

Learning from Ecosystems: The Deployment of Soft Systems in the Canadian Arctic

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The physical infrastructures of the twentieth century – those of roads, rail, air, data, sewage, and water amongst others – have tended to operate as singular and independent systems. The infrastructures of the twenty-first century, if they are to respond to impending urgencies with respect to resources and climate change, must investigate efficiencies and symbiotic relationships; to the pairing of infrastructure and landscape, infrastructure and public amenities, infrastructure and architecture. The pressure of urbanization in the Arctic provides an ideal site to test intelligent and soft systems that learn from ecosystems.

The thawing Arctic Ice Shelf is ironically yielding the same resources that evoked its depletion – massive oil and gas deposits that suggest the impending urbanization of the North. Once inaccessible, the Arctic is now under investigation to understand exactly how many resources were once trapped below the polar cap. According to estimates by the US Geological Survey and Norwegian company StatoilHydro, the Arctic contains twenty-five percent of the remaining oil and gas deposits of the world, equating to 90 billion barrels of oil, which are accompanied by 44 billion barrels of natural gas liquids and 1,670 trillion cubic feet of natural gas.¹ Further, the thawing ice is opening new shipping routes to export these resources to international markets. This has quickly incited economic interest in the north and perhaps the most critical territorial disputes of the past century. Eight countries including the US, Russia, Canada, Denmark, Norway, Sweden, Finland and Iceland are vying for territorial claims on these increasingly precious resources. In 2007, a Russian submarine planted a Russian flag 4,200 metres below the water on the site of the North Pole to declare their symbolic presence in the Arctic. Simultaneously, these resources sit below one of the most fragile and pristine ecosystems in the world and a richly diverse set of indigenous settlements. In fact, in Canada alone, over 18,500 people live above the Arctic Circle in approximately twenty-four settlements. In the longer term, as the effects of global warming take on their full impact, scientists

¹ Jessica Robertson, '90 Billion Barrels of Oil and 1,670 Trillion Cubic Feet of Natural Gas Assessed in the Arctic.' USGS: United States Geological Survey. 23 July 2008 at <http://www.usgs.gov/corecast/details.asp?ID=87> [accessed: 12 November 2009].

² Government of Canada, Invest In Canada: Iqaluit Quick Facts at <http://investincanada.gc.ca/eng/explore-our-regions/northern-canada/nunavut/iqaluit.aspx> [accessed: 23 February 2010].

³ Hints of such projects and research are already underway. Port and military infrastructure were announced by Prime Minister Stephen Harper in 2007. Harper stated a new army training facility in Resolute Bay and refurbishment to an existing deep water port in Nanisivik would assert Canadian sovereignty (see: CBC News. Harper Announces

Northern Deep-Sea port, training site 11 August 2007 at <http://www.cbc.ca/canada/story/2007/08/10/port-north.html> [accessed: 28 July 2010]. Upgrades are also planned in the Churchill Port in Manitoba, which holds a strategic location as it is connected into existing rail infrastructure. Other proposals currently underway include a resurgence of interest in the Mackenzie Valley Pipeline, which would connect the Beaufort Sea to markets in Southern Ontario and increased security measures (including new polar icebreakers and patrol ships) as recommended by the Standing Committee on National Defence. See Maxime Bernier, Canada's Arctic Sovereignty. Standing Committee on National Defence, (40th Parliament, 3rd Session: June 2010) at <http://www.scribd.com/doc/33202297/Report-of-the-Standing-Committee-on-National-Defence> [accessed: 28 July 2010].

predict that northern countries and regions will see the greatest migration patterns. Indeed today, Iqaluit in northern Canada is the fastest growing city in the country.² While it is unknown exactly when port, drilling and mining infrastructure will colonize the arctic, it is now understood as an inevitable outcome of thawing.

While Petropolises – cities born from resource extraction – such as Yellowknife and Fort McMurray in the Canadian north, continue to expand under the pressures of diamond and oil extraction, they have done so haphazardly with little concern for public infrastructure. The unveiling potential of resources in the North has incited the Canadian Government to plan³ deep-sea ports, military bases and new infrastructures in an effort to establish 'Arctic sovereignty'. However, with the urgency to service new Petropolises, there has been little thought afforded to development beyond economic efficiency and expediency. While territorial claims of this 'New Cold War' are being negotiated, they offer a unique moment to question how to build both ecologically and culturally sustainable settlements and infrastructure in the Arctic. Key to sustainable progress in the Arctic is in addressing existing issues, such as transportation and education, within current settlements to provide a functional infrastructure for future growth.

Creating a network of hard infrastructure in the Canadian North, however, has been difficult due to the harsh climate, immense scale, and remoteness of the region. Presently, the North is scattered with loose and fragmented systems of infrastructure and settlements that include defence networks (Distant Early Warning (DEW) Line, military bases and ports), research stations, oil rigs, mines, airports and roads amongst others. These developments have taken their cues from infrastructure of the south – designed as hard, permanent and independent systems that are difficult to upgrade or alter. The characteristic of ecosystems – as non-linear, self-organizing and complex feedback systems that are able to juggle various forms of hierarchies and scales – however, provides a more sensitive template to design new infrastructure in the Arctic. Learning from Ecosystems has incited the role of 'soft infrastructures' in the Arctic. That is, infrastructure that is adaptable, responsive, immaterial, temporary and/or small-scaled interventions that operate across a massive territory. Easily replaced or upgraded, these infrastructures double as landscape life support, creating new sites for production and recreation. The ambition of deploying soft infrastructures is to meld existing landscapes with emergent systems to catalyze a network of ecologies and economies for a new public realm in the Arctic. The two projects presented here focus on the critical issues of transport and education in the Canadian Arctic and utilize a series of soft systems that respond to climatic variation, programmatic needs, flexibility, and cultural diversity.

Liquid Commons

A functional democracy requires the active participation of all individuals. Participation is dependent, however, on free access to information. Without this basic necessity, polarities in education emerge and the system of active participation finds itself in peril. The issue of how to educate the native Inuit in northern Canada emerged in 1939 when the Supreme Court of Canada ruled that the Inuit people would be a Federal responsibility.⁴ Following WWII, in 1955, the Cabinet submission suggested a general system of education for northern Canada, which took its cues from established southern models. Before this moment, the traditional educational techniques amongst the Inuit population consisted of observation and practice via an oral tradition that was delivered in family groups. This methodology of teaching had occurred for centuries and was calibrated to the skills deemed necessary and important for the Inuit culture. A recent report⁵ by The Royal Commission on Aboriginal Peoples suggested that the Canadian government's goal of formal educational strategies during the 1950s and earlier, was to assimilate Inuit populations. This project of assimilation in education was running concurrently with a Canadian Government housing programme, which introduced 'fixed' housing in the Arctic that eradicated the previously nomadic lifestyle of the Inuit. The assimilation-strategy and general interest in the Arctic was undoubtedly linked to the Arctic's strategic position during the Cold War, which resulted in the line of DEW radar stations. The introduction of a formalized 'southern' teaching system focused on assimilation however, was not only undemocratic, it had vast repercussions to the various Inuit communities that still linger today.

⁴ Gordan Robertson,, To Educate or Not Educate, CBC News Magazine. Original Broadcast 20 January 1957, at <http://archives.cbc.ca/society/education/topics/529/> [accessed: 24 March 2010].

⁵ Inuit Tapiriit Kanatami. 'Backgrounder on Inuit and Education. For Discussion at Life Long Learning Sectoral Meetings, November 13th and 14th in Winnipeg and November 18th and 19th in Ottawa.' (Ottawa, 2004) at http://www.aboriginalroundtable.ca/sect/lrng/bckpr/ITK_BgPaper_LLL1_2_e.pdf [accessed: 24 March 2010].

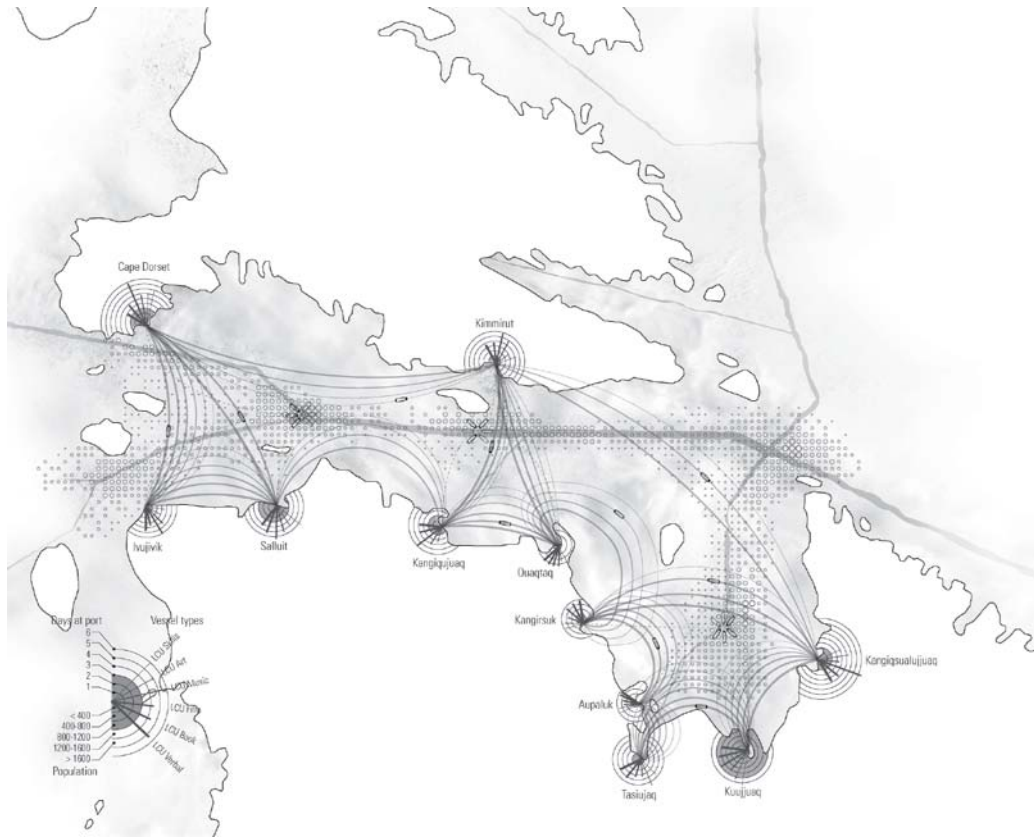


Fig 1. Liquid Routes: Map showing the network of boats travelling between settlements.

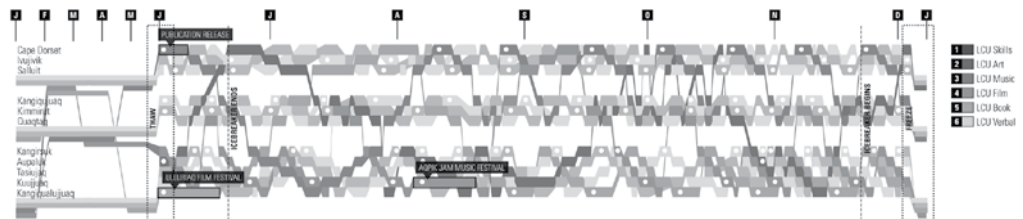


Fig 2. Soft Programming: Schedule of educational infrastructural network over one year, accounting for freeze/ thaw dates and festivals/ cultural events.

⁶ See: Nunavut Literacy Council. 'Literacy in Nunavut' at <http://www.nunavutliteracy.ca/> [accessed: 24 March 2010]; International Adult Literacy and Skills Survey (IALSS) / Stats Canada (2005), at <http://www.statcan.gc.ca/daily-quotidien/051109/dq051109a-eng.htm> [accessed: 24 March 24, 2010]; Learning a Living: *First Results of the Adult Literacy and Life Skills Survey*. (Paris: Organization for Economic Cooperation and Development, 2005).

⁷ Nunavut Literacy Council. 'Literacy in Nunavut' at <http://www.nunavutliteracy.ca/> [accessed: 24 March 2010];

While it is difficult to deem exactly how far the ramifications of such an educational strategy spread, there are several statistics that reveal a general pattern. Recent studies⁶ have found that more than half of Nunavut's working-age population and 80% of youth (age 16-25) struggle with literacy. More specifically, 88% of Inuit scored below level 3, which is considered the minimum skill level necessary to meet today's societal challenges, compared to 40% in the rest of Canada.⁷ While Nunavut's population density is the lowest in Canada, it is also one of the fastest growing regions. Not only is the Inuit population growing at twice the rate of the rest of Canada, its population is young – with a median age of 20.6 years⁸ (the rest of Canada's median age is 37.6 years), highlighting the important role education can play in this remote area. The premier of Nunavut, Aariak, goes further to suggest that the lack of education is at

⁸ Inuit Tapiriit Kanatami. 'Backgrounder on Inuit and Education. For Discussion at Life Long Learning Sectoral Meetings, November 13th and 14th in Winnipeg and November 18th and 19th in Ottawa.' (Ottawa, 2004) at http://www.aboriginalroundtable.ca/sect/lrng/bckpr/ITK_BgPaper_LLL1_2_e.pdf [accessed: 24 March 2010].

⁹ Bob Weber, 'Nunavut Premier Says focus should be on Education.' The Toronto Star, 31 March 2009 at <http://www.thestar.com/news/%20anada/article/611147> [accessed: 24 March 2010].

the root of poor housing conditions, high suicide rates, domestic violence, poverty and lack of job skills in the Inuit communities⁹. One of the largest challenges to providing education and knowledge in the Arctic is the geographic dispersal of many small settlements over a large landscape. If there was a soft system to provide knowledge, however, that was able to bridge the divide of small core populations and spatial distances, these remote areas could gain access to knowledge and more importantly to democracy.

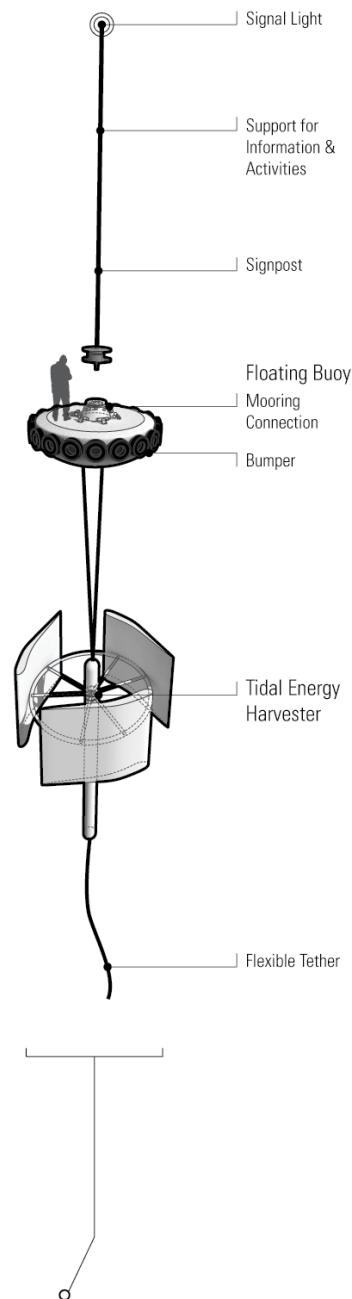


Fig. 3: Soft Mooring: A grid of floating buoys is flexibly tethered to the seabed. Equipped with tidal generators, these buoys also act as ice mooring locations for the nodal arrangement of boats.

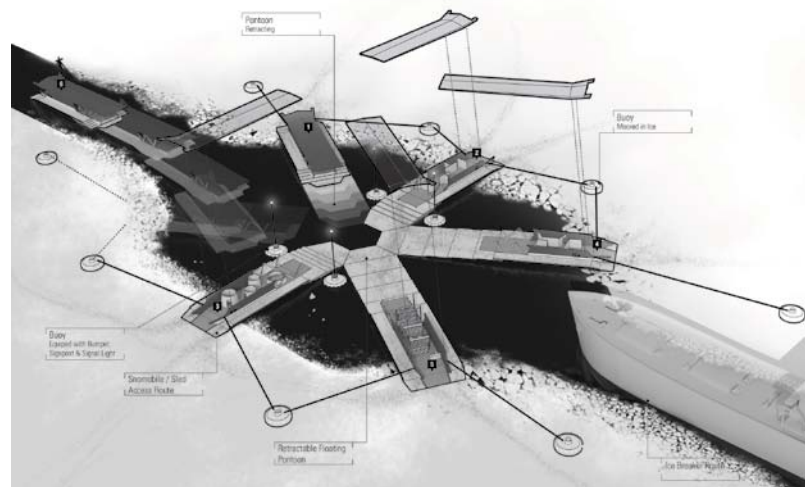


Fig. 4: Axonometric of Scheme in 'frozen state' showing flexible mooring, retractable floating pontoons and bridge configuration creating a crossroads.

The *Liquid Commons* aims to promote literacy, in official and recognized regional languages, by creating a malleable educational infrastructure in the form of community learning centres and libraries. By promoting action, speech and participation - the basic ingredients of a functioning democratic society - this growing region will strengthen its foundational populace. The proposed 'Hudson-Ungava' Library utilizes a series of 'knowledge boats' that travel between Northern Quebec and Nunavut to connect the harbours of: Cape Dorset; Kimmirut; Ivujivik; Salluit; Kangiqsujaq; Quaqtaq; Kangirsu; Aupaluk; Tasiujaq; Kuujuaq and Kangiqsualujuaq during the summer months. Currently, the area and number of books in a library is dictated by Capital Planning guidelines based on population. By having mobile libraries, smaller settlements in close proximity can consolidate their collections and share a larger selection of books. In these settlements alone a core population of 7,500 inhabitants is formed, which also allows for other educational spaces such as internet cafes, community rooms and areas to exhibit traditional culture through practice and art. Thus these boats allow for both the dissemination and creation of knowledge, which feeds back into the networked settlements. Various boat hierarchies tied to differential schedules allows for a dynamic system that is easily adaptable and conducive to expansion or contraction. During the fall season, before the Hudson Straight and Ungava Bay freezes, the boats dock at a series of flexible nodes, positioned at the junction of several winter ice trails. During the winter the anchored boats effectively transform the libraries into a central hub, located between the settlements, allowing communities to interact as well as harkening back to a traditional nomadic winter lifestyle. In the summer, this nodal meeting point serves as a habitat for native birds and a harvester of tidal energy. By utilizing water as a shared

connective platform in the winter and as a distributor and energy harvester during the summer the *Liquid Commons* becomes both a unifying network and node. More importantly, by creating a network of knowledge through liberating the static nature of educational typologies, a system of both disseminating and creating knowledge occurs that connects the surrounding settlements.



Fig 5. Grouping of boats in the *Liquid Commons* produces a new flexible crossroads where a public sphere emerges between the boats and between the settlements.

Soft Stations

North of 60° latitude, a combination of factors including the landscape pockmarked with boggy muskeg, lakes and ponds, a sparsely distributed population and a harsh environment, make building permanent all-season roads economically unfeasible.¹⁰ This reality, however, does not preclude the necessity of transportation routes to penetrate the arctic tundra, as increased mining activity in Canada's North requires overland transportation options to service their operations. As a result, the arctic landscape, especially in the Northwest Territories has expanded its road system to move beyond paved and gravel highways to include roads made of ice. Primarily comprised of the naturally frozen lake surfaces that cover almost half of the landscape, these winter roads are made passable by the construction of portages linking one frozen lake to the next. The use of winter roads as part of the highway-network effectively doubles the amount of roadway available.¹¹ In addition to the increased length, the winter roads extend the network up towards the Arctic Circle and beyond – servicing industrial operations and native communities along the way.

¹⁰ Canada. National Round Table on the Environment and the Economy, *True North: Adapting Infrastructure to Climate Change in Northern Canada*. (Ottawa: NRTEE, 2009).

¹¹ The Northwest Territories' highway network expands by 100% with the winter road season. The 2000km of paved and gravel roads are complemented with 2033km of ice roads.



Fig 6. The Contwoyto Winter Road: First constructed in 1982 to offer access to remote mining sites, the road is almost 600km long with about 87% of its surface built on frozen lakes.

The *Tibbitt to Contwoyto Winter Road (TCWR)* is Canada's longest and most heavily used ice road. This seasonal transportation system has been the sole supply channel for Canada's active mining industry. Following historic trappers' lines, TCWR begins 70 km east of Yellowknife and extends more than 600km northeast to reach the north end of Contwoyto Lake in Nunavut. The road is built by a joint venture of mining companies operating in the area, and shared by many users, from exploration companies to tourism outfitters and Aboriginal hunters of the region. This seasonal winter road is only open for eight to nine weeks each year, from February to the beginning of April (depending on weather and the season's load requirements), and it must be re-constructed each year to service mines in the area. Along the way the route services *Snap Lake Diamond Mine Project* (264km), *Gahcho Kue Diamond Mine Project*, *Diavik Diamond Mine* (373 km), *Etaki Diamond Mine* (405km), *Lupin Gold Mine* (568km) and *Jericho Diamond Mine* (600km). Because of the relative ease with which vehicles move across the mostly flat, smooth and unobstructed frozen water, the organization and routing of ice roads

privileges frozen water over permafrost. As a result 85% of TCWR lies on lake ice with the remaining portions of the route accounting for the 64 land portages between lakes.

- ¹² Don Hayley and Sam Proskin 'Managing the Safety of Ice Covers Used For Transportation in an Environment of Climate Warming', paper presented at 4th Canadian Conference of Geohazards, (May, Laval University, Canada, 2008).

Unsurprisingly, driving an 18-wheel tractor-trailer, hauling 64 tonne load, over 42-inch thick ice comes with certain risks.¹² To mitigate these risks several strategies with respect to construction, maintenance and operating procedures are put in place. During the construction phase, which involves first surveying the ice formation and thickness, then clearing the surface of its insulating snow, the type of vehicle used is calibrated to ice safety; starting first with helicopters monitoring and progressing through reconnaissance vehicles such as the buoyant *Hägglund* and snow-managers such as *Sno-Cats*. This process reveals a 50m wide swath of ice that, during cold temperatures, provides drivers with as much traction as a concrete tarmac. After this initial construction, the road is continually monitored for ice thickness; if the depth is insufficient or if wet cracks are identified, maintenance crews are called in to flood problematic zones in order increase the ice's integrity.

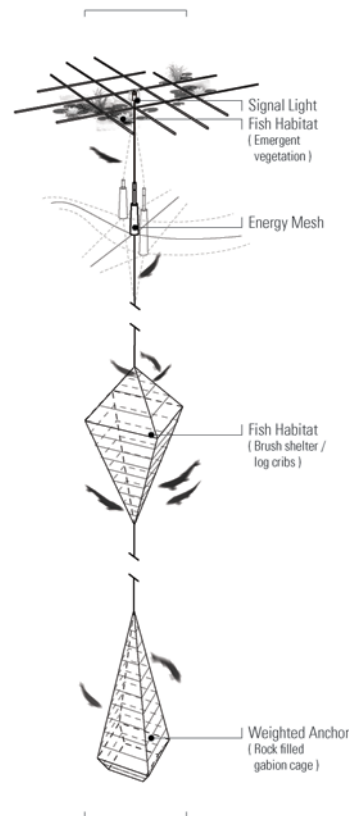


Fig 7. Productive Buoys: As trucks travel over the ice road, a hydrodynamic wave is created below the ice, which the mesh captures and converts to energy through a proposed buoy network.

Another critical factor in mitigating risk is the speed with which trucks move across the ice. While carrying a heavy load, trucks are limited to a maximum speed of 35km/h but often encounter limits of only 15km/hr. A one-way trip along the TCWR can take as long as 3 days and, as a result, a series of stations is distributed along the route. While some of these stations, like the Lockhart Rest Stop (170km) offer drivers a wide range of services including overnight accommodations, food, showers and laundry, others, like Lac de Gras Rest Stop (350km), are reserved for maintenance crews and emergency services.

Through continuous accumulation, the ice can be more than 60 inches thick at the end of the two-month operating season. Ironically, the end of the season has less to do with thinning ice and more to do with the degradation of the conditions of the land portions of the road. The heavy trucks moving across the portages melt the snow and soften the earth leaving an impassable mess. It is the road's interface with land that is most problematic during the operating season as well. Since the water around the rugged shore topography is typically warmer and with shallower depths, the distribution of the moving vehicle's load is further complicated, and given the sub surface waves its movement generates the approach and transition from water to land is identified as the moment of highest risk.

The winter road network is an inherently soft infrastructural system. Embedded in its construction, operation, and lifespan are notions of emergence, responsiveness, and flexibility. In fact using the term construction in describing how the network materializes is not entirely appropriate. While human agency does play a role in ensuring minimized levels of risk, the roads effectively emerge out of existing materials, namely the water, and changing environmental factors, namely declining temperatures. Thus the role of the, at least human-based, construction has less to do with assembling materials into a tectonic and more to do with marking and organizing the already existing assembly of frozen lake water and permafrost. This phase too is soft. The over-ice selection, choosing the specific route the road will take, is a process cantered on responsiveness. Recognizing the frontier nature of the enterprise, additional data is collected with respect to localized ice behaviour and formation, lake bathymetry and climatic conditions. Taking this feedback into consideration, routes are refined to trace the most durable and safest path each season. Further, morphological changes have also been made to the design of the roadway. For example: over time the basic organization of the network has expanded to include express-lanes allowing returning, empty trucks to travel the return trip at higher speeds. The softness of the system is also leveraged within a single operating season. The route established during construction is subject to change over the course of the road's two-month lifespan as, on some lakes, traffic is re-routed to new

lanes to avoid damaged or rough sections of ice. Day to day, season to season, the winter road network is continually in flux as it tunes itself to numerous sets of inputs.

Unlike the roads, the service stations and occupying populations are presently operating in a much more predetermined, fixed fashion. Focusing primarily on the mining operations, the supporting infrastructure along the road has little relationship with other potential occupants. Emerging tourism and nearby native communities have little to do with the logic and services currently embedded in the system that privileges a predominantly industrial workforce. Further, the scattered service stations are not capable of responding to changing conditions, as they are permanently located on the permafrost portions of the route. This, in turn, limits the degree of flexibility in the roads themselves as the path is forced to travel through these fixed points. The unilateral relationship that these stations have with the ice roads is also limiting. While the roadways do disappear for most of the year, there exists a potential for these stations to remain active, albeit in different ways, throughout the year. Recognizing the need for the winter-focused stations, is it possible to dualize this infrastructure in order to be useful throughout the year? Is it possible to learn from the softness of the roads themselves in order to strategize a more complex interplay of forces and occupants for these stations?

The proposed series of Soft Stations leverages the soft logics of the already existing ice roads in order to extend the winter road's operating season – a necessity as activity increases. Recognizing the network's weak moments at the transitions from frozen lake to land, the new stations straddle this condition creating a multilateral interface tuned to the complex interplay of forces at work. On the one hand, the stations maintain their traditional role with respect to providing drivers and maintenance crews with essential services. On the other hand, their shoreline orientation allows the stations to themselves become agents in the integrity of the road: by absorbing the sub surface waves generated by the trucks' movement and converting them into useable energy, the stations reduce the waves' reflection and thus reduce the stresses on the ice surface.

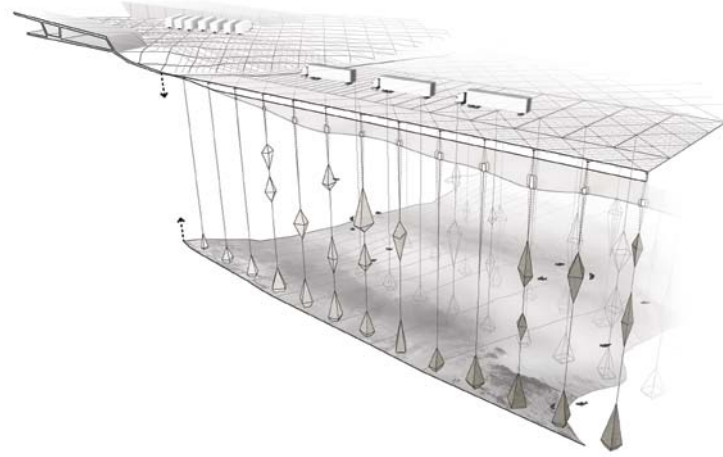


Fig 8. Dualized Reinforcement: The reinforcement meshes are installed at critical shorelines just below the water surface and serve to reinforce ice roads during the winter and lake ecologies during the warmer seasons.

The key element in this conversion is a series of intersecting meshes that serve not only as energy collectors but also as road reinforcement and ecological support. The mesh is installed along the approach vectors to the land-based stations, just below the water's surface, to reinforce the ice road during the winter, and lake ecologies during the warmer seasons. As trucks travel over the ice road, a hydrodynamic wave is created below the ice that is captured by the mesh and converted to energy through a proposed buoy network. These same buoys are also outfitted with flooding nozzles at the water surface and artificial reefs along the cable, and at the lakebed. As the mesh transitions from water to land it fills in to form a lattice for the primary shell of the winter station, allowing the stations themselves to be constructed of soft materials such as ice. The stations are further tuned to the environment as the orientation of the shell calibrates the emergent ice walls to use snowdrift and other forms of accumulation as a productive building tool. By focusing on the interface of land and water, these stations liberate the rest of the road network to further soften, dynamically situating itself in the most opportune locations from season to season. Ultimately, the softening of the system enables complete opportunism for it to dynamically adapt to emerging and unforeseen conditions.

The Canadian Arctic is defined by its extreme climate – from long to short days and freeze to thaw cycles. Architecture and infrastructure operating in such a context is typically designed for the most extreme of such annual conditions, creating a built form that is often permanent, static and imbued with high capital costs. Soft systems typically leverage an existing condition and find opportunities to engage in malleable relationships. These relationships are manifold – from existing ecologies,

government and economic systems to the actors of such systems and their individual perspectives. The complex feedback loops in such systems, and the ability to dynamically update the system as events unfold, allows for a designed openness. We have witnessed the failure of hard infrastructure throughout the 20th century – from the WPA (Works Progress Administration) projects to the 1960s mega projects – due to their inability to accommodate flexibility. Ultimately, the project of soft systems requires the designer to consider the complex networks that their intervention exists within, and position architecture and infrastructure within such networks to create systemic symbiosis, nested hierarchies and feedback loops.



Fig 9. Extended Season: The reinforcement meshes solidify the weakest moments of the network extending the operating period of the ice roads.

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