Northern Reach: Architecture for a Thawing Arctic
By: Allan Pernot

Thesis submitted to the Faculty of the Virginia Polytechnic Institute and State University in partial fulfilment of the requirements for the degree of Master of Architecture

Marcia F. Feuerstein, Chair Paul Emmons Scott Archer

ARCHITECTURE FOR A THAWING

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June 27, 2023 IC Alexandria, Virginia ALLAN PERNOT keywords: arctic, permafrost, experimental, prefab, housing, adaptability, climate research, spirit of place Copyright @ 2023 Allan Pernot As our climate continues to shift, it is fundamental to understanding these unprecedented changes through field research done in biomes most critically impacted. Due to the remoteness and extreme climatic nature of these research stations, they are typically either hastily built flat pack constructions or sterile pill boxes with little consideration of the immediate surrounding. This investigation looks at structuring the restrictions of environment to give the architecture a sense of place, rather than looking at these extremes as limitations. This proposal is sited in the Alaskan Arctic circle, where research is being conducted to understand the intertwined issues of climate change and permafrost melt. It is the intent of this project to present a prototype of a responsible and responsive architecture for Toolik Station, Alaska,a renowned destination for arctic climate research. This thesis synthesizes unpredictable site and environmental factors, elements which will become increasingly commonplace as our planet's climate shifts. The proposal for the Northern Reach interrogates and responds: How are we best equipped to live and work in a rapidly changing measure of extremes? What imbues an architecture with a sense of place when that place is inherently mercurial? 

This investigation seeks to understand the unprecedented effects of climate change on critical research, which is often conducted in remote and extreme areas of the planet. These challenging living conditions significantly impact the longevity and effectiveness of such research. The project focuses on examining the extremes of living and working as a field scientist in Toolik Station, Alaska, and proposes housing and accommodations that are better suited and more sensitive to the site than the existing ones. The proposed project can serve as a prototype for replacing other buildings at the selected site. 

Introduction Interview with Dr. M. Syndonia Bret-Hart of Toolik Lake Station Findings Process Proposal Conclusion References: Bibliography References: Images
INTRODUCTION

The rapidly changing climate will disrupt many natural cycles, and changes in the arctic landscape are no exception to this rule. The freeze-thaw cycles within the active layer of permafrost in the arctic has led to the altering of soil structures, and by association, an acceleration of collapse within this critical biome. Not only does permafrost collapse contribute to the degradation of existing infrastructure and the displacement of peoples within the Arctic, but lying trapped in the permafrost lies a massive amount of stored carbon, primed to be released into the atmosphere. 1,700 billion metric tons of carbon lie trapped in Arctic permafrost, including methane and carbon dioxide (NASA JPL, 2022). Only through extensive monitoring can scientists effectively provide appropriate interventions to address permafrost melt. For precise monitoring, ground measurements are used, which gives a clearer understanding of how quickly permafrost is melting and to the extent of its carbon emissions."

Nearly a third of Arctic research is based on data from just two field stations: Abisko, Sweden, and Toolik Lake, Alaska. And researchers usually collect data during the Arctic's short summer field season, even though winter conditions may look very different, making conclusions less accurate. (Parshley, 2022).

Research for this thesis began by looking at the season limitations for data collection at Toolik station. Through improved and more appropriate infrastructure at the Toolik station, more research can be conducted year-round to give a better perspective on changes to our climate. For this reason, this thesis is sited at the Toolik Lake field station, which is operated by the University of Alaska Fairbanks.

. Figure 1.

Tusk from a woolly mammoth discovered in a creek bed on Wrangel Island in 2017

. Adapted from "

Million-year-old woolly mammoth DNA discovered by scientists in northeast
INTERVIEW Interview with Dr. M. Syndonia Bret-Hart, Staff Biologist at Toolik Lake Research Station

In this interview, conducted on January 7, 2023, I had the privilege of speaking with Dr. M. Syndonia Bret-Hart, a renowned staff biologist at the Toolik Lake Research Station. Dr. Bret-Hart's extensive expertise and research contributions have played a crucial role in advancing our understanding of the unique ecosystem at Toolik Lake. Throughout the interview, we delve into Dr. Bret-Hart's experiences, insights, and valuable perspectives on the station's research activities, ecological dynamics, and the significance of their work.

(A: Allan Pernot S: Dr. M. Syndonia Bret-Hart) A: "Can you talk about the restrictions of working at Toolik?" S: "You form very tight friendships when living in the arctic here. Something to comment on is the separation of living spaces and residences, there are other stations in the arctic, particularly international stations which have integrated buildings, which have wonderful residences and integrated bathrooms...its all inside, everyone takes their shoes off when they come inside, they don't have to get dirty to access the lab spaces and the residences, but they rely on very different funding and philosophy. It's hard to have a super clean lab or living conditions when you have to walk across the gravel compound to access different amenities. It would be great to have a hud structure where all the labs and residences are connected, but that's just not very realistic. The Hud building in Sweden's Abisko station is ideal in that sense, but it's a very difficult challenge for them to expand their lab spaces and housing. You're also dealing with very different conditions here, where it can rain or snow at any time, but during the summers it's nice enough that some people elect to camp by the lake." Figure 2. Location of Toolik Lake Field Station on the Alaska map. To the right is the typical summer conditions at the station. Adapted from "Camp Map" by Toolik Lake Field Station,
How do researchers access their sites? S: The boardwalk to the south is used by a majority of the scientists to gain access to their data collection. Trucks are used to bring people back and forth from the Fairbanks campus. A: For folks that have work out in the field who need to be flown in and out, do they camp or do they fly back the same day? Do they overnight with fieldwork? S: Most people fly out and come back in the same day, due to the fact that the NSF sponsors the helicopters. There are some exceptions. There's a group which count fish at the nearby lake, the greylings, which are a kind of trout, and one of the 6 most significant species in the area...they leave their lakes to lay eggs in nearby streams and need to return to the lakes during the winters to not freeze, so we monitor their population changes and genetics, so we have a small group that camps out at their field site for days at a time. That lake is far enough away to necessitate a camp, and they stay for a week, up to 10 days at a time, but most of our other resident scientists who go far out into the field still will fly out and return the same day. There are groups that are looking at snow which use snow machines, and if they go far enough they will camp, and if that's the case they will supply all of their own equipment.” A: How often do the residents of Toolik interact or sight fauna, especially during migrations? Figure 5. Toolik Station boardwalk with typical outfitted researcher en route to their field site. Adapted from “Ecological Research in Alaska” by Drone Harmony, 2023, https://droneharmony.com/ecological-research-alaska/.

The caribou will pass by Toolik, we see them in the autumn and the spring during their migrations, those who study them will have tracking collars and fly planes overhead to track their migrations. A: Can you expand on the other groups’ research? S: Most of the groups we have working here are working on smaller mammals like ground squirrels or microbes. We've also been looking a lot into the effects of abrupt permafrost thaw, thermokarst, as the climate changes A: That's the actual permafrost collapse? Can you expand on that please? S: Yeah, so permafrost isn't uniform. Permafrost definition is ground that doesn't thaw for 2 or more years. Underneath the part that does thaw, the active layer, where all the life happens, is the part of permanently frozen ground. And that ground isn't uniform, there are parts that have big ice wedges, and parts with more soil and less ice, and whether those ice wedges thaw affects what happens on the surface. Sometimes you get catastrophic thaw, where a big ice wedge melts and it triggers a chain reaction around it. You get what is called a Thermokarst, where there is an abrupt thaw and a lot of local changes, and the frequency of these is increasing. We have groups that have been studying those in the last few years. When thermokarsts happen, you usually get a spike in emissions, at least for the short term. Figure 6. Abrupt permafrost thaw. Adapted from “Thawing Permafrost Could Leach Microbes, Chemicals Into Environment” by NASA Climate, 2023, https://climate.nasa.gov/news/3153/thawing-permafrost-could-leach-microbes-chemicals-into-environment/. Figure 7. The effect of uneven permafrost thaw on infrastructure. Adapted from “Tautender Permafrost bedroht Infrastruktur” by n-tv, 2023, https://www.n-tv.de/wissen/Tautender-Permafrost-bdroht-Infrastruktur-article23049411.html. Figure 8: Steve Jurvetson. “Permafrost thaw ponds in Hudson Bay, Canada in
FINDINGS

Toolik station seasonally hosts roughly 100 students, but the core of the program focuses on the 24 or so scientists that work year-round. The program was expanded to include year-round housing and facilities for 30 scientists, with ease of access to labs for environmental and biological research. The environmental and programmatic constraints are as follows:

Environmental (region specific) Polar night Midnight Sun Aurora Borealis Building on permafrost High wind/ snow drift Mild summers Programmatic (Toolik station specific) Mobility and lab access: (getting scientists out to conduct field work)

Views of the Brooks Range Cleanliness Waste and Water Management

PROCESS

Massing Work began experimenting with forms through sculpting foam to understand basic needs of a an adjustable foundation and its implications on entry. the idea of a sloping roof with a "conning tower" to house instruments and provide views, as well as to provide a visual point of reference for the station from a distance. Through these experiments in exterior form-finding the ideas which later show as the immediate recognition of the station, as well as ideas for the cladding of the final structure. Unit design The interior of the individual units was also explored in physical model format. For space-saving effectiveness the program for the Northern Reach explored dorm style bunks, however the bunk bed split the space of each dorm into two separate units to offer privacy and the ability for individual quarantine in the case of emergency. Extra attention was given to the allocation of individual storage within these rooms, which allow for cleanliness of the units:
seasonal clothing and individually supplied field equipment can be stored in overhead bins or within cavities created by the nested spaces. Figure 11. Massing and unit design. ©Allan Pernot

**PROCESS Plot** Selection The site chosen for the Northern Reach is the existing site of the outdated and disused community center at Toolik Station. This chosen plot is the furthest south on the compound, with ease of access to the field work boardwalk, as well as stunning uninterrupted views of the Brooks Range to the south of the site beyond the walkable field research areas. First Iteration The first iteration of the Northern Reach took the axis of the boardwalk and treated it as a structural and walkable backbone for the campus. Weather instruments were proposed to be mounted on this footbridge. The nested unit design was expanded into housing blocks and stitched together with niche community areas. A main community room took advantage of the wide views of the Brooks Range. A system of operable PV shutters was designed to screen the common room during the midnight sun phenomenon. An oculus viewing platform was proposed in the center of the massing to serve as a focal point and to allow viewing of the Northern Lights during the winter months. Many of these early ideas informed the final design. Figure 12. Aerial view of an early rendition of the Northern Reach, looking south towards the Brooks Range. Highlighted is the path from the Reach towards the field concept. ©Allan Pernot

**PROCESS Summer** 1 Prefabrication Due to the remoteness and extreme seasonal nature of the site, the Northern Reach is constrained in its construction methods, and bound to small windows of feasible construction time. To compensate for this, the scale of the project was cut down. Using the unit as a pre-fabricated block, a system was devised to construct the project over three summer seasons. The mass of the Reach is divided into three constructible segments. Each segment consists of a space-frame structured platform floor which will be constructed on site. This platform floor will house the adjustable footings which separate the platform from the permafrost ground below. Each unit (composed of two rooms split by a bunk bed) will be a prefabricated module composed of structurally insulated panels. These modules will be stacked and anchored to the platform floor, composing the main volumes of the Northern Reach. Summer 2 This early rendition illustrates the process of construction attaching 4 prefabricated housing modules to each platform structural floor, and how this process would be repeated over three seasons to produce the tri-segment Northern Reach. Figure 14. Prefabrication process for early Summer 3 design concept. ©Allan Pernot S Front Porch A series of photographs by Eirik Johnson known as “Barrow Cabins” depicts Alaskan native hunting cabins at the peaks of the summer and winter season. The simplicity and clarity of the hunting cabin typology was incorporated into the development of the project, the hunters being the scientists trekking out into the field to collect data and return. With its placement as the most prevalent point at Toolik Station, this focal segment of the project functions as a front porch during the warmer months and a hearth during the colder ones. Visibility To maintain a better
visual presence at a distance, the chimney from the hearth was extended upwards, as well as the moveable PV fins. For the same reason, galvalume cladding was chosen for the exterior of the building, with its ability to reflect the sky and blend in to its surroundings up close, but to be reflective when seen from far. The decision to extend the stove's chimney and porch panels upwards would later influence a massing change and introduce a stronger vertical element. Figure 15. Eirik Johnson.

Barrow Cabins Picture depicts seasonal hunting cabins built by the native Iñupiat, inhabitants of Utqiaġvik. Photo by Eirik Johnson. Accessed March 6, 2023. https://www.eirikjohnson.com/projects/barrowcabins. Figure 16: Approaching an early rendition of the Northern Reach, looking north, traversing the boardwalk from the field work sites south of the Station. ©Allan Pernot

Figure 17. Visualizing the effects of snowpack on an early rendition of the Northern Reach. Part of the galvalume cladding has been stripped away to visualize the stacking of the prefabricated units. ©Allan Pernot

Adjustable Foundation A foundation was devised which can raise and lower the building to accommodate heat radiation, lessen the buildup of snowpack, and to allow the uninterrupted movement of migrating animals during the winter time. In this section through an early rendition of the Northern Reach community room/hearth space, the summer configuration of the building can be seen low to the ground with the access ramp lowered to access the storage area, and a stair set to gain access to the community room and fireplace. The winter configuration can be seen raised up on the adjustable foundation, (Slavid, 98) with the ramp raised and the stairs raised up and configured as a railing. This concept was further explored for the ultimate proposal. Figure 18. Summer configuration concept. ©Allan Pernot Figure 19. Winter configuration concept ©Allan Pernot

Final Configuration The final process development sought to create a more distinct hierarchy of mass: Splitting and rearranging the masses for more distinct hierarchy of masses centralizing the porch, splitting the mass of the building into 3 distinct volumes. This was done to solve egress problems resulting from this construction taking 3 summer seasons to finish. This configuration has two means of egress per volume, resulting in 3 independent buildings linked to and unified by a distinct central building: a social hub and two housing wings. This configuration also saw a departure from the adjustable PV screens, replaced by a more controlled ETFE vestibule screen. final process central massing concept on site model Figure 20. “Facade of Award: Dynamic ETFE Façade.” Illustration by Architect Magazine, n.d. Accessed July 7, 2023. https://

www.architectmagazine.com/awards/award-dynamic-etfe-facade

Figure 21. Final massing and site configuration. ©Allan Pernot

The Architecture of a Thawing Arctic
Toolik Station's front porch is divided into 3 pieces: 2 wings of housing and a central community space stitching the masses together. Treating the middle mass as a veritable porch of Toolik station, during the warmer months residents can use the outdoor space, and during the cooler months it acts as a hearth to warm up and view the Brooks Range. Figure 22. Views of the Brooks Range and the hearth in the central portion of the Figure 23.

Approaching the station by foot, this also disperses the radiant heat from the winterized building, preserving the permafrost below. Without this feature, a thaw bulb could occur, resulting in uneven settling or foundation failure (Sheppard, 168). The adjustable foundation design can also account for minor uneven settling of the unstable ground to keep the building level (Sheppard, 190). 2. Adjustable ladder stair access to the front of the building is added to account for the winter height of the platform.

3. Fire escape ladders are lowered to accommodate for winter heights. Summer Configuration 7. Adjustable foundation is at its lowest height. The adjustable foundation design can also account for minor uneven settling of the unstable ground to keep the building level (190). 8. Wide summer planks are attached to the porch. The lowered configuration means fewer, wider stairs to accommodate the increased use of the Reach during the summer intern season. Adjustable ladder stair access is detached and stored for winter. 9. Fire escape ladders are raised to accommodate for summer height.

Figure 24. “Winter and Summer configurations of Northern Reach” ©Allan Pernot

©Allan Pernot

UP

GROUND PLAN DN UP South Elevation DN UP DN UP UP DN DN DN LEVEL 1 Summer: +2’ Winter: +8’ Ground Floor North Elevation DN DN DN OTB OTB DN OTB UP DN OTB DN Page 25. “Plans, section and elevations” ©Allan Pernot LEVEL 2 East Elevation West Elevation GROUND PLAN DN UP DN UP 1 2 9 8 7 UP DN DN UP 1 2 3 5 4 DN DN 6 LEVEL 1 Summer: +2’ Winter: +8’ Ground Floor 1 Housing wing prefabricated bunk units (typ) 2 Housing wing prefabricated bathroom unit (typ) 3 Residential Social Stair 4 Community Room 5 Hearth 6 Porch with adjustable vestibule 7 Locker room/shower room 8 Kitchen 9 Storage and loading ramp DN DN DN DN OTB OTB OTB DN DN DN Winter: +8’ Ground Floor 1 2 DN 7 DN DN DN DN 3 5 DN DN OTB OTB 4 UP 6 DN OTB DN LEVEL 2 1 Housing wing prefabricated bunk units (typ) 2 Housing wing prefabricated bathroom unit (typ) 3 Residential Social Stair (below) 4 TV/projector/meeting room 5 Library 6 Reading room 7 Station manager office 9 4 1 5 6 3 7 8 2 Section aA (enlarged) 1 Housing wing prefabricated bunk units (typ) 2 Residential Social Stair (below) 3 TV/projector/meeting room 4 Oculus 5 Library 6 Reading room 7 Community Room 8 Hearth 9 Viewing room South Elevation (enlarged) a
C TYP 2-UNIT BLOCK

Final unit design finalizes the development of the niche spaces created by splitting the unit envelope using the bunk to create two separate rooms accessed by separate entries. Each unit has its own sink and mirror. Attention was given to maximizing storage within the unit. Overhead bins store seasonal clothes and equipment. Built-in cabinets separate the desk from closet space. Tambour style doors conceal cluttered closet storage. The unit module is designed as a structural block, using structurally insulated panels (SIPs) to create a modular block, as seen in Amundsen-Scott South Pole Station (Slavid, 102).

PROPOSAL

unit model constructed at 1/4"=1'. Ceiling SIP removed for visibility unit model constructed at 1/4"=1' Figure 27. "Model of Living Units” ©Allan Pernot

PROPOSAL

Residential Social Stair Each of the two residential social wings is composed of 6 prefabricated unit blocks and 2 bathroom blocks. Two floors are held together by an open stair, which features built in areas for storage and seating. Above the volume carved out by the stair, an oculus bathes the space in light from above. Figure 29. "Model of social stair” ©Allan Pernot residential social stair model constructed at 1/4"=1' stair forming social space within housing wing connection to main residential social stair exit stair housing wing with exterior skin, over-framed pitched roof, and oculus Figure 28. “Social Stair” ©Allan Pernot Figure 30. "Residential social stair render” ©Allan Pernot Figure 31. "Approaching Toolik Station from the south via helicopter during polar night, 1 pm" ©Allan Pernot The Northern Reach is clearly visible with its illuminated ETFE vestibule 45 Figure 32. "Northern Reach during Aurora Borealis” ©Allan Pernot The adjustable cribbing foundation is raised during the winter months to allow snow clear under the station instead of accumulating in drifts

CONCLUSION

The hope of this thesis is to instill a sense of stewardship towards the environment and climate; that even as extreme weather and site become more commonplace, architecture of a place can still distill those factors down to unique expressions and experiences. At Toolik Station, this manifests as a strong sense of purpose for the work being done there: exploring elements of adaptability and resilience in the face of unique climate conditions and unstable foundations, forming a sense of unity and community in an insular environment. It is this work’s intent to act as a guide for making less than obvious connections to a building’s context, wherever and whenever that may be. -The Northern

Figure 1. Tusk from a woolly mammoth discovered in a creek bed on Wrangel Island in 2017. Adapted from "Million-year-old woolly mammoth DNA discovered by scientists in northeast Siberia" by ABC News, 2023, https://abcnews.go.com/International/million-year-woolly-mammoth-dna-discovered-scientists-northeast/story?id=75930587. Figure 2. Location of Toolik Lake Field Station on the Alaska map. To the right is the typical summer conditions at the station. Adapted from “Camp Map” by Toolik Lake Field Station, University of Alaska Fairbanks, https://www.uaf.edu/toolik/handbook/facilities/camp-map.php. Figure 3. Toolik Lake Field Station map. The location of the existing community center was cited as the most significant spot for intervention on the compound. Adapted from "Camp Map" by Toolik Lake Field Station, University of Alaska Fairbanks, https://www.uaf.edu/toolik/handbook/facilities/camp-map.php. Figure 4. Location of Toolik Lake Field Station on the Alaska map. To the right is the typical summer conditions at the station. Adapted from "Camp Map" by Toolik Lake Field Station, University of Alaska Fairbanks, https://www.uaf.edu/toolik/handbook/facilities/camp-map.php. Figure 5. Toolik Station boardwalk with typical outtted researcher en route to their field site. Adapted from "Ecological Research in Alaska" by Drone Harmony, 2023, https://droneharmony.com/ecological-research-alaska/. Figure 6. Abrupt permafrost thaw. Adapted from “Thawing Permafrost Could Leach Microbes, Chemicals Into Environment” by NASA Climate, 2023, https://climate.nasa.gov/news/3153/thawing-permafrost-could-leach-microbes-chemicals-into-environment/. Figure 7. The effect of uneven permafrost thaw on infrastructure. Adapted from "Taufender

File: Permafrost thaw ponds in Hudson Bay Canada near Greenland.jpg


File: Polar-Night Longyearbyen.jpg. Figure 11. "Massing and unit design" ©Allan Pernot Figure 12. "Aerial view of an early Northern Reach concept" ©Allan Pernot *All remaining figures within this work have been captured or created by the author. Images reproduced from external sources are utilized under the fair use doctrine, solely for educational purposes.

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