RAM

Remote Arctic Memory

by

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AUTHOR'S DECLARATION

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis including any required final revisions as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

ABSTRACT

The modern world is defined by networks. One network, specifically, has become the core component in how our societies function; the Internet. While the Internet may seem ubiquitous, seamless, and imperceptible, it is only made possible through physical connections – hundreds of cables running through our oceans unseen by the user. Fibre-optic undersea cables are the backbone of our age, joining together continents and their cities through a hidden network.

This infrastructure of fibre-optic Internet has been scheduled to make its way through the Canadian Arctic Archipelago via the fabled Northwest Passage, in order to connect the cities of London and Tokyo to facilitate faster financial trading. However, this long distance connection does not consider many other users. In its current projection, the "Arctic Fibre" cable will only serve a handful of settlements on the Canadian Arctic coast, with the rest of the coastal settlements remaining connected only through high-cost, low-bandwidth satellite technologies. Excluded, these communities will inevitably be further from the advances of the modern world.

There remains an opportunity to expand the use of this cable network by reaching out and connecting to these remote settlements, creating a greater purpose beyond its narrow mandate to shave milli-seconds off trading systems. An improved connective network in Canada's Arctic Archipelago is necessary to provide better healthcare, educate through remote access technologies, create efficient communications frameworks for emergency situations and most importantly, give equal access to inhabitants of the Canadian Arctic for an improved quality of life. Specifically, the relationship found between this enabled connectivity, the needs and work of Arctic researchers, and the unique cultures of the regions' Indigenous communities are of particular interest.

The Canadian Arctic Archipelago is a key site in understanding the consequences of climate change on the environment. However, the vastness of the Canadian Arctic, the lack of a fast and reliable Internet connection, distant communication and data, at times non-existent research infrastructure, and the cultural barrier between researchers and the Indigenous population all contribute to the problems of research in this region. There must be a way to create access to these technologies in remote territories, while respecting the existing cultures, rituals, needs of the Arctic landscapes, and restrictive resources to provide for both Arctic researchers and the Indigenous communities. Indigenous knowledge is now a key resource for understanding how climate change is progressing. If this knowledge is partnered with modern science methodologies through innovative technology networks, there is the possibility for greater and more accessible study into the global environmental future.

For these reasons Remote Arctic Memory [RAM] was envisioned. In developing a design proposal for a connected Arctic condition, this thesis investigates coupling communications and research infrastructure together to create a flexible and scalable connective network for the North. The proposal describes a "New North", an Arctic networked through a series of occupiable, intelligent monitoring towers deployed across the North to foster gathering of data and sharing of knowledge between researchers and the indigenous communities. This thesis aims to investigate the possibilities and benefits found through architecture, technology and advancing networks collaborating together to connect the Arctic frontier.

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To Mom and Dad

This is what I did for 2 years

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Image Backplate Source:

Northwest Territories Municipal and Community Affairs. 2007. *Tuktoyaktuk*. Image. http://www.maca.gov.nt.ca/cmtylist/tuktoyaktuk/#!prettyPhoto

THE CLIMATE OF DATA

Data

Output by a sensing device or organ that includes both relevant or irrelevant values. It must be processed to be meaningful.

Information

Data that has been process and can now be considered useful; can provide answers to "who", "what", "where", and "when" questions.

Knowledge

A personal understanding of facts, information, and/or skills. The application of data and information; can answer the "how" and "why" question. Enables the process of decision making.

Data is raw. It simply exists. Information is data that has been given some form of meaning, and can be put into use. Knowledge, then, is the collection of useful information. Until processed, data is meaningless. But without data there, can be no knowledge.

As the building block to information and knowledge, data plays a vital role. Today, we see data increasingly extracted through digital means. In Nicholas Negroponte's words, we live in a world that has become digital[1].

Data is collected about us, by us, and around us all the time, and controls many facets of our lives[2].

1 Nicholas Negroponte, *Being Digital*, 1 edition (New York, NY: Vintage, 1996).

2 While we live in the "Information Age", when we look back and dissect this age, we might very well find that our current age is the "Algorithm Age", an age where big data, data mining, and algorithms have (not so) slowly influenced the way our society functions.

But there are other forms of data that continue to have prevalence in our contemporary life. For example, data cultivated through event or 'experience', leads to a bank of information, which can be applied and transformed into knowledge as well. Experience leads us to make decisions. It is often remarked that the wisest are the ones who have experienced the most.

We now recognize two primary modes of acquiring knowledge. In the first, - used often in the Western world - the mode through which knowledge is gained is either formal (manned experiments and in-field research) or informal (remote data collection through a surrogate means such as a robot or device) data collection over a set period of time: hours, days, months, or years, depending on the scale of study and nature of information required. The resultant data is analyzed and then compared against a hypothesis. If the information corroborates the hypothesis, it becomes fact, and remains so until disproved.

The second is based on gathering information through experience. In many cultures, this is regarded as 'traditional knowledge'. This type of knowledge is epitomized in the Inuit of the Arctic, who have for generations lived there and passed on their experiences orally from generation to generation. While scientists are starting to use traditional knowledge to supplement and enrich scientific data, it is an ongoing process.

> The traditional knowledge of northern aboriginal peoples has roots based firmly in the northern landscape and a land-based life experience of thousands of years. Traditional knowledge offers a view of the world, aspirations, and an avenue to 'truth', different from those held by non-aboriginal people whose knowledge is based largely on European philosophies
>
> -Ellen Bielawski[3]

Through decades of data collection and analysis, we now know the globe is suffering from anthropogenic global-warming which has caused - is causing - climate change. With their particular sensitivity to global climate change, the Poles have become our advanced warning system.[4] It is paramount that research at the Poles is supported and encouraged as it provides valuable information about how climate change will affect us all. In its current state, the Canadian Arctic falls short in its ability to provide an adequate level of connection required for the scale of Arctic research currently envisioned.[5]

> We're living in a period of extreme uncertainty, and these perspectives add insight. I think it's fair to say that we need all the help we can get.
>
> - Gary Kofinas[6]

Simultaneously, these climate shifts offer the opportunity to expand global economic and political opportunities, as visions of global sea transport and natural resource extraction become increasingly tangible.

One such vision is the joining of London and Japan by a fibre-optic cable via the Northwest Passage, for the purposes of minimizing latency between these two major financial sectors, and allow for faster electronic trading. The potential cable will also bring new promise of broadband connection to the Canadian Arctic. As a result of these visions, the Arctic has garnered the interest of the media, governments and corporate boardrooms. Now, technologies of monitoring and communication concern this region. What was once frontier, foreign and distant, is today a harbinger of the future. At the Arctic, nature and technology exist in reciprocal need.

RAM explores the possibilities of a connected Arctic, in which intelligent infrastructural towers amplify the connection brought by the proposed fibre-optic cable and enable, both the consumption and generation of data, and foster the exchange of traditional and contemporary knowledge in the Arctic.

> The advent of broadband communications can enable Northern people to compress time and space [as shamans once did] and to live at the speed dictated by international markets and exchanges
>
> - Michael Bravo[7]

3 Ellen Bielawski, "Inuit Indigenous Knowledge and Science in the Arctic." *Canadian Arctic Resources Commitee* (1992)

4 The deterioration of the ozone layer was first noted when a hole in the ozone layer was discovered above the Antarctic continent.

5 Council of Canadian Academies, *Vision for the Canadian Arctic Research Initiative: Assessing the Opportunities* (2008).

6 Jennifer Couzin, "Opening Doors to Native Knowledge," Science, New Series, 315, no. 5818 (March 16, 2007): 1518–19, doi:10.2307/20035788.

7 Michael Bravo and Nicola Triscott, eds., *Arctic Perspective Cahier No. 2: Geopolitics and Autonomy* (Ostfildern: Hatje Cantz, 2011).

THE INFORMATION AGE

It would be an understatement to say our world has undergone a transformation over the past few decades, based on the rise of information and communication technologies. With the popular emergence of contemporary communications technologies beginning in the 1970s, they have since spread across the globe. By 1994, architect Toyo Ito already saw his own Japanese society

> ...permeated by information and penetrated by communications systems. [It is] a society in which each individual has two bodies: a 'real' body consisting of its physical presence, and a 'fictional' body shaped by the information directed at or received by it.
>
> \- Toyo Ito[8]

Since 1994, this condition has only amplified. We live in an era where bits exist at the centre of our lives. The storage of data and its subsequent global movement are becoming of utmost importance.

In the realm of trading and the financial sector, the movement of bits is valued perhaps greater than anywhere else. The stock market has/is transforming. What once began casually in coffee houses[9] is today wholly commodified and globalized by the invention of the 'bit'.

In one of the first significant moves to the 'digital', the Toronto Stock Exchange (TSX) implemented the world's first computer-assisted trading system in 1977[10], well before the British stock market was transformed to computerized operations in 1986. This trend towards the digital followed around the globe. As the early 1990s, trading floors were starting to become obsolete.

By 1992, Reuters, the Chicago Mercantile Exchange and the Chicago Board of Trade unveiled Globex, a 24-hour, e-trading system for futures and options contracts.[11] It took about four years and USD$70 million ($110 million today) to build, but it was considered the future of financial markets as all the buying and selling could be done in a manner of seconds. In 1993, the US Treasury announced plans to introduce electronic bond auctions, which mean Wall Street dealers could submit bids electronically instead of phoning them in to government clerks.[12] In Canada, 1997, the TSX shut down its trading floor, choosing a virtual trading environment instead.[13]

8 Toyo Ito. Quoted in *Architecture* New York, September. 1994

9 The London Stock Exchange, one the world's oldest stock exchanges, started life in the coffee houses of 17th Century London. Trading was done as early as 1698.

10 K.C. Staar, *The Fundemental Guide to Getting Started and Succeeding with Investments* (2011), 18

11 An option on a future is the right, but not the obligation, to buy or sell a specified number of underlying futures contracts or a specified amount of a commodity, currency, index or financial instrument at an agreed upon price on or before a given future date.

12 "Bond System Delay Asked," *The New York Times*, April 29, 1993, sec. Business, http://www.nytimes.com/1993/04/29/business/bond-system-delay-asked.html.

13 K.C. Staar, 18

Today, the speed of high-frequency trading has taken a quantum-leap forward, operating not in seconds but in milli-, or even micro-, seconds.[14] This continual, infinitesimal segmentation of time is all done in effort to increase profit. Undersea cables connecting financial capitals with sub-second data transfer speeds, like the Hibernia Express – a USD$300 million trans-Atlantic fiber-optic line – are becoming more prominent. In the case of the Hibernia Express, latency between New York and London has been reduced from 64.8 milliseconds to 59.6 milliseconds.[15]

"Reduce latency to increase profit": it's a new mantra. If you're an algorithm that plies the trade route between major global centres – like New York, London, Tokyo – and you're a few microseconds behind, you're a loser.

> But if you zoom out, if you zoom out, you would see an 825-mile trench between New York and City and Chicago that's been built over the last few years by a company called Spread Networks. This is a fibre optic cable that was laid between those tow cities to just be able to traffic one signal 37 times faster than you can click a mouse just for these algorithms... And when you think about this, that we're running through the United States with dynamite and rock saws so that an algorithm can close the deal three microseconds faster, all for a communications framework that no human will ever know, that's a kind of manifest destiny; and we'll always look for a new frontier.
>
> -Kevin Slavin[16]

14 To put this into context, it takes you 500,000 microseconds just to click your mouse.

15 Matthew Philips, "Cable Across Atlantic Aims to Save Traders Milliseconds," *Bloomberg.com*, accessed March 17, 2015, http://www.bloomberg.com/news/articles/2012-03-29/cable-across-atlantic-aims-to-save-traders-milliseconds.

16 Kevin Slavin. "How algorithms shape our world," TED video, 12:16, filmed July 2011, http://www.ted.com/talks/kevin_slavin_how_algorithms_shape_our_world/transcript?language=en#t-733000

UMBILICAL CORDS

WIRES THAT CONNECT US

Our information-centric context demands a constant delivery of data. This is accomplished through three methods: moving physical media, emitting radio-waves, or transferring digital information through wires.

A common misconception is that international communications only occur via satellite communication. The reality is over 95 percent of traffic is routed through undersea fibre-optic cables. The "Cloud" – our new global phenomenon – exists through tubes sitting at the bottom of the oceans.

According to TeleGeography, a leading telecommunications research firm, there are 277 of these tubes – also known as 'fibre-optic [communication] cables' – in the world today. These cables carry 99 percent of all international communications, which includes both Internet and telecom traffic as well. The total length of these cables is enough to span the Earth nearly 25 times over. Massive quantities of data is routed through them on a daily basis

Undersea cabling has been around since the 1840s, when cables were engineered for transatlantic telegraphs. Shortly after, these cables carried telephone calls and faxes. Now, this undersea network of cables carries nearly all voice and data traffic crossing the oceans.

> Wires warp cyberspace in the same way wormholes warp physical space: the two points at opposite ends of a wire are, for informational purposes, the same point, even if they are on opposite sides of the planet. The cyberspace-warping power of wires, therefore, changes the geometry of the world of commerce and politics and ideas that we live in. The financial districts of New York, London, and Tokyo, linked by thousands of wires, are much closer to each other than say, the Bronx is to Manhattan.
>
> – Neal Stephenson[17]

The societal and cultural pressure to engineer new cables that could cross vast distances, with increasing speed and capacity, resulted in new scientific fields and patents that anchor our modern society. For a time, undersea cables and long-distance communications even shared the same prestige as rocket science or quantum physics do today. Certain companies became highly-skilled at laying cables in the ocean – many of these companies still exist today, with some being better known than others. AT&T, for example, acquired a large share in the field early on, and they continue to hold that share today. While many Americans know AT&T for their service distribution, few know they played such an integral part in developing the field itself.

As the number of regions that are 'plugged in' to the global network increases, the world's dependency on these technologies increase as well. While much of the industry is now focused on planning and maintaining the cable systems already in place, still, more cables are being laid. One example is the Arctic Fibre cable that is proposed through the Northwest Passage for the purpose of better connecting London and Tokyo. Why is it so important? To help facilitate commerce and provide redundancy to the global network.

> This represents a noteworthy virtuous circle – a self-amplifying trend. The development of graphical user interfaces has led to the rapid growth in personal computer use over the last decade, and the coupling of that technology with the Inter has caused explosive growth in the use of the World Wide Web, generating enormous demand for bandwidth. That (in combination, of course, with other demands) creates a demand for submarine cables much longer and more ambitious than ever before, which gets investors excited – but the resulting project is so complex that the only way they can wrap their minds around it and make intelligent decisions is by using a computer with a graphical user interface.
>
> – Neal Stephenson[18]

The world's first test of a submarine fibre-optic cable came in 1979, in Loch Fyne. Trials proved to the industry these cables could withstand the stresses of cable-laying and possessed the required stability for communications transmissions. In 1986, TAT-8, the first International system, was installed to link the UK with Belgium. In 1988, the first trans-oceanic cable was installed. TAT-8 linked the United States, UK, and France. Since then cables have been connecting cities and countries for communication services. The remainder of the chapter looks at how these tubes are built, deployed, and maintained.

The Design

Submarine cables are designed to protect an data carrying core from external forces, similar to how our skin and tissue protect our internal organs. The fibre-optic strands are the heart of a cable system and cannot endure the external forces of water, pressure, waves, currents and other forces exerted on them without proper protection. The submarine cable is this protection.

During the era of telegraphy, this 'heart' was made of stranded copper wire, fibre-optic tubes came significantly later, wrapped with gutta-percha insulation, then further wrapped with tar soaked jute tape. Stranded steel wire acted as armour for the cable, adding strength and protection. Various layers were developed to meet different conditions. A double armour helped to protect against fishing gear and anchors, as well as coastal abrasion - specific hazards for shallow-lain cables. Single armour was used in deep water depths where the need for protection was least. Deep-ocean cable lengths are about the diameter of a garden hose, and expand all the way up to 50 millimeter diameter for shallow water, armoured cables.

While under continual consideration for the past 160 years, still, very little has changed about the design of these cables since the late 1800s. The inclusion of repeaters, though, was one of the few design advancements made after fibre-optics, in 1988 in the TAT-8 cable, had begun to be used in data transmission, light waves are sent down the fibre as a signal with a specific

17 Neal Stephenson, "Mother Earth Mother Board," *Wired* (1996): 1

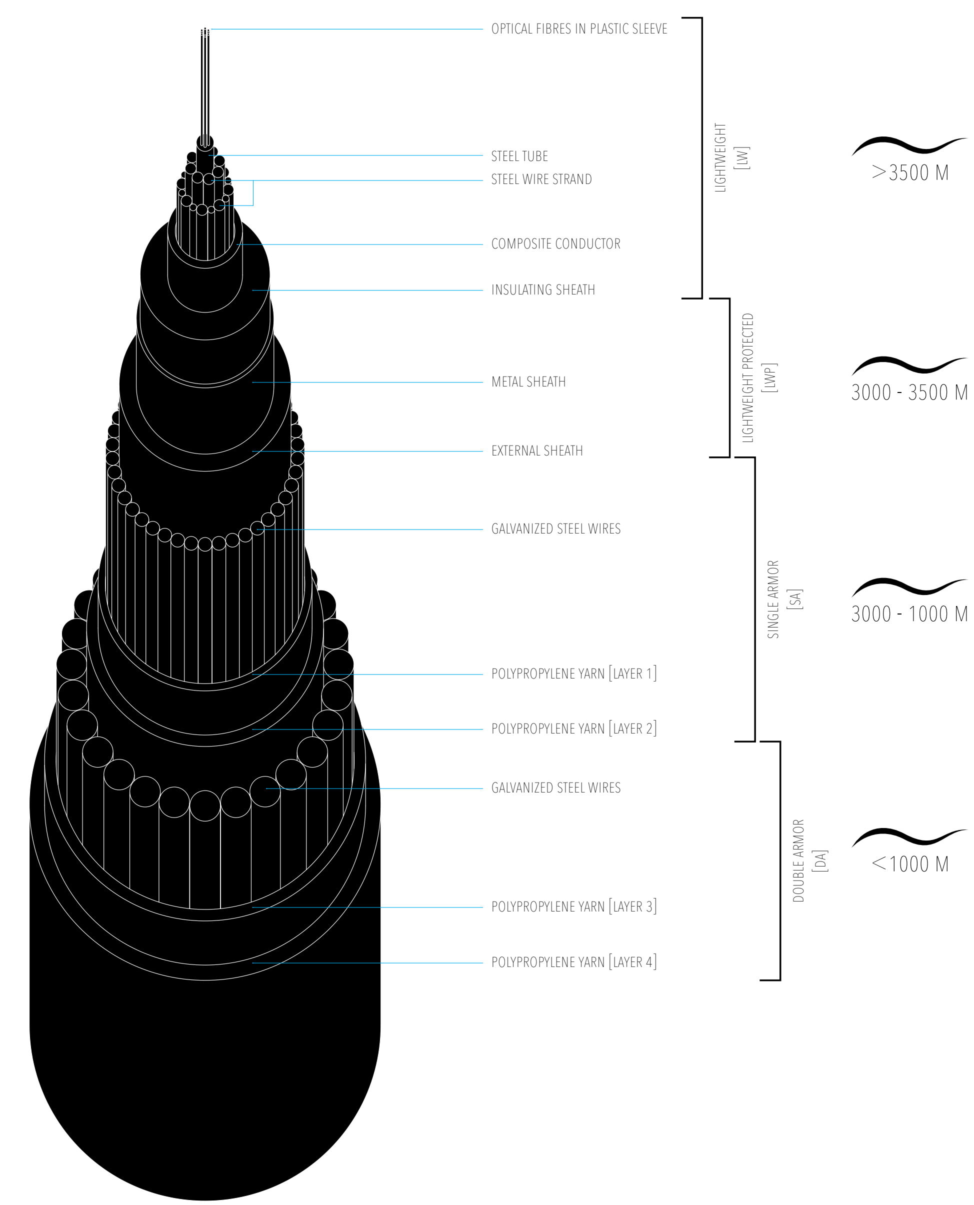
18 Ibid, 56.

wavelength in the infrared range. However, these signals will fade as they travel along the cable route. Signal repeaters help to solved this issue. Repeaters are placed along a cable route at specific intervals, generally in the range of 70 km.[19] The repeater will renew the signal as it moves down the fibre cable. This process is then repeated again, in the next repeater module, and so on until it reaches a point where the cable terminates into a terrestrial network system.

Data transmission through these cables requires a substantial amount of power to work. About 10, 000 volts of power is needed to power the repeaters, which has to be delivered down the same tube the data is traveling. Because of this requirement, the fibre-optic cable consists first of an inner core composed of these multiple optical strands, each of which is wrapped in a coloured plastic (to differentiate between them), sometimes with an additional thin copper wire used only for testing purposes. Their thicknesses are comparable to the lead of a mechanical pencil.

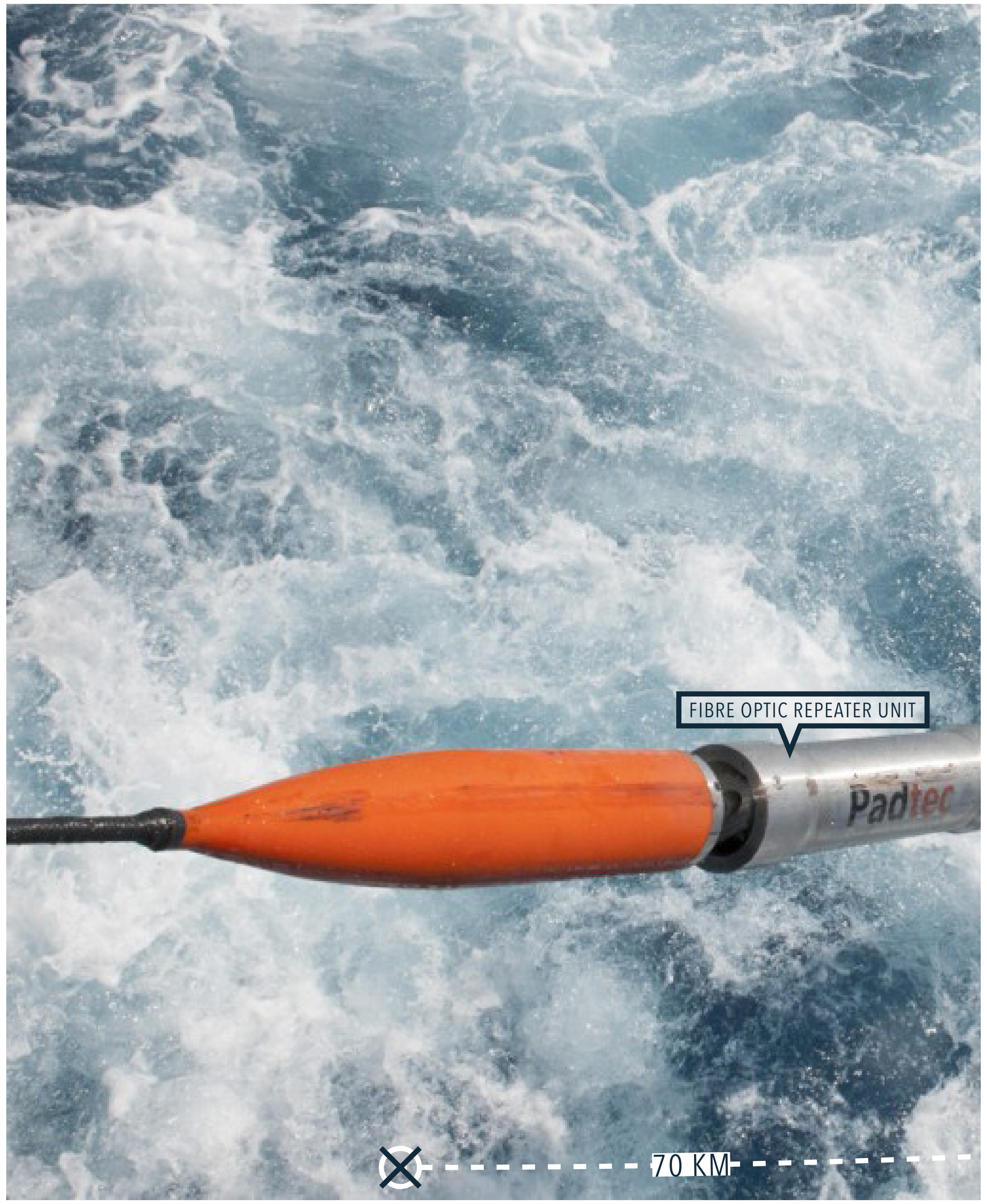
These strands, the 'heart', are then placed in a plastic tube, then the tube is filled with a thixotropic jelly - an insulator and water barrier - which is collectively surrounded by a steel tube. Next is a layer of strength wires: steel strands about two millimetres in diameter, wrapped around the fibre-optic 'heart' in a helix pattern. The composite conductor (in most cases a copper tube) acts as the conductor for the 10, 000 volt power feed that slides over the steel-strength wires. As the ocean serves as a massive ground, there only needs to be a single conductor. Finally, an insulating sheath is formed around the copper tube, normally composed of about one-inch thick polyethylene, which also makes the cable watertight. The final, and optional, component is tarred jute - today this is just plastic, to help protect the cable from the trials and tribulations of shipping and laying the cable through the ocean. Additional layers of galvanized steel wires and jute are added on to vary the amount of protection a cable gets at various points during its route based on the surrounding environmental conditions.

19 L. Carter, United Nations Environment Programme., and World Conservation Monitoring Centre., *Submarine Cables and the Oceans: Connecting the World*. (Cambridge; Lymington: UNEP World Conservation Monitoring System ; International Cable Protection Committee, 2009), 19



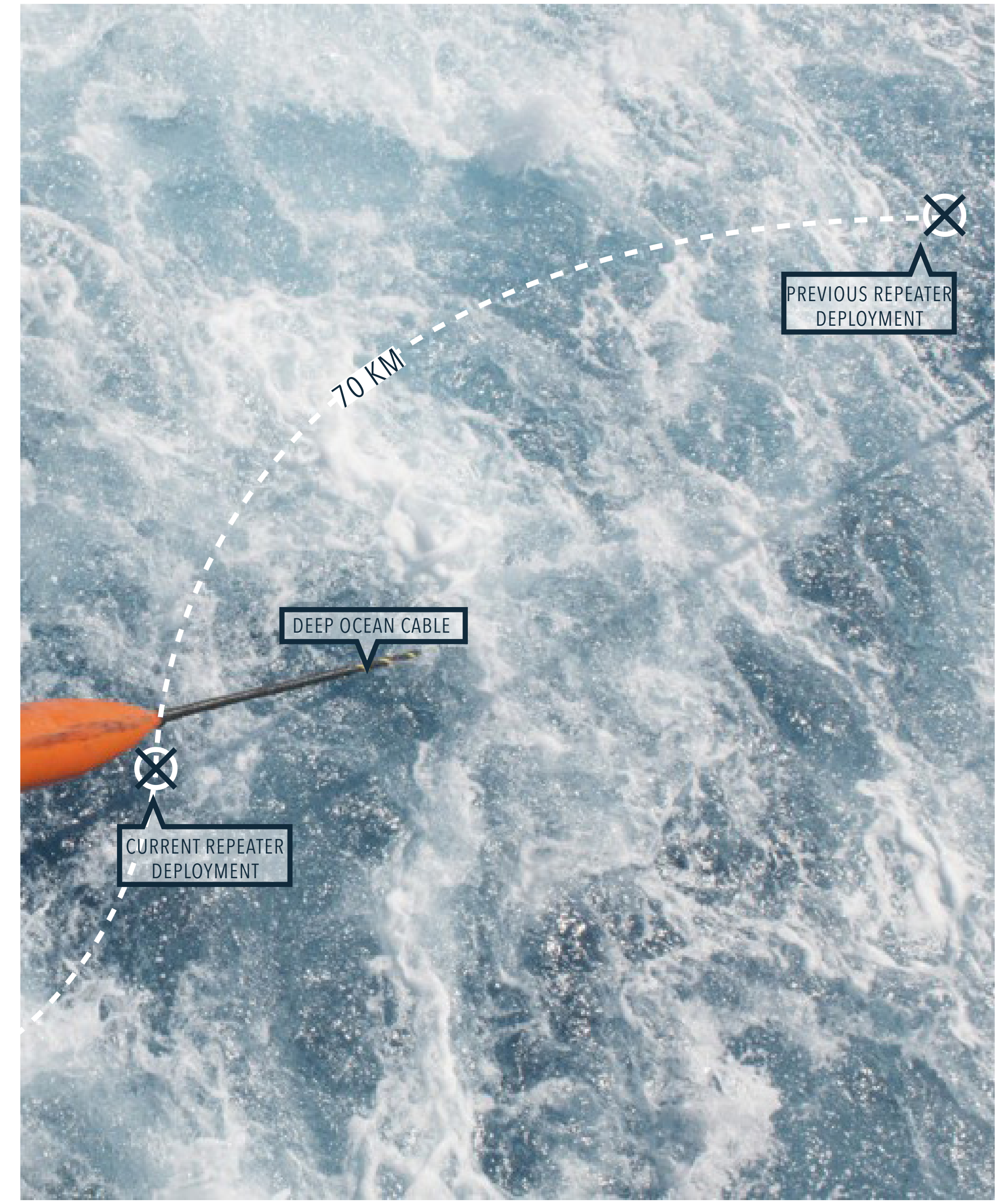
TOP [Fig 1.1]:

Typical fibre-optic cable construction. At its smallest, the fibre-optic cable is about the size of a garden hose, all the way up to the thickness of a golf ball.



TOP [Fig 1.2]:

An image showing the deployment of a sub-sea cable repeater. Without these pieces spaced along the cable's route, it would be impossible to send information using light. The repeaters are spaced approximately 70 km apart from each other and present the largest physical component part of the fibre optic cable from Point A to B.



Source: Subsea Cables,. 2015. *Repeater Deployment In Shallow Water*. Image.
Accessed April 30.
http://invisiblenetworks.co/wp-content/uploads/2014/07/S14_05651-1030x686.jpg.

Image edited by author.

RIGHT [Fig1.3]:

Cables are spooled in massive containers, like thread, aboard cable laying ships. As the ship makes it's journey, the cable is slowly spooled out and fed to the bottom of the ocean floor. They present the very real thread that connects millions of people worldwide.

Source: Subsea Cables,. 2015. *Cable tank onboard ship*.
Image. Accessed April 30.
http://invisiblenetworks.co/wp-content/uploads/2014/07/S14_1159-Edit1-686x1030.jpg

Laying It Out

To conceive how a specific fibre-optic cable will be laid, one first requires extensive knowledge of the route that will be used. For this, a survey must be conducted.

The survey begins with a desktop study, a 'DTS', which is executed by marine geologists with cable engineering experience. Their task is to assemble information: hydro-graphic, geologic, fishing permits, permitting reports, and any history of existing cables or obstructions. With this information, they can then begin designing the optimal route to be surveyed by ships.

Equipped with a multi-beam mapping system and guided by satellite navigation (somewhat ironically), these ships chart the seabed to provide a comprehensive coverage of the route's existing conditions. The route surveyed can be as wide as twenty kilometres, though the common width is about one kilometre. This mapping usually includes water-depth information, seabed topography, location of marine communities, and identification of any other potential hazards – be they man-made or natural.

Once the route is finalized, and all jurisdictions are accounted for – often taking months, sometimes years – it is time for the pre-constructed cable to be laid. There are three parameters that are key in the deployment of fibre-optic cable: the ship's ground-speed, the speed of the cable payout, and the variable water-depth. Today, this process is handled by on-board, advanced computers to accurately monitor and assess these factors, along with a slew of others, and to help lay the cable optimally along the route. There are moments in the process, however, that cannot be perfectly automated; such instances include the meeting of land and sea, or a cable-to-cable landing.

The most dangerous section of a cable's route is shallow water, as it approaches the shore. Extra precautions are taken to ensure that, in the transition from deep water to beach, the cable is not damaged, and will not be in the years of its operation by other ocean users, e.g. fishers, recreational boats, and occasionally wildlife. In some cases, as the cable is coming ashore, though it is already covered in a double layer of armour, it is contained within a cast-iron pipe, which is itself buried under the sand. The process of wrestling the cable through a cast-iron pipe is all done by hand, as opposed to the rest of the primarily-automated cable laying process.

Beyond 300 meters of water depth, if it is an area of seabed activity, the cable needs to be buried to protect it from anchors and chains. This is done with the use of a sea plough. A barge ship is generally used to execute this part of the cable laying process. The cable is spooled and kept in a tank, in the centre of the barge. The cable is then spooled into the sea plough. There are various methods of burying sea cables, one of which involves liquefying the sea bed wit ha high pressure water stream, then creating a trench with the blade as the sea plough moves along the seabed. The cable is then laid into the trench. Below a depth of 1500 metres, cables are normally laid out on the seabed without the need of burial, although in some special cases the cable can be buried if required.

TOP [Fig 1.4]

When the Atlantic was crossed via cable to establish telegraph connection between the United States (The Eagle) and England (The Lion) it was hailed as a monumental feat, and appropriately dubbed "The Eighth Wonder of the World" and speaks to how significant is was to be able to be of (near) instantaneous connection to another area of the world.

Source: Kimmel and Foster (1866). Lithograph, Library of Congress

At the sandy beach this manual work was done out in the surf by a team of English freelance divers based out of Hong Kong. At the cobble beach, it was done in a trench by a bikini-underwear-clad Frenchman with a New Zealand passport living in Singapore, working in Hong Kong, with a Singaporean wife of Chinese descent. Drenched with sweat and rain and seawater, he wrestles with the cast-iron pipe sections in a cobblestone ditch, bolting them patiently together. A Chinese man in a suit picks his way across the cobbles toward him, carrying an oversized umbrella emblazoned with the logo of a prominent stock brokerage, followed by a minion. Although this is all happening in China, this is the first Chinese person who has appeared on the beach in a couple of days. He is an executive from the phone company, coming to inspect the work. After a stiff exchange of pleasantries with the other cable layers on the beach, he goes to the brink of the trench and begins bossing around the man with the half-pipes, who, knowing what's good for him, just keeps his mouth shut while maintaining a certain bearing and dignity beside which the executive's suit and umbrella seem pathetic and vain.

– Neal Stephenson

TOP [Fig 1.5]

The final segment of the cable is hauled in with manpower. Often the cables are dug into a trench at the cable landing area, before being snaked through to the Landing Station where the cable is then connected to existing terrestrial networks.

Source: Cable Laying Team In 1906. Image. Accessed 30 March 2015. http://www.wired.co.uk/news/archive/2011-01/18/transatlantic-cables/viewgallery/264851.

The Landing Stations

As the cable is hauled onto land, it is terminated in a secure building. This building is known as the cable's 'landing point,' often referred to as a Landing Station. In the past, people working in these buildings were involved in the process of coding and decoding messages delivered via telegraph, or in the switching process for telephone calls. Today, workers are mostly caretakers for the machines, overlooking all the little processes that involve data packets sent between destinations.

The cable itself only needs to travel a few hundred metres from shore, before it comes up through the floor of the Landing Station, and is secured into a large steel grid bolted into the station floor. At this point the cable is stripped down to its core and continues in an overhead wiring plenum to "The Big Room Full of Expensive Stuff."[20] This room contains the equipment that funnels data through to the right location.

A large amount of the space in the Landing Station is dedicated to electrical equipment. It is imperative that the station not lose power, which means there are usually two (or more) emergency generators for redundancy. When you consider the number of repeaters that go into a cable route, sometimes a few thousand kilometres long, a lot of power needs to be fed from these stations. In the case of a power failure, generators are connected to a battery farm in an adjacent room.

The batteries kick right as the power goes out, giving the generators the seconds they require to start up and keep the station power.

20 Neal Stephenson, "Mother Earth Mother Board," *Wired* (1996): 22

ABOVE [Fig1.6]:

The small town of Porthcurno has been unusually well known due to its history as a major international landing point for submarine cable stations. In the late 19th century, the remote beach at Porthcurno was famous for the termination point of early British Telegraph cables. It remained a critical communications centre during World War Two, after which it continued as a place where many cable engineers were taught and trained. While Porthcurno acts as a landing point today, for many of the worlds largest fibre-optic networks: TAT, Gemini, FLAG, and RIOJA; the cables pass the small town to a nearby modern landing facility in Skewjack - about 3km inland from Porthcurno.

The old landing point now functions as a museum.

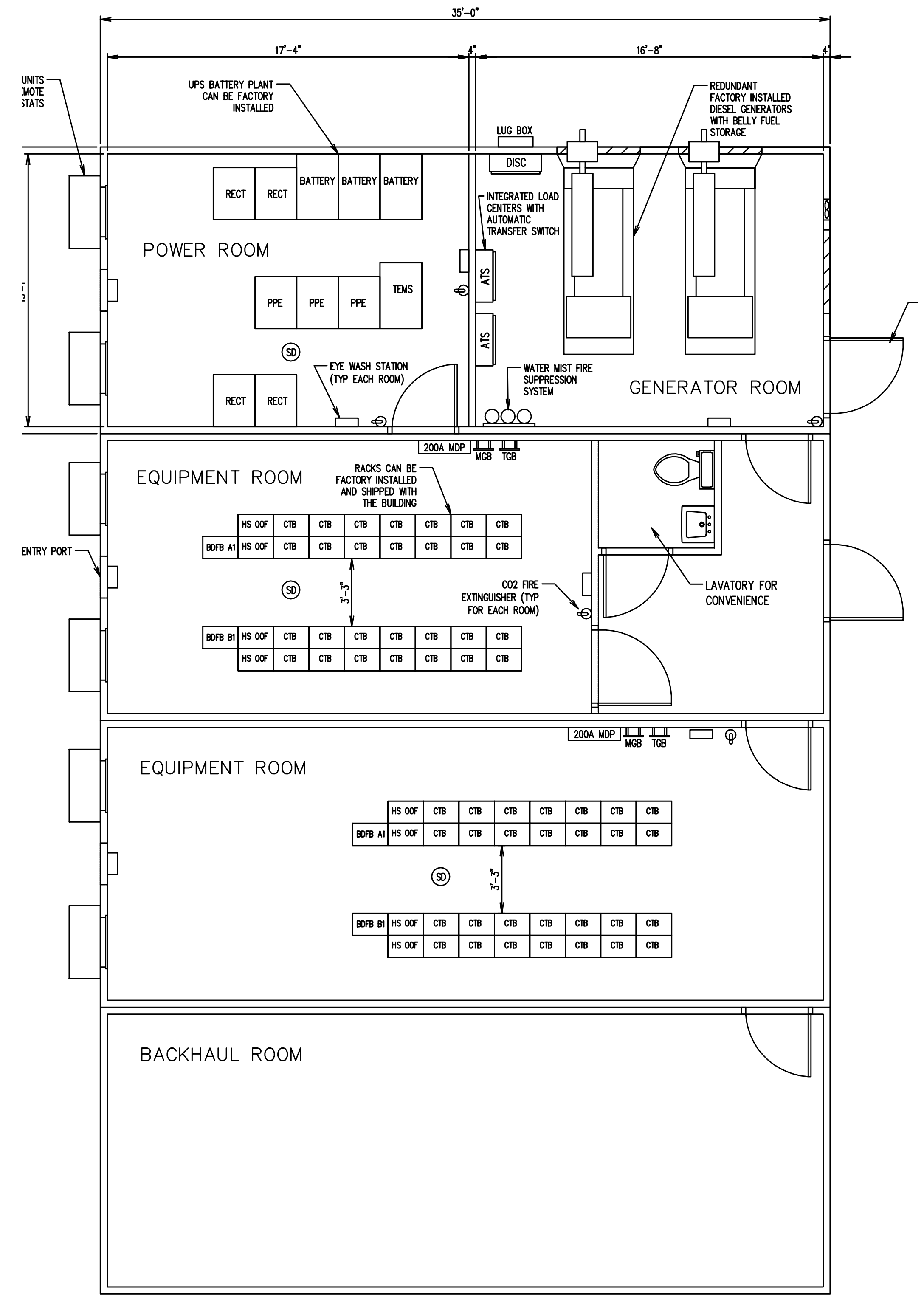
Source: http://static3.wikia.nocookie.net/__cb20111009160907/tractors/images/2/23/Porthcurno_telegraph_Museum_-_IMG_0439.JPG

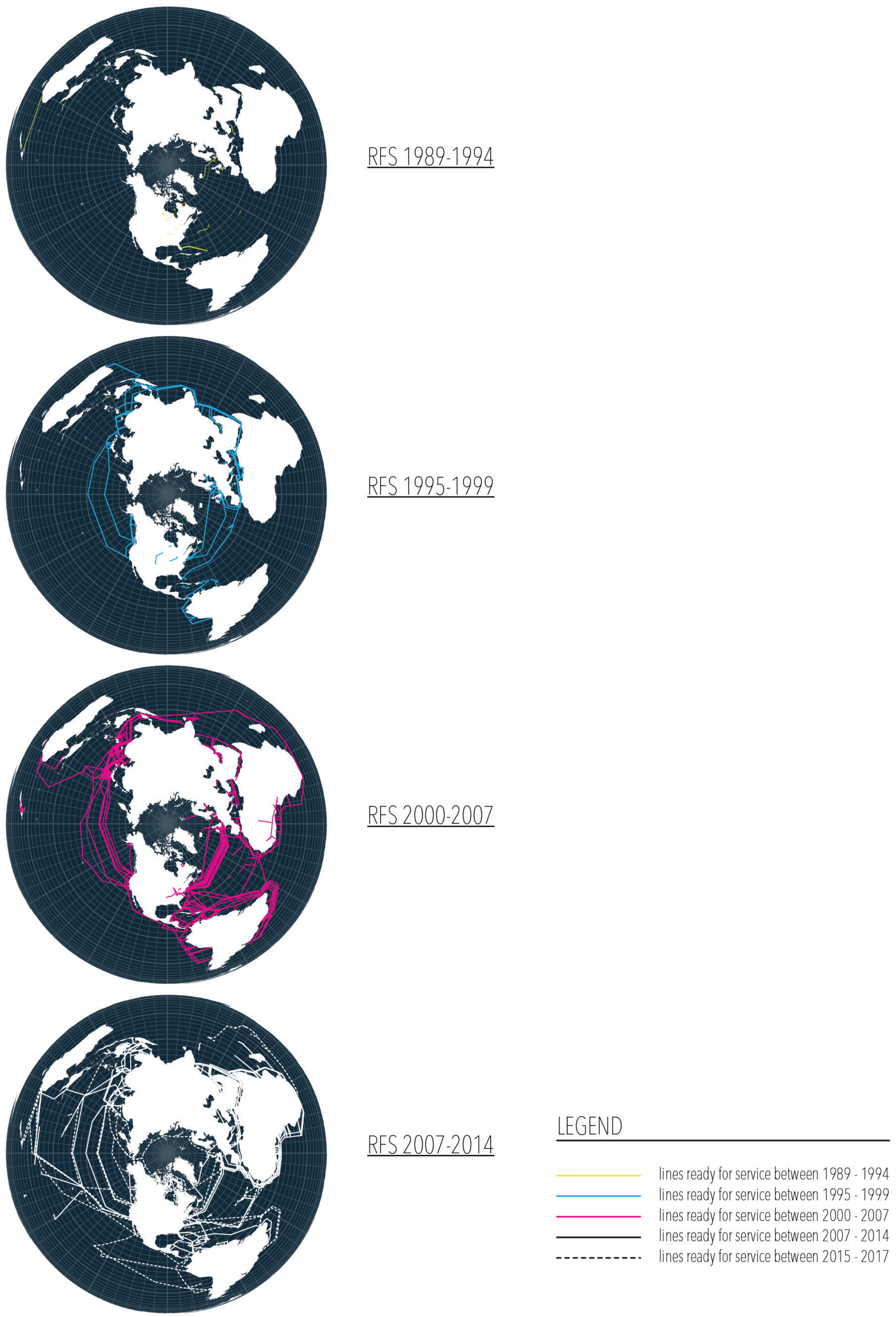
TOP [Fig 1.7]:
The new cable landing facility for fibre-optic cables landing at Porthcurno beach at Skewjack Farm. Most cable landing sites are intensely guarded, with restricted access and high security measures. Most stations are further hidden in a facade architecture to make them camouflage into existing urban fabrics.

Source: Google Maps Street View

RIGHT [Fig 1.8]
A schematic plan of what the components of a cable landing station are.

Drawing by AMSS (American Manufacturered Structures and Services) in Vienna, VA.





LEFT [Fig 1.9]:

Fibre Optic Cable laying between '95 and '99 largely consisted of EU-NA-ASIA connections with a small part of South America being connected into the growing global circuit.

Between '00 and '07 a significant number of fibre optic cables came into service, and substantially connected most of the world, all the while adding redundancy into the global interweb.

Currently there are many more cables scheduled to come into service by 2017, and with the average lifespan of a cable being approximately 25 years, many of the older cable routes are slowly going to be upgraded for cables with higher bandwidth capacities.

ABOVE [Fig 2.0]:

Map of the worlds submarine fibre-optic cables.

ARCTIC FIBRE

The Arctic Information Highway

The demand for minimized latency – especially in the financial sector, in which milliseconds mean large differences in profit margins – has led to the support of some of the more out-of-the-way routes that have yet to be cabled. As the speed of light – the speed used to transfer data down fibre-optic cables – is a constant, the length of the cable route determines its final latency. Therefore, the shorter the physical route, the shorter the final latency between destinations. This inevitably makes certain routes more appealing than others.

However, the shortest route doesn't necessarily win out every time. For example: though the curvature of the planet makes the shortest path between Japan and the United States an arc that lands near Seattle, Los Angeles was instead the chosen city to link the two countries. As a large producer and consumer of bandwidth, this is an example of another determining factor in the decision-making process, one that can cause companies to choose longer routes. A choice is made to take the longer route, sacrificing optimal latency. Still, the desire for optimal latency continues to be of great importance; today, it is pushing companies to revisit routes that were once deemed unnavigable.

For centuries, the Northwest Passage has been sought after as the shortest route to link Asia, North America, and Europe by water, a total distance of 1600 kilometres. The frigid climate has always been a massive hurdle in traversing this coveted passage: few dared attempt its navigation, and fewer still returned.[21]

Another significant advantage of the route lies in its position as a frontier. The region has little commercial shipping or fishing, which reduces the damage to cables from trawling, anchors and fishing lines. It also avoids high-risk security zones such as the Suez Canal, the Strait of Malacca, and the hostile geopolitical climate of the surrounding regions. Despite a few border disagreements between Canada and its Arctic neighbours Denmark and the United States,[22] there is no indication of any armed conflict or crisis set to emerge in Arctic waters.

Currently there are three major fibre-optic cable proposals:

21 The story of HMS Terror is a testament to the power of the Arctic Climate.

22 Both these border disputes are being handled amicably between the respective governments with joint charting of seabeds to determine the rightful drawing of borders in accordance with the UN Law of the Sea (UNCLOS).

ROTACS [Russian Optical Trans-Arctic Submarine Cable System]:

The Russian Company Polarnet was formed to lay a fibre-optic cable to connect Tokyo to London via the North Sea Route – a total of 1700 kilometres. The ROTACS is financed by Russian oligarch Oleg Kim, but despite receiving approval to lay the cable there is yet no information available as to the status of the project.

Arctic Fibre:

Arctic Fibre is a Canadian-led project with the aim to lay a cable in the Northwest Passage, also to connect Tokyo and London. The Arctic Fibre route will cover 15,700 kilometres in this effort. Tentative plans are to lay the cable in the summer of 2015, using the most southern route through the Northwest Passage, linking seven communities in Nunavut and seven more in Alaska along the way. The targeted communities in the Canadian North are: Cambridge Bay, Gjoa Haven, Taloyoak, Igloolik, Hall Beach, Cape Dorset and Iqaluit. Linking to Canada's Arctic communities remains a secondary objective, with only a few thousands households to be connected; it is not considered to be worth any additional investment. Most of the financing for this project is to come from the private sector, with financial institutions and international telecoms representing the key stakeholders.[23]

23 Rita Trichur, "Shrinking Arctic Ice and a Golden Fibre-Optic Opportunity," The Globe and Mail, accessed April 1, 2015, http://www.theglobeandmail.com/report-on-business/shrinking-arctic-ice-and-a-golden-fibre-optic-opportunity/article4714817/.

Ivaluk Network:

Announced in January of 2014, the Ivaluk Network will be designed by Canadian company Nuvitik Communication, and is unique from both the Arctic Fibre and ROTACS as its primary objective will be to serve the Eastern Arctic communities skirting Baffin Island. This proposed cable will form an 8000 kilometre loop linking James bay, Ungava Bay, Hudson Bay, Hudson Strait, Baffin Bay, Davis Strait, and part of the Northwest Passage. Currently, the project seems unlikely to be initiated in the near future, as the current cost is estimated at about CDN$800 million.[24] Given the small client base envisioned, private funding is all but out the window. Thus most of the funding – if not all – for such a project will need to come through public funds.

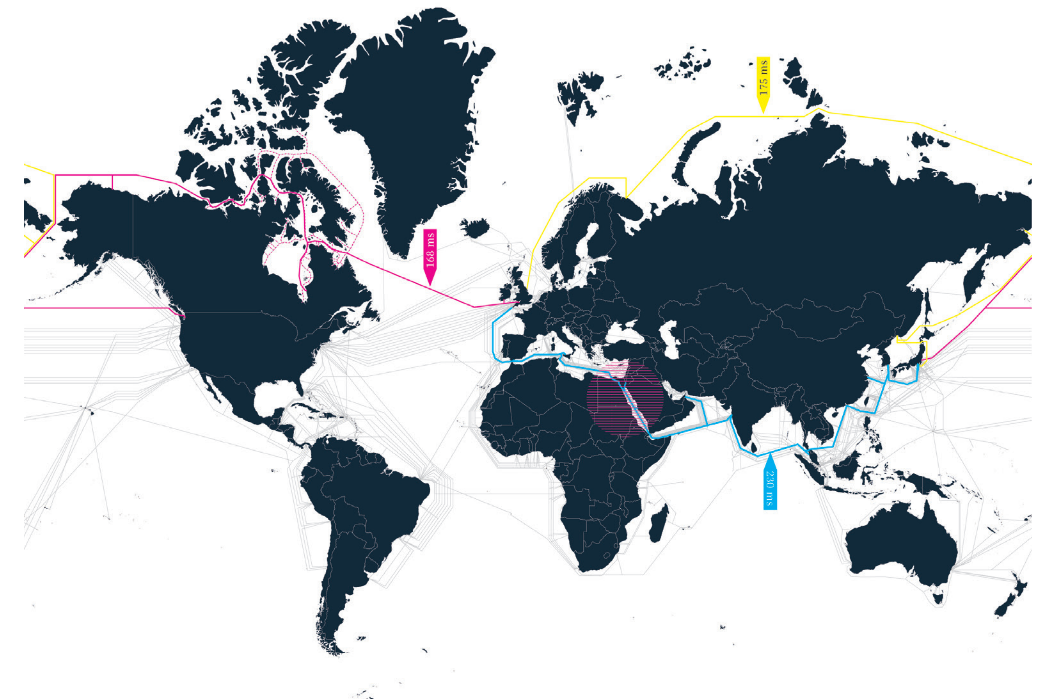
As latency optimization demands new passages be laid with fibre-optic cables, the Canadian Arctic is set to literally be 'plugged-in' to the rest of the global network. The Arctic Fibre™ cable route has the potential to not only reduce latency between the financial markets of London and Tokyo, but also reduce latency in the exchange of information and knowledge between scientists working in the Canadian Arctic and the native Inuit – locals who possess years of knowledge of the location and environment – with the globe at large.

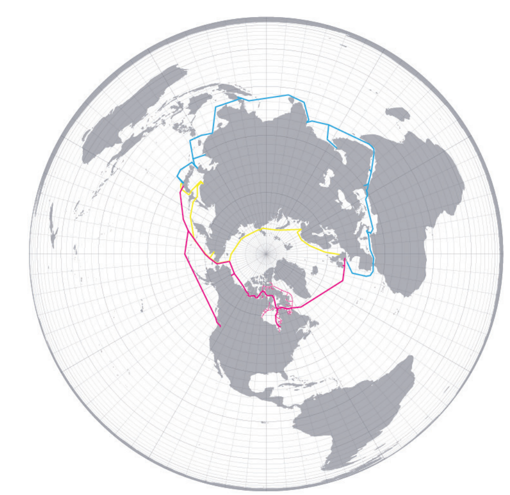
24 Michael Delaunay, "The Arctic: A New Internet Highway?," in *Arctic Yearbook 2014*, ed. Lassi Heininen (Arctic Portal, n.d.), 5

RIGHT [Fig.2.1]:
The map to the right shows the projected path for the Arctic Fibre, ROTACS, and Ivaluk Network fibre optic cables through the Northwest and Northeast Arctic Passages to connect the financial capitals of London and Tokyo.

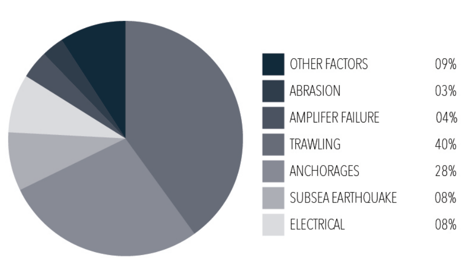
The map also shows the current cable's - FLAG Europe-Asia [FEA] - path in connecting Tokyo and London. As mentioned, the current path is a slow 230 ms (milliseconds), while the newer cables are projected to have speeds in the 160-170ms ranges.

The Arctic Fibre route has advantages outside of speed as there is currently very little shipping that is being conducted through the Northwest Passage - and there is doubt any real substantial commercial shipping will take a foothold anytime soon; which will greatly reduce the likely-hood of a cable break. The Suez canal is a potential minefield for cable breaks to occur in. On top of this, Canada is seen as a very geo-politically stable country, in comparison to the current climate in the Middle-East region, where the FEA cable runs through.

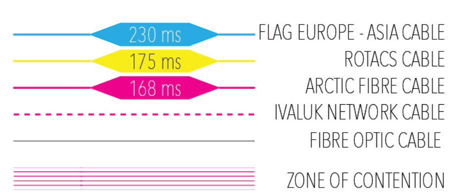




CAUSE OF SERVICE IMPACTING CABLE BREAKS



LEGEND



THE POLES AND SCIENCE

Throughout history, the unique natural properties of the North and South Poles have made them highly significant to our understanding of the planet. Historically, this significance has been tied to their distance from civilization, unique geography and magnetic properties. Today, this has been extended to include the role of the Poles as a potential warning system – a 'canary in the coal mine' – of anthropogenic climate change. The axial tilt of our planet creates the unusual solar conditions at the Poles, which produces the extremely harsh climatic environment that serves as natural barriers to most of humanity. The Poles are now experiencing temperature increases at alarming rates, threatening to melt the ice caps, which will have a direct effect on global weather patterns and coastlines.

According to David Hess, a professor whose focus is the sociology and anthropology of science, technology, and the environment, locating environments to study that have been largely untouched by human technologies is becoming increasingly difficult because of 'denaturalization'. Hess suggests technology has played a significant role in producing these denaturalized environments, that is, environments in which human impact is greater than any other.[25] This is no better exemplified than in the problem of anthropogenic climate change. Humans have occupied almost every landmass for thousands of years, slowly changing their environments, usually with the use of constantly-evolving technologies at our disposal.

> Society creates its environment as much as it adapts to it, and that technology has changed the environment into an increasingly synthetic produce of human activity. Perhaps there is no better example of 'denaturalization' that the looming uncertainty regarding the effects of human activity on the global climate.
>
> – David Hess[26]

The Poles offer an environment that is comparatively untouched by humans to most other regions of the world. And yet, the impact of human-induced climate change is most apparent here. Research at the Poles has been of interest for many years, but their harsh environment and relative remoteness have always compounded the problem of establishing research projects. Now, however, there is a growing urgency to develop research projects throughout each polar biome in an effort to understand and document how climate change is transforming the global environment and what the long term effects of such changes will be.

25 Jane D. Marsching and Andrea Polli, eds., *Far Field: Digital Culture, Climate Change, and the Poles* (Bristol, U.K.: Intellect Ltd, 2011).

26 David Hess, *Alternative Pathways in Science and Industry*. (Cambridge: MIT Press 2007), 9

The Poles have become a proving-ground for scientific reasoning in matters of climate change.

Drivers of Research

> Canada has a choice when it comes to defending our sovereignty over the Arctic. We either use it or lose it. And make no mistake, this Government intends to use it. Because Canada's Arctic is central to our national identity as a northern nation. It is part of our history. And it represents the tremendous potential of our future.
>
> – Stephen Harper[27]

Sovereignty over territory remains a key driver of Arctic research, with a focus towards regulatory concerns in the region. Agreements such as the United Nations Convention on the Law of the Sea (UNCLOS) represent attempts to determine international boundaries in the Arctic sea-bed; these issues of territorial control are now emerging prominently, representing some of the most important Arctic-related issues in the short term, especially for governments. The soon-to-be melted Northwest Passage, with ice cleared from obstruction, looms ahead, and will bring with it increased international interest in territorial control as potential to traverse the region becomes easier. This is evidenced by the insistence of such governments as China and India to be included as observers on the Arctic Council – both countries that have shown very little interest in the Arctic region until recently. Science will be necessary to support long-term regulatory frameworks and environmental controls.

Economic development will also become a critical driver for research in the near future. Already, extensive reserves of gas have been located in the western Arctic, and there is real potential of oil reserves in the Beaufort Sea. Mineral exploration is continually expanding; still, more baseline information is needed before this becomes a reality.[28]

However, for some, the most important research drivers in the region are in relation to global warming and climate change. As countries look toward the North for data in understanding climate change, Canada's expansive Northern regions will play an important and integral part of this data collection. Canada, from an international perspective, has an obligation to provide an active development of, and participation in, a robust Arctic research program. Of the Arctic Eight, Canada is the second largest Arctic coastal landmass – second only to Russia – with a large variety of ecosystems. Canada also has the unique potential to collaborate with the Inuit who have lived in the North for generations, and have with them a strong traditional knowledge of the Arctic region.

For years, this potential has been offset by significant challenges that face Arctic research in the North, which includes:

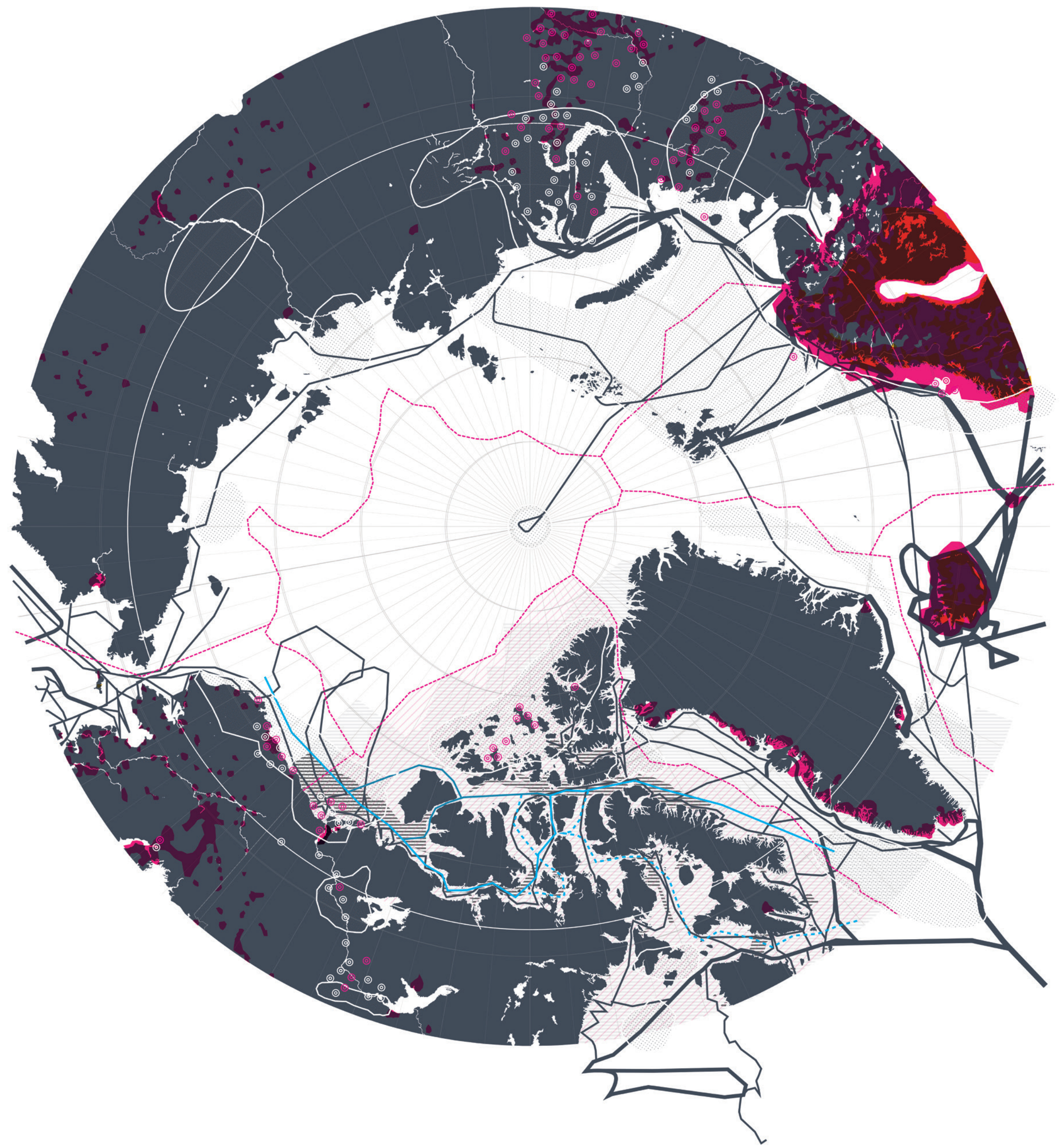
[1] A lack of research infrastructure to support a western and central Arctic transect.

[2] Unavailability of broadband due to a lack of infrastructure.

[3] A harsh Arctic climate.

27 Times Colonist (Victoria), "Harper on Arctic: 'Use It or Lose It,'" *Canada.com*, accessed March 26, 2015, http://www.canada.com/topics/news/story.html?id=7ca93d97-3b26-4dd1-8d92-8568f9b7cc2a.

28 Caron-Vuotari, Maragert, and Gilles Rheaume. 2013. *The Future Of Mining In Canada's North*. The Conference Board of Canada. http://www.miningnorth.com/wp-content/uploads/2013/01/Final-13-201_FutureofMining_CFN.pdf.



LEFT [Fig 2.2]:
Undoubtedly, a lot of pressure towards research in the Arctic is/has come from potential resource extraction. The Arctic has gone through multiple peaks and lulls in regards to its hydrocarbon potential.

Resource extraction companies know that understanding the region will better allow them to determine the feasibility to drill or survey in the Arctic.

At the same time increased regulatory measures also require that the companies have a "worst case scenario" plan in place and in order to determine a course of action, there needs to be a baseline knowledge of the ecosystems in place in the Arctic and how a large catastrophe - like an oil spill - effect such an ecosystem and how it would be dealt with.

LEGEND

Ship traffic by number of trips. [1 year period]

1-10, 11-20, 21-50, 51-100, 101-200, 200+

Exclusive Economic Zone Boundary
Primary NWP Route
Deep Draft NWP Route
Projected NWP Route
NODREG Zone
Basic Chart Coverage
Adequate Chart Coverage
Proven Oil Deposit
Natural Gas Production Site
Oil Production Site

LEFT [Fig 2.3]:
Climate change has been most readily experienced at the Poles. Due to this, both Antarctica and the Arctic are home to a number of research stations and outposts.

The map on the left shows the current ecosystem of science outposts and research stations in the Canadian Arctic. Few of these points are true research stations by nature, most are simple cabins or sheds appropriated seasonally for research and monitoring use.

LEGEND

- ▲ Primary Research Station
- ■ Experimental Research Station
- □ Community Research Station
- △ Seasonal Field Camps
- ● Observing (Monitoring) Locations
- ✕ PCSP Field Site(s)
- — CCGS Amundsen Summer Route

> Currently, the availability of broadband in Canada's Arctic is far less extensive than in some other parts of the Arctic and certainly less than is required for the new scale of research recommended by the panel. Affordable broadband communications in Canada's northern territories will be an essential component of any future distributed observation system as well as of the region's economic development.
>
> – CARI Report[29]

A 2008 report called "Vision for the Canadian Arctic Research Initiative: Assessing the Opportunities" noted one of the most significant barriers to supporting Arctic research was the unavailability of broadband in the North, and the need to implement new infrastructure.[30]

This need is illustrated by the case of Resolute Bay, where researchers currently use the local QINIQ network to link anyone in the field to their base camp. Due to the nature of the work, scientists returning from the field often need to move large amounts of data daily, which easily reaches the bandwidth caps publicly available on the network. Sometimes, they also need to be able to reach researches that are outside the network range, putting even more strain on the system.[31]

Current State of Arctic Research Stations:

Research in remote locations, especially locations as harsh as the Canadian Arctic, requires field stations with decent accommodation, safe access, basic laboratory facilities, storage, and excellent communications.[32] While there has been a surge in polar research, little has been done to improve the concerns of aging research infrastructure (with some notable exceptions, most of which are located in the sub-arctic region of Nunavik in Northern Quebec). Some field stations are beyond capacity, and need to turn researchers away; some have even been closed down.[33]

Terrestrial Infrastructure

Northern research has suffered significant losses in the past decade with the sale of Devon Island Research Station by the Arctic Institute of North America, the closure of research bases such as the Polar Continental Shelf Project (PCSP) base at Tuktoyaktuk, and the reduction of Meteorological Service of Canada sites.[34] The western Arctic and southern Nunavut are areas where new research facilities are greatly needed. Much of the current terrestrial infrastructure are cabin-type architectures, some of which are in questionable condition. Most are certainly without a reliable method of communications outside of the odd provision of satellite phone or VHF (very high frequency) radio.

29 Council of Canadian Academies, *Vision for the Canadian Arctic Research Initiative: Assessing the Opportunities* (Council of Canadian Academies, 2008), 7

30 Ibid.

31 Imaituk Inc. 2011. *A Matter Of Survival: Arctic Communications Infrastructure In The 21St Century*. Canada: CanNor. http://www.aciareport.ca/resources/acia_full-v1.pdf.

32 Jean-Marie. Beaulieu, "Beacons of the North: Research Infrastructure in Canada's Arctic and Subarctic" (Ottawa, Ontario: Canadian Polar Commission, 2008), 9, http://www.polarcom.gc.ca/index.php?page=publications&hl=en_US.

33 Ibid, 9.

34 Ibid, 14.

What follows is a series of photos cataloging the various cabins, sheds, and temporary structures that currently make up a large portion of the terrestrial research infrastructure in the North.

[Fig 2.4] - ANDERSON RIVER BIRD SANCTUARY CABIN

Description	Seasonally-Operated Research Station. This facility is used on an informal agreement basis by a family from Tuktoyaktuk sporadically during the late winter and early spring for both subsistence and guided hunting. The condition of the facility has not been assessed since 2009.
Application	Historically, research and monitoring on white goose populations.
Geo Coord.	69N 128W
Established	-
Closest Town	Tuktoyaktuk (100 km)
Power	None
Comms.	None
Lab Facility	None
Access	Access is by charter plane or helicopter.

[Fig 2.5] - POLAR BEAR CABIN, BANKS ISLAND

Description	Seasonally-Operated Field Camp. Built for Polar Bear Research, it's also been used as a base for Caribou, Muskox and Bird monitoring.
Application	Monitoring
Geo Coord.	74N 119W
Established	-
Closest Town	Sachs Harbour (300 km)
Power	None
Comms.	None
Lab Facility	None
Access	Access is by charter plane or helicopter.

[Fig 2.6] - POLAR BEAR PASS RESEARCH FACILITY

Description	Seasonally operated permanent, insulated, oil-heated building capable of housing 4-5 persons comfortably. Basic supply of standard equipment required for day-to-day living including kitchen gear, tools.
Application	Site for Observing/Monitoring. Wetland hydrology and snow research; vegetation and muskox research; bird research.
Geo Coord.	75N 98.5W
Established	-
Closest Town	Resolute Bay (130 km)
Power	Generator
Comms.	None
Lab Facility	None
Access	Access is by charter plane or helicopter. Snowmobile access is possible in winter.

[Fig 2.7] - GREEN CABIN

Description	Unstaffed basic shelter with an unmaintained landing strip immediately adjacent to it. No power, heat, or communication. Comfortable for a maximum of six.
Application	Archaeology, Environmental Sciences, Geology and Sedimentology, Hydrology, Limnology, Terrestrial Biology/Ecology
Geo Coord.	73N 119W
Established	-
Closest Town	Sachs Harbour (250km)
Power	None
Comms.	None
Lab Facility	None
Access	Access is by charter plane or helicopter.

[Fig 2.8] - CAPE PROVIDENCE POLAR BEAR CABIN

Description	Seasonally operated field camp. Sleeping space for four persons. Extremely remote field location. Need to be self-sufficient with appropriate survival and communication equipment. Built for Polar Bear research, it has also been used as a base for Caribou and Muskox monitoring.
Application	Archaeology, Atmospheric Chemistry and Physics, Climatology, Environmental Sciences, Oceanography, Paleoecology, Terrestrial Biology/Ecology
Geo Coord.	74N 112W
Established	-
Closest Town	Sachs Harbour / Resolute Ba y (500km)
Power	None
Comms.	None
Lab Facility	None
Access	Access is by charter plane or helicopter.

[Fig 2.9] - COATS ISLAND SHOREBIRD CAMP

Description	Small cabin, 12 x 14' space. Sleeps up to four. Frame tents are erected seasonally for kitchen facilities and storage.
Application	Intensive studies of wetland birds, 2004-2006. Studies of polar bears circa. 2008. Studies of wetland ecosystem, 2013-present.
Geo Coord.	62N 82W
Established	-
Closest Town	Coral Harbour (100km)
Power	Generators
Comms.	Satellite phone, VHF
Lab Facility	None
Access	Access is by charter plane or helicopter.

[Fig 3.0] - PRINCE LEOPOLD ISLAND SEABIRD RESEARCH STATION

Description	Seasonally operated field camp. Established in 1975 to study seabird ecology, it is also the site of the longest running seabird egg contaminants monitoring program in the Circumpolar Arctic; it is not used every year.
Application	Seabird and marine ecology research and seabird contaminants research and monitoring.
Geo Coord.	74N 90W
Established	1975
Closest Town	Resolute Bay
Power	Generator, Solar
Comms.	Satellite phone, VHF
Lab Facility	Limited
Access	Access is by twin otter plane.

[Fig 3.1] - EAST BAY MAINLAND CAMP

Description	There are three main cabins. A sleeping cabin which sleeps eight, a lab cabin and kitchen cabin. Seasonally operated field camp.
Application	A research camp was established here in 1997 on the south shore of East Bay to study the ecology of shorebirds.
Geo Coord.	63N 81W
Established	1997
Closest Town	Coral Harbour
Power	Generators
Comms.	Satellite phone, VHF
Lab Facility	Smaller sleeping cabin is typically dedicated to lab activities
Access	Access is by twin otter plane. Accessible by snowmobile from Coral Harbour.

[Fig 3.2] - TERN ISLAND RESEARCH FACILITY

Description	Seasonally operated field camp. Site for observing and monitoring. Three cabins are on site; storage, cooking and sleeping cabins. Capable for comfortably housing up to 8 people. There is no fresh water. Snow must be melted and stored in barrels.
Application	Monitor population trends, reproductive biology, migration routes, and contaminant profiles of Arctic Terns, Sabine's Gulls, Ross's Gulls.
Geo Coord.	75N 96W
Established	2007
Closest Town	Resolute Bay
Power	Generator
Comms.	None
Lab Facility	Limited
Access	Access is by plane or helicopter.

[Fig 3.3] - MCGILL ARCTIC RESEARCH STATION

Description	One of the oldest university operated field stations in the Canadian Arctic. A combination of permanent heated all season buildings and unheated weatherhaven structures. Seasonally operated field camp.
Application	Since the 1980s the multi-disciplinary nature of research has expanded to include questions about planetary analogues, astrobiology, microbial ecology and climate change.
Geo Coord.	79N 90W
Established	1960
Closest Town	Eureka Weather station (120km)
Power	Generators, Solar, Wind
Comms.	Satellite phone, HF & VHF, Internet
Lab Facility	Dedicated lab space
Access	Access is by plane or helicopter

[Fig 3.4] - IGLOOLIK RESEARCH STATION

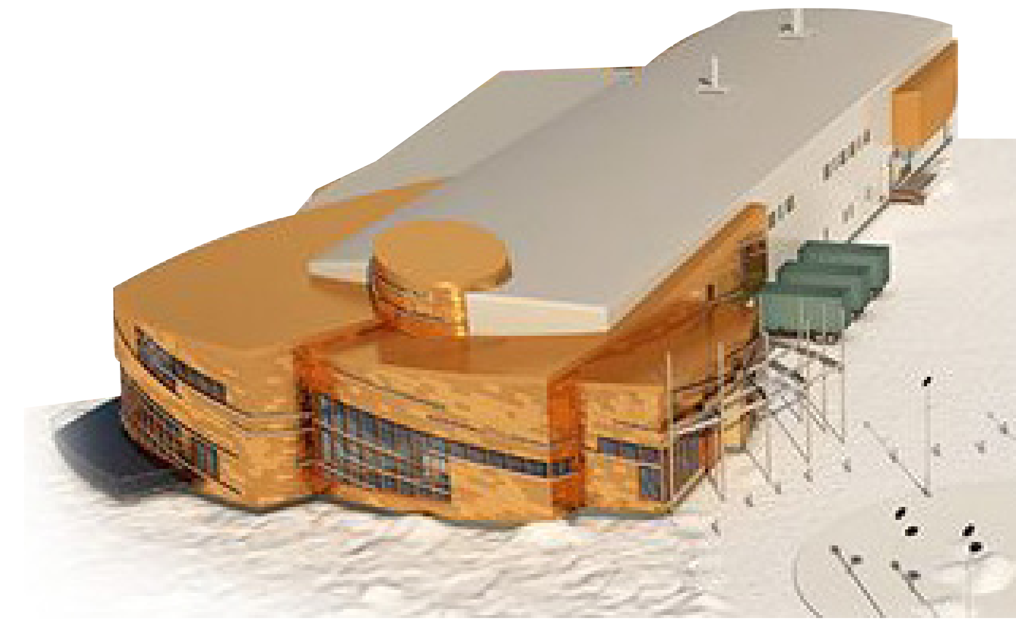
Description	Established in the early 1970s to strengthen research in the Eastern Canadian Arctic. Main building has 8 offices and two labs.
Application	Research conducted here is in relation to terrestrial wildlife and habitats with a special mandate on species directly linked to the traditional life of Inuit.
Geo Coord.	69N 81W
Established	1970
Closest Town	Igloolik (0km)
Power	Grid Supply, Generator
Comms.	Satellite phone, VHF, Satellite Internet
Lab Facility	Dedicated lab space
Access	Access is by plane

[Fig 3.5] - FLASHLINE MARS ARCTIC RESEARCH STATION

Description	Built in 2001, the Flashline station is a cylindrical object used to house researchers in the effort to simulate a Mars colonization.
Application	Research conducted here is to help develop key knowledge needed to prepare for human Mars exploration and to inspire the public by making real the vision of human exploration of Mars.
Geo Coord.	75N 89W
Established	2001
Closest Town	Grise Fiord
Power	Diesel Generator
Comms.	Unknown, most likely VHF radio
Lab Facility	Dedicated space
Access	Access is by plane or helicopter.

[Fig 3.6] - PEARL RESEARCH STATION

Description	Year round research station. Operational for over 60 years, the building and laboratories provide access for viewing and housing atmospheric instruments. The facilities can also accommodate up to 40 people.
Application	Research conducted here is in relation to atmospheric research. Current measurements include a variety of atmospheric recordings such as ozone and upper atmosphere particulates, temperature and wind.
Geo Coord.	80N 86W
Established	1990s
Closest Town	Grise Fiord
Power	Generator, External Electrical Grid
Comms.	Satellite Internet
Lab Facility	Dedicated lab space(s)
Access	Access is by plane



[Fig 3.7] - CAMBRIDGE HIGH ARCTIC RESEARCH STATION

Description	Year round research station. The CHARS is set to provide a world-class hub for science and technology. It's design consists of a central research facility with smaller mid-rise housing units to accommodate scientists and researchers.
Application	The CHARS is meant to attract international scientists to work in Canada and help strengthen Canada's leadership in Arctic research.
Geo Coord.	80N 86W
Established	2017
Closest Town	Cambridge Bay
Power	Grid Supply
Comms.	Satellite phone, Satellite Internet, VHF.
Lab Facility	Dedicated lab space(s)
Access	Access is by plane

Marine Infrastructure

The Canadian Arctic is the second largest coastal Arctic landmass on Earth. The general trend of warming in the Arctic is causing changes to the hydrology – most notably, a reduction of sea ice, permafrost, and snow cover in the region – that, among other concerns, is having a direct effect on the local flora and fauna.

But the most pertinent global concern associated with Arctic warming has to do with the 'feedback loop's caused by the melting of sea ice. The Arctic Ocean functions as a large heat sink, white sea ice and snow cover help reflect the sun's light, decreasing the amount of solar radiation that is absorbed. However, as sea ice melts, areas of open water increase, and inevitably these areas absorb an increasing amount of the sun's radiation, further warming the region. In return, this melts more sea ice and so on and so forth. This establishes the 'feedback loop' of warming, affecting the Earth's overall temperatures.

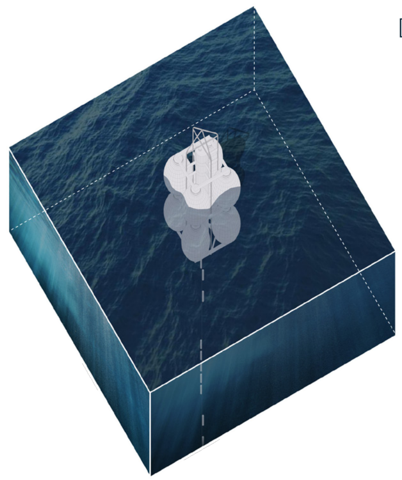
These issues of global warming make research related to the marine Arctic environment all the more important, especially so in the Canadian Arctic. Currently, the major piece of marine infrastructure in the region is the CCGS Amundsen (previously known as the CCGS Sir John Franklin, renamed in honour of Arctic explorer and researcher Roald Amundsen), a Canadian Arctic Icebreaker that also serves as a research vessel for conducting study in the Arctic. It is arguably superior to any other Arctic science-icebreaker in the world due to the scientific technology carried on-board. However, the Amundsen is currently contracted to the Canadian Coast Guard Services (CCGS) between December and mid-April, performing ice-breaking and escort operations. This prevents the infrastructure from being used as a research base for nearly half the year. And while the Amundsen has increased northern marine presence, it is not equipped to penetrate the thickest ice, rendering a large portion of the northwest Arctic inaccessible.

Outside of the CCGS Amundsen, oceanographic research can also be conducted by buoys that have the ability to track multiple variables, such as: water salinity, temperatures at varying depths, wind speed, and ocean currents, among others, and perform some simple automated tasks. Generally the buoys are deployed out to sea, most often from the CCGS Admunsen, and then transmit their data via satellite. In some cases, other types of data, such as water column profiling, are collected when researchers return to perform maintenance on them, before their next assignment. These buoys are often left for months at a time. However, current maps of the Arctic region show that, in general, there is far less buoy activity around the Canadian Arctic compared to other countries. [35]Again, this may have to do with the fact the Amundsen is not able to make trips far up the western coast of the Canadian Arctic archipelago, or perhaps that there is insufficient support for regular buoy deployment.

35 Maps are found off of the National Data Buoy Center, and International Arctic Buoy Programme. Neither provide commentary on why there might be a lacking presence of buoys off of Canadian waters.

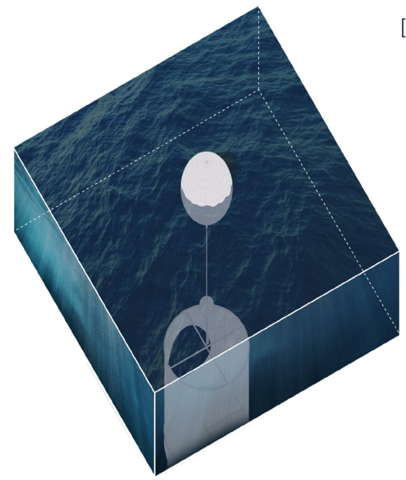
What follows is a series of diagrams cataloguing the instruments, buoys and ships that make up a large portion of the marine research infrastructure in the North and their use in Arctic-based research.

[Fig 3.8]



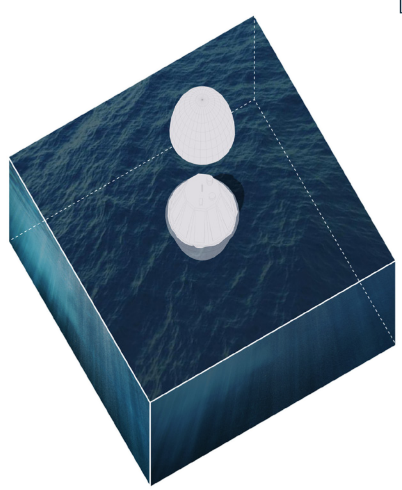
Name	Ice Pack Buoy
Description	Ice buoys are used extensively in Arctic and Antarctic regions to track ice movement and are normally deployed from ships, and sometimes aircraft. These types of buoys are equipped with low temperature electronics.
Application	Collect Ice Draft and Ice Velocity data in the Beaufort Sea.

[Fig 3.9]



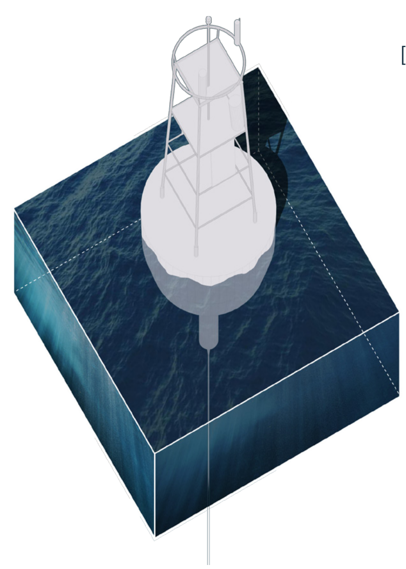
Name	Drifter Buoy
Description	Drifter buoys are generally attached to some form of drogue or sea-anchor. They are easy to deploy and are inexpensive. They typically have an operational time of 400 days.
Application	Collect ocean current data in the Arctic Ocean.

[Fig 4.0]



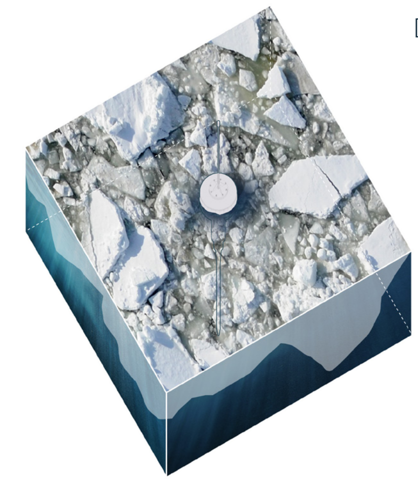
Name	Wave Buoy
Description	Wave buoys exist to capture and model information about ocean dynamics on their surface(s). These buoys measure the frequency and size of waves. This data can be used to improve the prediction of dangerous storms.
Application	Collect sea surface data, nominally associated with waves and understand sea storms.

[Fig 4.1]



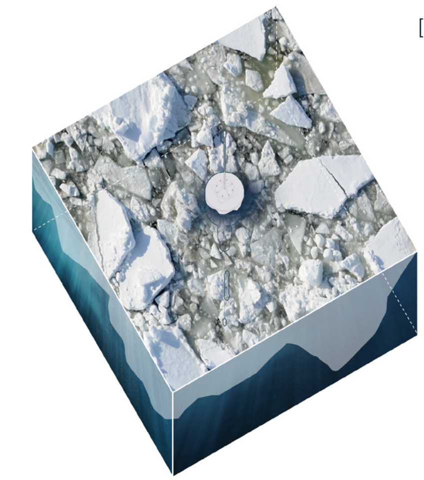
Name	Moored Buoy
Description	Moored buoys are anchored at fixed locations and collect observations using multiple atmospheric and oceanographic sensors. These types of buoys are usually deployed to serve forecasting, and observing climate patterns
Application	Collect ocean current data in the Arctic Ocean.

[Fig 4.2]



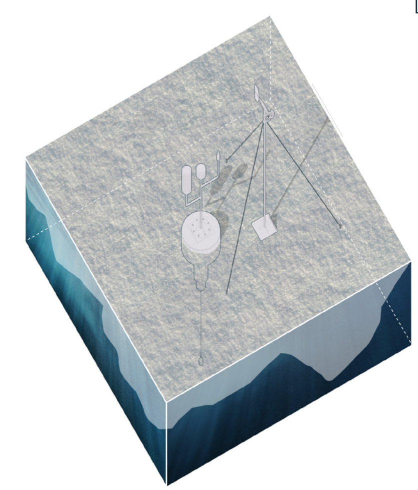
Name	Ice Beacon
Description	Ice beacons can be deployed on pack ice (or icebergs) and left to measure ice drift and ice related properties. Data is stored on board and transmitted. GPS sensors are used to report beacon location.
Application	Measure ice movement, atmospheric parameters, ice thickness, temperature and sub-surface parameters

[Fig 4.3]



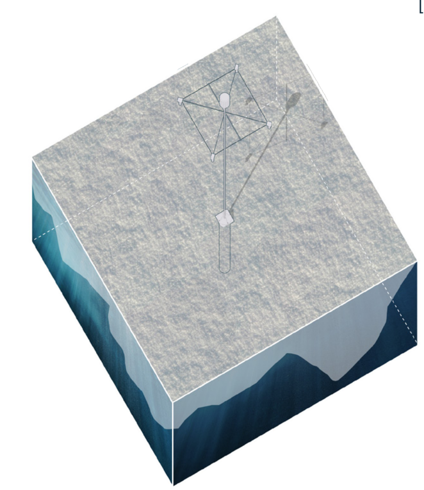
Name	Polar Ocean Profiling System
Description	The Polar Ocean Profiling System is being used on the Arctic Ice cap and in the Arctic Ocean. It can be deployed in a similar manner as an ice beacon.
Application	Collect meteorological and oceanographic sub-surface data.

[Fig 4.4]

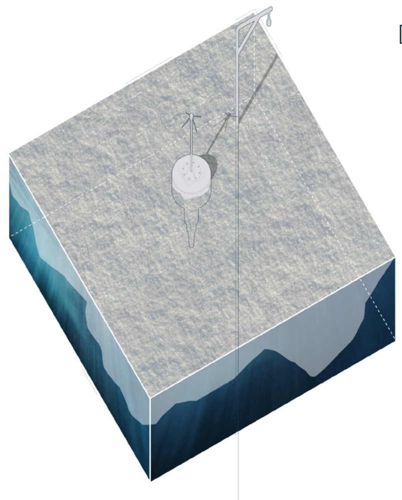


Name	Polar Weather Station
Description	.The surface unit is equipped with GPS, an air temperature sensor, barometer port and a humidity sensor as well as a wind speed sensor. It is capable of transmitting data on a three hour interval.
Application	Provide general weather data in harsh remote conditions.

[Fig 4.5]

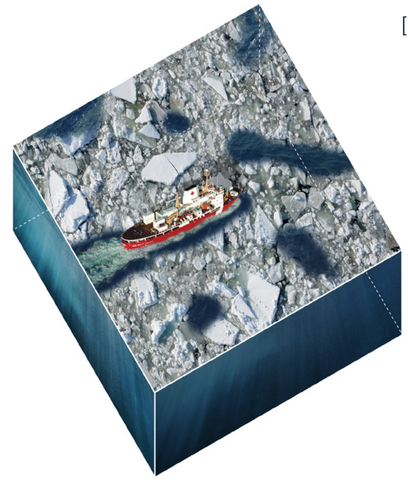


Name	Snow Beacon
Description	The beacon's primary function is to measure snow depth at remote sites where high reliability, low power consumption and operation is critical. It can provide up 12 to 18 months of autonomous operation.
Application	Collect snow depth information.



[Fig 4.6]

Name	Ice Mass Balance
Description	
Application	Measure ice thickness and ice temperature as well as acquiring meteorological and upper oceanographic data.



[Fig 4.7]

Name	CCGS Amundsen
Description	The CCGS Amundsen functions as a research vessel during the summer, where it travels through the Northwest Passage allow for scientists to perform a variety of research missions.
Application	Allow for the conducting of research along the Northwest Passage.

CCGS ADMUNDSEN

ABOVE [Fig 4.8]:

The CCGS Amundsen research icebreaker.

Source: The Wild Image Project,. 2012. *CCGS Amundsen*. Image. https://extremepolarislandsconservation.files.wordpress.com/2012/04/ngcc_amundsen_f.jpg.

Data Monitoring and Observation Networks

Monitoring has received little support in federal science and many networks, such as the reduction of Meteorological Service of Canada sites, have been downsized to save money. While the CCGS Admundsen does partake in scientific exercises annually, there still remains a lack of comprehensive data. The same can be said for terrestrial-based ecosystem data, and activities such as permafrost monitoring are currently not supported at the level they should.

Both frequency and resolution of monitoring need to be addressed. Frequency relates to how often a study is conducted. Increasing the number of researchers or the number of days research is conducted would result in a more fruitful data-set, which could potentially lead to far better knowledge of the Arctic. Resolution, on the other hand, relates to the physical location of data collection. For example, if you have a JPEG file of two varying qualities, even if you are able to get an idea of what the image is depicting at a lower resolution, the higher resolution provides a far better reading of the subject matter, with a greater number of pixels per inch. This is a useful analogy for scientific data: while a lower resolution of data may be sufficient in understanding larger trends, you lose the reliability of the higher resolution, and lose the ability to describe what is occurring at a finer detail as well.

Currently, research in the Canadian Arctic is limited to a short summer period when researchers and scientists can travel to the North to conduct experiments or collect data. This mostly has to do with seasonal climate issues. Outside of research bases at Inuvik, and Resolute Bay, there is no infrastructure capable to house researchers for an extended period of time in the winter months (should they need to) 'out in the field'. These seasonal researchers, alongside emergency responders and military personnel – all of who travel to and from communities and work 'in the field' – each require the ability to communicate back to base at all times.

The implementation of a reliable system of broadband communications in the North will allow for a trickle down effect that would strengthen other services in the North, such as the ability to conduct timely search and rescue, or encourage a new wave of eco-tourism, amongst a myriad of other quality-of-life enhancements.

In its current state, science in the Canadian Arctic is due for an infrastructural upgrade. Many research cabins remain under-equipped, with no real form of communication or connection to each other, local communities, or the outside world. Most of the current infrastructure reinforces the requirement that researchers mostly come during a shorter, seasonal period of time, and thus potentially miss out on conducting certain types of research or experiments that could prove valuable in understanding climate change. The Northwestern portion of the Canadian Arctic remains inaccessible to the CCGS Amundsen, and there remains little infrastructure along the Western front and parts of Southern Nunavut. While the Canadian government has broken ground on a new research facility at Cambridge bay, named the Canadian High Arctic Research Station (CHARS), it remains to be seen how the facility will be able to service a region as vast as the Canadian Arctic.

NORTHERN COMMUNICATIONS

Today, the state of Canadian Arctic communications pales in comparison to technologies and infrastructure of other Arctic Nations. The cost to purchase Internet access in the North is, not only much higher compared to the places further south, even with government subsidies, but also speeds are slower and monthly bandwidth caps make heavy data use nonexistent. The key challenge is the North's insufficient communications "backbone"[36], or rather, a lack of one altogether. There is a need for a significant investment in creating this backbone infrastructure to meet current and future communications needs.

Current State

Of all the Canadian territories, the Yukon has the most established communications infrastructure. This likely has to do with the fact it is also the most road-connected territory. It has only one fly-in community (Old Crow) on the coast of Beaufort Sea in the Arctic Ocean, unlike the Northwest Territories (NWT) and Nunavut. The NWT lies somewhere between the Yukon and Nunavut in terms of connectivity, having both fly-in communities near the coast, while also having communities further south that are connected by microwave and fibre technologies. In Nunavut, most communities are fly-in only, and are served by satellite services. These communities suffer the most when it comes to cost and use of the Internet.

There are a relatively small number of service providers in the Canadian Arctic. In the NWT and Nunavut there are two major service providers, while the Yukon has only one. Northwestel is the most established service provider in the North, providing both cabled and wireless-based access to all three territories in the North; the company is headquartered in Whitehorse. Also headquartered in Whitehorse is SSI Micro, who provides service throughout the NWT and Nunavut via a satellite delivery platform. Telesat, primarily used by government and corporate customers is headquartered in Ottawa and uses a series of geosynchronous satellites to deliver communications to the North.

Looking at the network architecture for Northwestel (NWtel) (figure 4.9) we see the majority of land-based connectivity occurs in the Yukon and the Northwest Territories, while all of the communities past the 60th parallel and all of Nunavut are supported exclusively by satellite-based service. NWtel operates a network that is a combination of fibre, microwave, and satellite services, which results in connections between communities that are of varying speeds and types. Most connections between communities are single path; in cases where there are multiple paths, the technology is different (i.e. most likely one path is fibre based while the other is wireless), resulting in a significant difference in the amount of bandwidth availability. One of the major reasons the Yukon is so well connected is because of its existing infrastructure (such as sewer networks, extensive road networks, shipping passages) with which most communications infrastructure bundles well. In the case of these terrestrial links, communications connections become a chain, connected like a series circuit. For example, a data packet traveling from Dawson to Whitehorse must traverse the series of links that connect Dawson to Mayo, Mayo to Pelly Crossing, Pelly Crossing to Carmacks, and finally Carmacks to Whitehorse. A disruption at any one of those links would thus prevent data movement from Dawson to Whitehorse.

By contrast, satellite-based communications can be likened to a hub and spoke system. In the NWtel system, Whitehorse is the hub and all the communities served by the satellite act as the spokes (endpoints). Data traveling from one community (spoke) to the Internet first has to travel to Whitehorse and then to the backbone connection over a terrestrial link. For data exchange between communities, data must first travel to the hub and then continue to the destination community. For example, data traveling from Old Crow to Sachs Harbour must go from Old Crow to Whitehorse and then from Whitehorse to Sachs Harbour. In a satellite-based communications system all data goes through one of the many geo-stationary satellites orbiting the Earth. In the case of Canadian Arctic communications, all data goes through a group of five geo-stationary satellites known as the Anik satellites. The Anik[37] satellites are operated by the company, Telesat.

What can be gathered from the network map is that all data travels through Whitehorse which means that if a network problem occurs in Whitehorse, it will quickly disrupt all communications in the North.

Certain core realities have led to the current state of Arctic communications infrastructure.[38] Geographically, the Arctic remains a challenging environment. Building, maintaining and evolving communications systems to meet user needs without significant public investment is an economic challenge, which is one of the reasons it is unlikely the Ivaluk fibre link will be realized anytime soon. There is also currently no comprehensive strategy for connecting all Arctic communities to a standardized level of service, resulting in a shortage of affordable bandwidth in both terrestrial and satellite-served communities. While there can be more capacity available for purchase, few can afford the cost of a bandwidth cap increase. Most residents in the North already have to deal with exceptionally costs for the level or service they receive.

Satellite-served communities also face challenges of antiquated networks that amplify satellite latency, making certain applications on these networks unusable. Additionally, satellite ground station equipment and network design require regular upgrading to continually minimize the amount of latency that occurs. The upgrading of ground station equipment can be

36 Backbone here refers to: 1) the part of a network that connects other networks together, generally the backbone of a communications network that carries the heaviest traffic loads. 2) a central cohesive source of support and stability.

37 Meaning "little brother" in Inukitut

38 Major issues were determined by the ACIA assessment report: no service parity, bandwidth shortage and latency, high costs to the consumer, reliability, geographic coverage between communities, emergency response challenges.

expensive, the cost of which is compounded by the remoteness of communities in the Canadian Arctic.

Reliability and redundancy also remain as primary concerns.[39] In more populated areas of the world, this is achieved through redundant ring architecture, which ensures any point in the network path can fail without having significant effect on the end-user. Without similar network architecture, the North faces constant communication service outages. Satellite services are especially at risk, even with two service providers with distinct ground station equipment, as they both connect their equipment to the same satellite. In a recent case, when a rogue satellite wandered through the commercial satellite space, there was concern the Telesat satellite(s) serving the Arctic region could be interrupted.[40] Since both services providers, SSI and NorthwesTel, use the same satellite, all communications could comprehensively fail to service all satellite-served communities (in other words, Nunavut in its entirety would go 'dark').

> We are so used to being cut off, that we didn't even see it as a unique event worth raising.
>
> – Yellowknife Resident[41]

39 These are the same factors that cause cable companies to lay multiple cables connecting countries of the world, and it is one of the reasons the Arctic Fibre cable is of great interest to lay.

40 Denise Chow, "Frustrating Zombie Satellite Still Adrift In Space," *Space.com*, accessed July 2, 2015, http://www.space.com/8724-frustrating-zombie-satellite-adrift-space.html.

41 Imaituk Inc. 2011. "Arctic Communications Infrastructure Assessment Report." CanNor. p.99

A lack of geographical coverage between communities is another major issue that has been identified. Emergency responders, the military, and researchers all noted it as a key issue in concerns over Northern connectivity. Satellite phones do not have the required bandwidth to allow for use of network-based applications required for use by researchers.[42]This is of utmost importance as research is often conducted in remote locations, at a considerable distance from any communities. In an ideal world, researchers would be able to collect data, and upload it almost simultaneously. Instead, in most cases they have to cache the data (either manually or digitally) and forward/upload it when they return to nearby communities. While much of this information is not time-sensitive, still, data can be easily lost or damaged in transportation. For safety purposes, researchers also require communication between the field and these communities to ensure their own safety while out working in the field.

In the case of Canadian Rangers operating in the field, communication is also of extreme importance. Rangers carry ground-wave HF (high-frequency) radio gear, as well as Iridium satellite phones. Each day they are required to set up and call in their coordinates to a base. However, because Iridium phone calls are of a high cost[43], HF radio is the preferred method to conduct every-day communications to keep costs down, even though setting it up takes far more time.

42 Ibid, 101.

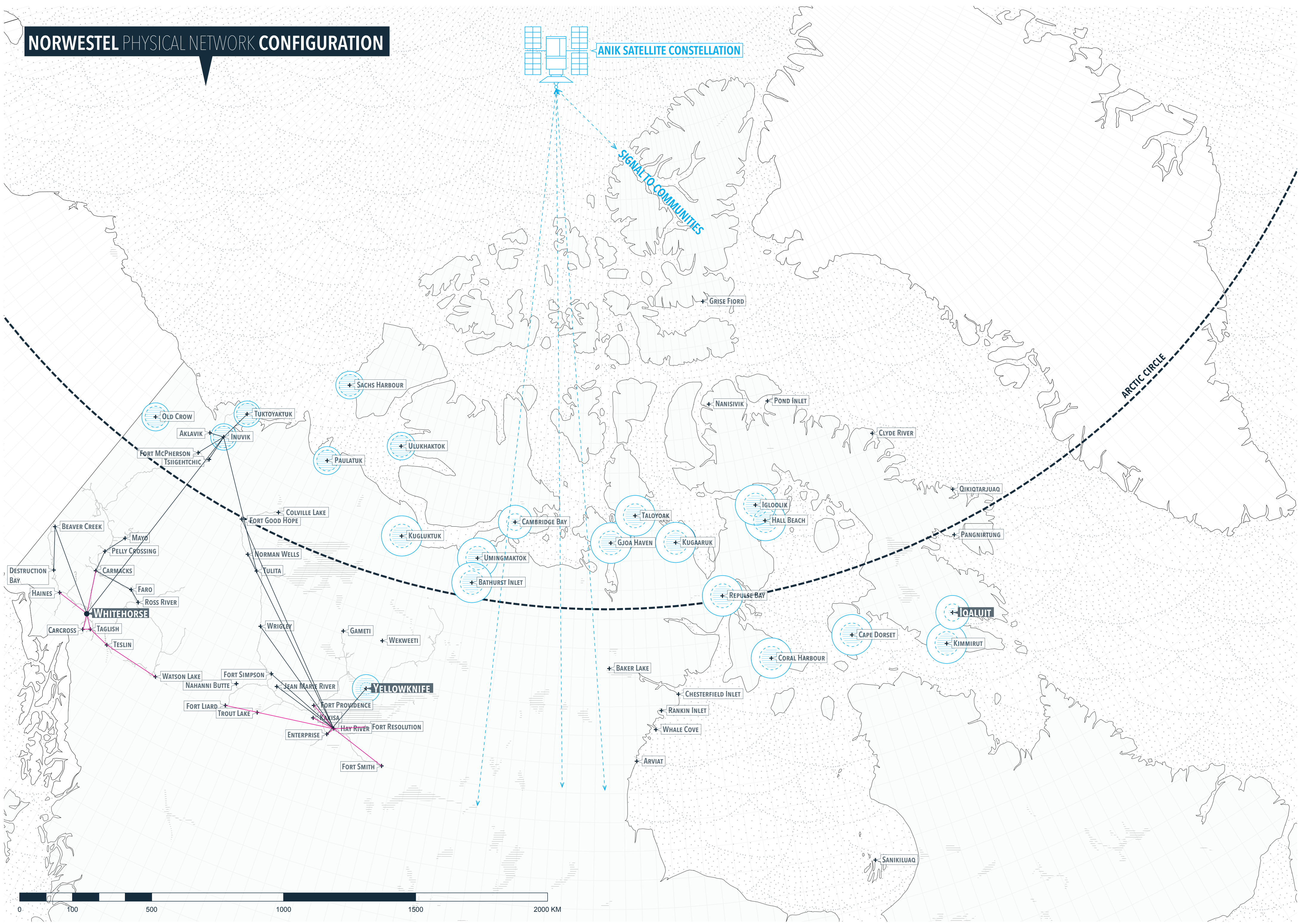
43 Calls from an Iridium phone can cost up to 1.5 cents/minute.

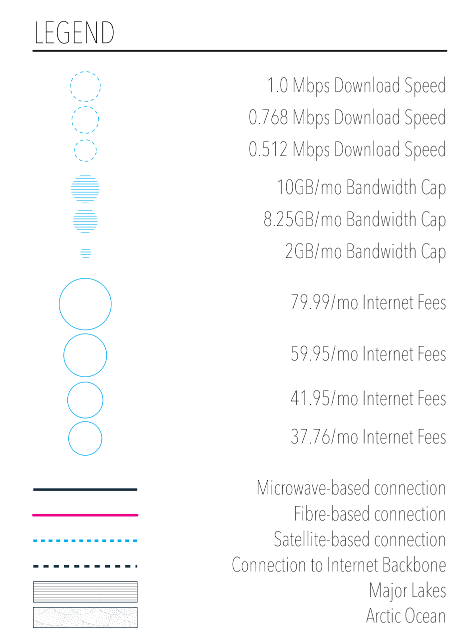
> Our experience in the field is that there are spots where satellite phones simply don't work in the NWT. So our ability to communicate is limited. It's hard to be safe in the field, and get important information back to people in order to respond.
>
> – Participant in the Yellowknife Visioning Workshop[44]

Canada's Arctic region has rarely received the level of attention it has today, with sovereignty discussions, military exercises, prospective trade routes, and its current and potential role in environmental research. Nearly everyone sees the Arctic as an important emerging region for the country.

In its current state, the inadequacies of the communications networks only exasperate the fragmented nature in the North. With no redundancy and a lack of coverage, the Canadian North struggles to provide adequate connection to its residents and visitors. Where connection is provided, it is done so at a higher-cost and lower quality than the rest of the country. As people all over the world become more and more reliant on communication services, the Arctic must keep pace in order to be able to engage with the rest of the world. This will rely on the opportunities broadband connectivity promises. A better-connected Canadian Arctic can become an integral part of future research in understanding global climate-change.

44 Ibid.





LEFT [Fig 4.9]:

Norwestel Physical Network Configuration.

The map here shows the current system of connection in the Canadian Arctic, based off of the regions most ubiquitous Internet service provider. Outside of towns closer to the borders of the lower provinces (British Colombia, Saskatchewan, Manitoba) the Arctic is linked via satellite based or microwave based technology. There are very few cities in the North that are linked by fibre, and of the three capitols in the North, only Whitehorse is linked via fibre. This makes Whitehorse the most important city in the North in regards to information communication systems as most data will pass through Whitehorse on it's way in or out of the North. The resulting consequence is that for the price that many Northerners pay, which is comparable to Southern standards, the quality of connection they receive is far less than what many other Canadians receive.

RIGHT [Fig 5.0]:

Communication from some remote research outposts require a direct link to the satellite dish. The McGill High Arctic Research Station is unique in that it is only one of two remote stations that has a satellite up-link for communications. The other station with this privileged is PEARL. Apart from this, researchers need to resort to using Satellite phones or Very High Frequency (VHF) radios for communications for basic communications. The possibility to send electronic data over either is unavailable.

Source: Andersen, Dale. 2009. *Communicating Via Satellite Dish*. Image. http://images.spaceref.com/news/2008/mac.dish.lrg.jpg.

COMMUNICATING VIA SATELLITE AT MCGILL HIGH ARCTIC RESEARCH STATION

RIGHT [Fig 5.1]:

Similarly, in coastal Arctic towns Internet communications are done via satellite currently. The communications dishes are larger, and link up to the Anik geostationary satellite constellation. Satellite communications allow for such remote communities to be connected to the global Internet commons at the cost of the connection being expensive and slower than the alternatives found further South.

The pictured dish is in downtown Iqaluit.

Source: Windeyer, Chris. 2010. *Satellite Dish In Downtown Iqaluit*. Image. http://www.nunatsiaqonline.ca/pub/photos/NWTel_dish_350.jpg.

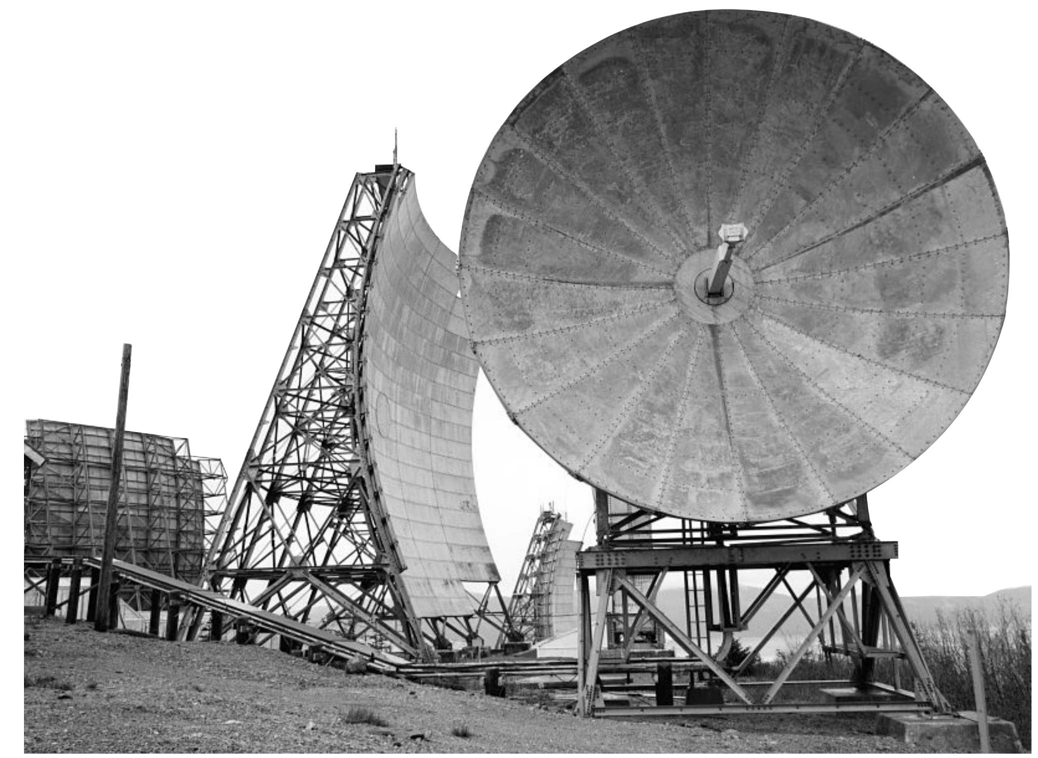
RIGHT [Fig 5.2]:

Large communication infrastructure is not foreign to the Canadian Arctic. During the building of the Distance Early Warning (DEW) sites, a reliable method of communication between the 58 scattered sites was necessary.

"White Alice" was a communications network that used tropospheric scatter and microwave relays to link the 58 separate DEW line sites together.

Pictured to the right are the large tropospheric antenna and radio receiver used at many of the DEW sites spanning form Alaska, across the Canadian Arctic, and into Greenland. In the Arctic, these pieces of infrastructure are still some of the largest pieces of infrastructure on the land.

Source: Historic American Engineering Record. 1968. *Boswell Bay White Alice Site, Tropospheric Antennas, Chugach National Forest, Cordova, Valdez-Cordova Census Area, AK.* Image.
http://lcweb2.loc.gov/service/pnp/habshaer/ak/ak0200/ak0215/photos/000932pv.jpg.

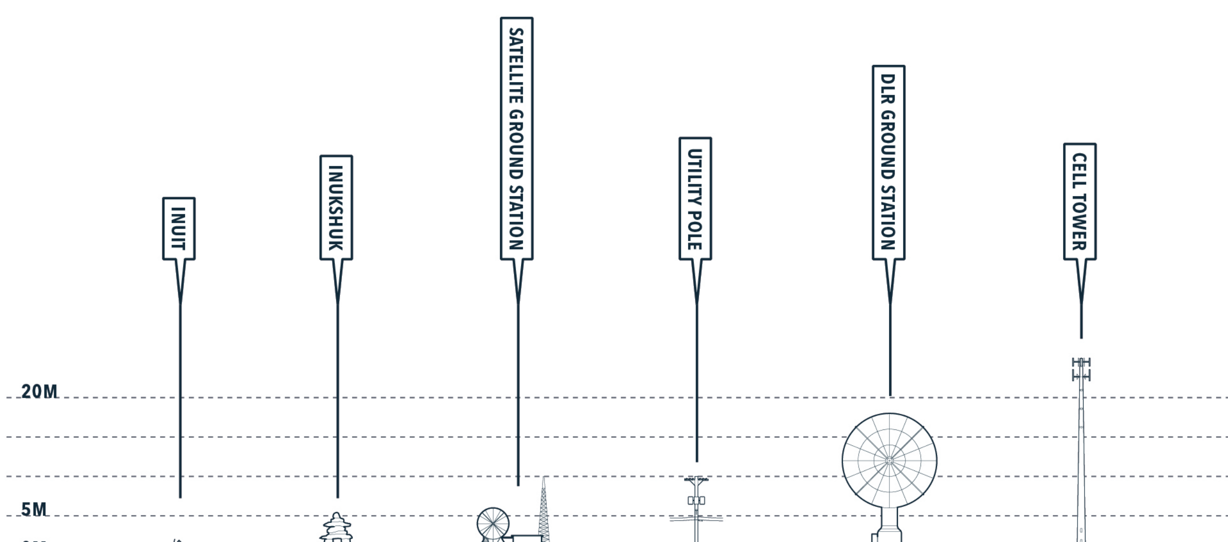


COMPARISON OF NORTHERN INFRASTRUCTURE

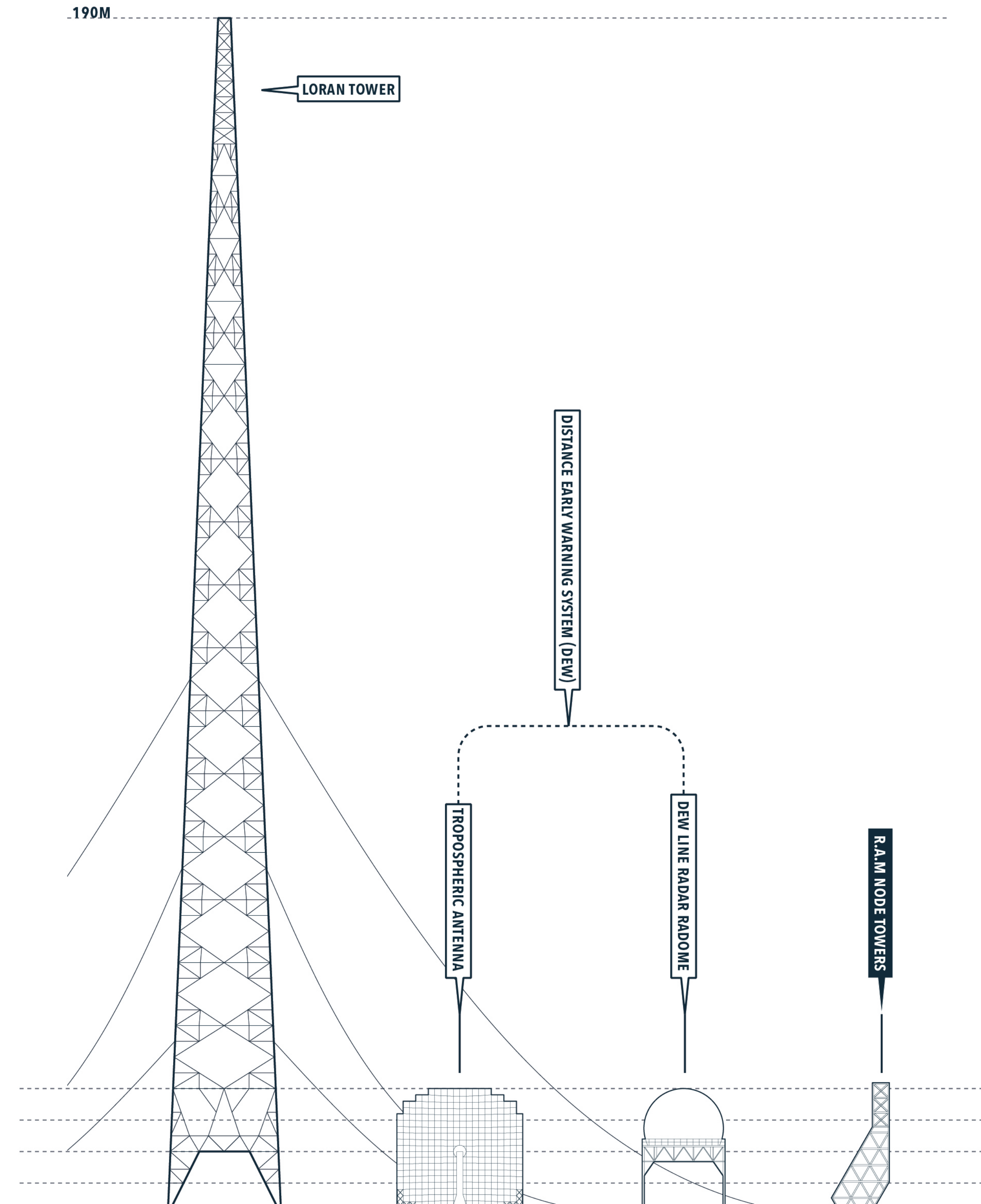
[Fig 5.3]:

Below is a comparison chart of some Northern communications infrastructure. The average height for most of the larger pieces of infrastructure; the DEW line equipment, cell towers, and some larger ground station satellite equipment, all stand around an average height of 20 metres. The only piece of infrastructure that was considerably larger than other was the LONAR Tower in Cambridge Bay, which was used for radio communications. While the tower was not in use for some time, it served as a landmark for the Inuit in the region, some of whom lament the decision to have the tower removed.

The RAM tower design stands just above 20 metebrs tall, and is within the scale of other Pan-Arctic infrastructural objects.



	INUIT	INUKSHUK	SATELLITE GROUND STATION	UTILITY POLE	DLR GROUND STATION	CELL TOWER
LOCATION		PAN-ARCTIC	PAN-ARCTIC	SELECT COMMUNITIES	INUVIK	SELECT COMMUNITIES
DATE		-	2000S+	-	2010	-
STATUS		ACTIVELY USED	ACTIVELY USED	ACTIVELY USED	ACTIVELY USED	ACTIVELY USED
PURPOSE		COMMUNICATE INFORMATION SUCH AS HUNTING GROUNDS OR ACT AS WAYPOINTS	PRIMARY METHOD OF COMMUNICATION BETWEEN SATELLITES AND COMMUNITIES	DELIVER POWER AND VOICE COMMUNICATIONS IN COMMUNITIES. PRESCENCE INDICATES ELECTRICAL GRID	THE SATELLITE STATION IS USED TO TRACK AND RECEIVE DATA IN REAL-TIME FROM POLAR-ORBITING SATELLITES FOR SCIENTIFIC, MAPPING, WEATHER, AND SURVEILLANCE.	ALLOW FOR CELL COVERAGE IN THE CANADIAN ARCTIC. COVERAGE IS LARGELY INADEQUATE



	LORAN TOWER	TROPOSPHERIC ANTENNA	DEW LINE RADAR RADOME	R.A.M NODE TOWERS
LOCATION	CAMBRIDGE BAY	COASTAL CANADIAN ARCTIC , ALASKA, GREENLAND	COASTAL CANADIAN ARCTIC, ALASKA, GREENLAND	PAN-CANADIAN-ARCTIC
DATE	1947	1957 - 1980'S	1957 - 1980'S	-
STATUS	REMOVED ON AUGUST 5 2014	PARTIALLY IN USE	PARTIALLY IN USE	CURRENTLY INACTIVE
PURPOSE	BUILT FOR LORAN TRANSMISSIONS. LATER WAS USED AS A NON-DIRECTIONAL BEACON. ALSO USED AS A WAYMARKER BY THE INUIT IN THE REGION BECAUSE OF ITS HEIGHT AND VISIBILITY.	THE DEW SYSTEM WAS PUT INTO PLACE DURING THE COLD WAR ERA TO PROVIDE EARLY WARNING AGAINST A RUSSIAN AIRBORNE INVASION AND LIMITED NUCLEAR STRIKE	PARTS OF THE DEW LINE HAVE BEEN DEACTIVATED, AND CLEAN-UP OF THESE SITES IS UNDERWAY.	THE RAM NETWORK IS USED TO EXTEND THE COMMUNICATION CAPABILITIES OF THE ARCTIC FIBRE CABLE AS WELL AS PROVIDE MUCH NEEDED SCIENCE INFRASTRUCTURE IN PARTS OF THE CANADIAN ARCTIC.

REMOTE ARCTIC MEMORY

At the current estimate of CDN$825million, the Arctic Fibre cable will cost approximately fifty thousand dollars per kilometre to lay from London to Tokyo. But just running the cable through the Northwest Passage itself will be a costly endeavour. Even though ice is clearing, special attention will be needed as the passage will still freeze in winter months, leading to various ice phenomena, with the potential to scour the bottom of the Passage, potentially cutting the cable if it is not properly protected.

In high risk areas, such as Cambridge Bay, additional methods of horizontal drilling may be required to allow the cable to penetrate to shore safely. These additional procedures only increase the cost of installing and maintaining the cable's integrity. To some, trying to extend the cable inland serves little purpose as Arctic communities past the 60th parallel are coastal; but the potential for research, resource extraction, and local and military assets suggest the influence of broadband connection should still be expanded. However, due to the struggles of trenching through permafrost, it is unlikely the cable will ever become truly land-borne.

But even though major communities are located along the coast, still many are not scheduled to be connected in the current scheme. At present only seven communities in Nunavut – Iqaluit, Cambridge Bay, Cape Dorset, Igloolik, Taloyoak, Goja Haven, and Hall Beach – are slated for connection. While there are plans for extending the network to the remaining communities in the Canadian North, it is unclear whether the government is willing to fund broadband fibre[45] for connection, as the government is currently supporting satellite based technologies through subsidies. When the Arctic Fibre cable arrives — what of the remaining communities in the North?

Research in the region relies on similar connectivity needs. Canadian Arctic research stations require some form of connectivity to ensure in-field operational safety, as well as to send data further down to more southern institutions if required. While the use of satellite technologies is available, their cost and low-bandwidth caps hinder the capabilities of conducting science in the North – especially in cases where large data transfers are needed regularly. Research stations provide a much needed refuge for scientists working in harsh, remote climates and allow for long-term experiments and observations to take place, even going so far as to enable year-round accommodation in remote areas should the need arise. While these advanced stations have been implemented in the Eastern Arctic, starting in

45 Jordan Press et al., "Federal Government Balks at Backing Arctic Internet Project," Ottawa Citizen, accessed March 25, 2015, http://ottawacitizen.com/news/national/federal-government-balks-at-backing-arctic-internet-project.

the sub-arctic region of Quebec, there is still an opportunity to expand the capacity of research in the Western Arctic, Central Arctic, and some minor zones in the Eastern Arctic.

More concerning is the continued reduction of science-based resources in the North. Closing of research bases in communities like Tuktoyaktuk, in spite of repeated lobbying by intellectuals to funnel more resources to research in the Arctic in response to previous funding cuts, represent the heart of the issues in continuing Arctic research.[46] Canada's greatest assets in the North remain its extensive Arctic landmass – second only to the Russian Arctic – and its native population, who already have an innate, embedded knowledge of how the environment of the Canadian North is changing due to anthropogenic climate change.

How can the network support the pursuit for Arctic knowledge, both traditional and contemporary? The fibre optic cable through the Northwest Passage does not so much bring with it potential to the region, but rather unlocks it. With the addition of the cable will come the ability to tap into an existing, abundant pool of data, information, and knowledge – both from Inuit expertise and from the surrounding environment.

46 Emily Chung, "Foreign Scientists Call on Stephen Harper to Restore Science Funding, Freedom," *CBC News*, accessed April 2, 2015, http://www.cbc.ca/1.2806571.

The Network

RAM proposes a network of infrastructural towers that would amplify and extend the connectivity potential of the proposed Arctic-Fibre cable. These towers function as signal repeaters, much like repeaters on a submarine cable, to enable data connection from communities out to the vast Arctic environment through a long-distance, point-to-point based WiFi network. In addition, the towers have the possibility of connecting via satellite should the need arise, in the event a tower is compromised or is taken down for maintenance reasons.

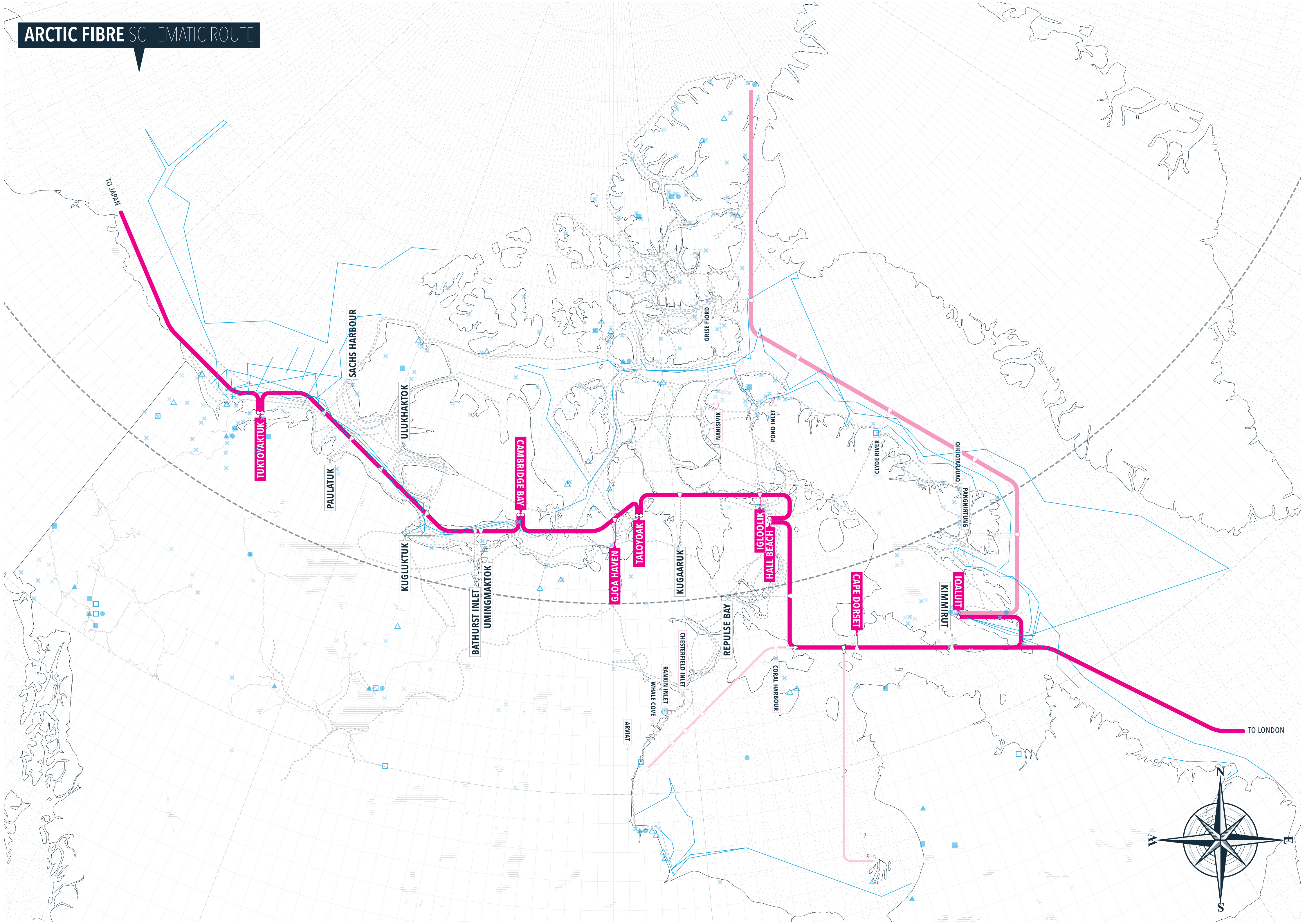
The RAM network will provide assistance for environmental research in the North, a space for enabling the exchange of traditional and contemporary knowledge, will deliver a more robust communications network for emergency situations, and will become an integral part of the fibre-optic cable upkeep.

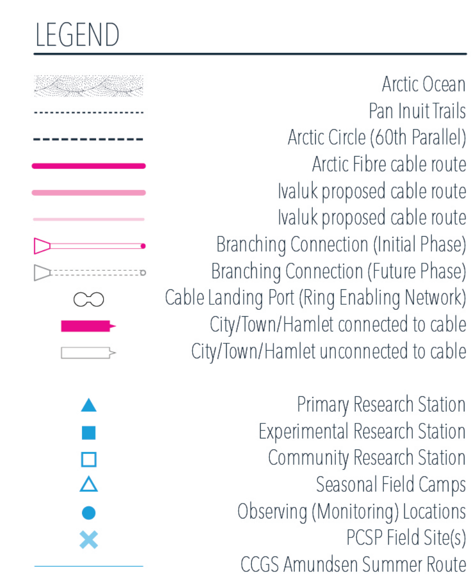
[Fig 5.4]:

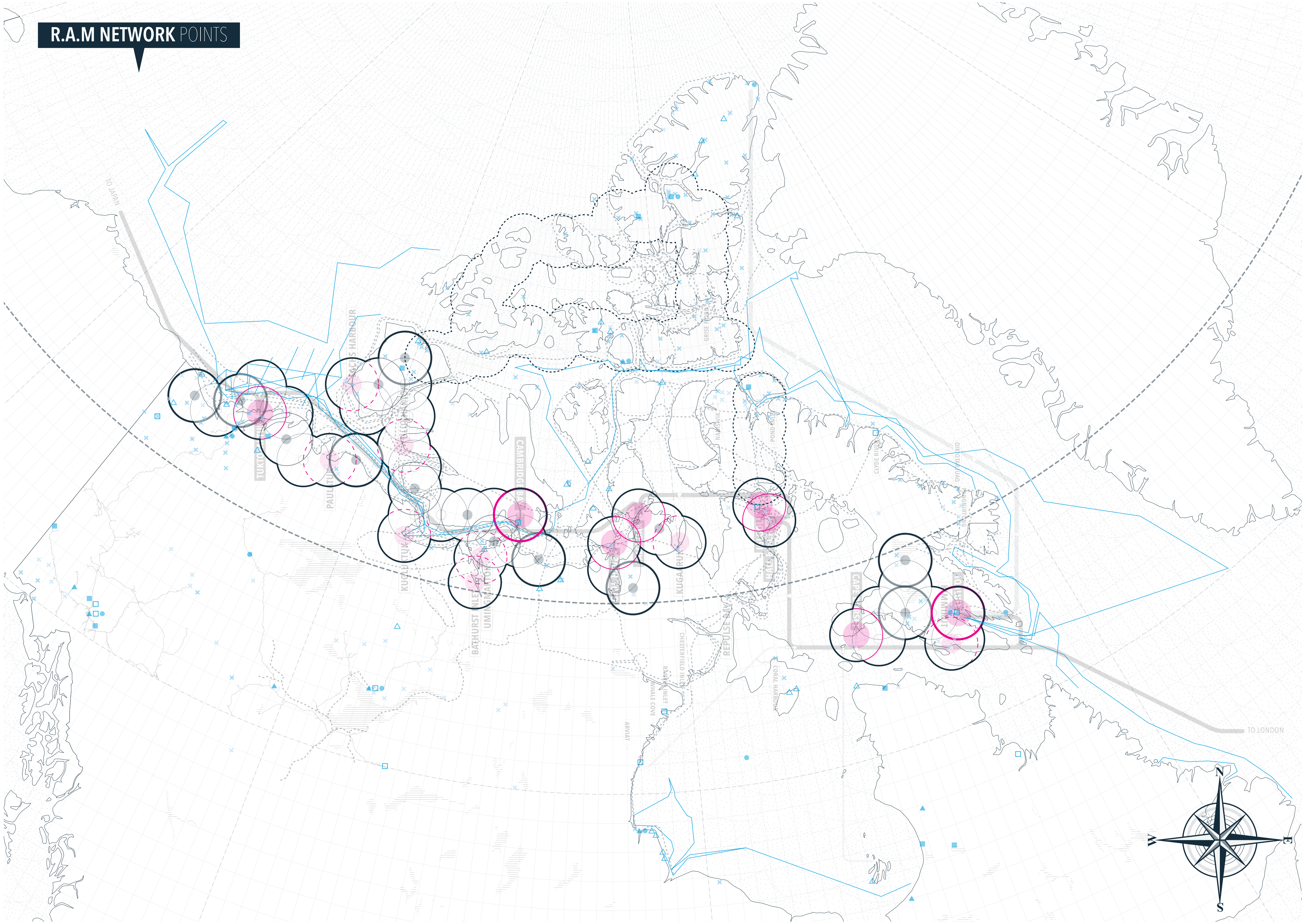
Arctic Fibre - Schematic Route

Mapped to the left are the current proposed routes and landing points for the Arctic Fibre and Ivaluk fibre-optic cables. The Arctic Fibre proposal connects much of the eastern Arctic mid-coastline, while only two towns are subject to be connected via fibre on the western front. Also it is worth noting that the Arctic fibre ignores the upper and lower cities of the Arctic coast, though the proposal suggest that those omissions can be rectified at a later date by expanding the fibre system North-South.

The are of research to would benefit the most with just the implementation of the fibre-cable connections would be the areas around Cambridge Bay and Tuktoyaktuk, both of which tend to serve as regional research hubs because of the new Cambridge High Arctic Research Station being built in Cambridge Bay and the proximity of Tuktoyaktuk to Inuvik.







[Fig 5.5]:

RAM Network Points

While the Arctic Fibre cable will bring connection to towns and cities on the coastline where the cable lands, it will have little effect outside of those areas in regards to research and Arctic life.

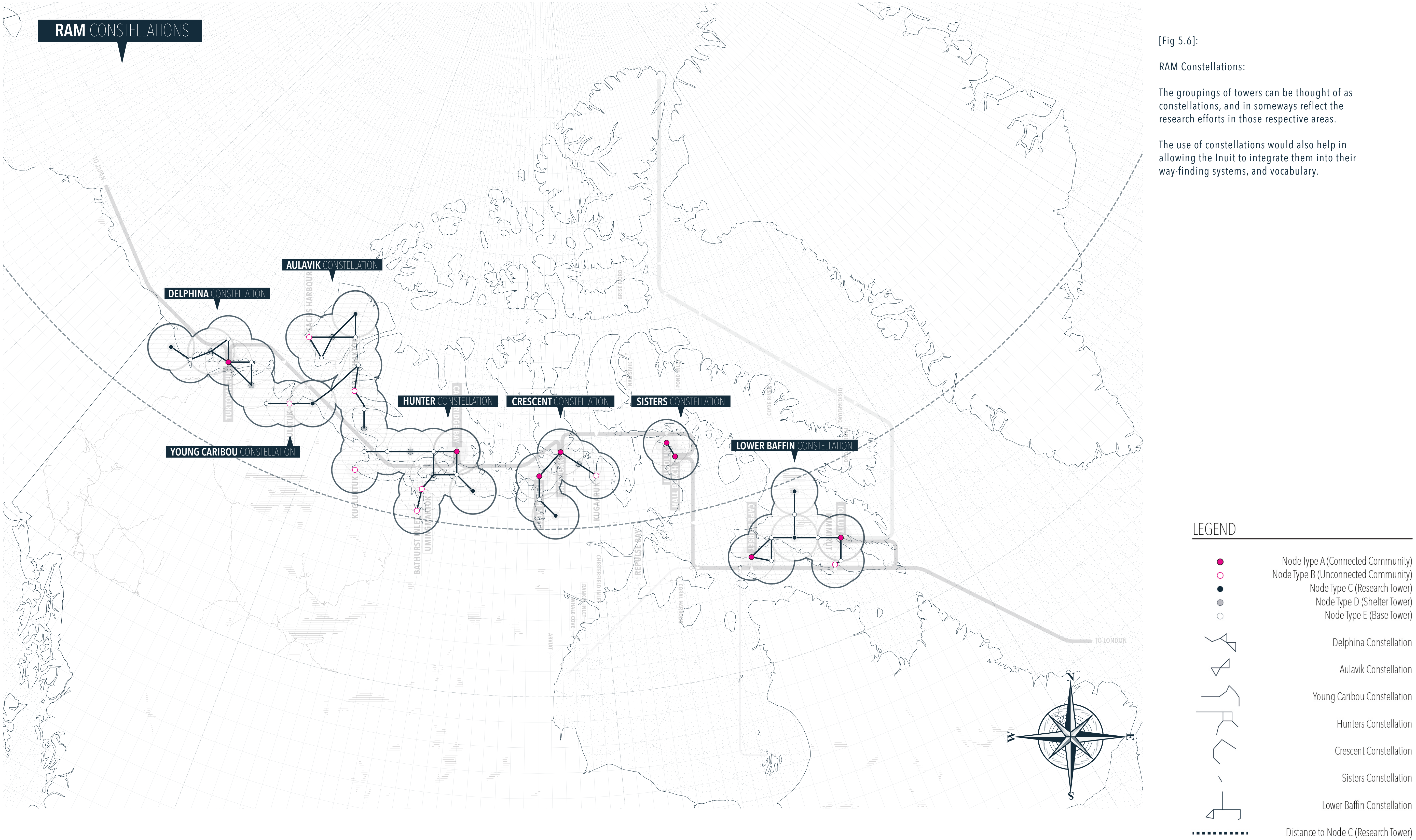
Instead the RAM network towers work in conjunction with the fibre-optic cables landing points at Tuktoyaktuk, Cambridge Bay, Iqualuit and other towns. Network towers at these towns and cities will disseminate Internet signals out to other towers in the Arctic landscape and towns not yet linked to the fibre-cable.

The resultant network at its inception would create a few small pockets and one continuously connected region in the Western Arctic. The benefit of this system, lies in its scalability moving forward (as depicted in the map), towers could slowly populate the Arctic landscape, encapsulating key areas where communication requirements are high, such as the far North for research purposes or potential expanding North and South to provide communities with better communications.

The network points are categorized into five types of nodes, which are covered in the next section.

LEGEND

- Arctic Ocean
- Pan Inuit Trails
- Arctic Circle (60th Parallel)
- Active Field
- Potential Future Expansion
- Node type A Major Landing/Minor Landing
- Node type B
- Node type C
- Node Type D
- Node type E

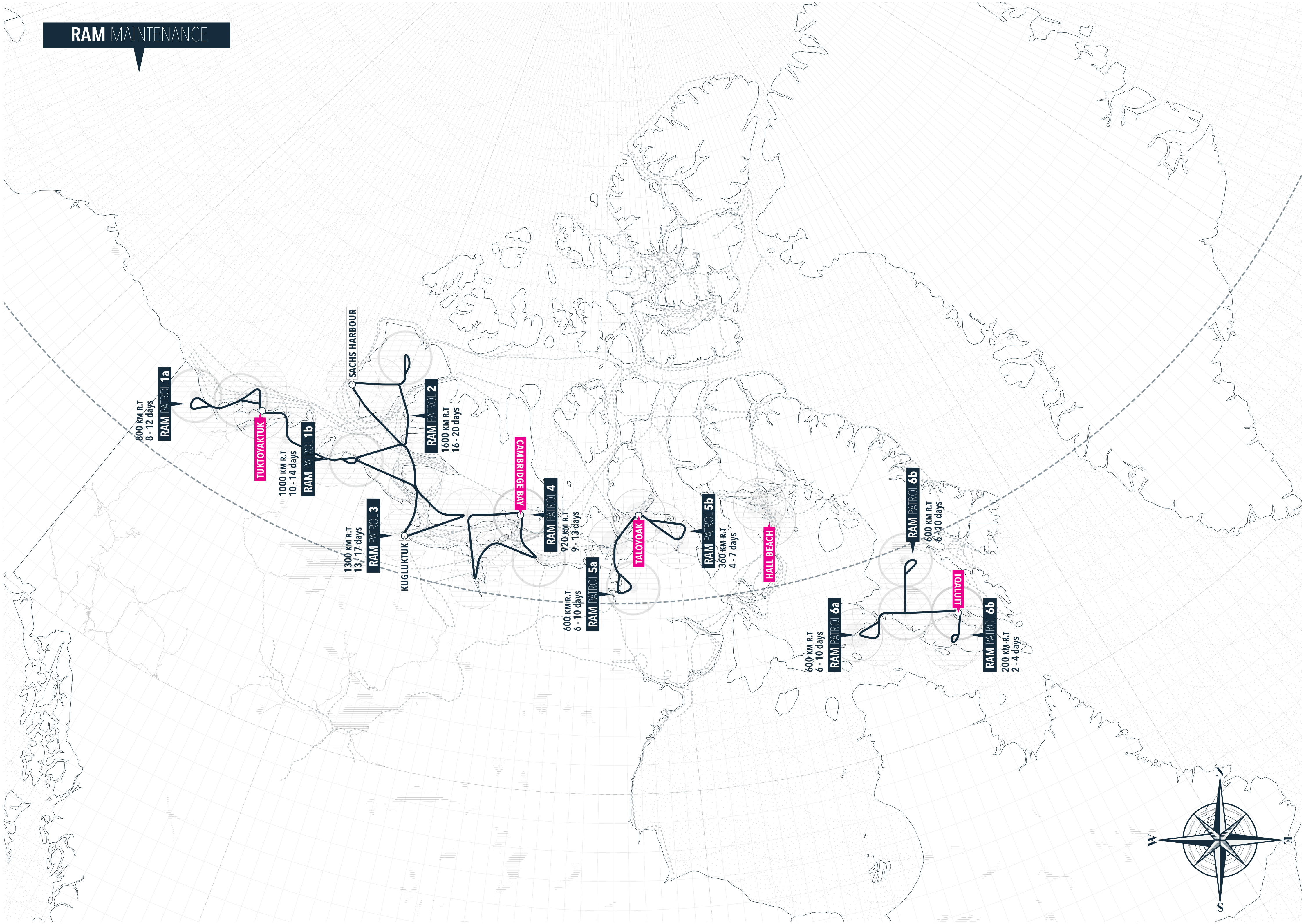


[Fig 5.6]:

RAM Constellations:

The groupings of towers can be thought of as constellations, and in someways reflect the research efforts in those respective areas.

The use of constellations would also help in allowing the Inuit to integrate them into their way-finding systems, and vocabulary.



[Fig 5.7]:

RAM Maintenance:

Any maintenance for the towers would be preformed by the Canadian Arctic Rangers, or a potential subset - the "Digital Arctic Rangers", or which a smaller regiment would be responsible for each of their assigned constellations.

Most of the patrols in the eastern Arctic would result in a conservative estimate of a maximum two week patrol, taking into consideration unforeseen circumstances such as bad weather or injury or longer than anticipated repairs. Patrols in the western Arctic will likely be a minimum of a two-week patrol. Patrols for the regions will likely originate and terminate at Iqaluit, Cambridge Bay, Taloyoak and Tuktoyaktuk as they are key connection points for the fibre cable itself and have access to more goods.

LEGEND

RAM Network Maintenance routes
Pan Inuit Trails
Point of departure

The Users

Both scientists, home and abroad, and the Inuit, including members of the community, hunters, and travellers, act as users of this proposed distributed network, potentially having use of all three of the primary node types. For instance, should a pair of scientists at a research node decide they would like to perform field research for a week outside of their current node area, they can travel to a shelter node to use as a makeshift base camp. The flexible and extensible nature of the network allows them to still be connected and in contact with their colleagues at their home-base, but allow for moments of expansion within the user agenda. Similarly, Inuit hunters can use the nodes for making camp, or butchering meat, and helping scientists gain animal data by providing them with samples of fresh kills as they travel back to their communities. Or in another instance, travellers journeying from one town to another have the opportunity to stop at these nodes for refuelling needs, or to take a break and exchange news from their respective towns.

Thus the nodes can potentially help to create new trails[47] in the Canadian Arctic, provide support for existing ones, and ultimately increase likelihood of chance encounters on these routes. These nodes not only foster the exchange of traditional and contemporary knowledge, but also general information, and the kinds of activities users are participating or planning to participate in.

An additional user of the RAM network – and an important caretaker – would be a branched division of the Canadian Rangers, the new Digital Arctic Rangers (DAR). These members of the Canadian Rangers would be responsible for ensuring the upkeep of the network i.e. performing routine patrolling, checking on network diagnostics, being in charge of repair operations for both the RAM network and Arctic-Fibre Cable, and function as an eyes-on-the-ground technician when required. Current Canadian Ranger members could receive additional training to become certified to perform upkeep and maintenance on the RAM network. Due to the nature of the Arctic, often workers will need to fly in from the south for periods of time to perform specialized construction and repair work. But by training members of the Canadian Rangers – a company of men and women who already have extensive knowledge of the land – it is possible to reduce costs associated with upkeep and repair.

Consider this: a cold snap in the Arctic winter has created ice ridges that have cut the Arctic-Fibre Cable where it begins to transition from the Northwest Passage to land at Cambridge Bay. Even with contractors on stand-by in the larger region, it could take more than a week to reach Cambridge Bay due to potential weather restrictions, time that would cost money as the cable sits cut. But by having a trained team already in place, and as part of the Canadian Rangers (many of whom are already part of communities in the North), there is almost no downtime in having a team in place performing repair operations – saving time and money for the cable's clients, as well as ensuring that the downtime of connectivity is kept to a minimum for scientists who might be in the process of sending valuable data, and locals who might be using it for personal tasks.

Finally, it is entirely possible tourist activity would generate scenarios in which a visiting user group makes use of Shelter nodes as makeshift areas for camping. Eco-tourism is on the rise in the Arctic as southerners rush to see and experience the "last frontier," and many Inuit view tourism as a sustainable economic endeavour over resource extraction – the major export of the Canadian North.

47 Claudio Aporta, "The Trail as Home: Inuit and Their Pan-Arctic Network of Routes," *Human Ecology 37*, no. 2 (April 1, 2009): 131–46, doi:10.2307/40603011.

The Stakeholders

There are several key stakeholders in the realization of the RAM network: this includes the telecommunication companies, the Government of Canada, Educational Institutions, and the private sector.

Telecommunication Companies

Telecommunications companies operating in the North (NorthwesTel, Telesat, SSI Micro) will be key in helping to secure funds for both the Arctic-Fibre cable and RAM network. As well, a secure and sophisticated network ensures lower upkeep costs for the companies, as they can potentially step away from expensive satellite infrastructure. They will also be able to provide the technical expertise, training, and man-power for maintenance of the RAM network and Arctic-Fibre Cable, or at the very least be a major partner with the Canadian Rangers in training their Digital division.

Educational Institutions

It is likely that Canadian universities will have an interest in funding towers in exchange for exclusive rights to use them at certain times of the year. The McGill Arctic Research Station (MARS) serves as precedent for initiating this type of partnership. The MARS was established in 1960 at Expedition Fjord on Axel Heiberg Island in the Canadian High Arctic, and is one of the longest-operating seasonal field research facilities in the Northern region. Since then, McGill researchers have had a long history of Arctic science interest, and it is more than reasonable to imagine other universities may have similar interests in establishing operational research bases in the North, either autonomously or in partnership with other institutions, both at home and abroad.

Government of Canada

There are multiple intra-governmental agencies that would benefit from a reliable and robust communications infrastructure, including Environment Canada, Canadian Coast Guard (CCG), and the Canadian Military, to name a few. For Environment Canada, the RAM network would be useful by increasing the amount extractable weather data in the Arctic – something which is of central importance in predicting larger weather patterns. This, too, can also be of assistance to the CCG services. Additionally, a secure method of communication is, quite simply, of great importance in times of emergency. For the Canadian Military, who performs multiple annual operational exercises in the Arctic, a flexible network would help prevent overloading of communications. Such was the problem in 2009, during Operation Nanook, in which an in-flux of military personnel arriving in one community overloaded the local communications (cell and Internet) network, severely hampering communication capabilities of emergency responders. Flexible networks ensure this type of problem would not arise in the future.

Private Sector

While research infrastructure primarily serves the governmental and academic communities, there are still demands by private sector clients looking for use of regional facilities and networks. Accommodating for private sector use does create some cause for concern in regards to intellectual property, in which the strict ethical clearance applied to university researchers is not necessarily required by private sector research. However, private sector use also brings potential for increased monetary funding for the application, building, and even the expansion of the RAM network. Furthermore, there is a desire for public-private partnerships as contemporary issues call for more research into innovative technologies. These types of partnerships in the region are not without precedent. During the formative years of the Canadian Rangers organization, the Rangers developed partnerships with private entities such as the Hudson's Bay Company (HBC), as there was a mutual benefit to be had. The Rangers were given access to the extensive network of posts already established by the HBC during their years of the fur trade, and many of the HBC staff had an excellent knowledge of the surrounding area, and had continuous contact with the Inuit. Just as the private sector was important in the growth of the fledgling Canadian Ranger's program, it could similarly play as crucial a role in allowing for the RAM network not only to persist, but also to expand.

THE TOWER

The proposed method of connection throughout the Canadian Arctic region requires a direct line-of-sight to exist between one tower and the next. However, due to the relatively flat terrain in Nunavut and the Northwest Territories, the towers do not need to be massive. The proposed towers stand at a height of twenty metres above the Arctic ground.

The towers are built with a diagrid structure, from which various technological appendages assist in keeping both the tower and network functioning. The hollow form created by the tower allows it to be "filled" in with – or encapsulated by – program, depending on its context and as program needs desire.

Operational Technology

The proposed network will function with a consistent baseline bandwidth, download speed, and upload speed. Bandwidth is the amount of data a user can download or upload in a set period of time (usually a monthly cycle). While the established required bandwidth might grow (or shrink, if there is bandwidth going unused), the RAM network's baseline speed should be between 60 Megabytes per second (Mbps) to 250 Mbps.[48] A conservative estimate of around 100 Gigabytes (GB) of Bandwidth[49] for a heavy user, or a single family, provides a good baseline to work with.

The RAM network utilizes Wi-Fi based Long Distance networks (WiLDNet), enabling linkages as long as 100 kilometres to provide connectivity between network nodes. WiLDNet systems[50] make several essential changes to the 802.11 MAC protocol, but continue the usage of standard Wi-Fi network cards.[51] WiLDNet systems make several essential changes to the 802.11 MAC protocol but continue the usage of standard Wi-Fi network cards. WiLDNet is emerging as a cost-sensitive solution that is increasingly being deployed in developing regions of the world such as India and Africa.[52] These networks are different than short-range mesh networks, such as those found in University Campus access or urban Wi-Fi hotspot areas, which use omni-directional antennas to create an active field around a one to two kilometre radius. Rather, the RAM network is comprised of point-to-point wireless links that use high-gain (directional) antennas[53] with line of sight to enable the long distance range between towers. Operational technology at each tower will include low-power – less than five watts – computers running Linux, with an 802.11 a/b/g wireless cards on-board.

Using this type of operational system, it is possible to get up to 5 mbps (with a starting signal speed of between 6 and 8 mbps) of speed even over three hops.[54] Thus, it is reasonable to assume a base node emitting a signal of 100 - 250 mbps speed could retain a similar signal strength at the end of a three to four hop network.[55]

At each RAM network node, a series of battery banks will provide power to the equipment. These batteries work in tandem to solar panel cladding on each RAM tower, storing solar energy that would keep towers in operation for a considerable amount of time during zero-daylight months of the year, while enabling continuous operation in the summer months. Each tower will also be equipped with a small 2000 watt diesel generator to recharge the batteries should they need it.

The top of the towers have four directional antennas to allow for the network to be linked from any direction. The antennas are also capable of linking up to the Anik satellite constellation in the event of a failure at another tower point in the network, allowing for seamless network adjustment, while reserving satellite bandwidth for emergency situations only.

48 This is in-line with what Internet Service Providers, like Rogers and Bell, provide in Southern Canada.

49 Bandwidth is the amount (usually in megabytes or gigabytes) of data a user can download or upload in a set period of time (usually a monthly cycle).

50 A WiLDNet system is short for WiFi over Long Distance Network. These networks are typically defined allowing for internet access to occur in remote locations that separated by extreme distance through the use of repeater stations and WiFi.

51 Rabin K. Patra et al., "WiLDNet: Design and Implementation of High Performance WiFi Based Long Distance Networks.," in *4th Symposium on Networked Systems Design and Implementation (NSDI 2007), April 11-13, 2007, Cambridge, Massachusetts, USA, Proceedings*, 2007, http://www.usenix.org/events/nsdi07/tech/patra.html.

52 The Digital Gangetic Plains (DGP) is a project that has being exploring the use of 802.11 as a long-distance access technology in an ongoing manner.

53 High-gain antenna (HGA) is an antenna with a focused, narrow radio-wave beam width. This narrow beam width allows more precise targeting of the radio signal. High-gain antennas are also known as Directional Antenna.

54 A "hop" in the network refers to signal being bounced from node x to node y to finally reaching its intended host at node z. The process of the signal going from x – y – z is a one hop system.

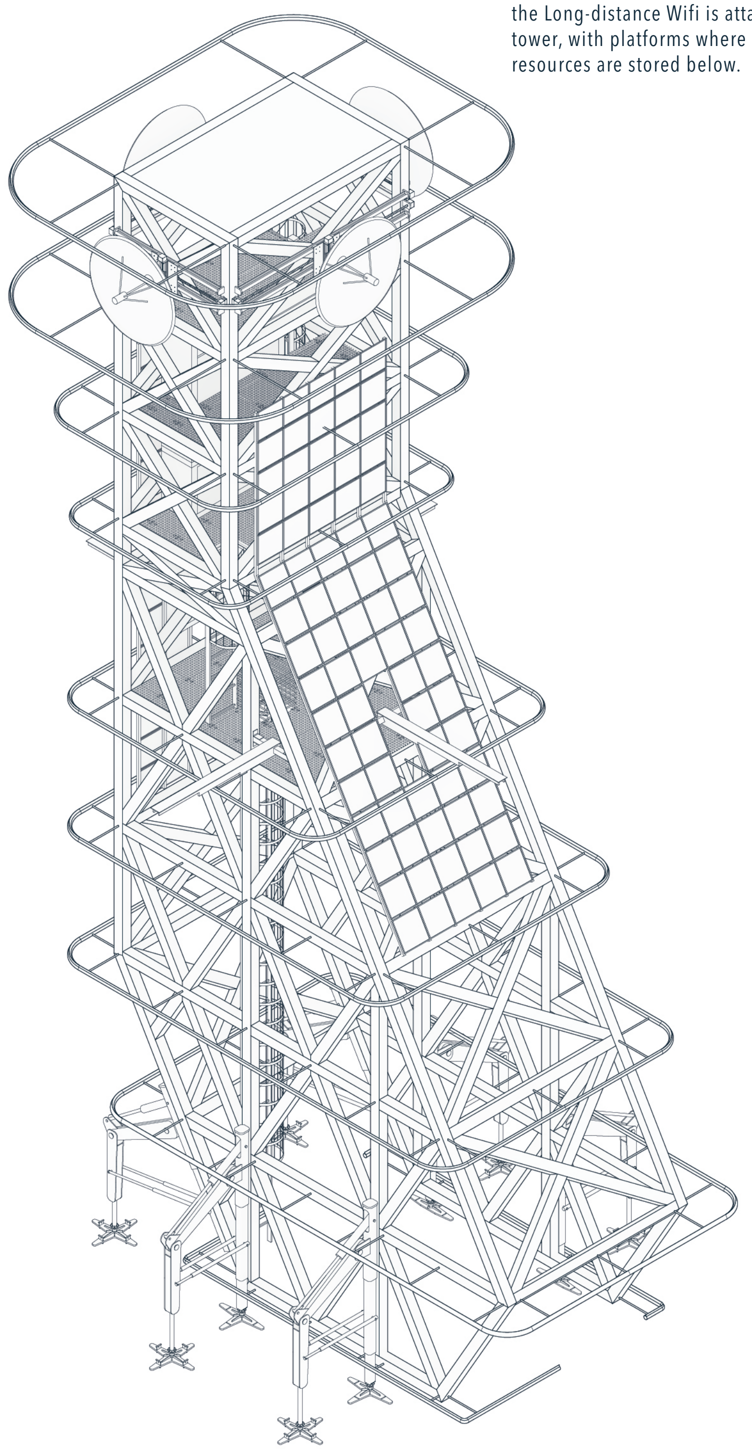
55 Rabin K. Patra et al.

TYPICAL TOWER

[Fig 5.8]:

Typical tower

A typical RAM tower node. The technology to enable the Long-distance Wifi is attached to the top of the tower, with platforms where equipment and power resources are stored below.

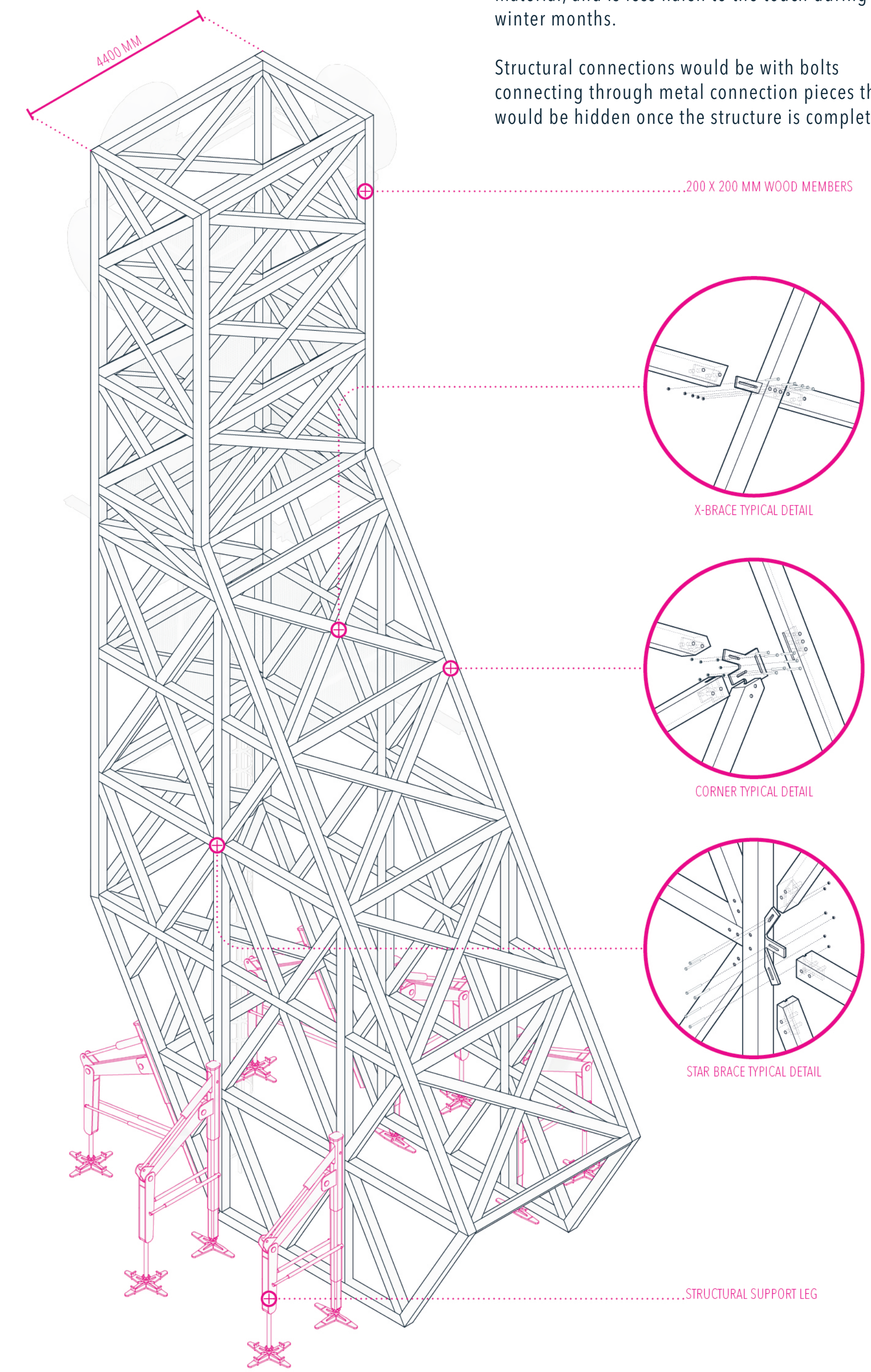


STRUCTURE - TYPICAL TOWER

[Fig 5.9]:

The structure used in all the towers would be wood. Wood, when treated right, can hold up exceptionally well in the Arctic environment, is a sustainable material, and is less harsh to the touch during the winter months.

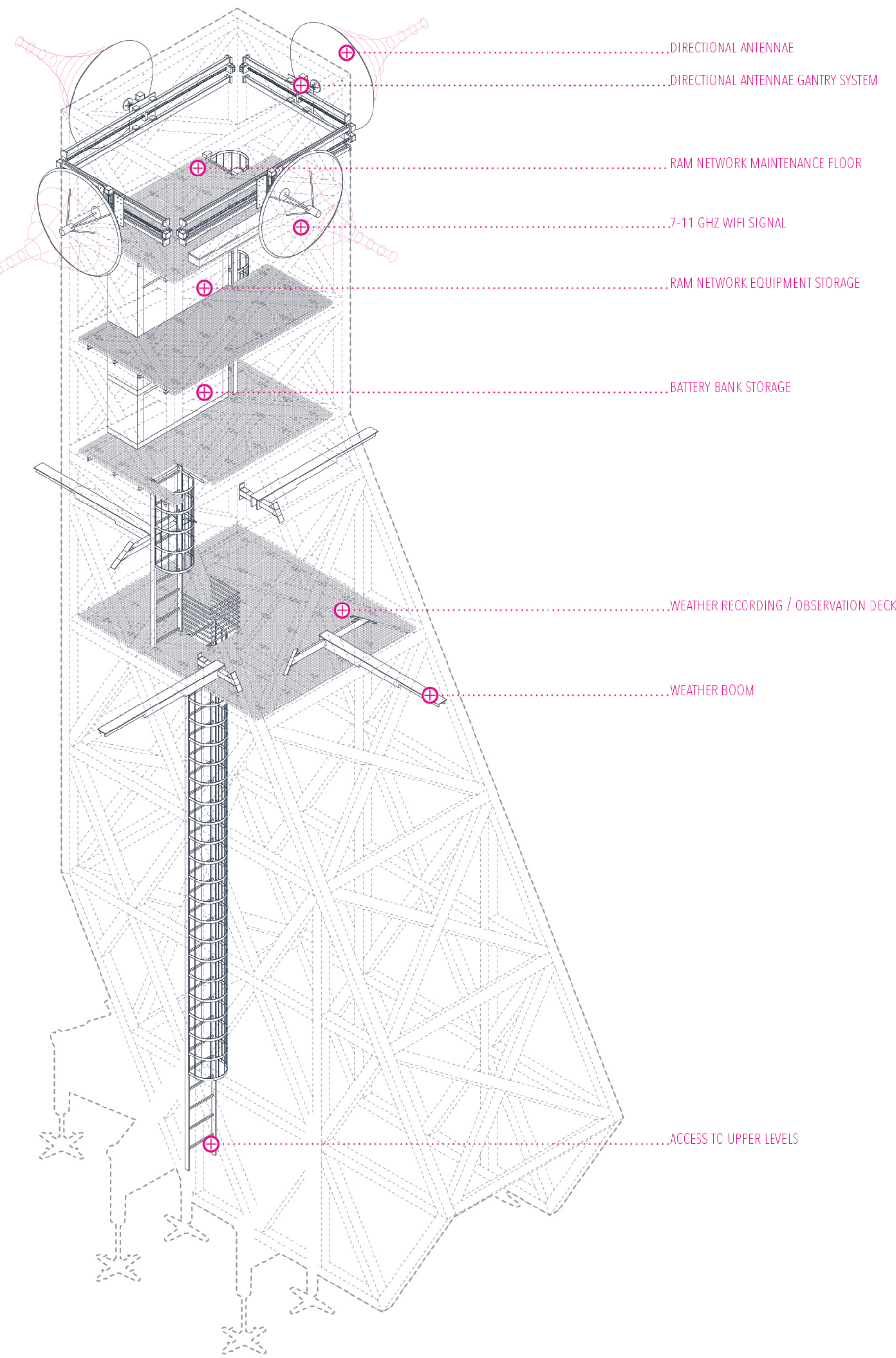
Structural connections would be with bolts connecting through metal connection pieces that would be hidden once the structure is complete.



PROGRAM PLATFORMS - TYPICAL TOWER

[Fig 6.0]:

The program platforms are shown below, access to and between the platforms are by ladders as they are the most space efficient method of moving vertically allowing the tower to optimize it's massing.

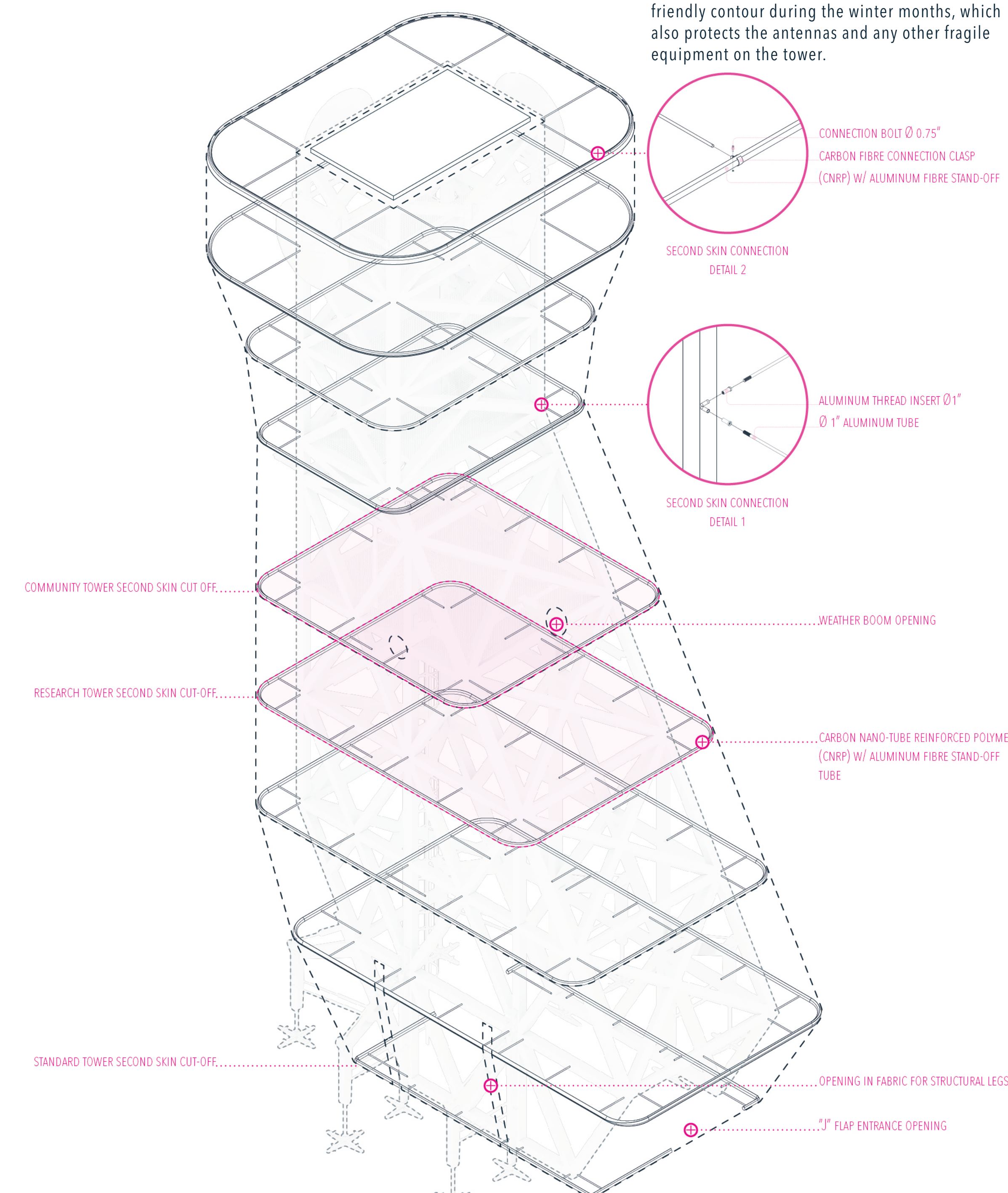


SKIN - TYPICAL TOWER

[Fig 6.1]:

Tower Skin

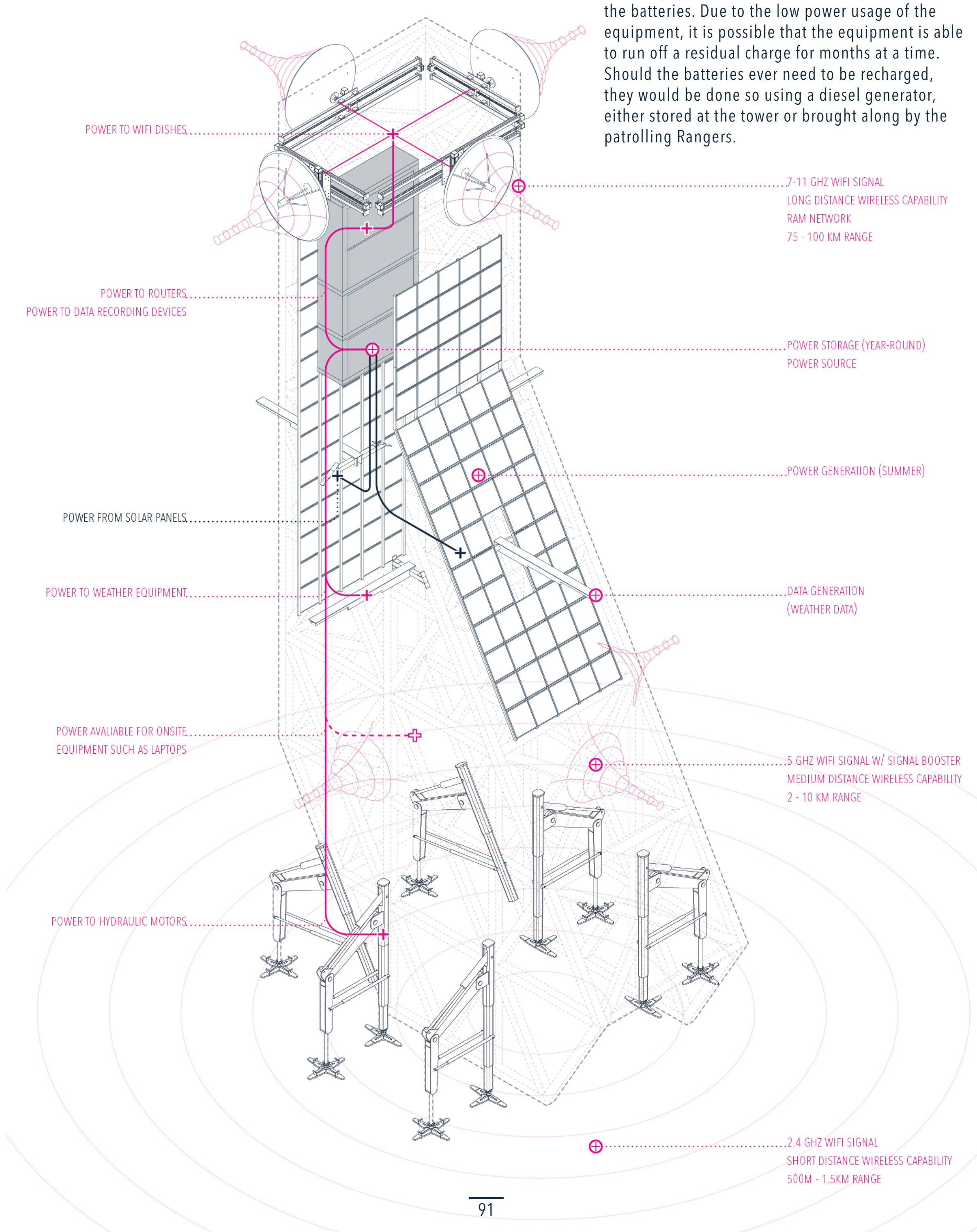
The tower skin is used to create a more wind-friendly contour during the winter months, which also protects the antennas and any other fragile equipment on the tower.



TECHNOLOGY SYSTEMS - TYPICAL TOWER

[Fig 6.2]:

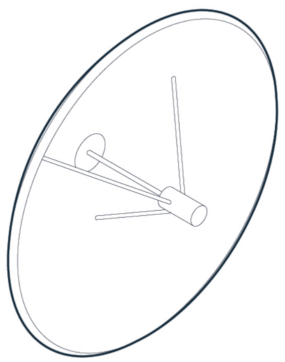
The main source of power, during the summer months, are solar panels. The power is routed to a solar battery bank from which all equipment on the tower is powered. During the winter months, the tower equipment will continue to be powered from the batteries. Due to the low power usage of the equipment, it is possible that the equipment is able to run off a residual charge for months at a time. Should the batteries ever need to be recharged, they would be done so using a diesel generator, either stored at the tower or brought along by the patrolling Rangers.



What follows is a small catalogue of the integral technological components that are a part of making the RAM network system function in the Arctic.

PARABOLIC DISH

[Fig 6.3]



Type: High-Gain Dish
Frequency Range: 5 - 6 GHz
Gain: 30dbi
Beam Width: 6 degrees
Operating Temp: -40ºC to 60ºC
Dimension: 2000 mm ø

The RAM network is comprised of point to point wireless links that use high-gain directional antennas to establish the 100km link nodes.

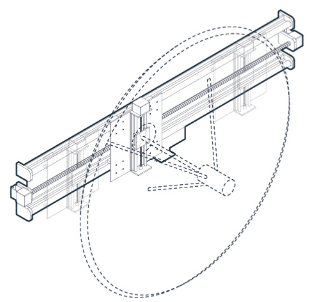
The dishes can be die cast out of aluminum and perforated to reduce its weight, or made out of a plastic resin material.

Each tower node will have 4 dishes at each cardinal direction simulating an omni-directional distribution of the WiFi signal.

1

SATELLITE GANTRY

[Fig 6.4]



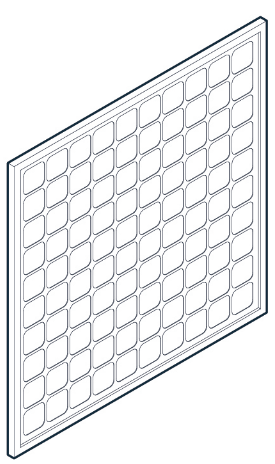
The parabolic dishes sit on a gantry system to enable the dishes to move in both horizontal and vertical positions to ensure that connections between towers can be optimally linked, reducing signal loss over the distance between the tower nodes.

The gantry is made from aluminum. Operated by step-motors, mounting plates on linear pillow blocks can guide the satellite to ensure optimal signal strength is kept between tower nodes. This can be done autonomously (or controlled from a base community).

2

SOLAR PANEL

[Fig 6.5]



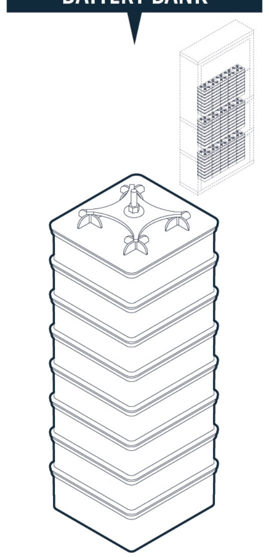
Taking advantage of the few months of near continual daylight, the tower's main energy source during the spring and summer months will be solar energy. The spring and summer seasons are, additionally, the seasons of most scientific activity and the power draw at the tower nodes will be higher than normal making solar ideal as the sun rarely sets during the spring and summer.

The 600 mm x 600mm panels will be mounted on the faces of tower that will receive the highest solar radiation over the course of the year in regards to the tower location and it's orientation to North.

3

BATTERY BANK

[Fig 6.6]



Battery stacks will be trickle charged by the solar panels during the spring and summer and will be responsible of delivering power to the various equipment attached to the RAM Towers. During the winter months, because the activity at the towers is likely to be lowered the batteries will only be operating low power equipment used to maintain the RAM network operational, and will be sufficient as a power source for months at a time.

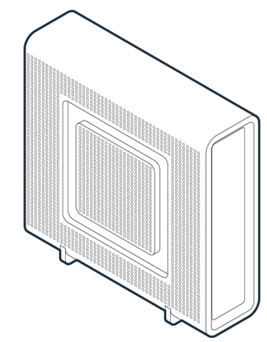
A small diesel generator will be located on site to help recharge any battery banks that are low in power over the course of the winter months.

The batteries will be kept in an insulated cabinet to keep them at their required operating temperature.

4

MODEM + ROUTER

[Fig 6.7]



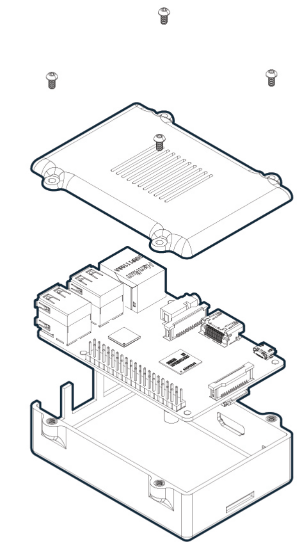
A modem and router will be required at each tower to help move signal requests around.

These are simple off-the-shelf models and need no modification which makes their replacement easy and simple, if ever needed.

5

PORTABLE COMPUTER

Fig [6.8]



A portable computer will be programmed to monitor signal strengths between towers and make and movements to the parabolic dishes as necessary.

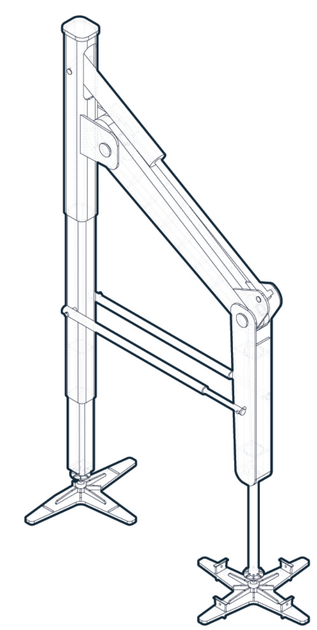
These will be low power computers, running only the programs required to keep the network working. These computers could either be monitored remotely (via a remote desktop application) or adjustments could be made on site.

An example of a programmable low power computer is the RaspberryPi™.

6

HYDRAULIC LEG SYSTEM

[Fig 6.9]



One of the problems with building in the in Arctic is permafrost. There are varying levels of permafrost in the Arctic region from continuous permafrost to seasonal permafrost. During the last several decades much of the Arctic region is seeing a rise permafrost temperatures. Buildings are generally lifted off of permafrost to help prevent thawing with some form of frame or pile support system. However, having to pile in remote regions would require a lot of energy to be used with having to transport the proper equipment to sites. While this can remain the preferred method in communities, further out in the remote areas of the Arctic it may become more unfeasible.

Instead the tower can be effectively placed on the ground but supported by a series of hydraulic legs that carry all the weight of the tower. In this way, if the permafrost begins to thaw or melt seasonally, the hydraulic legs can mechanically keep the tower at its original position and help maintain a level base.

7

NODE TYPOLOGIES

The towers in the RAM network function for three primary usages, each distinguished as a certain type of node. Each node is positioned in relation to the influence of the Arctic Fibre Cable, and with consideration to the needs of researchers, indigenous peoples, resource management, and military assets.

Node types are defined as: Node Type A (Connected Community), Node Type B (Wirelessly Connected Community), Node Type C (Research Base), and Node Type D (Basic Shelter). Since Node Type B is a variation of Node Type A, we can say the three major node types include A, C, and D.

Node Type A : Connected Community

This node type occurs at communities that have a direct (physical) connection to the Arctic Fibre cable. The communities of Iqaluit, Cambridge Bay, Cape Dorset, Igloolik, Taloyoak, Goja Haven, Hall Beach, and Tuktoyaktuk are each located in places where the cable is brought to shore, making them ideal to serve as base stations for originating the Long Distance Wi-Fi (LDWi-Fi) network signal. Additionally, these communities will help to create the network ring-architecture that will add necessary redundancy to the fibre-optic cable system. This would allow, for instance, a cable break occurring between Iqaluit and Cape Dorset to have no effect on the communities elsewhere along the network.

Cambridge Bay, Iqaluit and Tuktoyaktuk are all sites that additionally function as support nodes for major repair operations along either ends of the cable's length. Other program relating to maintaining signal and cable integrity is also included. This programs consists of both an Equipment Room and a Generator space.

Equipment Room

The dry-plant of a submarine communications system requires multiple types of equipment to deal with signal and physical cable termination and repetition. Equipment at the dry-plants in Cambridge Bay and Iqaluit will consist of: Power Feeding Equipment (PFE)[56]; equipment that supplies electric power the signal repeaters along the cable's route, Cable Termination Unit (CTU)[57]; equipment that connects terrestrial cable to submarine cable, SDH[58] Interface Equipment (SIE); equipment that interfaces with a terrestrial SDH network, System Surveillance Equipment (SSE)[59]; equipment that enables tracking of the function and performance of the cable line as a whole, Element Management System (EMS); equipment that serves as the control panel for the cable system and is the main interface for all the equipment in the dry-plant, and finally the Submarine Line Terminal Equipment (SLTE), which is the main piece of equipment required to transmit and receive data signals over ultra-long distances. In addition to equipment specific to the fibre-optic cable, the equipment room will also be where the battery bank is housed. The battery bank will ensure none of the operation equipment goes offline between the time of an electrical outage and the diesel generators start up – which usually lasts only a few seconds.

56 Yoshimura, V. Hiroshi Oikawa V. Junichi, and V. Haruki Watanabe. "High-performance submarine line terminal equipment for next-generation optical submarine cable system: FLASHWAVE S650." *FUJITSU Sci. Tech. J* 42, no. 4 (2006): 469-475.

57 Ibid.

58 SDH or Synchronous Digital Hierarchy is a standardized protocol that was developed for transporting large amounts of telephone and data traffic over the same fibre without synchronization problems.

Generator Room

The Generator Room is included so that in the event of a community power outage, the cable remains functional. The room will house two 13,000 Watt diesel generators for redundancy.

Node Type B: Wireless Community

These nodes relate to the communities that will not be connected to the current Arctic-Fibre Cable plan. The communities included in this criteria are: Sachs Harbour, Paulatuk, Ulukhaktok, Kugluktuk, Kugaaruk, Coral Harbor, Pangnirtung, Qikqtarjuaq, Clyde River, Pond Inlet, Resolute Bay, and Grise Fiord.

These nodes will not have an extensive equipment or generator room, but will allot space for expansion to a Node A type, should future funding allow for the cable to make its way to shore at these communities. The equipment will consist of a small generator (4000 watts) to power the Wi-Fi dishes in the winter-months when battery power is no longer usable, or in communities where electric grid stability is a concern. These nodes will also have multi-use space that will primarily serve as a knowledge-sharing nexus between researches and locals in the communities.

TEST SITE NODE A: Tuktoyaktuk

The town of Tuktoyaktuk (Tuk) sits on the banks of the Beaufort Sea, a site of unique intersection between stakeholders. Oil and gas companies like British Petroleum and Imperial Oil are greatly interested in the potential hydrocarbon reserves in the Beaufort Sea a mere few hundred kilometres off the Tuk coastline. The region also sits at the end of the Mackenzie Delta, and is part of one of the most ecologically diverse regions in the Arctic. At the same time, climate change, rising seas and warming temperatures are starting to exacerbate the coastal erosion Tuk has faced for decades. This makes the surrounding area an ideal place for research, and true to this potential, Tuk was home to the Polar Continental Shelf Program lasting from 1967 to the late 80s, when it was shut down from lack of funding.[60]

59 The SSE can also be referred to as LMS or Line Monitoring System.

60 The Edmonton Journal, "Arctic Scientists Frozen out," *Canada.com*, accessed June 29, 2015, http://www.canada.com/story.html?id=3bfaa689-df9f-4693-b989-97a4b73d2b1f.

In the RAM proposal Tuk is also set to become a key landing point for the proposed Arctic Fibre cable.

The region is also starting to garner the interest of countries outside of the Arctic 8. Chinese scientists, eager to tap Canada's oil and gas, want to build a research outpost in the North that will provide permanent monitoring of the environment and lay the groundwork for energy development in the future. While it may sound obtuse, China has gained observer status in the Arctic council and by partnering with other countries, Canada has a real possibility for increasing funding towards Arctic science and preventing further funding cuts, which could lead to the closure of important research foundations such as the Canadian Foundation for Climate and Atmospheric Research.[61] Canada has a record, albeit only with the United States, of extensive joint-operations in the North. The Distance Early Warning (DEW) line and a series of high-Arctic weather stations (many of which never came to fruition) were built during and just after the cold-war era with U.S. cooperation. It is not too bold to imagine a similar effort between China and Canada emerging.

> I know that researchers are struggling to maintain their programs and do what's needed. This government (Steven Harper) tends to look at most research through the lends of economic development, so there has been some shifts in the research funding.
>
> - James Durmmond[62]

Additionally, a road connecting Inuvik to Tuktoyaktuk, scheduled to be finished by 2018,[63] is set to bring more tourism to the town, shifting money northward from Inuvik. is set to bring more tourism to the town, shifting money northward from Inuvik. But Tuktoyaktuk currently lacks some of the amenities to support a large increase in overnight tourism, including a dedicated visitors' centre.

As a response to these issues, the RAM node at Tuk is one that will support the multiple agendas seeking to be active in and around the area. Here, the base to the four metre-wide tower is encapsulated by two large programmed blocks. The building sits on a hilltop on the Eastern shoreline of the town, away from the more erosion-prone western shore. Its design is reminiscent of a lighthouse. An exterior deck leads down to the beach-shore, and this is where the fibre-optic cable will make its journey up into the building to be connected to a terrestrial network.

At the ground floor level, the first third of the building consists of a reception area, and mechanical / equipment rooms that are integral to the fibre-optic cable operation. It is programmed to encourage chance encounters between scientists who study the Arctic closely, and the people who live there, and know it innately. The middle portion of the building acts as a multi-functional space. Here a three metre-wide, programmed-closet block on the east of the building houses three lab spaces, which can be opened up and expanded during peak research season and closed in off-season periods. Rather than segregating a large portion of the building, making it potentially unused space for months at a time, this flexible lab can also be used as space for community engagements such as seminars and meetings, teaching labs, or even simple exhibition space. The final third of the building is an open space reserved for whatever use the community might need of it, ensuring that even in peak research season, community members have a place for gathering.

The third level of the building is a media and information access space where members of the community or visiting scientists can have access to computers for their needs. Part of this space is also envisioned to be used as a documentation space. As the Inuit share their knowledge in an oral fashion, through stories and recollections, members of the community, especially elders, can record their experiences and have it digitally archived such that the knowledge can exist for the presumable future and be shared to future generations, other communities in the Arctic, and the world at large.

The fourth level, now the tower proper, is a publicly-accessible observation deck. Here, the older generation can teach the younger how to spot for whales during hunting season, provide researchers a platform from which to conduct minor weather monitoring (most weather monitoring already occurs at airports in the Canadian Arctic), or simply become a place of repose for the community and visitors alike. The uppermost levels are restricted access and contain the battery bank used for emergency power purposes and the Wi-Fi equipment at the top of the tower.

61 CBC News, "China Seeks to Establish Northern Canadian Research Outpost," *CBC News*, accessed June 29, 2015, http://www.cbc.ca/1.3006806.

62 Ibid.

63 CBC News, "Tuktoyaktuk Road May Shift Tourism Dollars North from Inuvik," *CBC News*, accessed June 29, 2015, http://www.cbc.ca/1.2741121.

[Fig 7.0]:

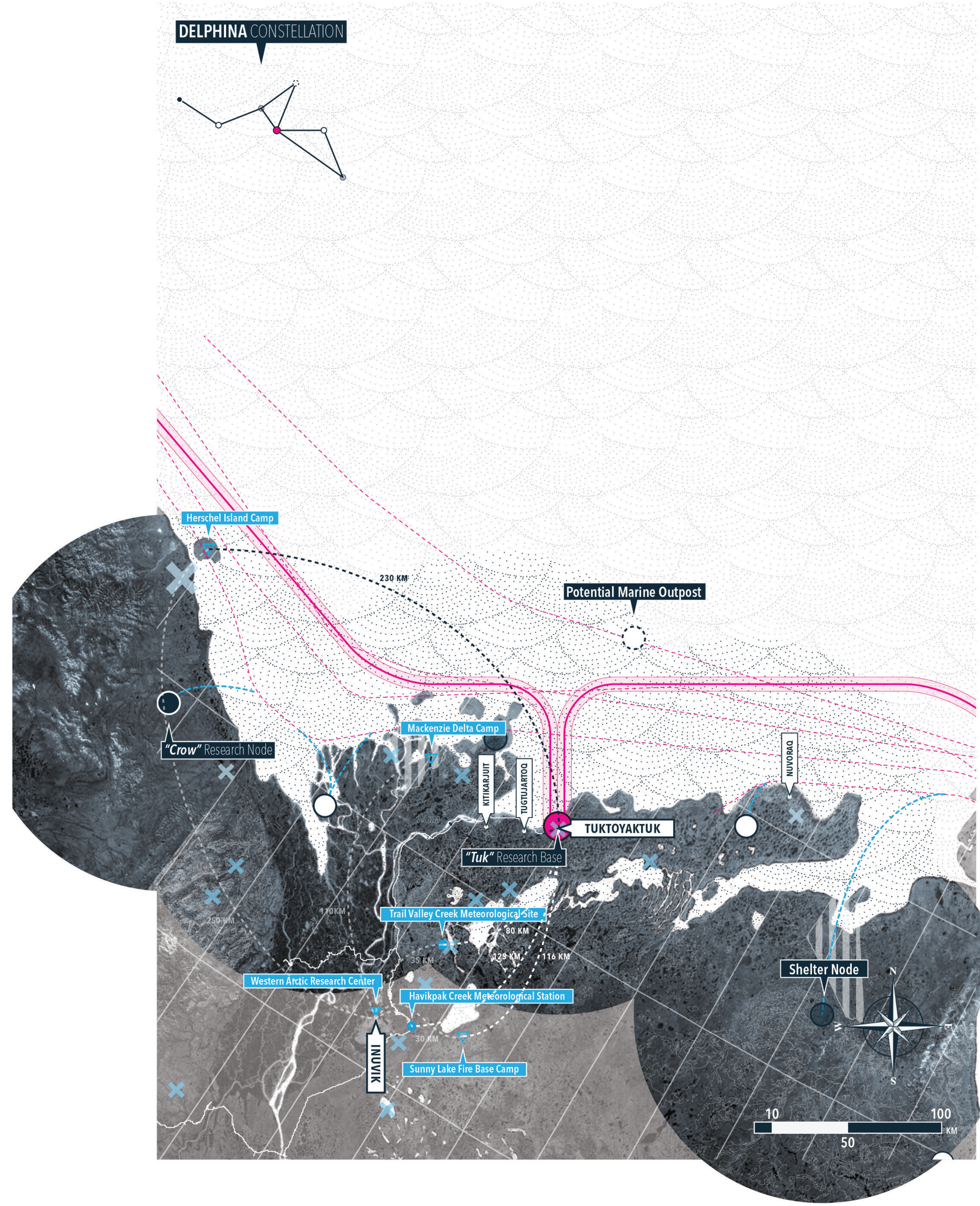
Node Type A Regional Site Map

The highlighted sections represent the RAM tower's area of influence. Objects within these fields are able to connect to the tower if they are capable. As the Tuk region is in the Beaufort Sea, a lot of marine research is being conducted in regards to hydrocarbon retrieval, sea-bed mapping, and general sea ice observations - which is why in the future it is possible that some form of marine outpost be built at the edge of a tower's communications range.

Currently Inuvik is the major research town hub in the region, though Tuk once did have a Polar Continental Shelf Project supported research base, it has since been decommissioned. The RAM tower here would be a spiritual successor to that previous research facility.

LEGEND

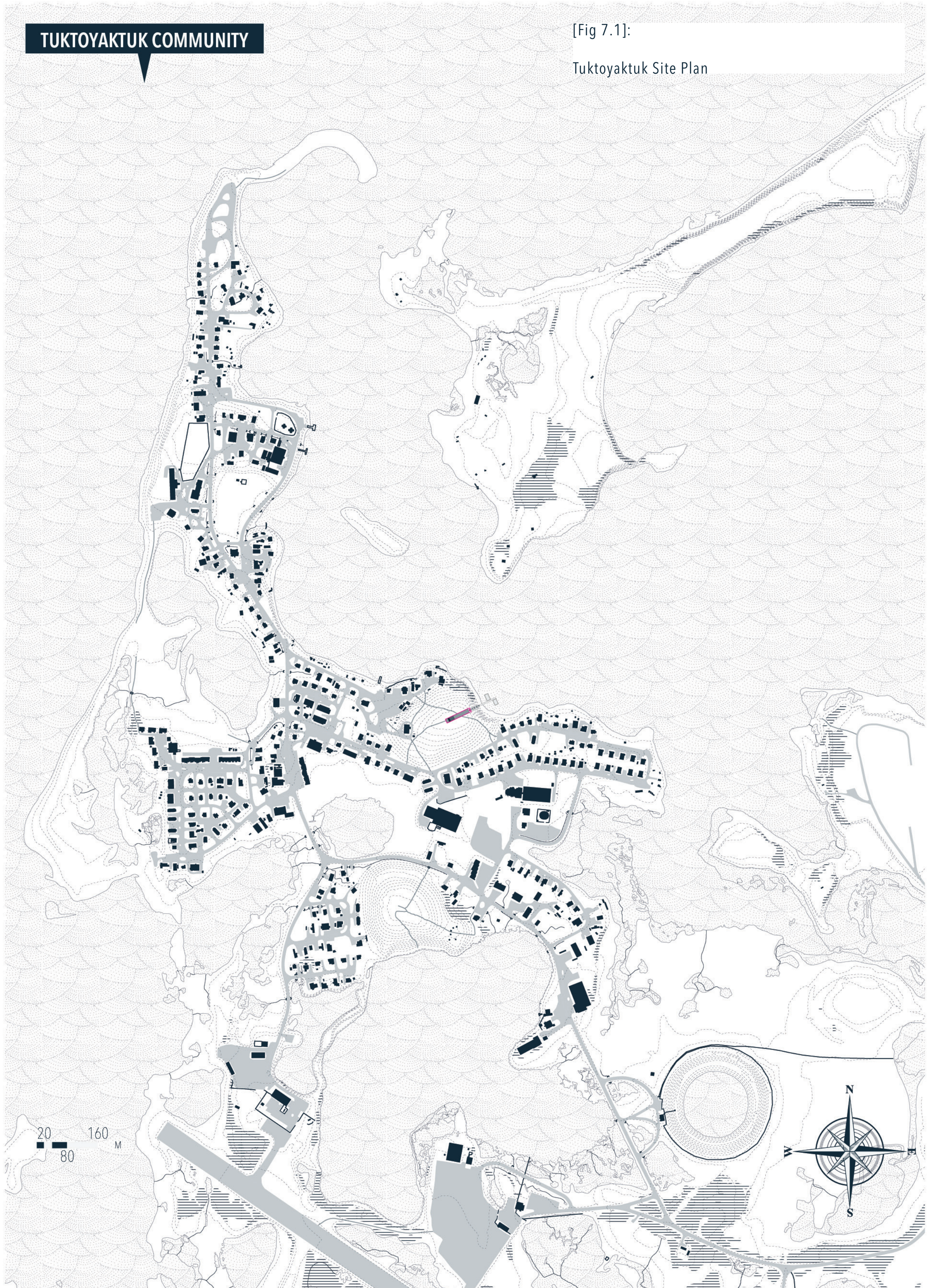
- Fibre Optic Cable Route
- Pan-Inuit Trails
- New Pan-Inuit Trails created
- PCSP Field Site
- Experimental Field Station
- Seasonal Field Station
- Community (Node Type A)
- Research (Node Type C)
- Shelter (Node Type D)
- Arctic Ocean
- Provincial Park / Protected Area



TUKTOYAKTUK COMMUNITY

[Fig 7.1]:

Tuktoyaktuk Site Plan



NODE TYPE A - SITE PLAN

[Fig 7.2]:

"Tuk" Research Base Site Plan

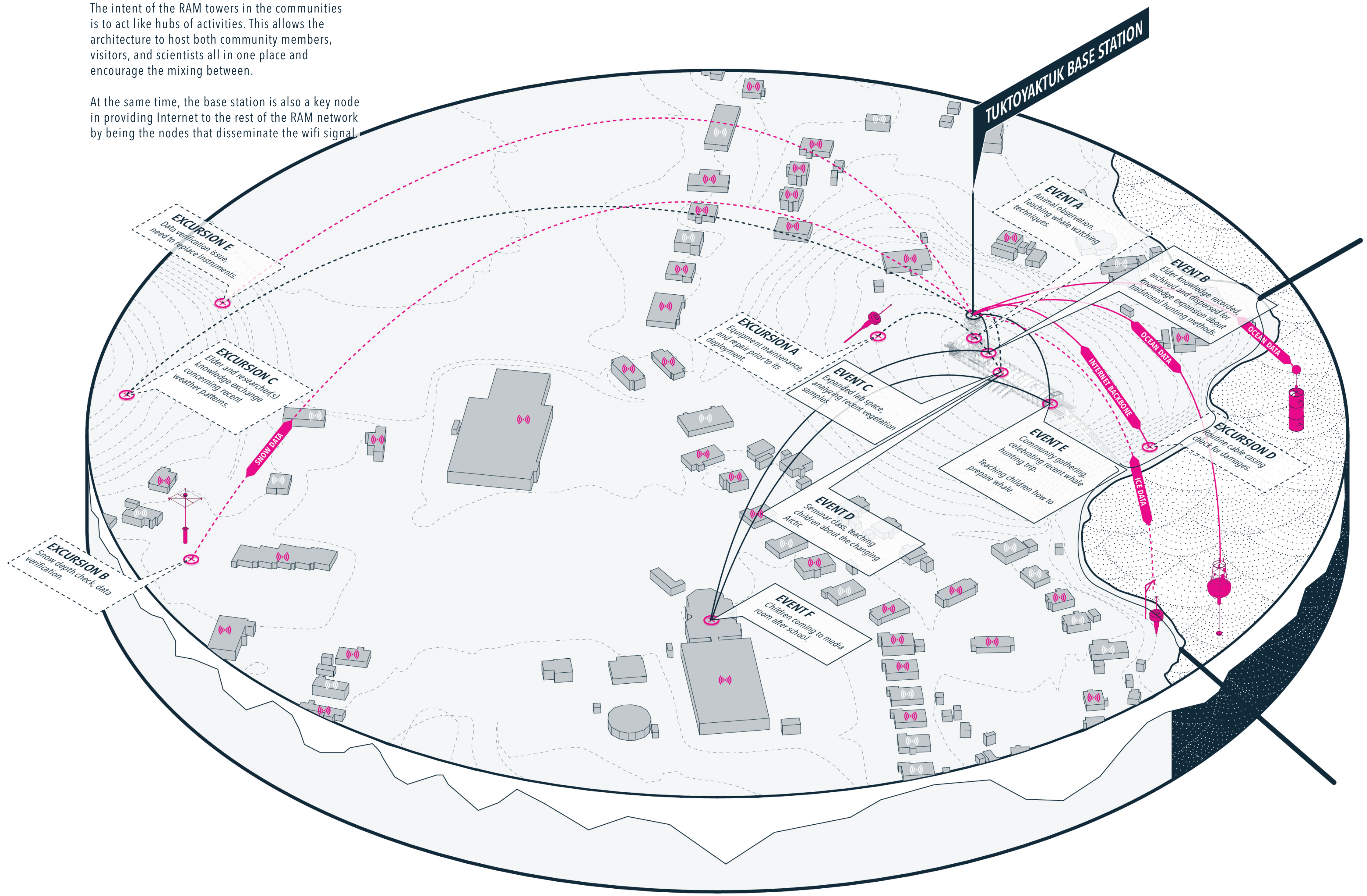
NODE TYPE A - ACTIVITY DIAGRAM

[Fig 7.3]:

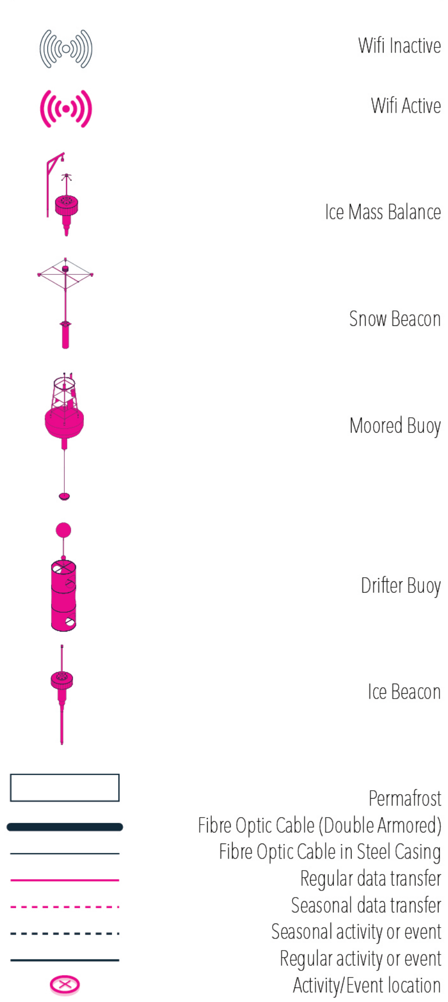
Tuktoyaktuk Base Station (Node Type A) Activity Diagram:

The intent of the RAM towers in the communities is to act like hubs of activities. This allows the architecture to host both community members, visitors, and scientists all in one place and encourage the mixing between.

At the same time, the base station is also a key node in providing Internet to the rest of the RAM network by being the nodes that disseminate the wifi signal.



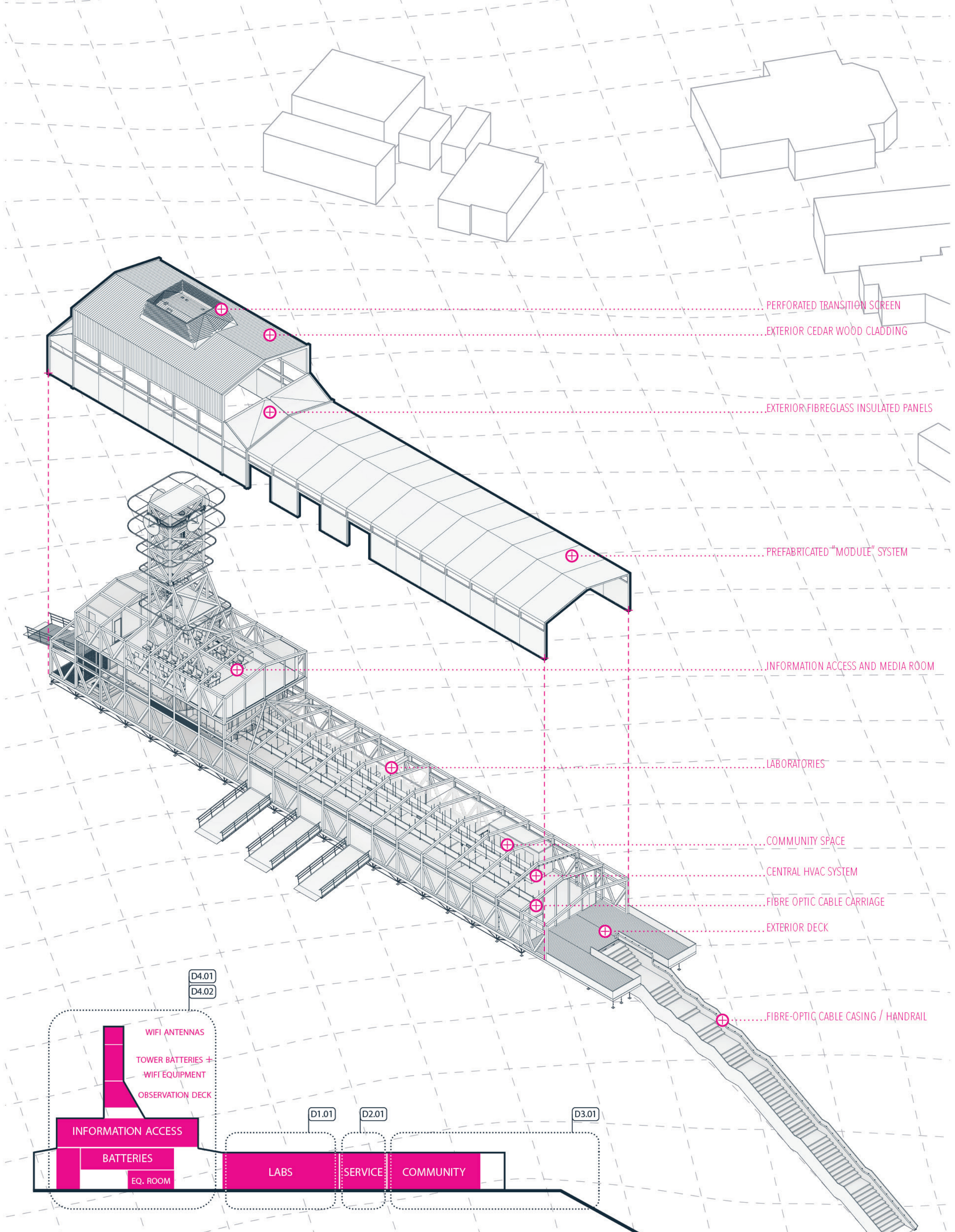
LEGEND



NODE TYPE A - WIRED COMMUNITY

[Fig 7.4]:

Node Type A Axonometric

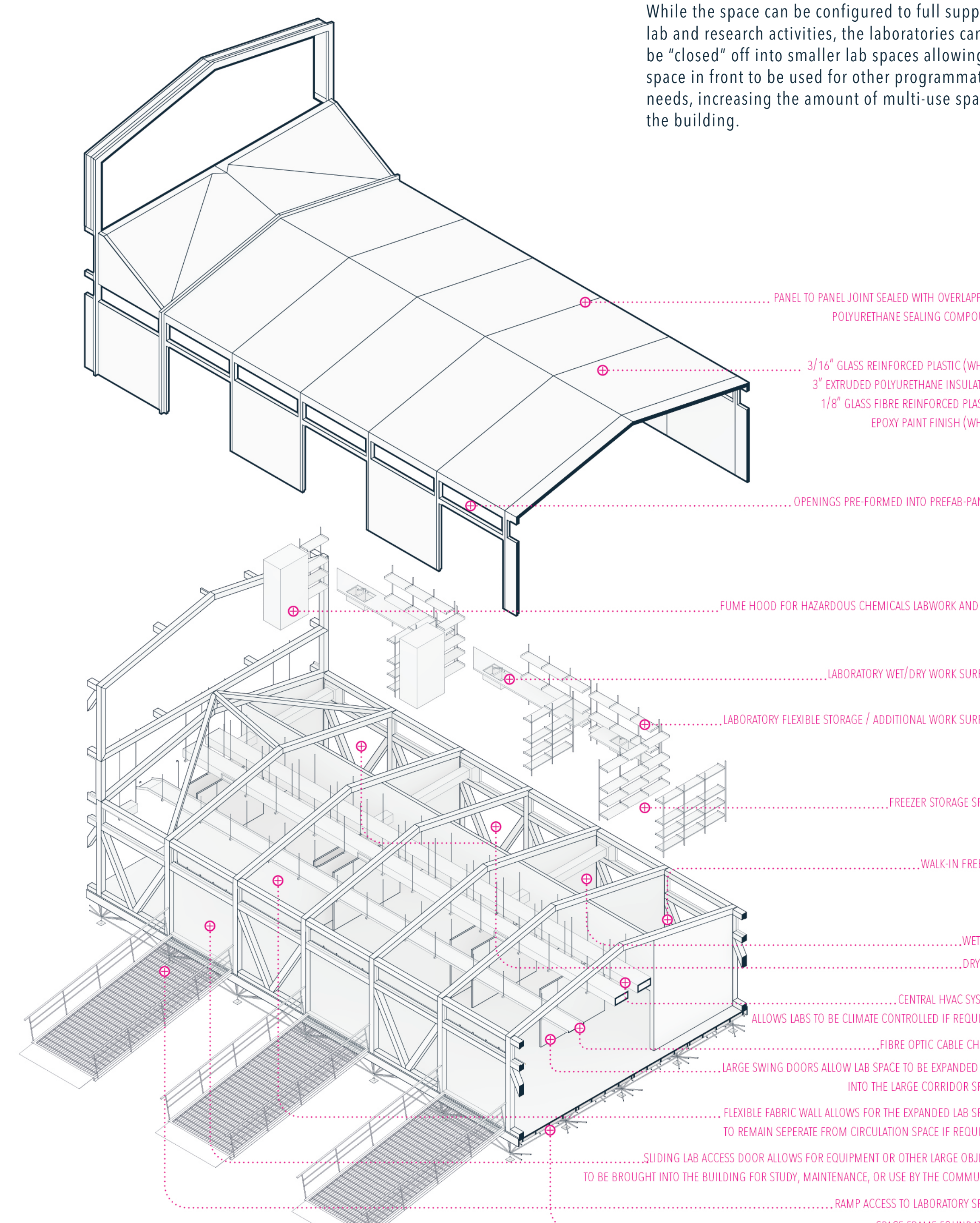


NODE TYPE A - D1.01 LABORATORY BLOCK DETAIL

[Fig 7.5]:

Laboratory Block Axonometric

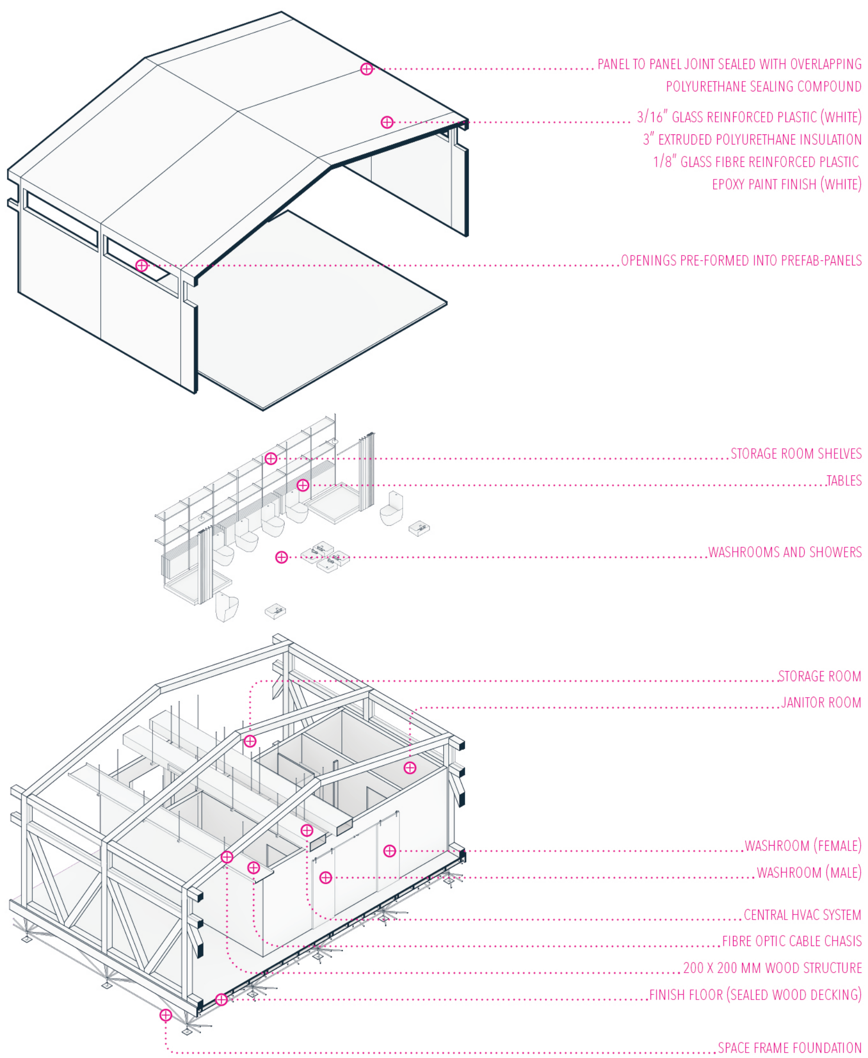
While the space can be configured to full support lab and research activities, the laboratories can also be "closed" off into smaller lab spaces allowing the space in front to be used for other programmatic needs, increasing the amount of multi-use space in the building.



NODE TYPE A - D2.01 SERVICE BLOCK DETAIL

[Fig 7.6]:

Service Block Axonometric



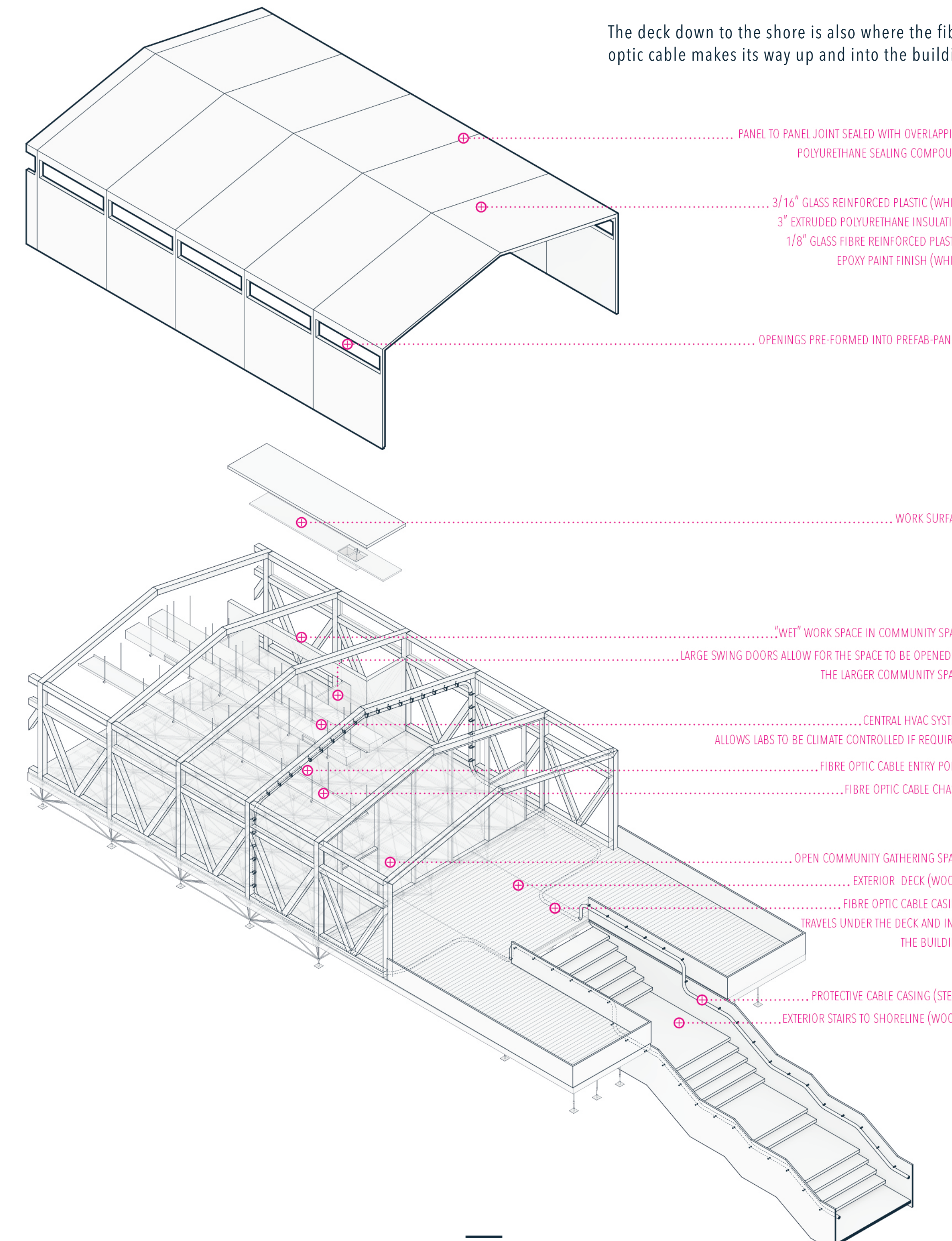
NODE TYPE A - D3.01 COMMUNITY BLOCK

[Fig 7.7]:

Community Block Axonometric

The community space is an open space to allow for it to be flexible and handle a variety of events and activities that may occur throughout the course of the year.

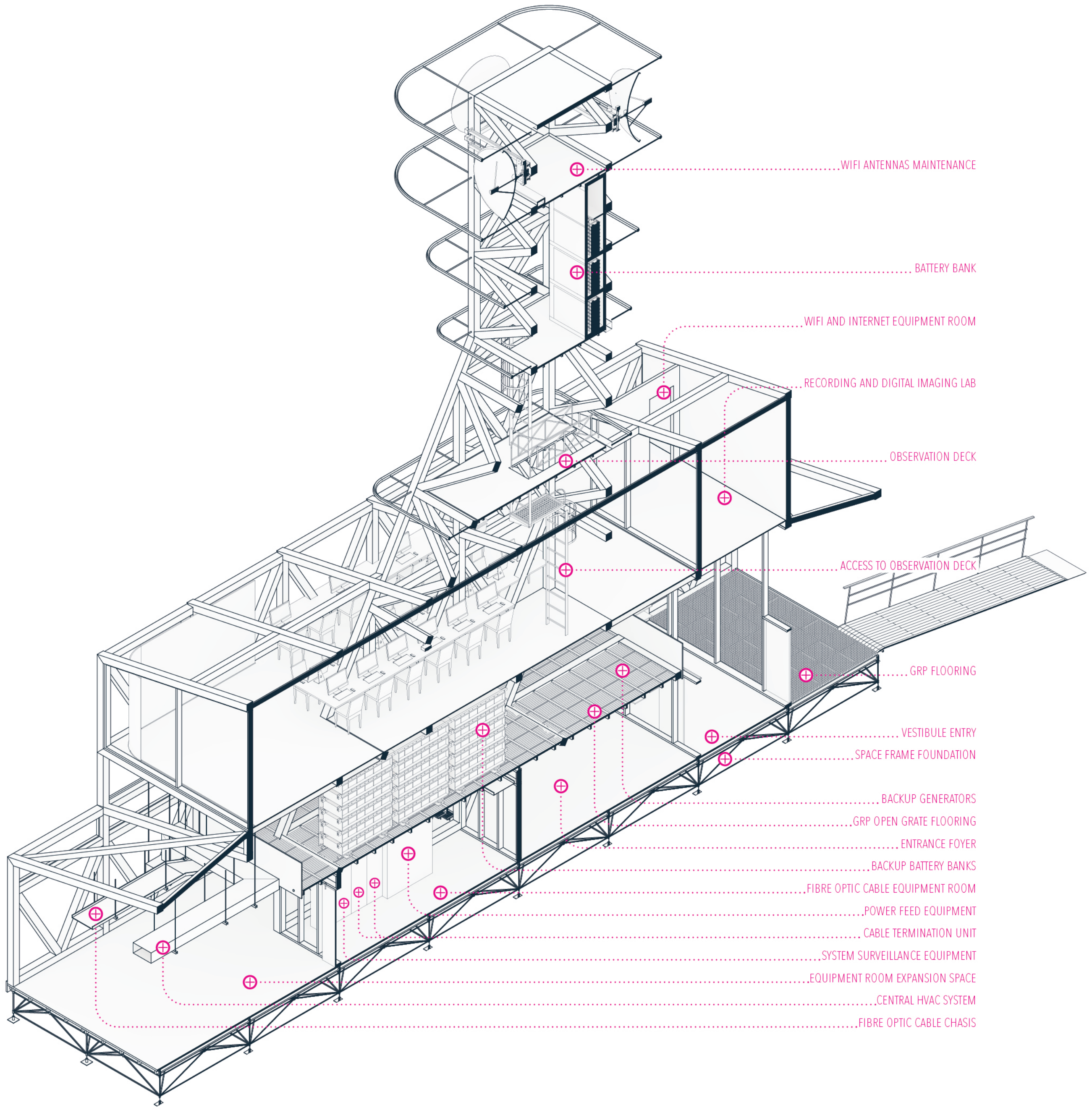
The deck down to the shore is also where the fibre-optic cable makes its way up and into the building.



NODE TYPE A - D4.01

[Fig 7.8]:

Sectional Axonometric - Media Lab



NODE TYPE A - D4.02

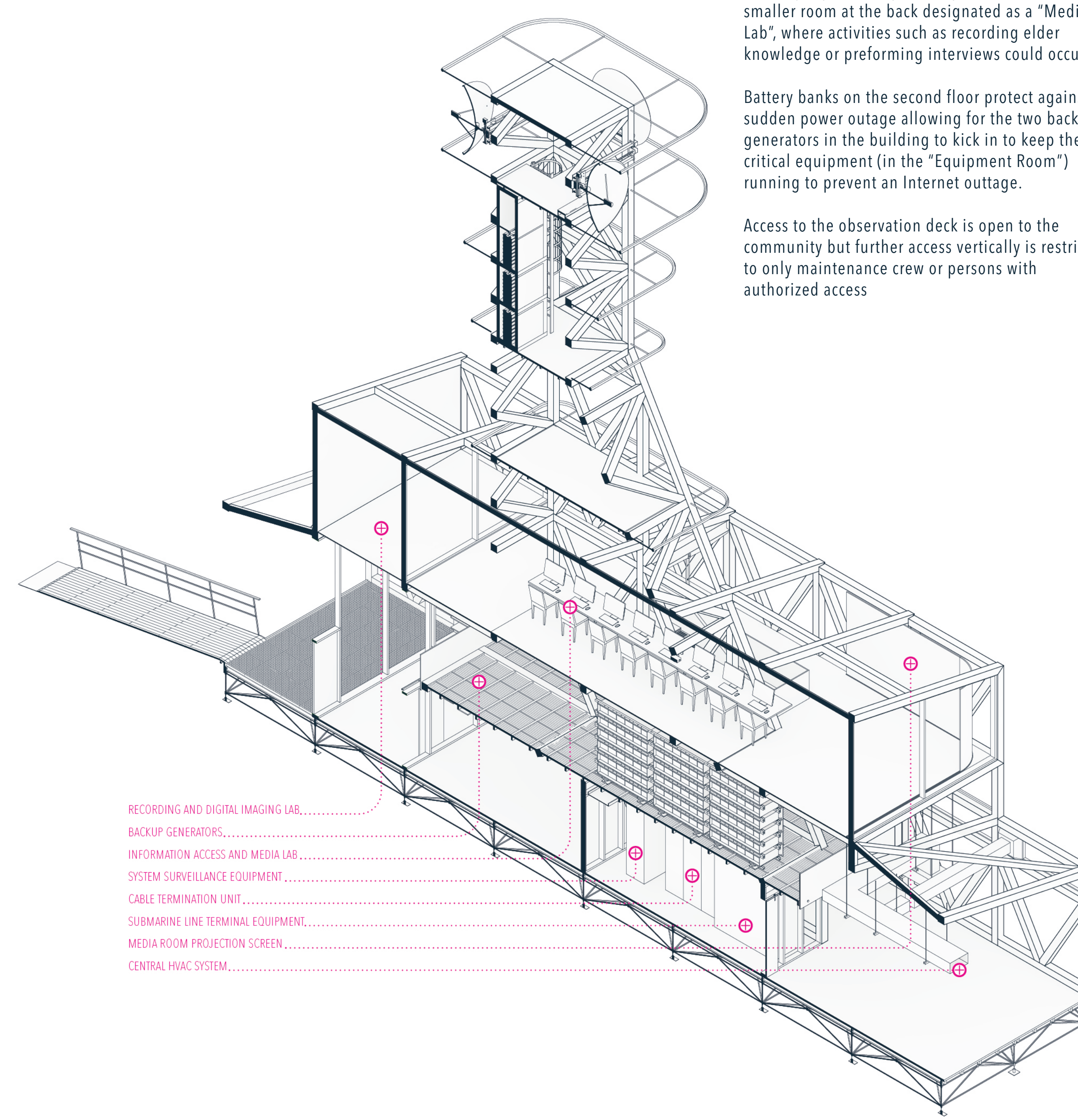
[Fig 7.9]:

Sectional Axonometric - Media Lab

The media lab on the second floor is composed of one large space for open computer access, with a smaller room at the back designated as a "Media Lab", where activities such as recording elder knowledge or preforming interviews could occur.

Battery banks on the second floor protect against a sudden power outage allowing for the two backup generators in the building to kick in to keep the critical equipment (in the "Equipment Room") running to prevent an Internet outtage.

Access to the observation deck is open to the community but further access vertically is restricted to only maintenance crew or persons with authorized access



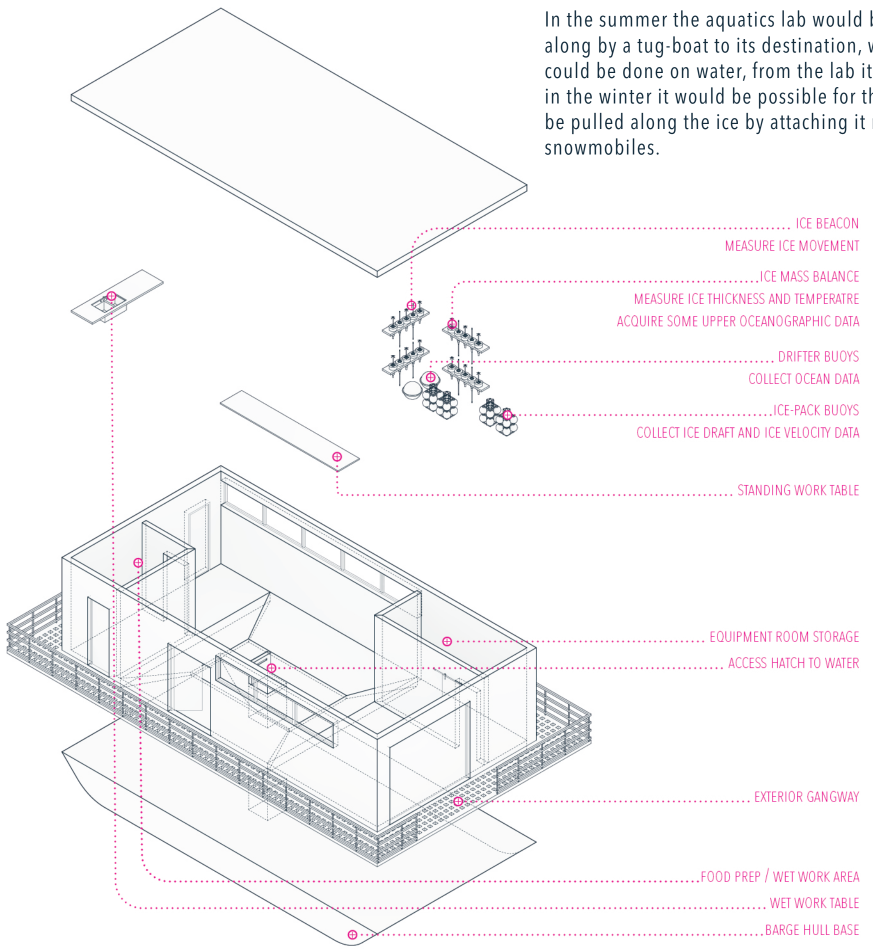
NODE TYPE A - AQUATICS LAB DETAIL

[Fig 8.0]:

Aquatics Lab

The aquatics lab serves as a mobile extension of the lab space at the Tuktoyaktuk Node. Because the CCGS Amundsen, the only marine research vessel with lab space on-board, is only available for a short-season to the researchers in the Arctic, the aquatics lab could serve as a smaller lab directly for the Beaufort Sea region, allowing the CCGS Amundsen to provide support for marine research in other areas of the Arctic.

In the summer the aquatics lab would be pulled along by a tug-boat to its destination, where work could be done on water, from the lab itself and in the winter it would be possible for the lab to be pulled along the ice by attaching it multiple snowmobiles.



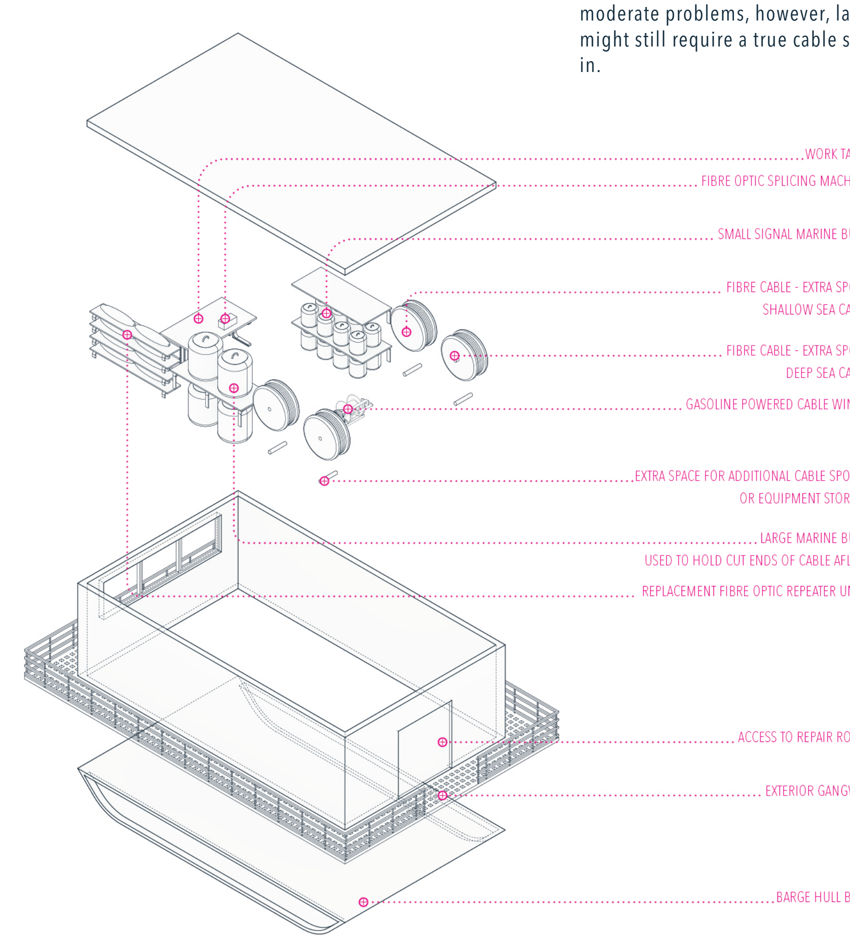
NODE TYPE A - FIBRE REPAIR LAB DETAIL

[Fig 8.1]:

Fibre Repair Lab

The fibre repair lab would only ever need to be used should there be a cable break, or transmitter malfunction along the cable route within the region. This unit would also be stationed at Cambridge Bay, Iqaluit, Coral Harbor,Gjoa Haven, and Taloyoak. Similar to the aquatics lab, this unit would need to get towed to its destination.

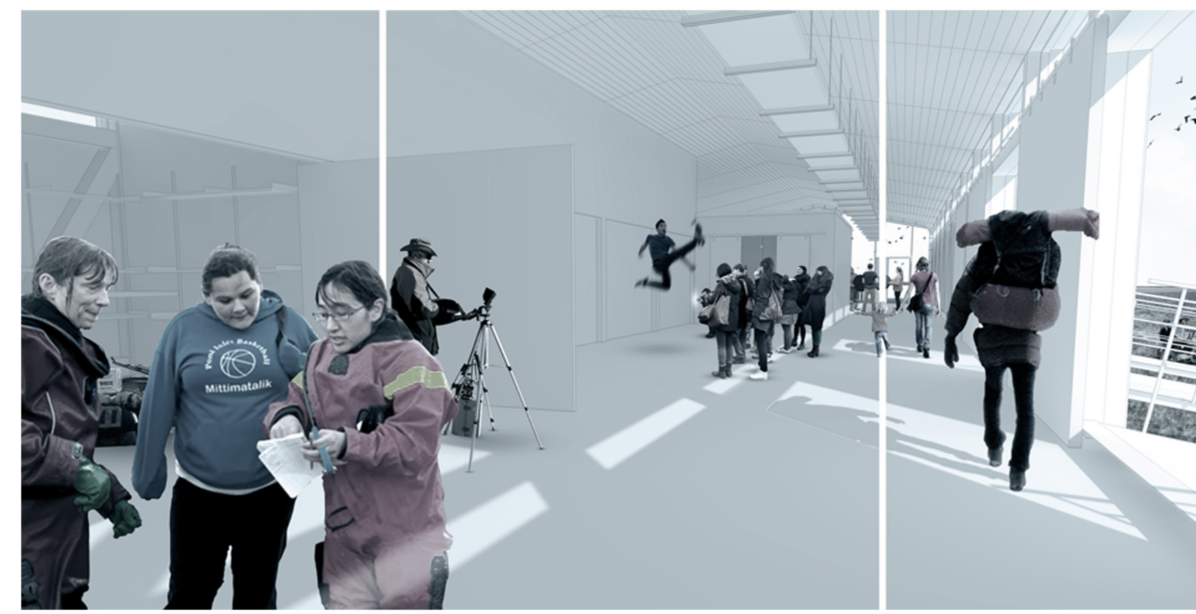
The unit also acts as “first-responders” unit for cable related issues, able to take care of minor to moderate problems, however, larger cable repairs might still require a true cable ship to be brought in.



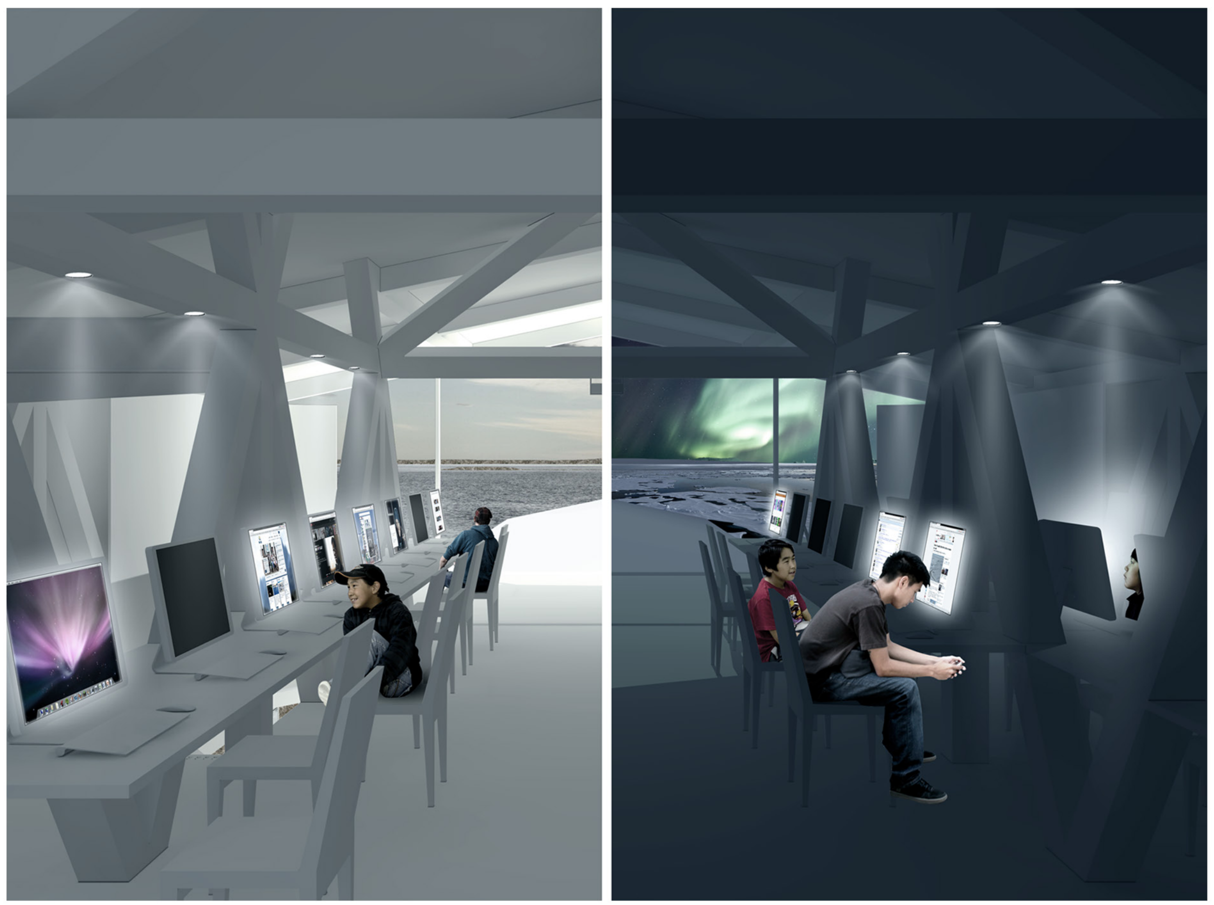
[Fig 8.2] - Arriving into Tuk

[Fig 8.3] - Tuk Harbor

[Fig 8.4] - Station through the seasons



[Fig 8.5] - Walking through the laboratory



[Fig 8.6] - Media Lab

[Fig 8.7] - Wayfinding

Node Type C: Research

Research nodes are located around locations of current and future scientific interest. These nodes will provide a refuge for scientists to enable long-term experiments in Central and Western Arctic regions. The towers also serve as data repositories or backups for any automated scientific equipment in-the-field nearby, enabling scientists to monitor and assess information safely in the winter, or to be able to determine which equipment to travel to in order to check and perform any routine maintenance required. The main users of this station include scientists who want to stay in remote locations for extended periods of time, local hunters and travellers needing a temporary place to rest or to scout, or finally a bunking area for tourists wanting to experience the Arctic landscape.

Access to the towers would need to be arranged ahead of time, and coordinated with one of the Node A sites, as these towns can also serve as staging areas for individuals embarking onward to a more isolated tower site.

The Canadian Rangers, or a subset of, would be responsible of any on-site maintenance that would be required at the tower.

TEST SITE: Banks Island Research Base (Aklavik Constellation)

The Banks Island Research base is nestled between the two provincial parks on the Island – the Banks Island Migratory Bird Sanctuary and the Aulavik National Park of Canada. The tower's current position also places it equidistant from two smaller research cabins in the region, the Polar Bear Cabin and Green Cabin. Like all other research tower nodes in the RAM network, the Banks Island node is there to help assist researchers in performing experiments, be it long-term or short, and provide them with a safe and technologically up-to-date outpost.

The ground level is used for equipment storage and repair, one-half of which can be used as vehicle storage. Access to the second level is provided by ladder-stair. The second level and mezzanine level is the main occupied space at this node. Here, a large table provides workspace for scientists, alongside a small kitchenette area and an area to socialize and interact. The mezzanine level consists of collapsible bunk-beds for sleeping.

A weather platform occupies the level above. Here, four weather booms continuously monitor and record the weather at the current location of the tower. This imitative design is in part inspired by the network of weather stations established in the Canadian North during World War II, which were set up as supportive elements in connection with large enterprises in the Northeast and west of the Canadian Arctic – the majority of which were subsequently abandoned post-war. The need for weather stations during 1940s had much to do with providing adequate weather reports for plane transit to the European theatre of war[64]

> Captain Edward H. Smith of the U.S. Coast Guard explained the American plan, designed primarily to obtain meteorological information in the Far North which would help in flying to Great Britain and Alaska. American authorities were interested also in the ice and hydrographic information, magnetic observations, and studies of the "heavy side layer" in connection with radio. They wanted to establish three meteorological and scientific stations along Lancaster and Melville Sounds. They were anxious to discover whether Canada would undertake the entire project herself or, alternatively, cooperate with the United States in getting it under way[65]

64 Gordon W. Smith, "Weather stations in the Canadian North and sovereignty." *Journal of Military and Strategic Studies* 11, no. 3 (2009), 1.

During the postwar years, the interest to establish weather stations in the Far North was renewed by Lieutenant Colonel Charles J. Hubbard of the U.S. Army, garnering the Senate Bill S. 765 "concerning the establishment of meteorological observation stations in the Arctic region of the Western Hemisphere". This bill was supported by Vilhjalmur Stefansson (a Canadian Arctic explorer and ethnologist) who suggested the scope of the stations be enlarged so they compared more favourably to Soviet stations, which were larger and "not so much weather stations as general stations for Arctic study."[66]

Around that time, Canadian authorities had not left the question of northern weather stations entirely out of their considerations. In 1944, the following note was a correspondence between two Canadian authorities:

> If we wish to strengthen our claims to Arctic sovereignty by setting up weather stations and other scientific stations, that is still another matter and rather outside the scope of the existing U.S. weather stations, which are all in regions where no one is likely to question our sovereignty. As I understand the matter, it is the far northern and western islands, which are reached by our administration mostly in theory, where our claims to sovereignty are most likely to be questioned. In similar cases, Russia has strengthened her claims to islands north of her mainland of installing and operation scientific stations in those areas. We may have to do something like that ourselves, in which case we would require weather stations to service air travel to reach some of our otherwise scarcely accessible islands.[67]

Today, while the sovereignty claims are less disputed, weather stations can still provide valuable data as to how and why the Arctic region is changing due to climate-change. While all towns accessed by plan have designated weather stations, additional data is never a bad idea, as it would improve the quality of weather forecasting and prediction in the region, a sentiment consistently shared throughout the years when discussing the Canadian Arctic. The benefit of having this data logged at the tower sites is that it can be easily archived, backed-up and distributed simultaneously. The system can work autonomously as long as it is provided with regular maintenance. As the towers are all connected, it would be possible to call up information on weather conditions at any other node with an operational weather platform.

For this node type, platforms above the weather platform house the battery banks, which are recharged by Solar panels during the late-spring and summer seasons, and allow the WiFi equipment to function over the winter months. The uppermost platform is where the WiFi networking equipment is attached to the tower.

65 Ibid, 17.

66 Ibid, 18.

67 Ibid, 18.

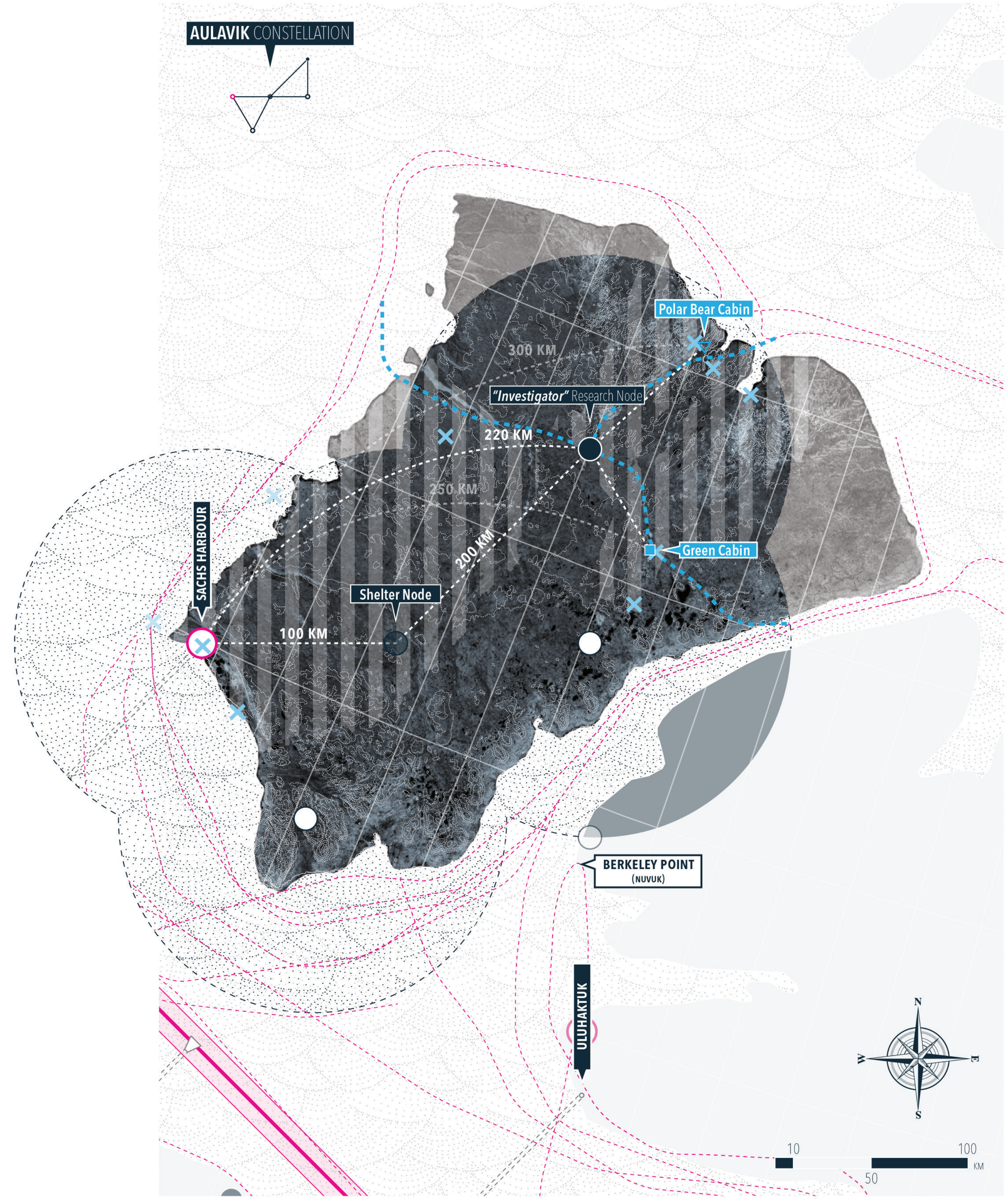
[Fig 8.8]:

Node Type C Regional Site Map

The highlighted sections represent the RAM tower's area of influence. Objects within these fields are able to connect to the tower if they are capable.

The benefit of the RAM network is its ability to scale and augment already existing research infrastructure, such as the Green Cabin and Polar Bear Cabin, to be able to connect to the Internet with the use of proper equipment.

The "Shelter Node" is simply a typical RAM tower with an sheltered ground floor, similar to what the research towers are constructed as.



LEGEND

Fibre Optic Cable Route
Pan-Inuit Trails
New Pan-Inuit Trails created
PCSP Field Site
Experimental Field Station
Seasonal Field Station
Community (Node Type B)
Research (Node Type C)
Shelter (Node Type D)

Arctic Ocean
Provincial Park / Protected Area

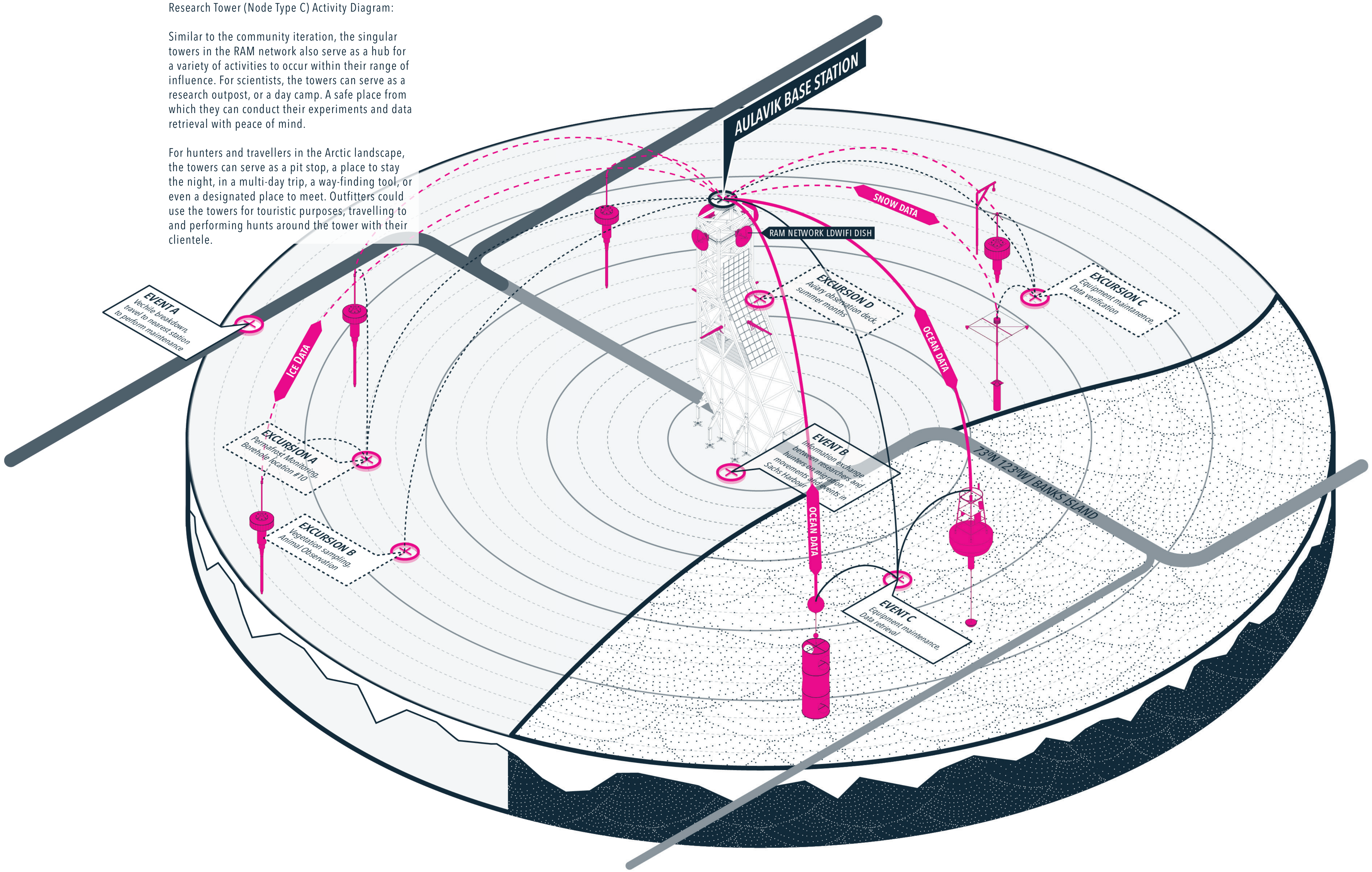
NODE TYPE C - ACTIVITY DIAGRAM

[Fig 8.9]:

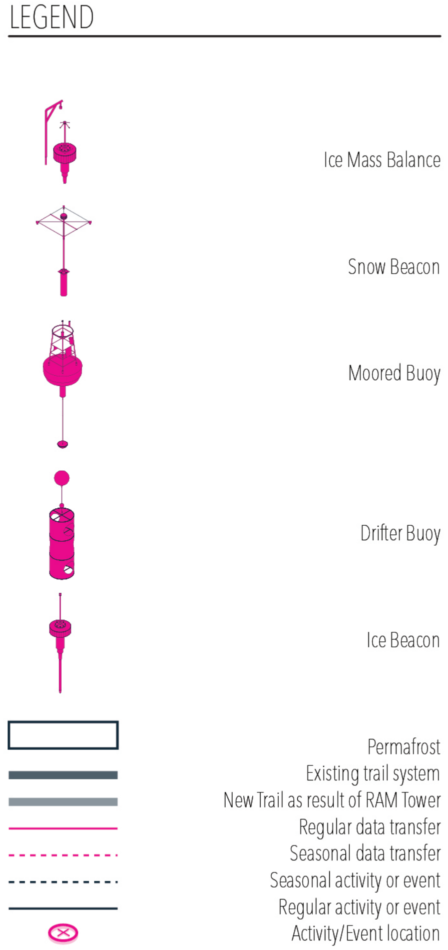
Research Tower (Node Type C) Activity Diagram:

Similar to the community iteration, the singular towers in the RAM network also serve as a hub for a variety of activities to occur within their range of influence. For scientists, the towers can serve as a research outpost, or a day camp. A safe place from which they can conduct their experiments and data retrieval with peace of mind.

For hunters and travellers in the Arctic landscape, the towers can serve as a pit stop, a place to stay the night, in a multi-day trip, a way-finding tool, or even a designated place to meet. Outfitters could use the towers for touristic purposes, travelling to and performing hunts around the tower with their clientele.



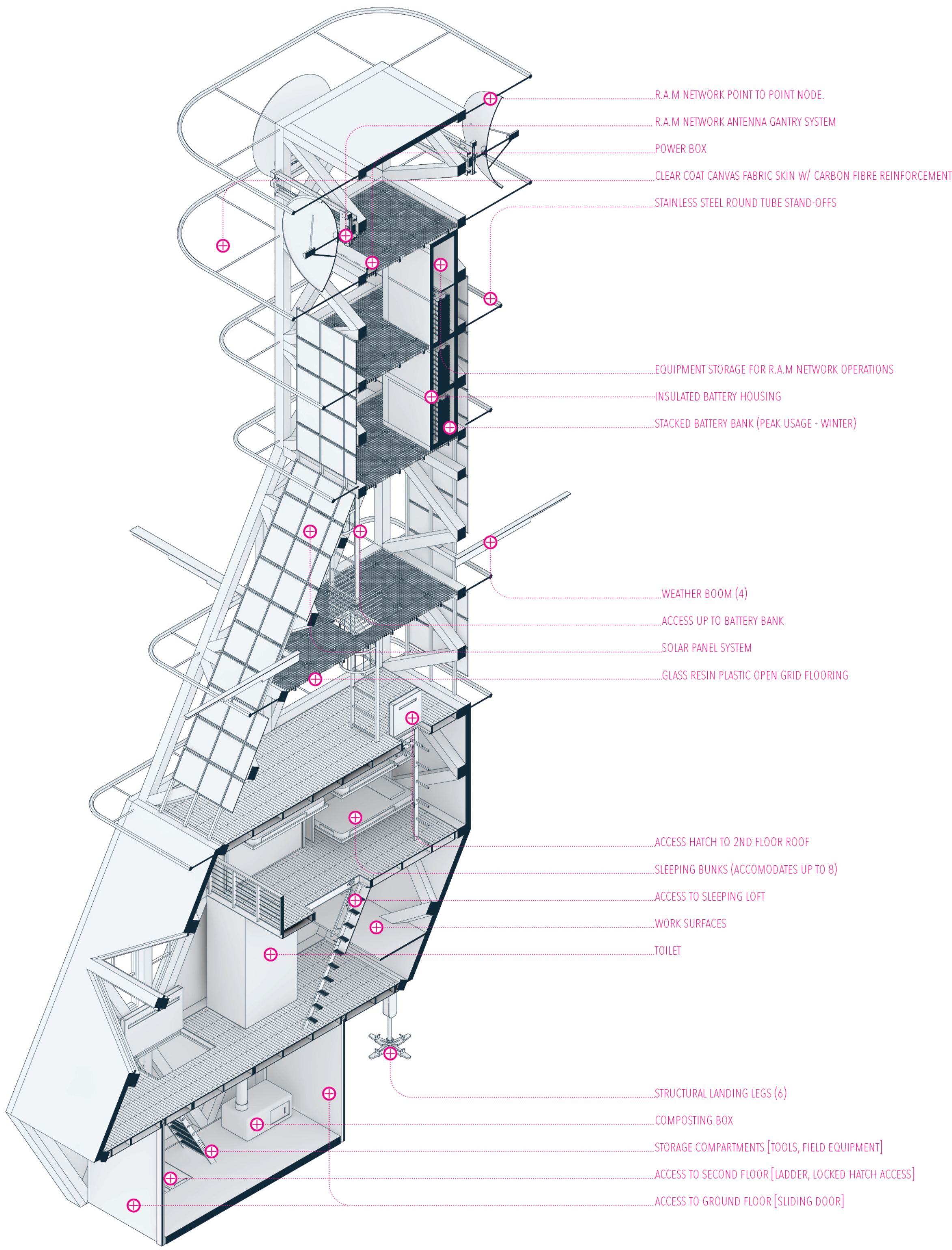
LEGEND



NODE TYPE C - SECTIONAL AXO

[Fig 9.0]:

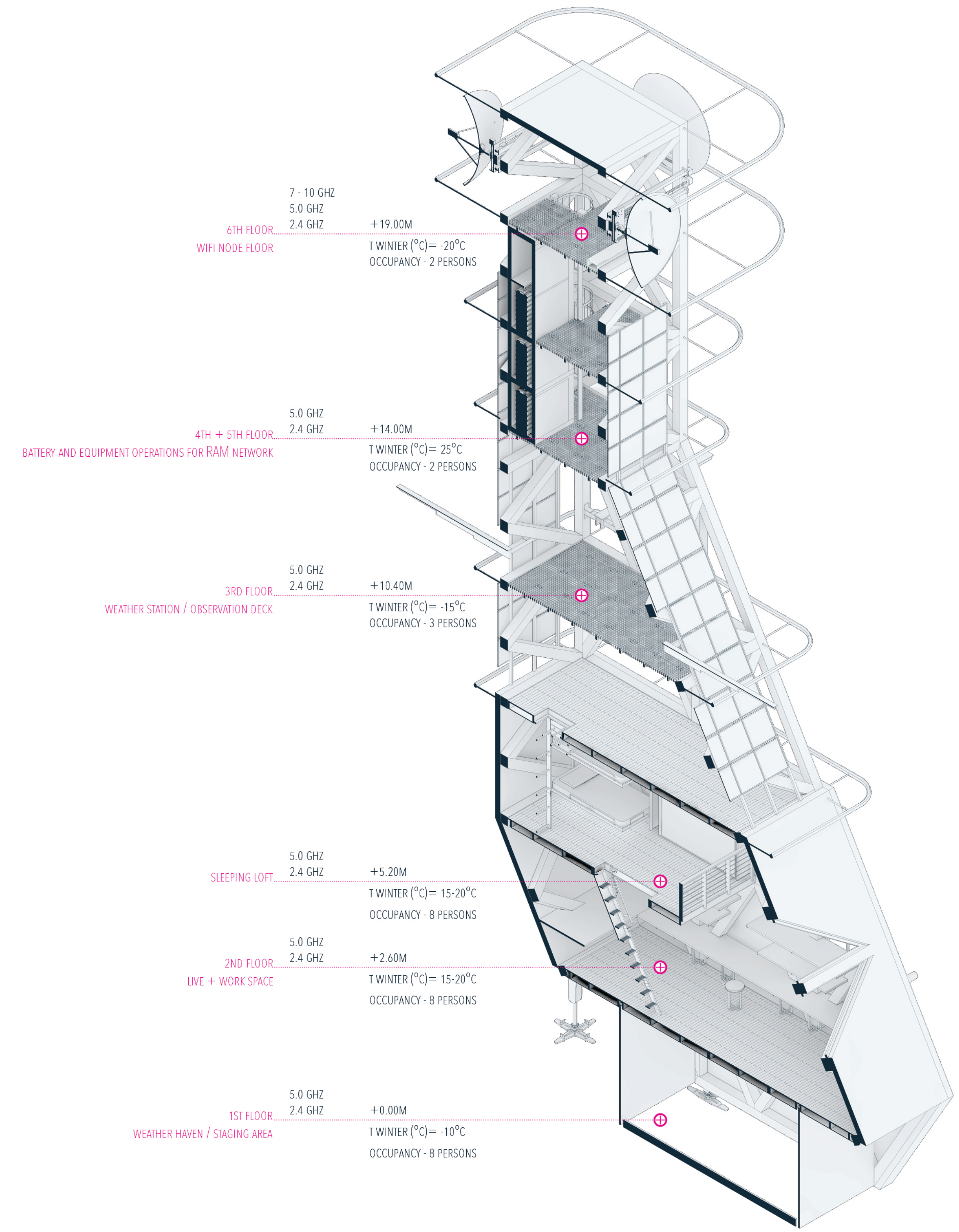
Node Type C Axonometric



NODE TYPE C - SECTIONAL AXO

[Fig 9.1]:

Node Type C Axonometric



[Fig 9.2] - Equipment Check

[Fig 9.3] - The Caribou Hunt

[Fig 9.4] - Ground Truth

[Fig 9.5] - Hunter's Reprieve

[Fig 9.6] - Inukshuk

COMMON GROUNDS

In August 2014, Prime Minister Stephen Harper traveled to the isolated hamlet of Cambridge Bay for the groundbreaking ceremony of the Canadian High Arctic Research Station (CHARS) - a core architectural piece of the "Northern Strategies" set forth by the Harper government. The ceremony is proof that science in the Arctic is an issue of significant importance for the future of our planet.

> I know Inuit, old and young, want to be informed of outside influences of global warming...I also know that given the opportunity to partake in data keeping, Inuit are more than willing. Inuit see themselves as part of the ecosystem and want to be included: not as victims, but as a people who can help.
>
> - Jose A. Kusugak[68]

Scientific understanding of the arctic environment is based on short-term, and at times fragmentary, records. Data is not always available in all locations, can vary in quality and rarely extends back before the twentieth century. Satellite monitoring has improved the quantity of information available within the Arctic, although only dating back a limited number of years. The simple fact that "Change", of varying degrees and frequencies, is a basic characteristic of the region makes identifying trends and causal relationships all the more difficult without a great deal of data and information. While the use of sophisticated instruments and computer models can help us understand climate change, some of the best knowledge about the ecosystem remains with the Inuit. Interacting with locals is still one of the best ways to understand how the Arctic is changing. However, the use of indigenous knowledge requires a perspective on how their knowledge is formed and used in their own culture. For the most part, scientists that had traditionally left natives of the region alone, rarely wanting to tap into their "traditional knowledge"[69]are now incorporating Inuit knowledge into more scientific research. Examples of this can be found during the International Polar Year of

68 Ibid, XV

69 The Traditional Knowledge Working Group, created by the Government of the Northwest Territories, debated the meaning of traditional knowledge for more than two years before reporting the following:

The lack of common understand about the meaning of traditional knowledge is frustrating for those who advocate or attempt in practical ways to recognize and use traditional knowledge. For some, traditional knowledge is simply information which aboriginal peoples have about the land and animals with which they have a special relationship. But for aboriginal people, traditional knowledge is much more. One elder calls it "a common understanding of what life is about."

Knowledge is the condition of knowing something with familiarity gained through experience or association. The traditional knowledge of norther aboriginal peoples has roots based firmly in the northern landscape and a land-based life experience of thousands of years. Traditional knowledge offers a view of the world, aspirations, and an avenue to 'truth', different from those held by non-aboriginal people whose knowledge is based largely on European philosophies.

(Department of Culture and Communications, Government of the Northwest Territories 1991:11)

2007-2008, when local observers were integral to many projects. The local Inuits kept logbooks that recorded information in relation to ice, weather, vegetation, and wildlife in their home areas for several years.[70] In other areas within the Canadian Arctic, the Canadian Rangers assist in conducting ice monitoring studies in the winter months.[71] These are just two examples out of many of the involvement of Inuit peoples in Arctic Science.

Underlying all this is the need for better communications - the central premise of this thesis. The research and consequent design compiled in this thesis seek to begin to address the issues of appropriate research and communication in the face of a changing environment in the North and to also provide an architecture which seeks to provide for the needs of different cultures and stakeholders in the North. The towers, in the indomitable landscape and occupied regions of the Canadian Arctic, allow for a higher level of communication in the Arctic. allowing not only for the Indigenous to reach out with the power of the Internet, but to also promote a cross-cultural exchange between scientists and the people who have had an innate knowledge of the Arctic - older than many Western records.

It is, at this junction, important to recognize that the design of the thesis was realized by addressing a specific, contained, problem - the role of science in Canada's Arctic. There are still many questions and problems that need to be answered with regards to the use of communications infrastructure in remote regions. While the towers are, perhaps all-too much, altruistically envisioned as beacons of knowledge gathering, there remain questions to their use past a post-scientific vision in the Canadian Arctic. Is the network - like the DEW line before it - destined for an eventual abandonment as they become outdated or is there a possibility for their use as armatures for other stakeholders in the Arctic? Can for instance, can the very same area of scientific investigation in the future also become a gridded zone of resource extraction?

The towers open up the possibility of a level of data collection not yet undertaken in the North, generating useful data for understanding global and local climate systems. The tower becomes a point of intersect between the Arctic landscape, its observers, and its inhabitants. In local communities, the tower is a hub for information brought forth in a variety of ways. Researchers explaining their work, a community elder storytelling, or a child simply spending time on the Internet, like many of us already do, can all occur at this intersect. The towers may represent something different to each group; scientists might view them purely for their means of shelter, remote location access, and data collecting capabilities, while the Inuit of the North may primarily see them as pit stops in their continual navigation of the Arctic, or perhaps a place to scout for Caribou, but they are useful.

While these examples serve to illustrate the potential uses of, and within a close proximity of, the tower; there is still the question of what can occur within the footprint of the tower nodes.

70 Igor Krupnik and Dyanna Jolly, ed., *The Earth Is Faster Now: Indigenous Observations of Arctic Environmental Change* (Fairbanks, Alaska: Arctic Research Consortium of U.S., 2002), XXV

71 Meagan Wohlberg, "Rangers Take on Scientific Monitoring Role in Arctic | Northern Journal," accessed August 13, 2015, http://norj.ca/2014/03/rangers-take-on-scientific-monitoring-role-in-arctic/.

The air of connection cast by the towers and its active digitizing of the Arctic environment also bring up questions of sovereignty, security, resource extraction and ownership - all of which are tied back to the use of land in the Arctic. This line of questioning is best investigated by Ann-Sofi Rönnskog and John Palmesino, in *Arraying Territories*, who look at the intensification of remote-sensing technologies and their role in the shifting geopolitical conditions in the arctic and subarctic regions - resulting in a landscape of agencies.

This landscape of agencies is, for instance, tied back to the building the RAM network in the North. The construction effort would likely require a partnership between the Canadian Government and resource-sector companies more interested in the newly accessible land and marine resources in the Arctic, all being made available due to climate change. Amongst these economic stakeholders exist local and international stakeholders, such as the indigenous population, the Canadian military and the collective scientific community. The confluence of all these stakeholders is bound to cause friction and conflict in how the towers and their connective augmentation are used for. On one hand universities such as McGill, which already have an invested presence as Arctic Research stewards, might be willing to help pay or lease out a RAM tower as an upgrade to their current facilities or to expand their research capabilities. On the other, resource extraction companies invested in understanding how climate change will allow them more access to the land's resources might offer a significant amount of capital in exchange to use the subsequent information gathered from these nodes as a way to further their agendas of resource extraction. In these instances to whom is the tower privileged? Does the Canadian government have the power to retroactively assign towers to different stakeholders? And what of the local indigenous population - and their role in deciding how towers are used? They are the group with the most to gain and lose by how such interventions are ultimately used. Will incidents such as the decommissioning and destruction of the Cambridge Bay Lonar Radio tower, in spite of protest by community members, continue? In cases like the former, and the DEW Line, Arctic infrastructure is often adopted into how indigenous wayfind through a changing Arctic environment - one where even the most experienced hunters can no longer predict how the weather may behave.

Issues of network management also remain a matter of discussion and investigation. How is the RAM tower maintained and taken care of? Does it call for a set of roving patrols? What are the vehicles by which individuals arrive to the nodes? The cities of Cambridge Bay and Iqaluit present themselves as ideal locations to be major nodes in the system for these reasons, while Tuktoyaktuk may become an important node once its connection to Inuvik is established. The central location of Cambridge Bay, and the High Arctic Research Station, can easily become the major node for the network, serving as an arrival point for scientists and researchers before they head off to a specific network node - by land or charter flights. The physical maintenance of the network will need to be addressed by a qualified group of individuals. The Canadian Rangers can fill this role well because of their knowledge of the local land, ability to survive through harsh situations, and their role as cultural bridges to local communities in the region, they will also require additional training in regards to the network equipment. Also the act of building a pan-arctic network opens up job opportunities in the North, both during its construction and after in regards to IT and maintenance. In addition, the intensive environmental remediation required at past DEW Line sites ask questions about the waste created here. How will it get managed here and at other infrastructural occupancies in the North? What of Fuel?, Food? Are these part and parcel in the operation of the network or can they, as they are currently, remain as requirements met by the users of the network themselves?

The changes in the North are operating at both local and global scales; changing, both, the landscape and setting linkages between individuals, NGOs, institutions, nations, and companies. While this thesis begins to investigate issues at a local and pan-arctic scale, an investigation into its wider net of influences is warranted.

The North is, almost always, imagined as the ultimate horizon: a vast open frontier expanse outside the influence of the remaining global players. Yet the introduction of new technologies, the implementation of connective networks, and the rising influence of climate change are opening up the North to new possibilities of interaction between local and global agents active in the North. These new territories - digitized landscapes - created by the RAM network, will ultimately become decentralized and involve the role of multiple agencies - not just science and the local indigenous population.

Change is an integral part of the Arctic environment and its inhabitants. It requires an architecture that is cognisant of new territories — resilient, receptive, and adaptive to the environment, its inhabitants, and its observers.

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