheet on
- Base sheet on
- Primer on
- Sloping suspended concrete with radiant pipes cast in the slab.

6 Radiant piping in the slab.

7 Concrete slab band (sloping)

8 Reveal.

9 HSS frame inn wall

10 Puddled earth

11 Continuous clear finish ash wood window stop and trim (at window head and cill)

12 Continuous double glazed sealed frameless window - silicone in place.

13 Continuous timber stud (at window head and cill)

14 Wall construction:

- 250mm rammed earth wall - reinforced on
- 100mm PIR insulation on
- 250mm rammed earth wall - reinforced.

Note: Lift heights vary from 125mm to 170mm.

15 Recessed halogen light centred in 76mm dia opening.

16 400 x 400mm double glazed frameless window - silicone in place.

17 Solid ash window stop and trim.

18 Concrete column.

19 Caulk.

20 Floor construction:

- Concrete slab on
- Grade cast with radiant slab heating/cooling pipes on
- Vapour barrier on
- 50 x 610mm rigid insulation around the outside perimeter of
- Gravel base on
- Native soil.

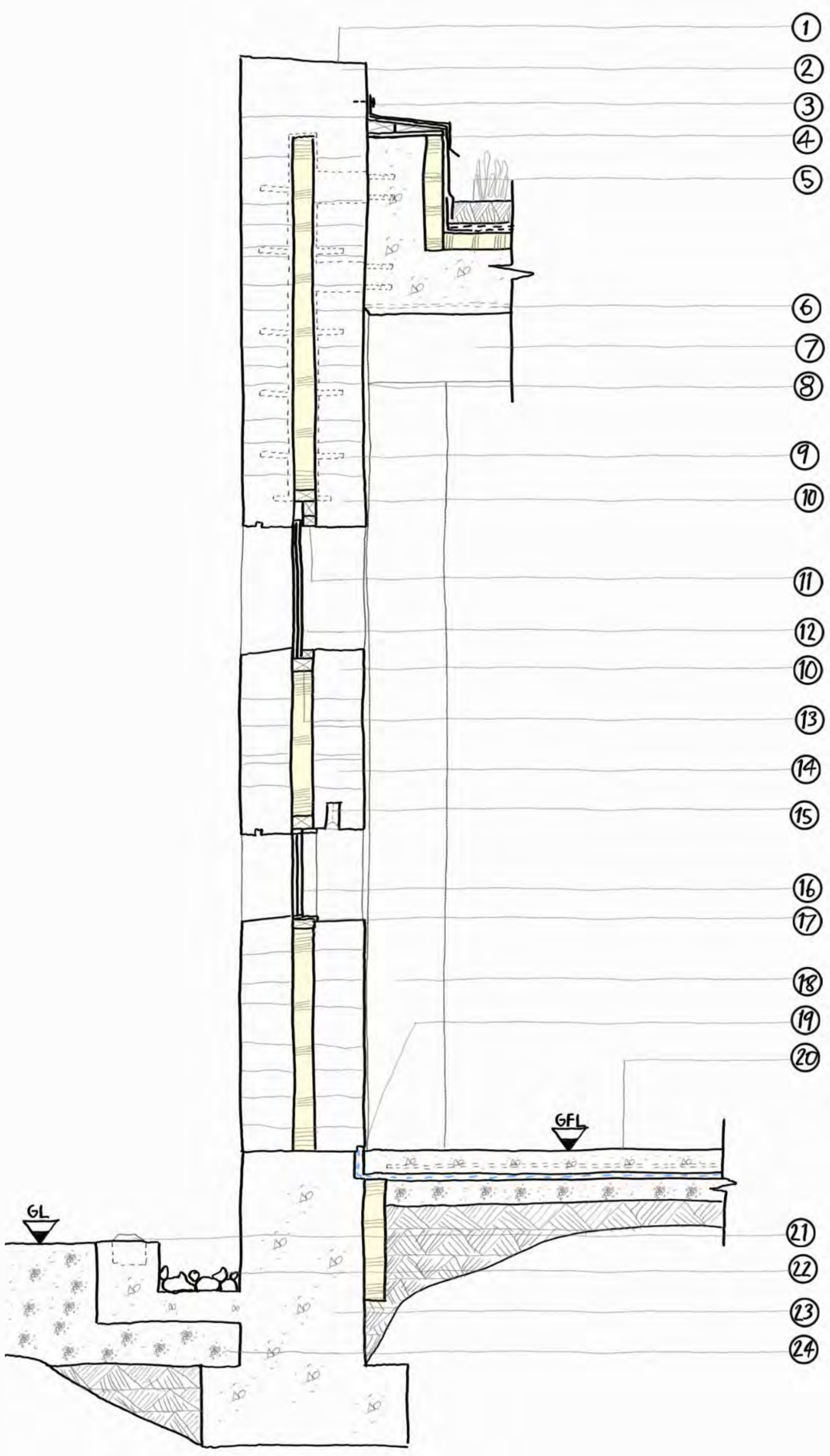
21 Recessed in-slab light @ 3200mm centers.

22 Sloping continuous water trough.

23 Concrete strip foundation.

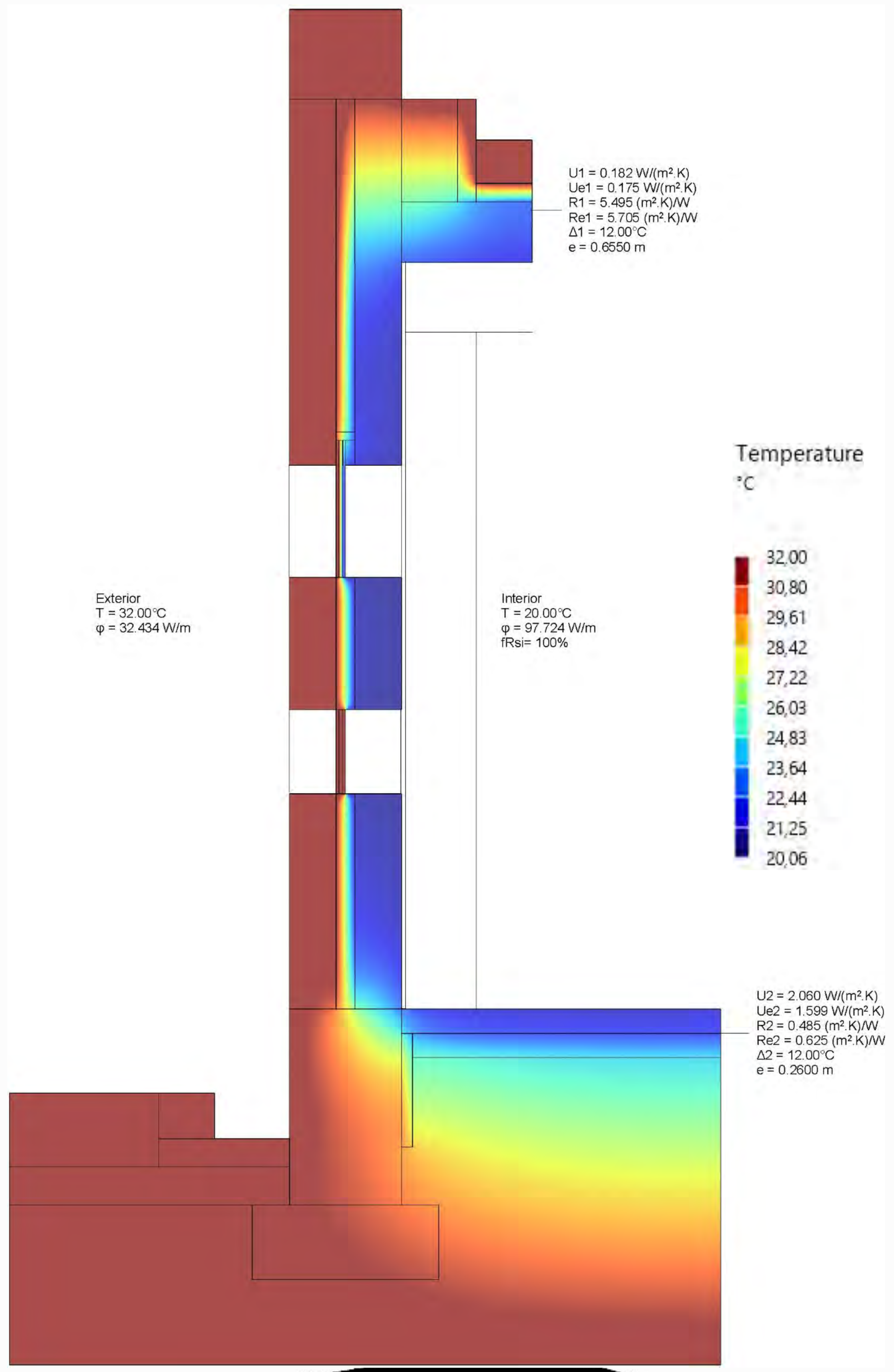
Ref. 5

SECTION - 1:20



Ref. 5

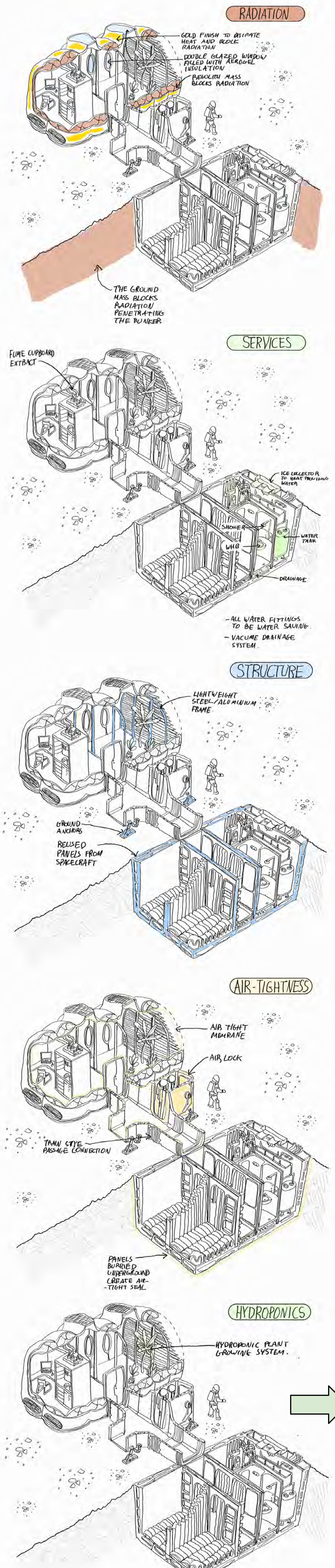
SECTION - 1:20 THERMAL ANALYSIS

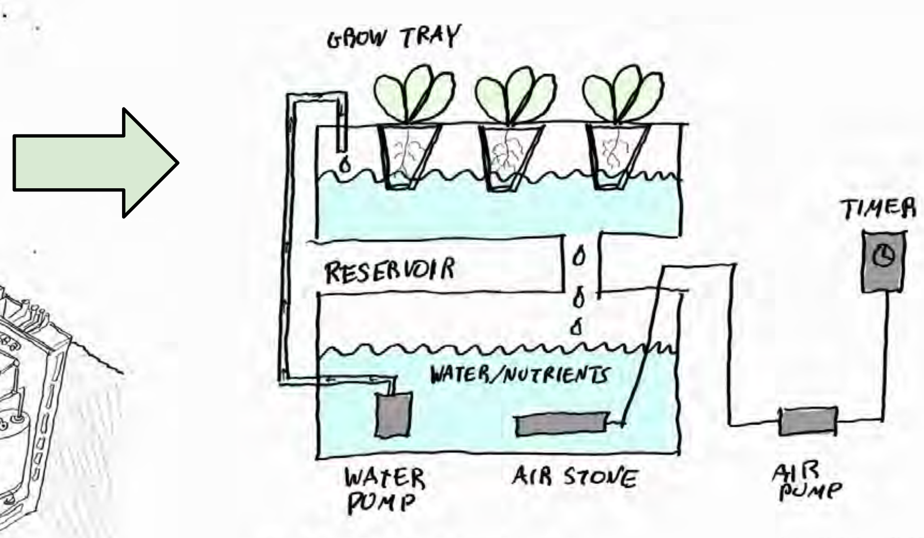


HOW DOES EXTREME CLIMATE CONDITIONS IMPACT BUILDING ENVELOPE DESIGN?

CASE STUDY 3: THE MARTIAN HOUSE, MARS

DESIGN FEATURES





Ref. 8

PROJECT INFORMATION

Name:	The Martian House
Location:	Bristol, United Kingdom (prototype)
Architect:	Hugh Broughton Architects & Pearce+
Proposed completion date:	Summer 2022

PROJECT DESCRIPTION

Hugh Broughton Architects is working with multidisciplinary studio Pearce+ and the artists to produce the concept design of a Martian house based on the public's ideas.

The house will comprise two levels with an external staircase and a platform lift. The upper level, designed to sit on a Martian landscape, will be formed using a pressurised inflatable gold-coated foil, making it lightweight enough to be transported to the fourth planet from the sun and filled with local soil to provide protection from galactic and solar radiation.

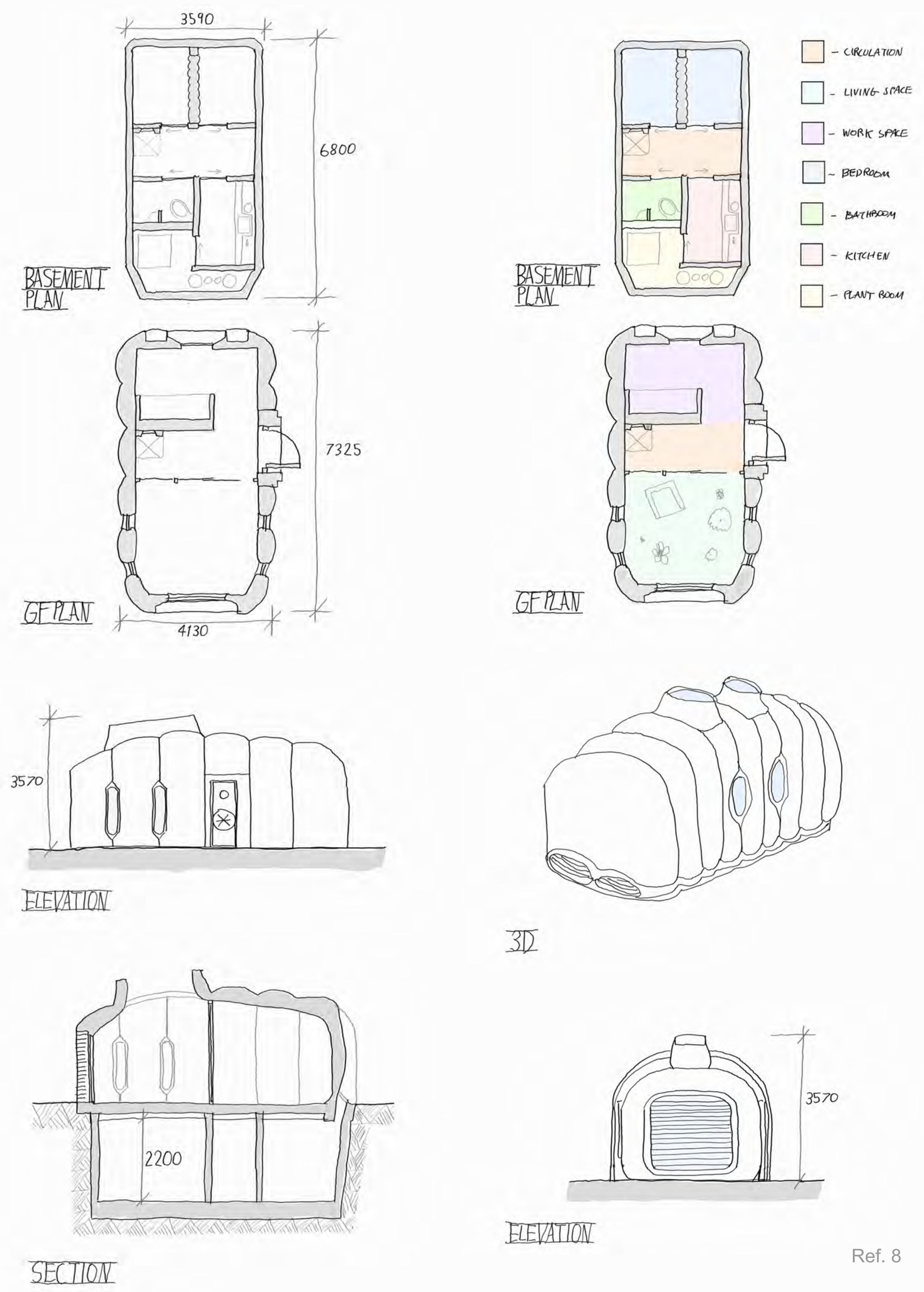
The lower level of the house is designed to be built below the ground, and so the prototype in Bristol will be surrounded by a scaffold hoarding, printed with information about the project and illustrations.

A hydroponic living room is designed to surround occupants with plants to aid relaxation. Flexible, private living spaces can be used as bedrooms, virtual reality rooms or opened into a dining room. Other facilities include a toilet and a kitchenette.

The house is due to open in April 2022 and be taken down in August the same year. It will be presented in partnership with M Shed and funded by The Edward Marshall Trust.

Ref. 9

DRAWINGS - 1:100



Ref. 8

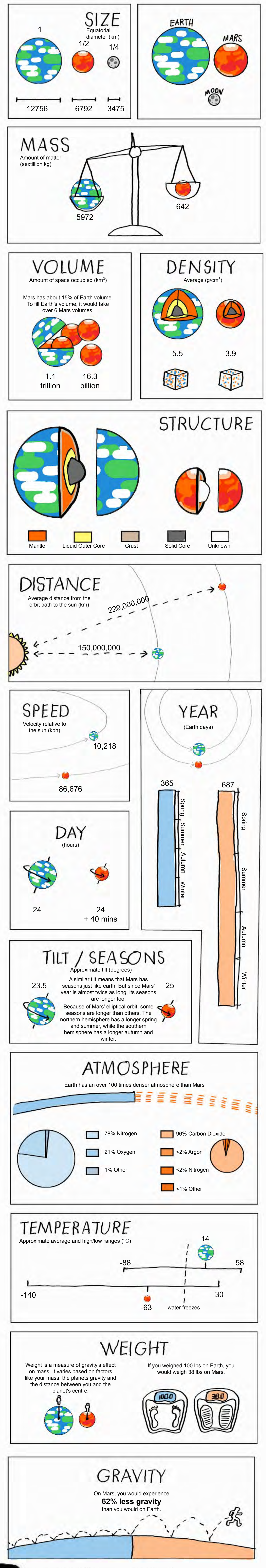
HUGH BROUGHTON QUOTES

"We've learned how to drive down water usage and how to make the best use of recycled water and I think that's going to be important on Mars where water could be quite scarce."

"We look very carefully at the ergonomics of the social spaces to make sure that you could still provide space that people could be as a community but also on their own and very importantly on those missions where you are in very low gravity, where you would be able to take lots of exercises to keep your muscles in shape."

Ref. 10

MARS FACTS

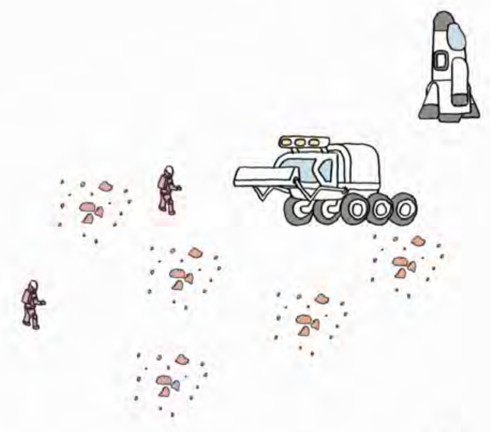


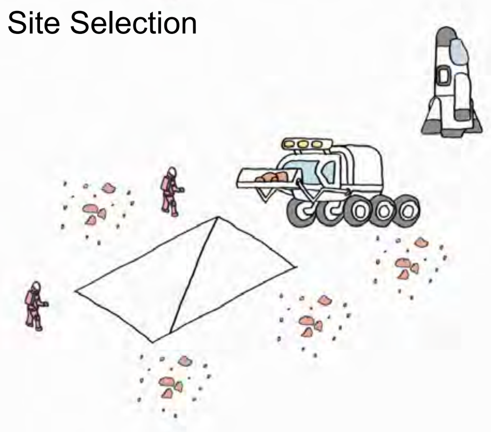
Ref. 11

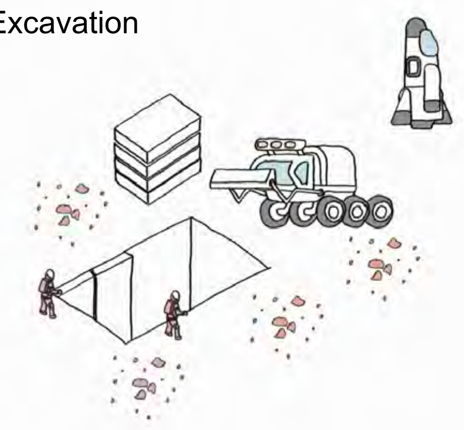
HOW DOES EXTREME CLIMATE CONDITIONS IMPACT BUILDING ENVELOPE DESIGN?

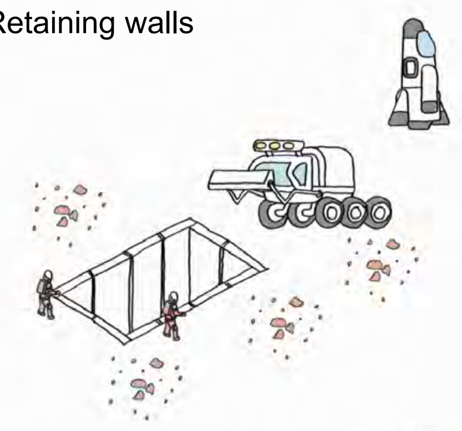
CASE STUDY 3: THE MARTIAN HOUSE - EXTERNAL ENVELOPE ANALYSIS

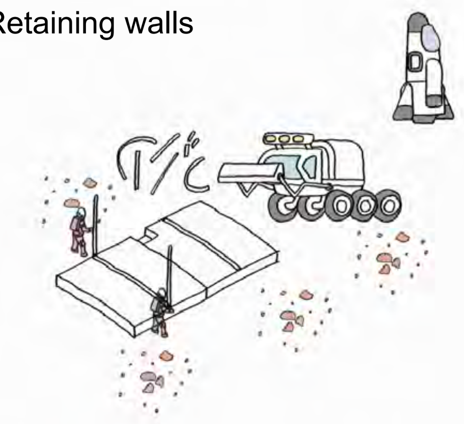
MODULAR CONSTRUCTION

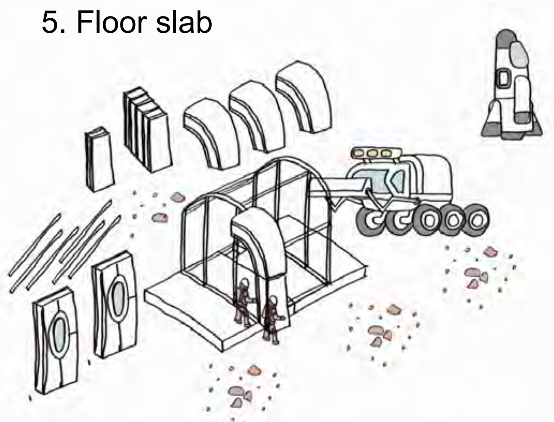

1. Site Selection

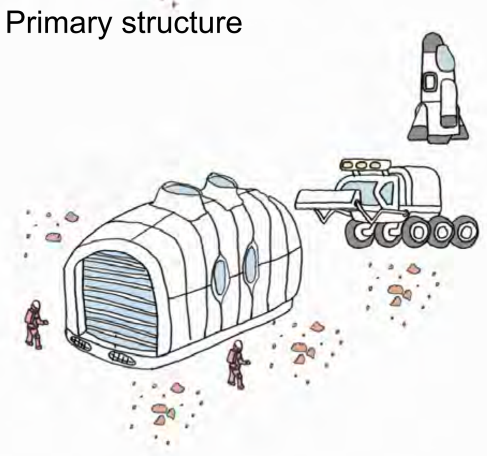

2. Excavation


3. Retaining walls

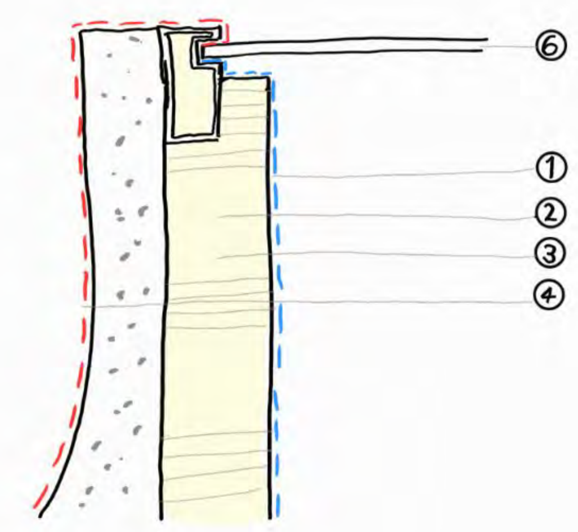

4. Retaining walls


5. Floor slab

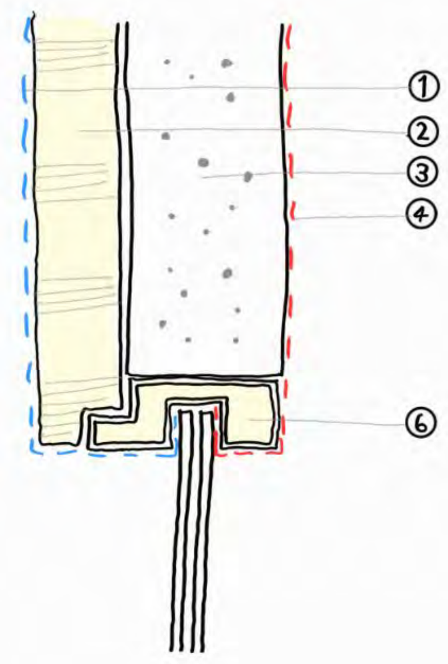

6. Primary structure


7. Cladding

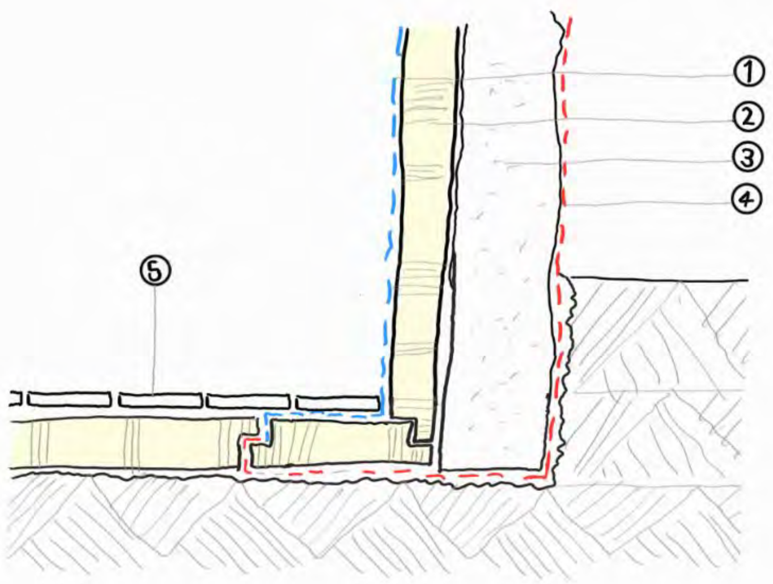
PROPOSED CONSTRUCTION DETAILS



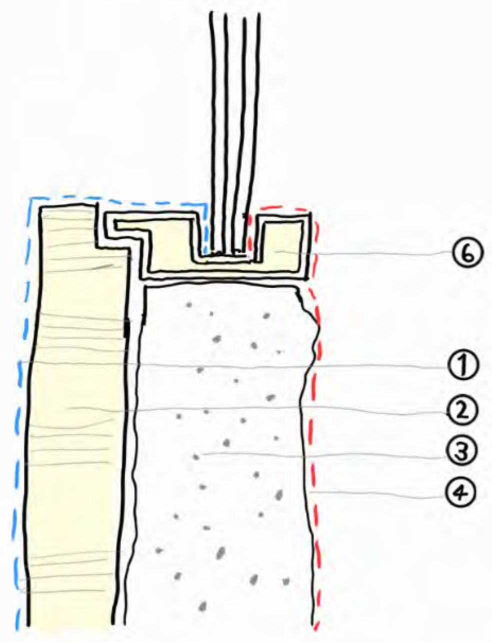
A - ROOFLIGHT CONNECTION
NTS



B - WINDOW HEAD
NTS



C - WALL TO FLOOR JUNCTION
NTS



C - WINDOW CILL
NTS

Legend

1 Internal inflatable membrane.

2 Modular insulation system.

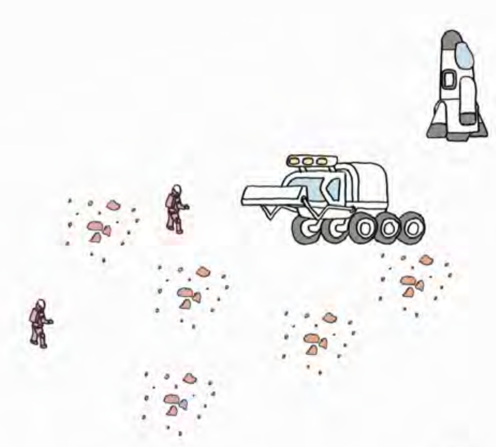
3 Martian regolith infill.

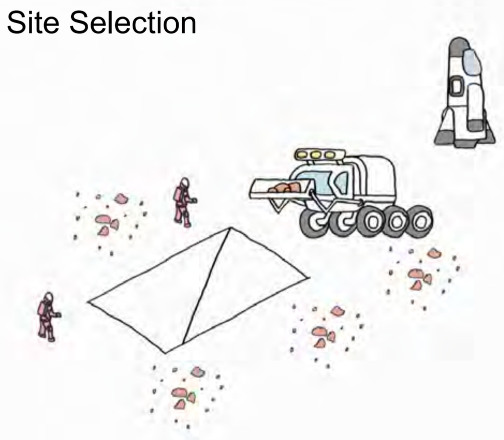
4 External gold-coated inflatable membrane.

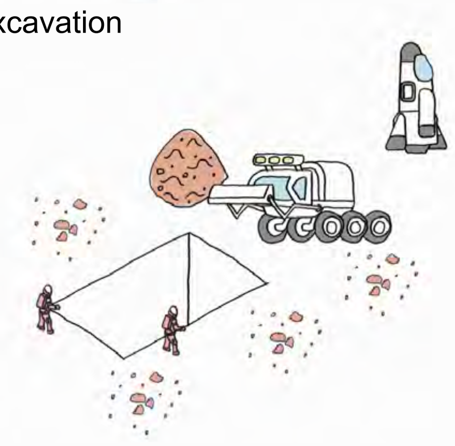
5 Floor tiles.

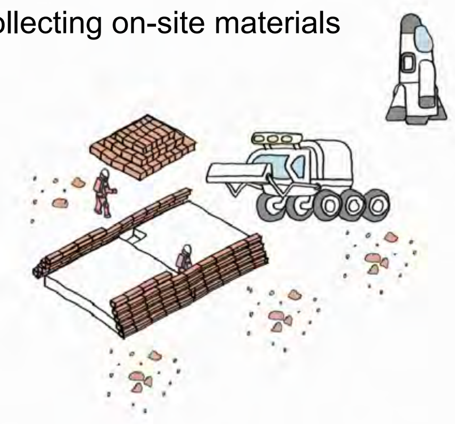
6 Window module.

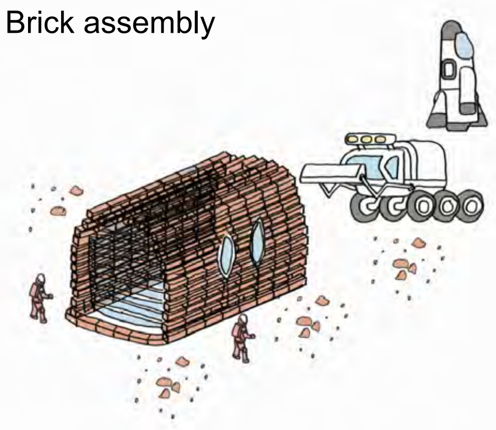
ON-SITE MATERIALS CONSTRUCTION

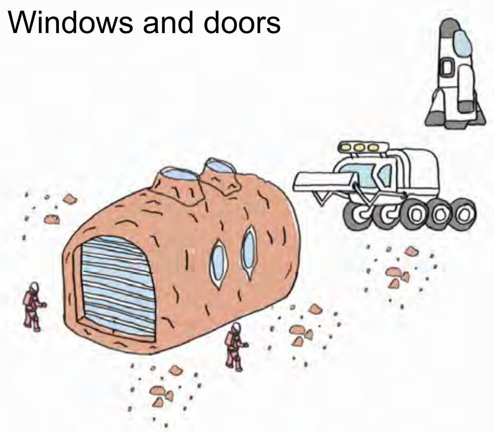

1. Site Selection


2. Excavation

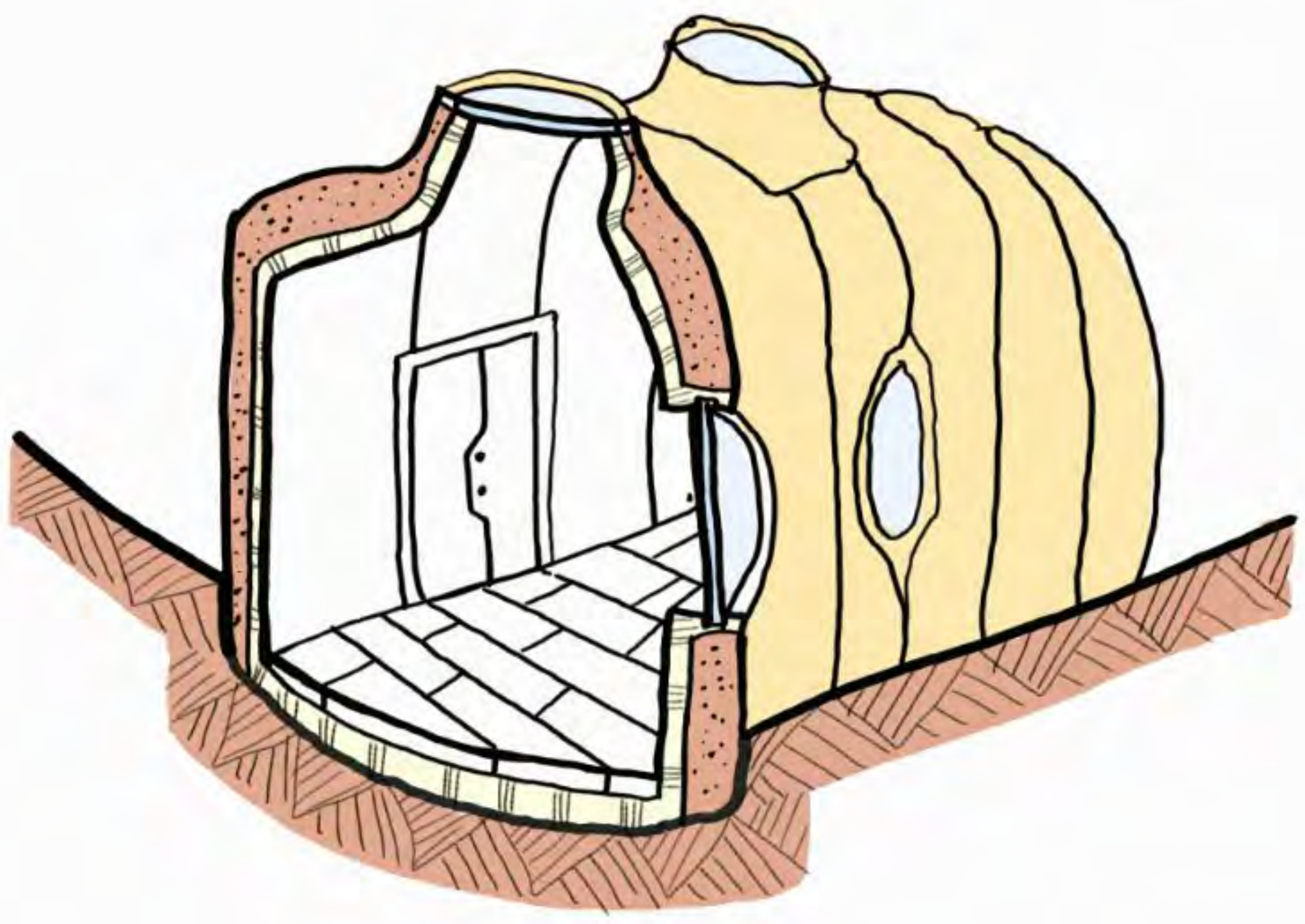

3. Collecting on-site materials


4. Brick assembly

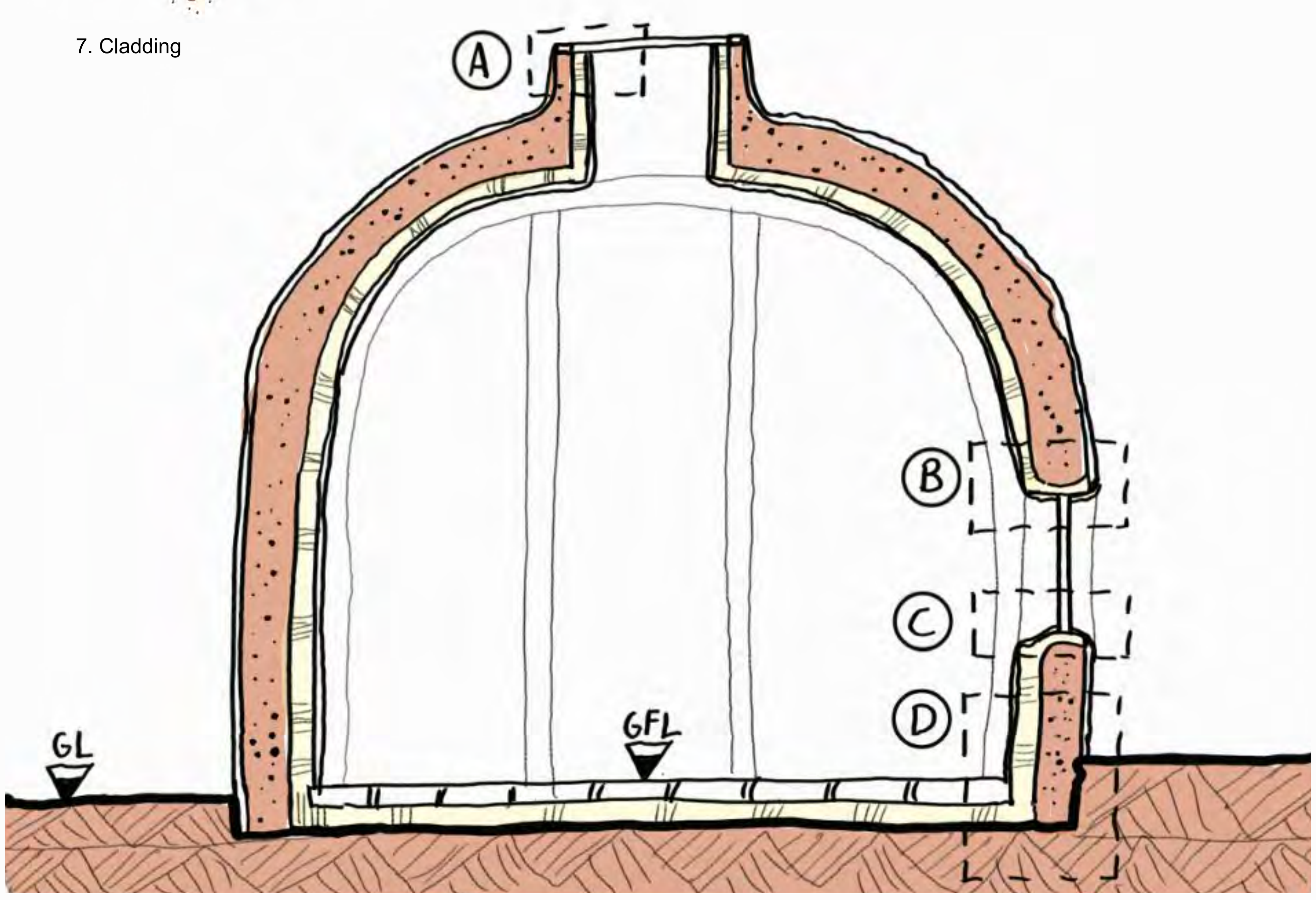

5. Windows and doors


6. Airtight regolith cover

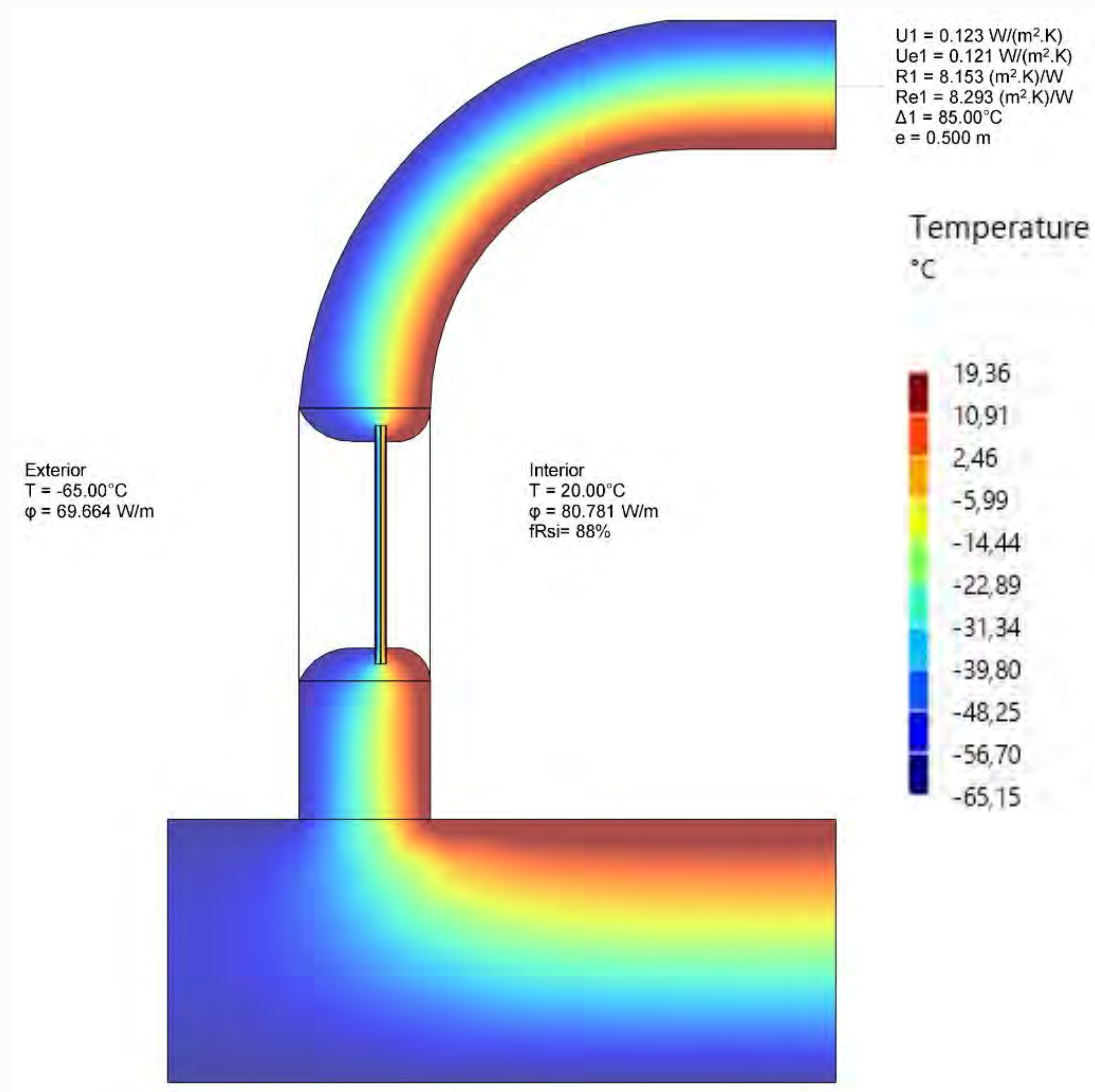
3D SECTION



SECTION - 1:20



SECTION - 1:20 THERMAL ANALYSIS



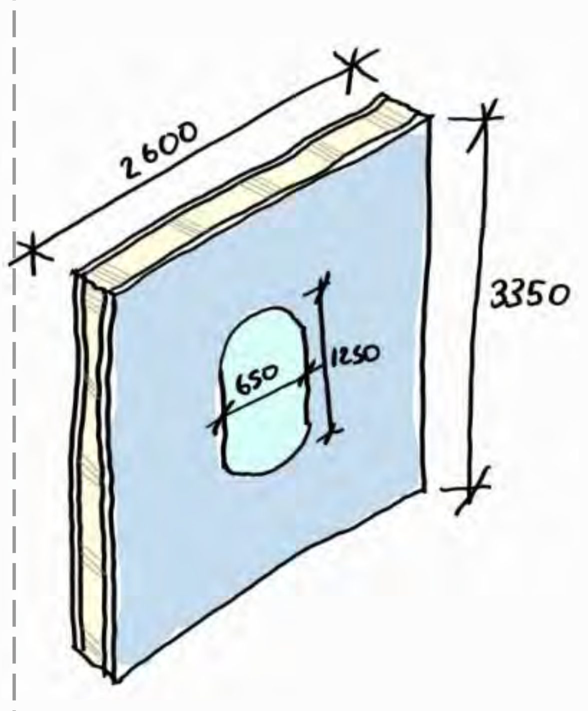
HOW DOES EXTREME CLIMATE CONDITIONS IMPACT BUILDING ENVELOPE DESIGN?

RESULTS, ANALYSIS AND CONCLUSIONS

ENERGY LOSS CALCULATION

Area (m^2) x U-Value (Wm^2K) x Temperature Difference (°C) = Heat Loss (Wm^2h)

HALLEY VI, ANTARCTICA



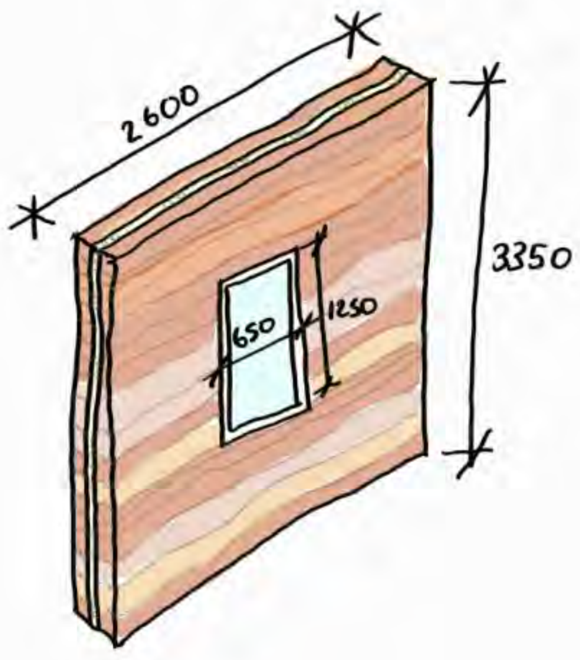
Area
Total Area: 8.72m^2
Wall Area: 7.91m^2
Window Area: 0.81m^2

U-Value
Wall: 0.113Wm^2K
Window: 1.0Wm^2K

Temperature
Outside: -28°C
Inside: 20°C

Calculation
(7.91 x 0.113 x 48) + (0.81 x 1.0 x 48) = 81.78Wm^2h

DESERT CENTRE, OSOYOOS



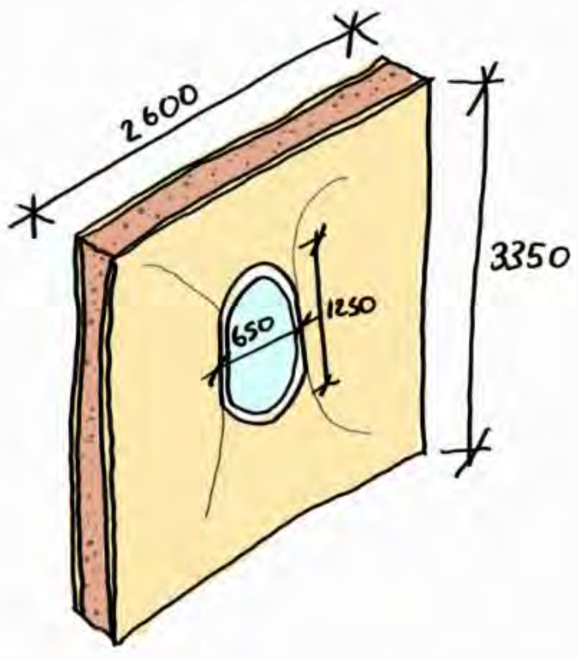
Area
Total Area: 8.72m^2
Wall Area: 7.91m^2
Window Area: 0.81m^2

U-Value
Wall: 0.21Wm^2K
Window: 1.2Wm^2K

Temperature
Outside: 32°C (Summer)
-4°C (Winter)
Inside: 20°C

Calculation
(7.91 x 0.21 x 12) + (0.81 x 1.2 x 12) = 31.59Wm^2h

MARTIAN HOUSE, MARS

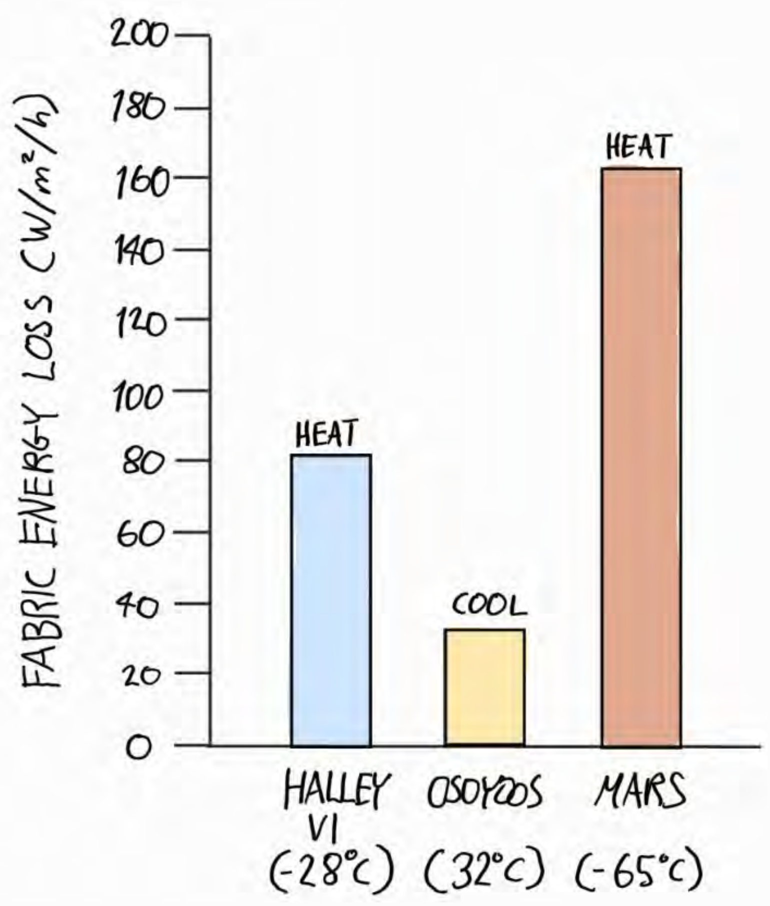


Area
Total Area: 8.72m^2
Wall Area: 7.91m^2
Window Area: 0.81m^2

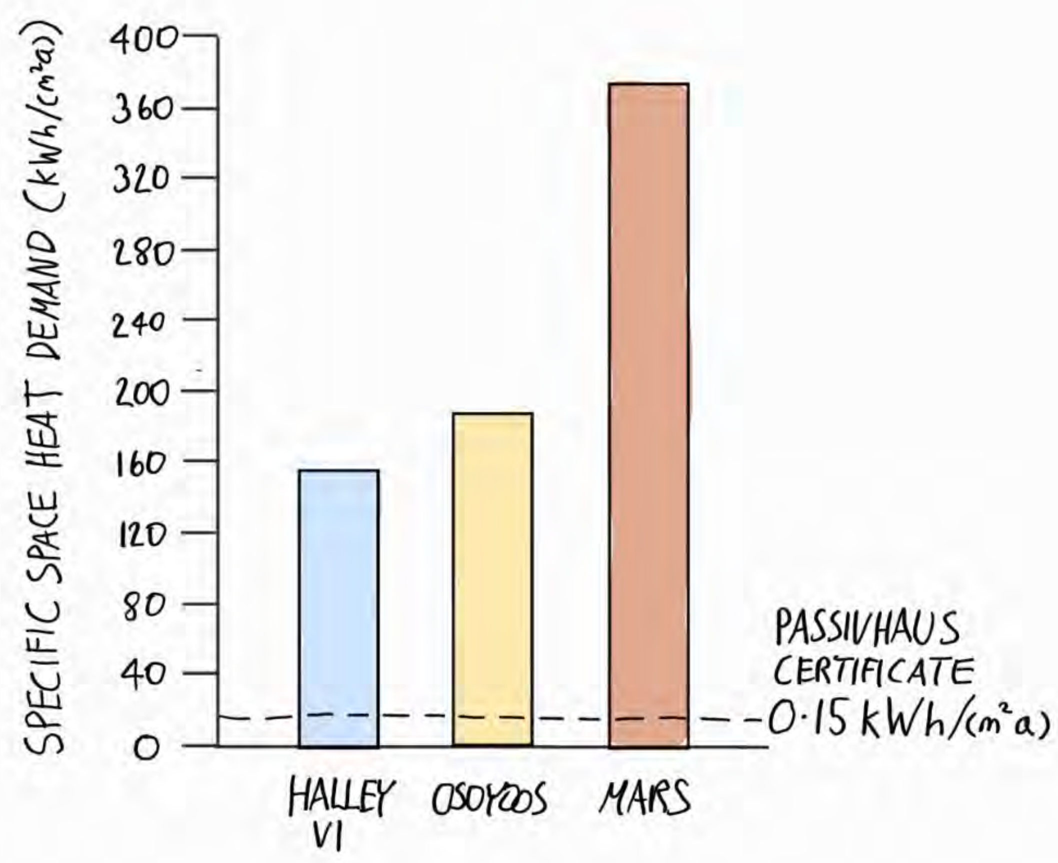
U-Value
Wall: 0.18Wm^2K
Window: 1.4Wm^2K

Temperature
Outside: -65°C
Inside: 20°C

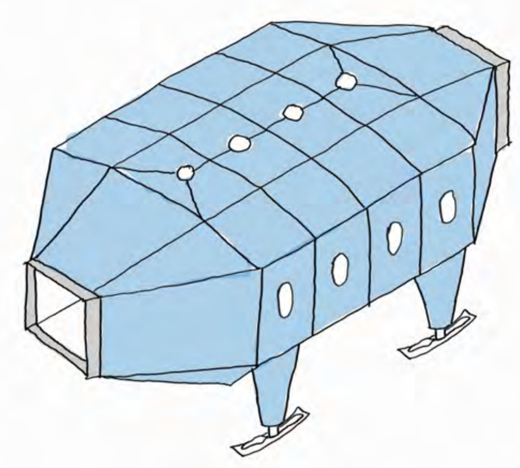
Calculation
(7.91 x 0.12 x 85) + (0.81 x 1.2 x 85) = 163.3Wm^2h



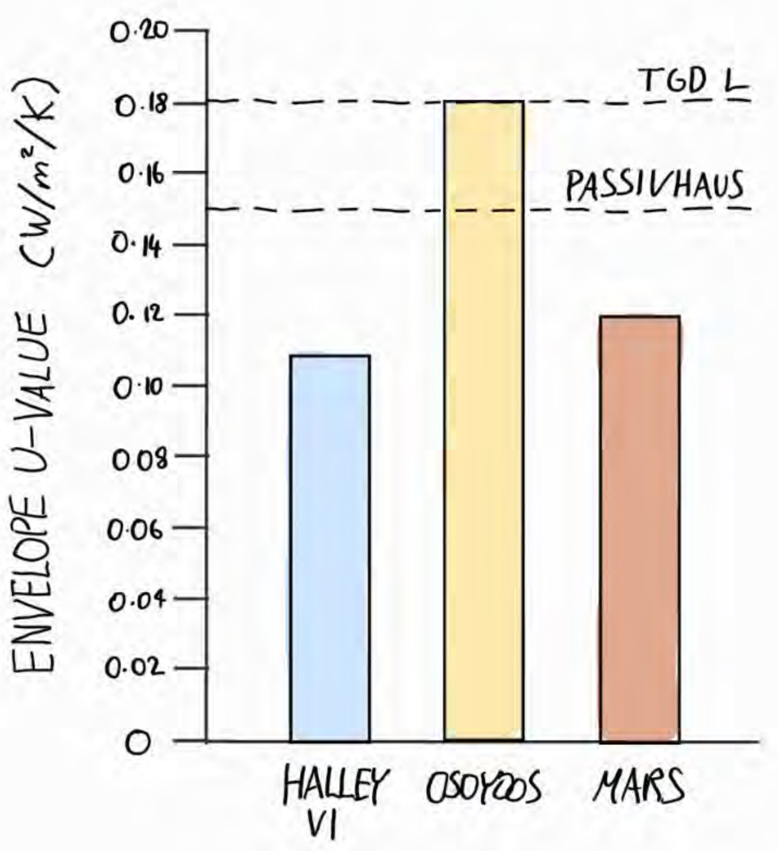
PHPP CALCULATION

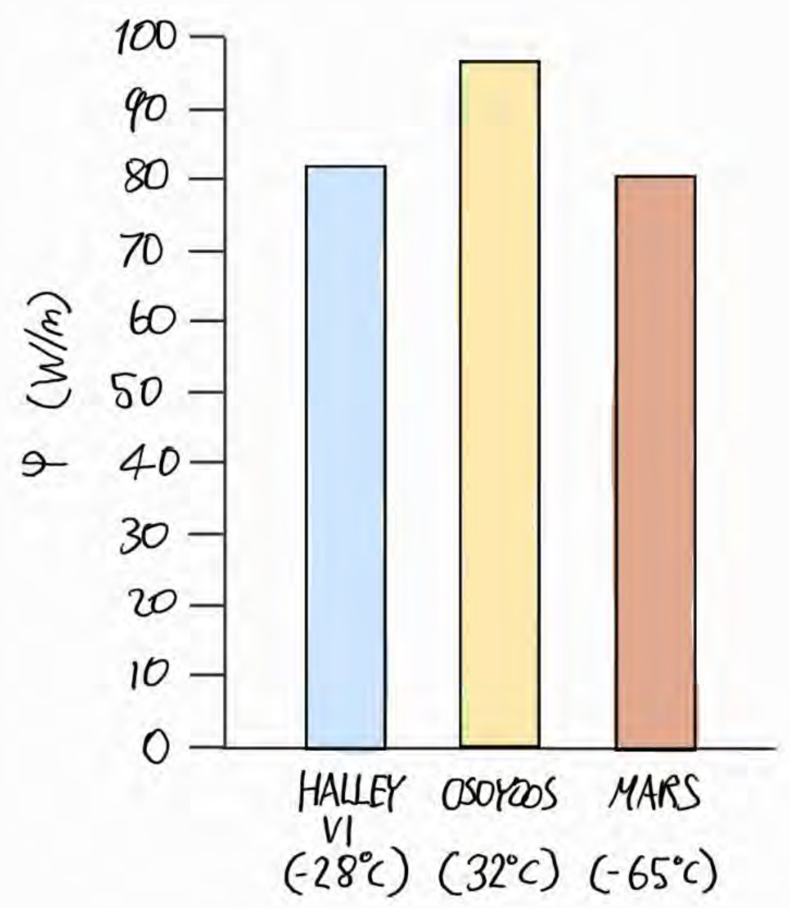


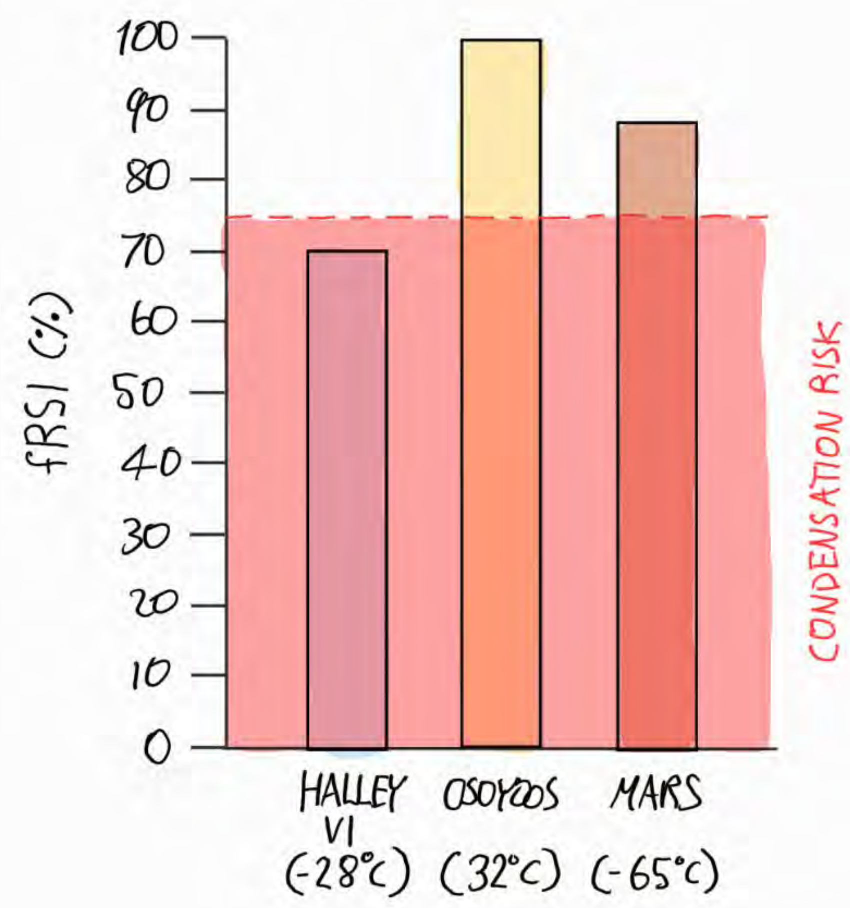
- Halley VI, Antarctica
- Desert Centre, Osoyoos
- Martian house, Mars



THERMAL ANALYSIS







CONCLUSIONS

- Halley VIs building envelope was modular to minimise construction time on-site and make transportation of materials to the site easier.
- The cladding panels design was impacted by the defects due to the extreme cold temperatures.
- The desert cultural centre took advantage of the on-site materials to create a building that submerges into the landscape to utilise earth cooling.
- To use the on-site materials to create the external envelope meant that a rammed earth construction was selected.
- The Martian house's design was impacted by the fact that limited construction materials can be transported to Mars.
- It does this by specifying a lightweight inflatable membrane that will be filled with Martian regolith to create a mass that will shield occupants from radiation.

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HOW DOES EXTREME CLIMATE CONDITIONS IMPACT BUILDING ENVELOPE DESIGN?

INTRODUCTION

MOTIVATION

An interest in space exploration.

Pushing the limits of architectural technology to the cutting edge of designing buildings for the most extreme environments on Earth and beyond.

To learn how to design for the most extreme environments outside of Ireland.

Climate change may result in us adapting our approach to designing buildings in Ireland.

AIMS

Understand what design considerations are made when designing a building and external envelope for Earth's most extreme climatic conditions.

Show how designing a building on Mars compares to the extremes on Earth.

OBJECTIVES

Produce an analytical exquisse exploring how two case study buildings are designed for the most extreme climate conditions on Earth.

Compare the two case studies on Earth to a case study concept building designed for Mars.

Carry out a thermal analysis of each case studies external envelope.

Carry out interviews with experts in designing buildings for extreme climate conditions.

SCOPE

The research acknowledges the many design considerations faced with designing a building for Mars but focuses on the external envelope design and boundary conditions.

RESEARCHERS IN THIS SPACE

Elon Musk claims SpaceX will be building a base on Mars from 2028.

NASA has held three 3D-Printed Habitat Challenges. The competition aims is to advance the construction technology needed to create sustainable housing solutions for Earth and beyond.

TIMELINE OF RESEARCH KEY EVENTS

25/01 — **Ted Talks**

30/01 — **Hugh Broughton Webinar**

03/02 — **Esquisse**

04/02 — **The Case For Mars book**

17/02 — **Ice Station book**

25/02 — **Macro Presentation**

05/03 — **Contacted Hugh Broughton Architects**

10/03 — **Documentaries**

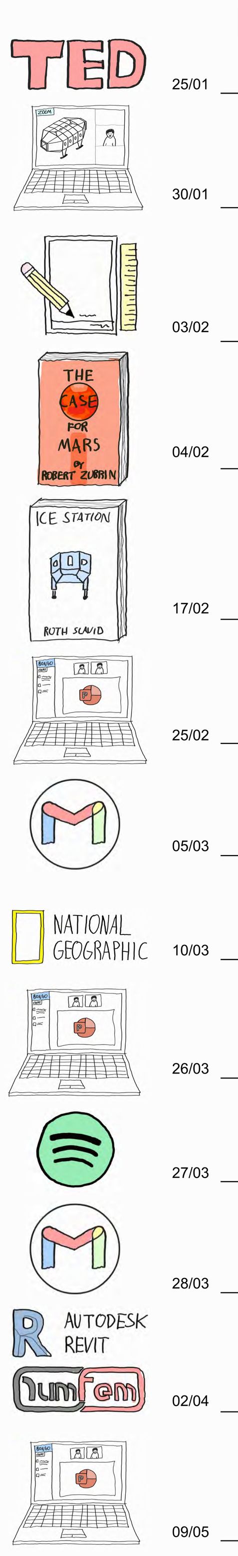
26/03 — **Micro Presentation**

27/03 — **Listened to Podcast on building a Martian House**

28/03 — **Contacted Rob Annable**

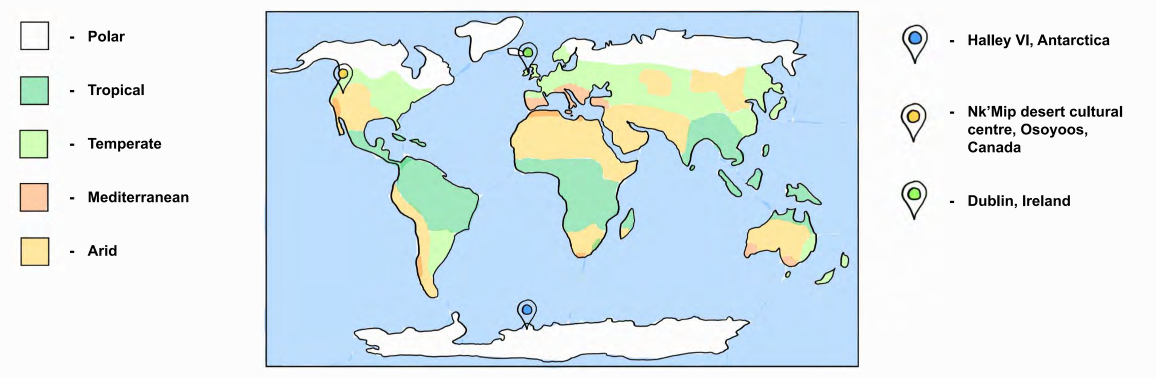
02/04 — **Thermal Analysis**

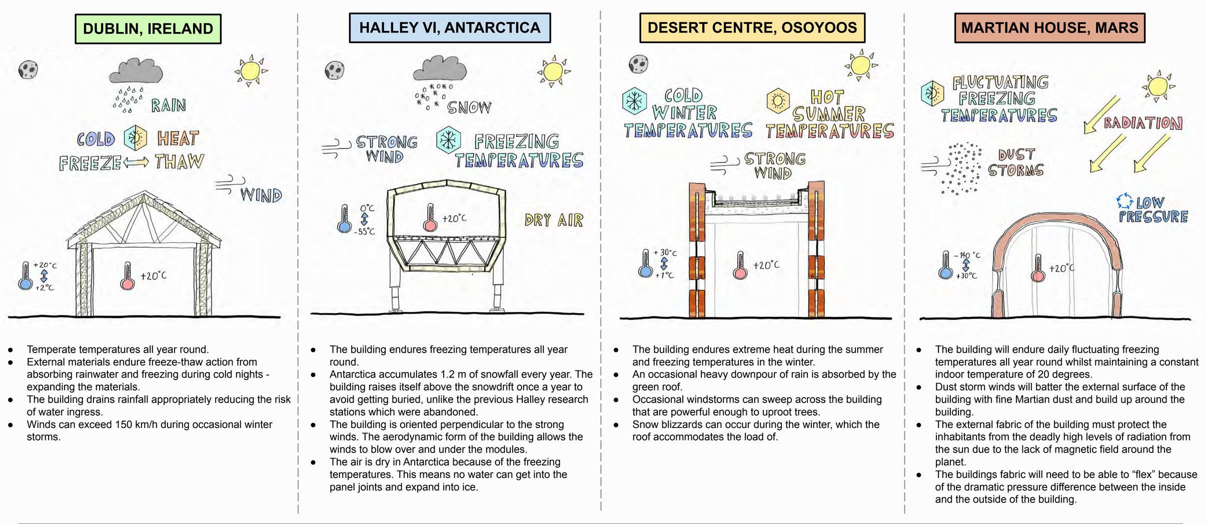
09/05 — **Final Presentation**



HOW DOES EXTREME CLIMATE CONDITIONS IMPACT BUILDING ENVELOPE DESIGN?

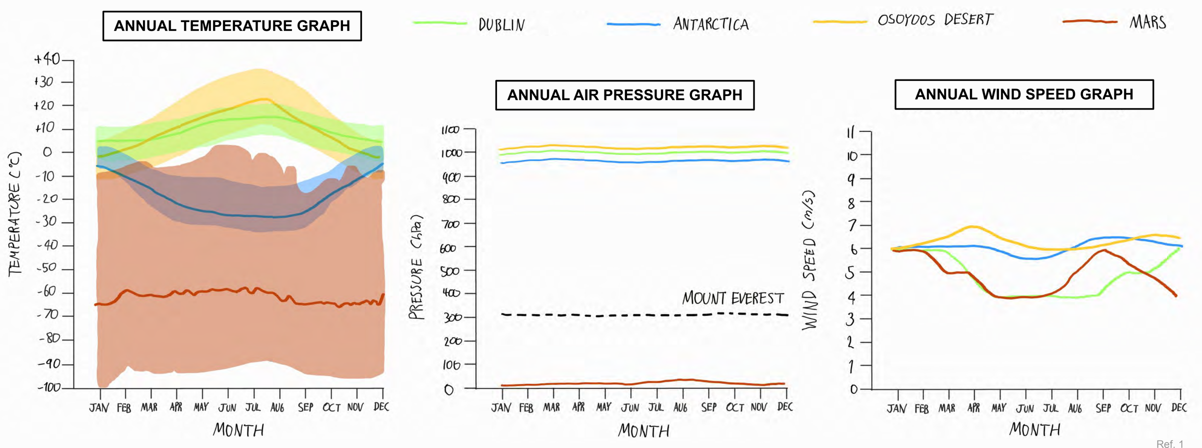
CLIMATE COMPARISON





WEATHER DATA (27/02/2021)

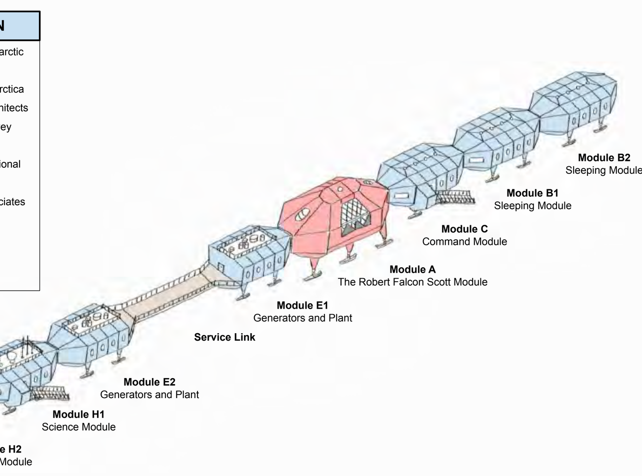
	Dublin	Antarctica	Osoyoos	Mars (NASA InSight probe, Elysium Planitia)
Temperature (°C)	11	-7	7	(-15/-73)
Pressure (hPa)	1041	981	1010	6
Wind Speed (kph)	6	14	4	14
Wind Direction	SW	S	NW	-
Maximum Gust (kph)	-	16	-	-
Humidity (%)	84	95	88	-



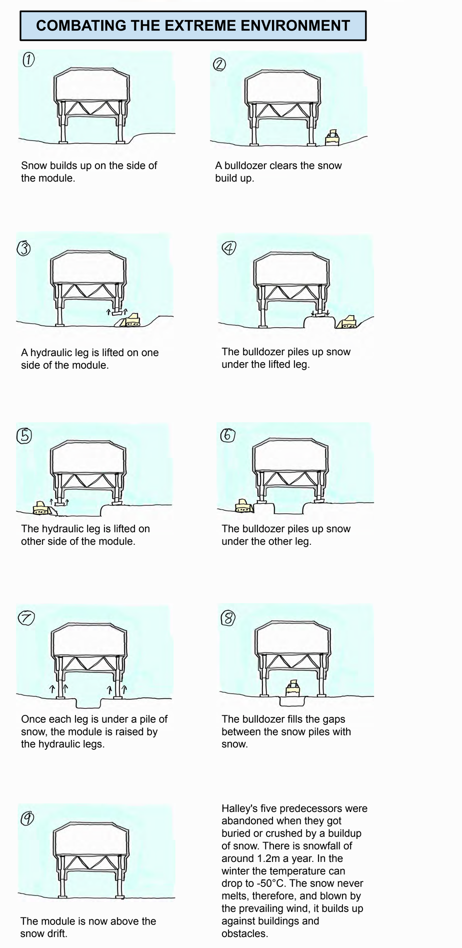
CASE STUDY 1: HALLEY VI, BRITISH ANTARCTIC RESEARCH STATION

PROJECT INFORMATION

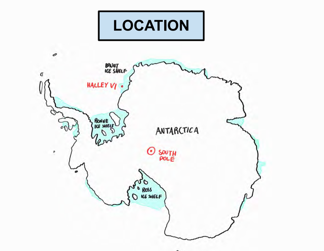
Name:	Halley VI, British Antarctic Research Station
Location:	Brunt Ice Shelf, Antarctica
Architect:	Hugh Broughton Architects
Client:	British Antarctic Survey
Engineer:	AECOM
Contractor:	Galliford Try International
Subcontractors:	Bennett Associates Billings Design Associates Colour Affects
Completion date:	February 2013
Occupant Capacity:	52 (during winter) 16 (during summer)



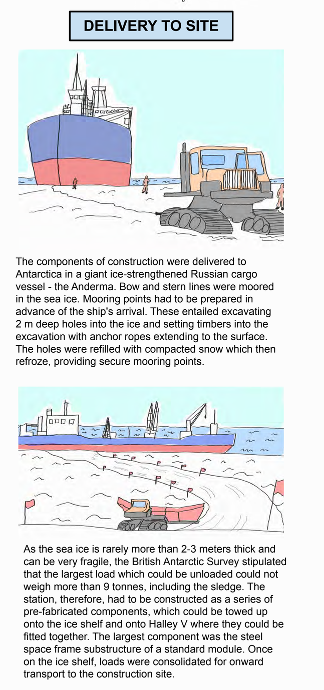
COMBATING THE EXTREME ENVIRONMENT



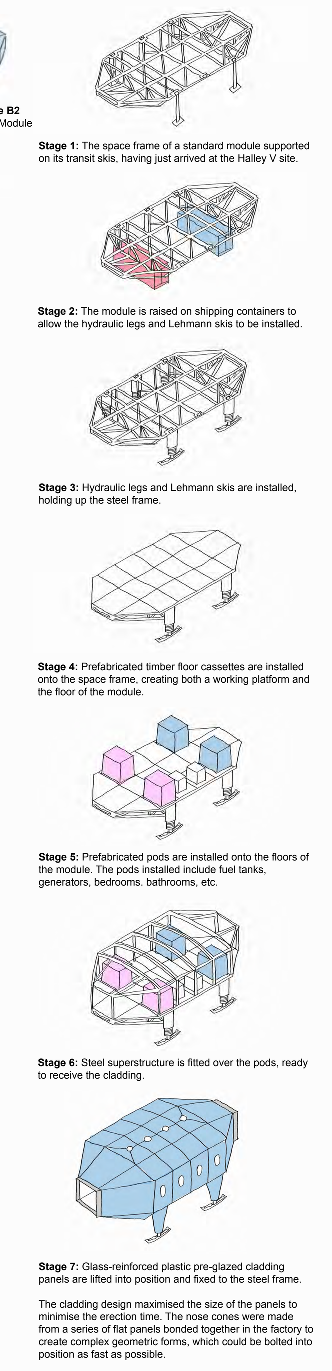
LOCATION



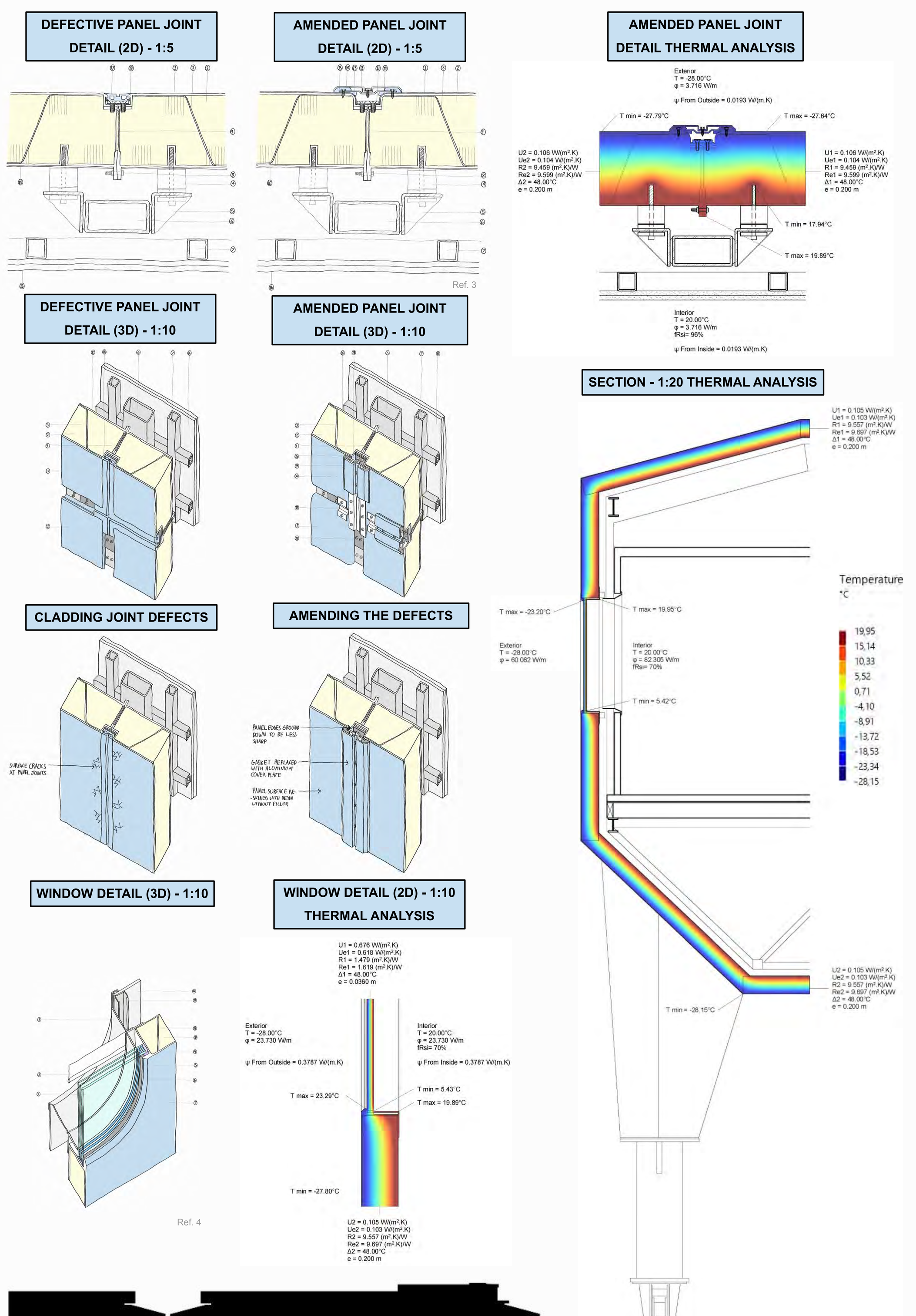
DELIVERY TO SITE



CONSTRUCTION SEQUENCE



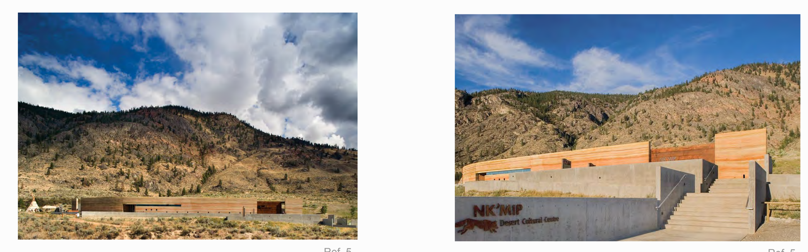
CASE STUDY 1: HALLEY VI - EXTERNAL ENVELOPE ANALYSIS



CASE STUDY 2: NK'MIP DESERT CULTURAL CENTRE, OSOYOOS, CANADA

PROJECT INFORMATION

Name:	Nk'Mip Desert Culture Centre
Location:	Osoyoos, Canada
Architect:	DIALOG
Client:	Osoyoos Indian Band
Contractor:	Greyback Construction
Engineers:	Cobalt Engineering Equilibrium Consulting MCL Engineering
Completion date:	2006
Size (area):	775m²



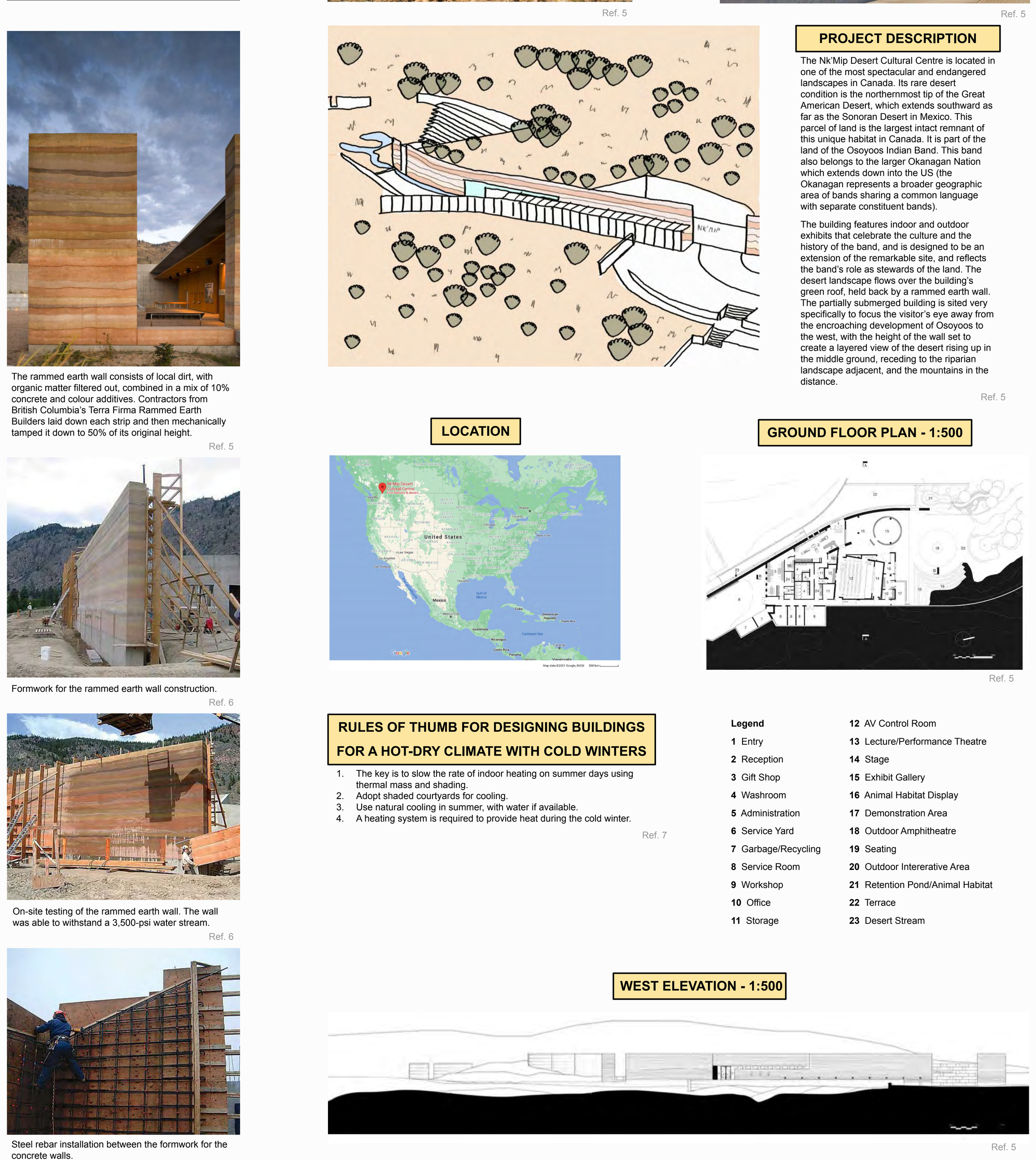
PROJECT DESCRIPTION

LOCATION

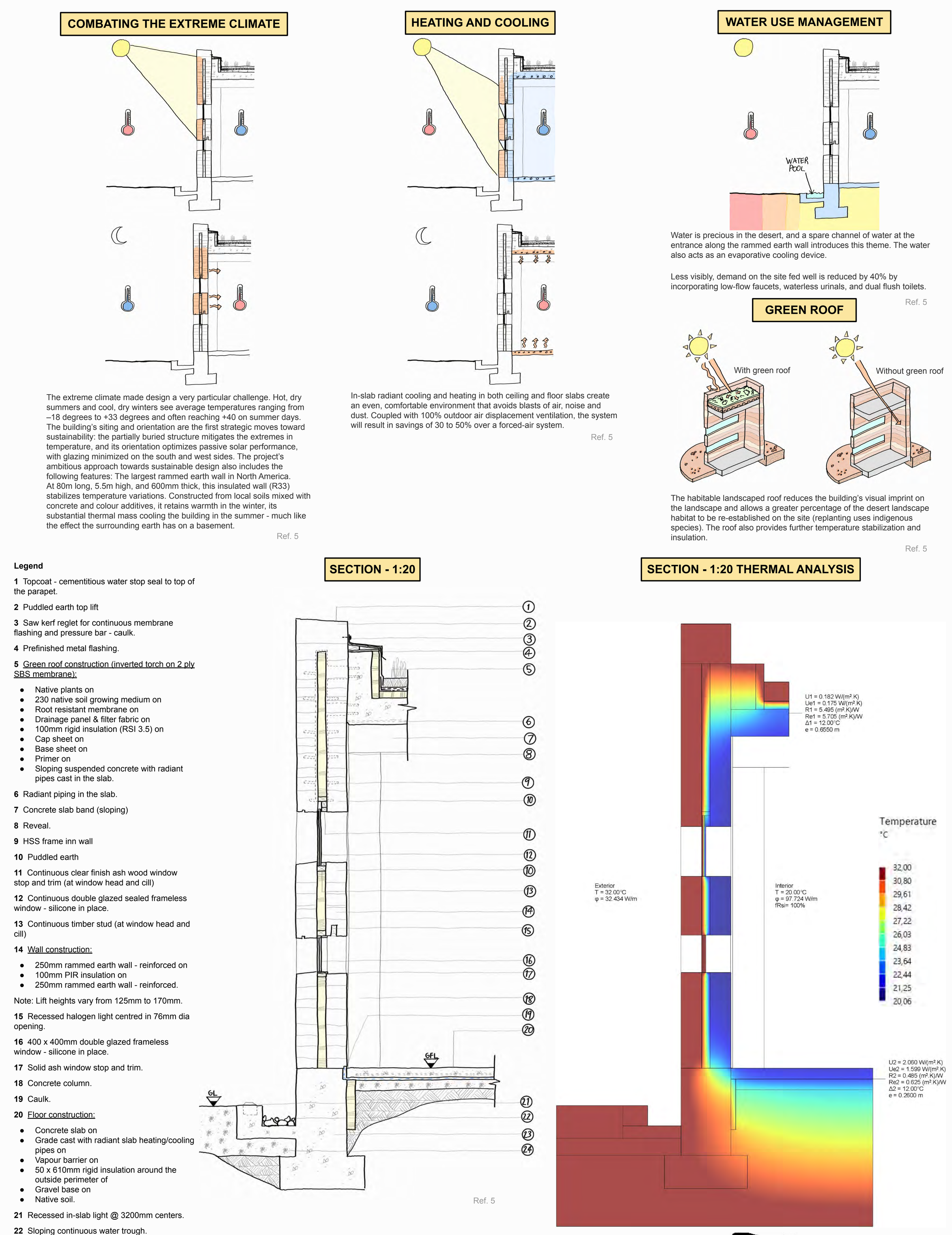
GROUND FLOOR PLAN - 1:500

RULES OF THUMB FOR DESIGNING BUILDINGS FOR A HOT-DRY CLIMATE WITH COLD WINTERS

WEST ELEVATION - 1:500

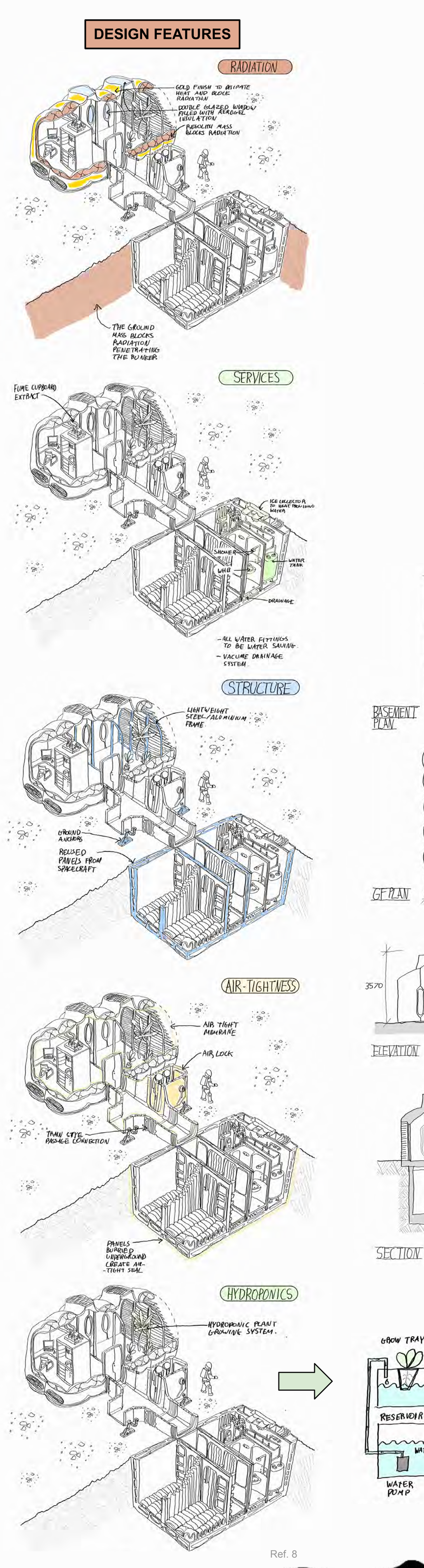


CASE STUDY 2: NK'MIP DESERT CULTURAL CENTRE - EXTERNAL ENVELOPE ANALYSIS



CASE STUDY 3: THE MARTIAN HOUSE, MARS

DESIGN FEATURES



PROJECT INFORMATION

Name:	The Martian House
Location:	Bristol, United Kingdom (prototype)
Architect:	Hugh Broughton Architects & Pearce+
Proposed completion date:	Summer 2022

PROJECT DESCRIPTION

Hugh Broughton Architects is working with multidisciplinary studio Pearce+ and the artists to produce the concept design of a Martian house based on the public's ideas.

The house will comprise two levels with an external staircase and a platform lift. The upper level, designed to sit on a Martian landscape, will be formed using a pressurised inflatable gold-coated foil, making it lightweight enough to be transported to the fourth planet from the sun and filled with local soil to provide protection from galactic and solar radiation.

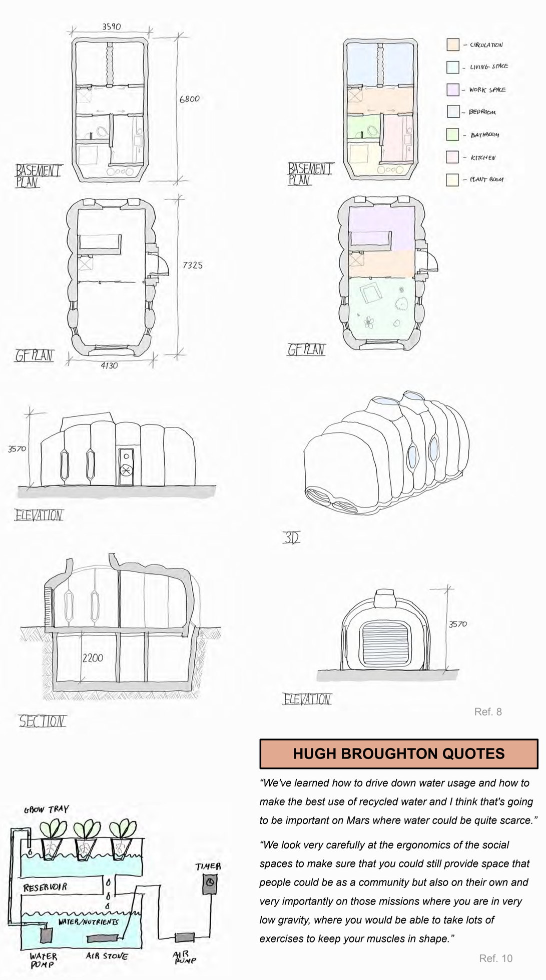
The lower level of the house is designed to be built below the ground, and so the prototype in Bristol will be surrounded by a scaffold hoarding, printed with information about the project and illustrations.

A hydroponic living room is designed to surround occupants with plants to aid relaxation. Flexible, private living spaces can be used as bedrooms, virtual reality rooms or opened into a dining room. Other facilities include a toilet and a kitchenette.

The house is due to open in April 2022 and be taken down in August the same year. It will be presented in partnership with M Shed and funded by The Edward Marshall Trust.

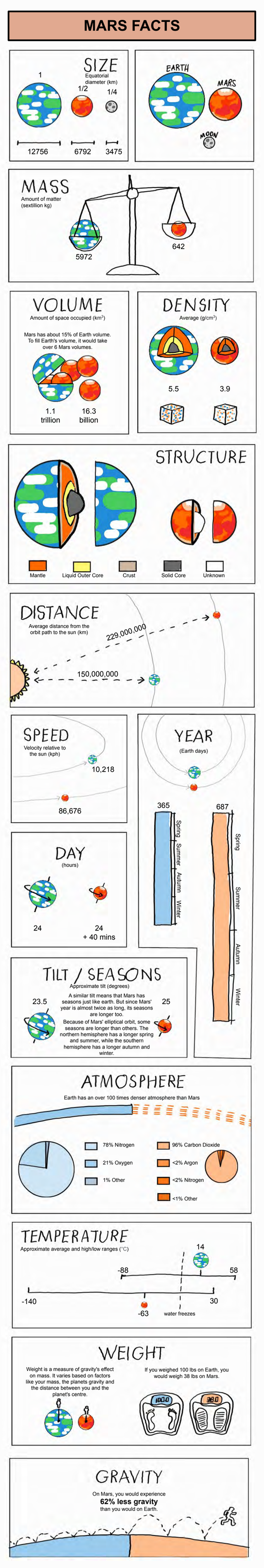
Ref. 9

DRAWINGS - 1:100

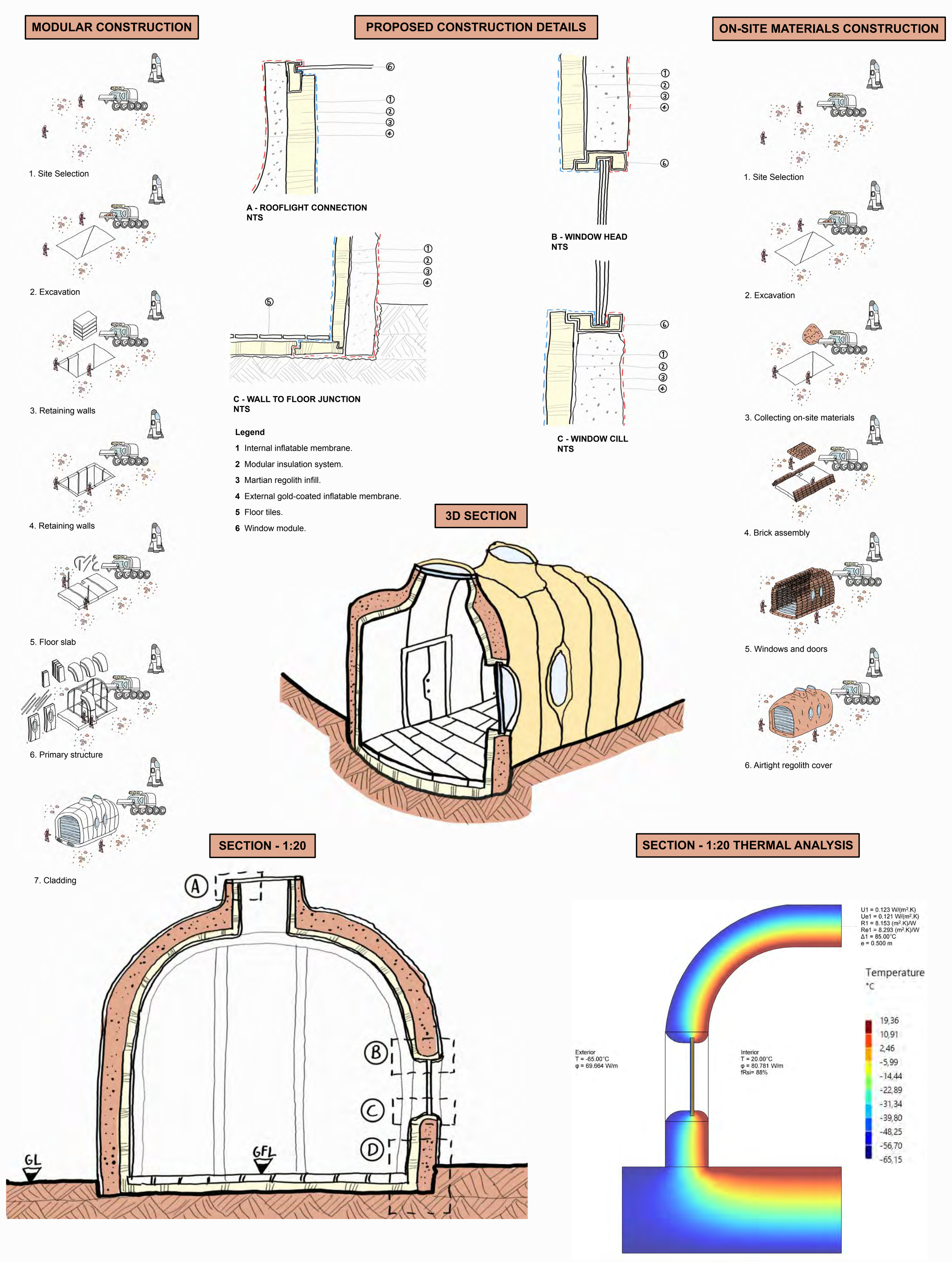


HUGH BROUGHTON QUOTES

MARS FACTS



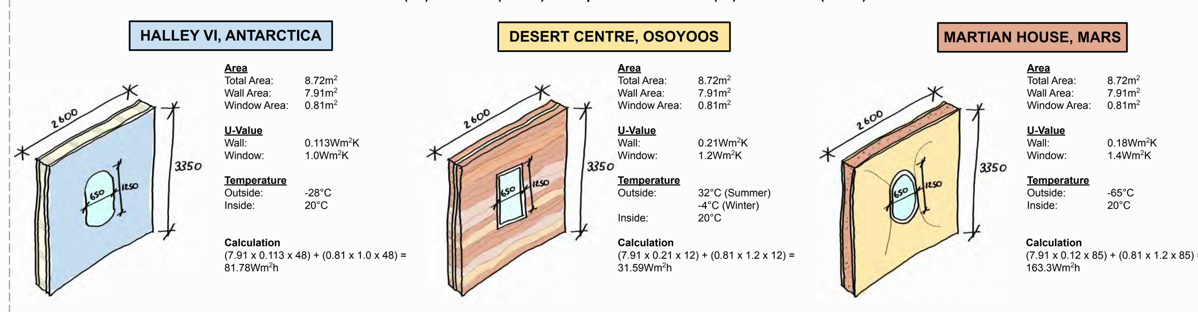
CASE STUDY 3: THE MARTIAN HOUSE - EXTERNAL ENVELOPE ANALYSIS



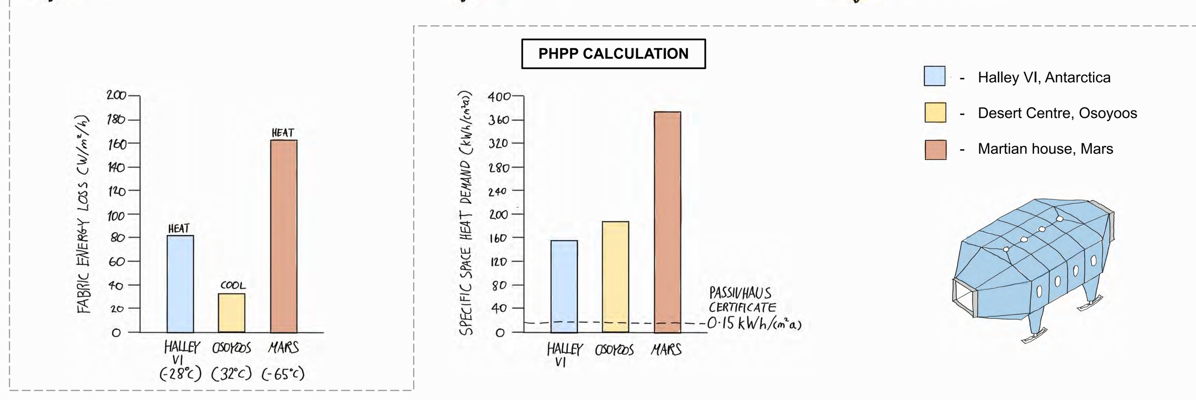
RESULTS, ANALYSIS AND CONCLUSIONS

ENERGY LOSS CALCULATION

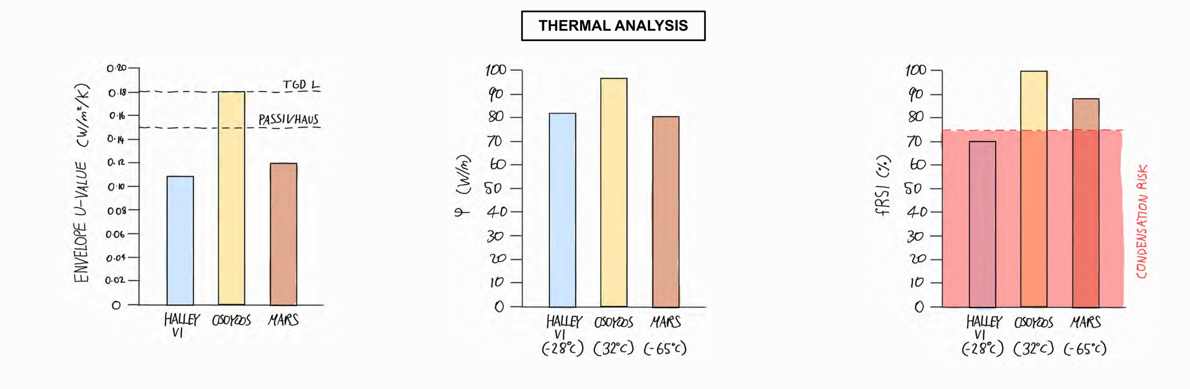
Area (m²) x U-Value (W/m²K) x Temperature Difference (°C) = Heat Loss (W/m²)



PHPP CALCULATION



THERMAL ANALYSIS



CONCLUSIONS

- Halley VIs building envelope was modular to minimise construction time on-site and make transportation of materials to the site easier.
- The cladding panels design was impacted by the defects due to the extreme cold temperatures.
- The desert cultural centre took advantage of the on-site materials to create a building that submerges into the landscape to utilise earth cooling.
- To use the on-site materials to create the external envelope meant that a rammed earth construction was selected.
- The Martian house's design was impacted by the fact that limited construction materials can be transported to Mars.
- It does this by specifying a lightweight inflatable membrane that will be filled with Martian regolith to create a mass that will shield occupants from radiation.

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