

**CIFAR**

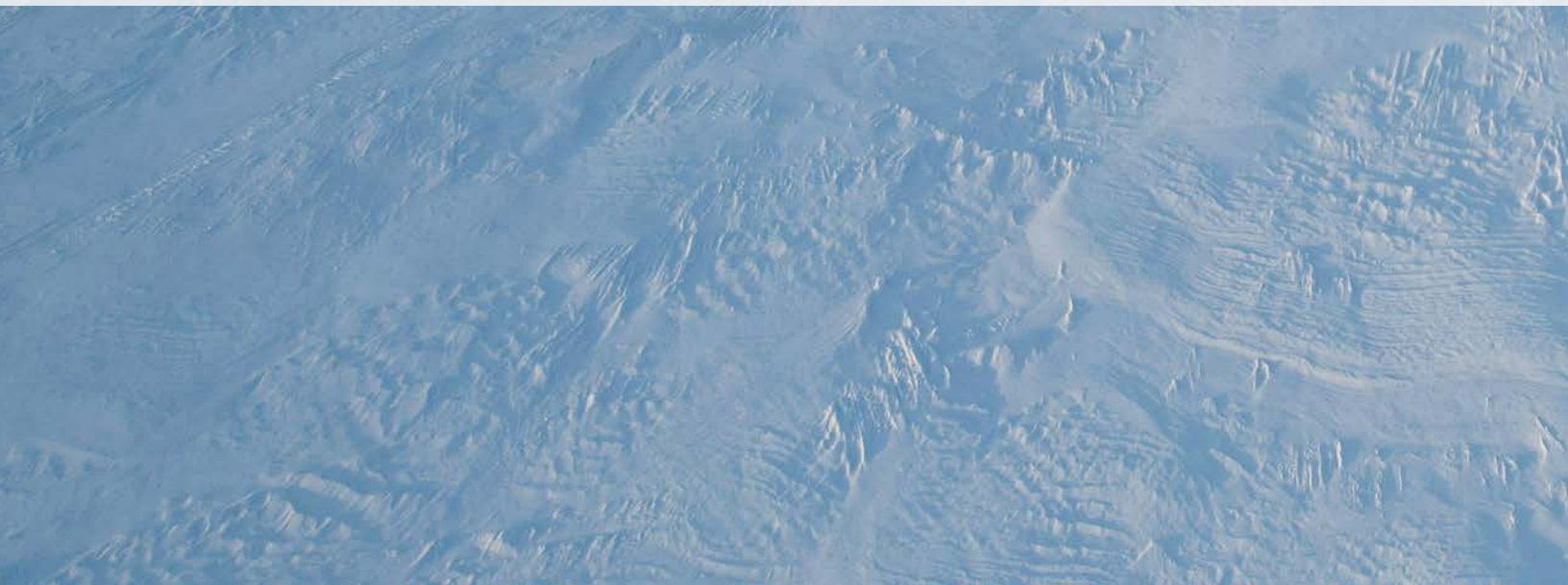
THE NEXT LEAP STARTS **HERE**

# CIFAR Panel on the Future of the Arctic





**CIFAR's Discovery Panel on the Future of the Arctic was developed in partnership with the Swiss National Science Foundation (SNSF) and made possible through the CIFAR Ralph M. Barford Discovery Initiative.**





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# Executive Summary

In February 2026, a panel of 14 interdisciplinary experts convened to explore potential future research directions for the Arctic, specifically evaluating the utility of CIFAR's international and interdisciplinary convening model for research in the region. Through a series of virtual meetings and a two-day workshop in Geneva, Switzerland, the group used foresight exercises to identify novel, interdisciplinary research priorities. The resulting report outlines these findings.

The report begins with a critical examination of the key considerations and tensions inherent in current and future Arctic research. Several foundational questions are highlighted. It asks how our understanding of preparedness must shift in the face of deep uncertainty caused by unprecedented rates of environmental change, and how research frameworks are transformed when we view the Arctic as a home that is cared for, rather than territory to be owned. Furthermore, the panel emphasizes the need to broaden the current understanding of Arctic land-water interfaces, recognizing that ice, snow, and permafrost function as essential infrastructure for mobility and survival. Finally, the report interrogates the primary objective of future Arctic research, contrasting traditional resilience-based models with emerging frameworks of rupture and renewal.

The report introduces three transformative research areas for the Arctic that draw on diverse ways of knowing and being. These themes, which emerged from the panel's exploratory interdisciplinary discussions, offer compelling and provocative directions capable of sustaining long-term programs of inquiry. The first, "mobility as place," challenges traditional, static definitions of geography by framing place as a dynamic field of movement. The second, "Arctic 'Kininfrastructures,'" examines the transformative potential of applying human relationality — specifically kinship — to the infrastructure of the region. The third theme focuses on "knowledge integration modeling," proposing an approach to synthesizing multidisciplinary data to better inform governance, manage systems change, and identify critical environmental tipping points.

Ultimately, the insights within this report suggest that the future of Arctic research lies not in seeking to master its complexity, but rather in informing how we might operate responsibly within it. Rather than providing a rigid roadmap, the panel has outlined a series of critical tensions and research directions designed to empower scholars to ask more profound questions that can shape the future of the Arctic.



# Background

The Arctic is increasingly a region of profound change: rapid environmental transformation driven by climate change, growing global strategic interest in economic development and security, and a proliferation of research funding flowing into the region.

Rapid environmental change — most visibly the loss of sea ice, warming temperatures, and shifting ecosystems — is transforming the Arctic's physical and ecological infrastructure at a pace unmatched elsewhere on the planet. At the same time, these changes are intersecting with increasing geopolitical and economic attention. Governments and industries are examining opportunities related to shipping routes, natural resource development, critical minerals, fisheries, and infrastructure, while Arctic states are also strengthening their presence and policy frameworks in response to evolving questions of sovereignty and security. Together, these dynamics have heightened international interest in Arctic knowledge and governance. Scientific research in the Arctic has therefore expanded substantially in recent decades, reflecting the need for robust evidence to understand environmental change, inform responsible development, and support sustainable and equitable futures for Arctic communities.

Taking a step back, though, how do we define the Arctic? In practice, the Arctic may be best understood as a circumpolar region characterized by northern latitude, distinctive climatic conditions, and interconnected ecological, cultural, and political systems. And yet, a clear and agreed-upon definition remains elusive. For some, the Arctic is home. For others, it is an opportunity. Still others see it as a frontier — language that evokes colonial

attitudes that have shaped the Arctic over the past two centuries and continue to do so. What defines the Arctic, and where its boundaries lie, is also changing, as once-defining features such as the extent of permafrost evolve and shift. New entrants and interests, including industries and nation-states, complicate existing cooperative arrangements, while emerging technologies enable forms of influence and extraction by geographically distant actors.

Against this backdrop, Arctic research interests are proliferating. Global Arctic research output has more than doubled since the late 1990s, reaching roughly 11,000 publications annually, reflecting increasing scientific attention to rapid environmental change and geopolitical interest in the region. Global Arctic research funding now likely exceeds USD \$1–2 billion annually, with the United States as the largest contributor alongside sustained and growing investments from the European Union, the Nordic countries, and Canada. What might these investments be oriented toward in the near future? How might global interdisciplinary and transdisciplinary research partnerships imagine programs of research capable of supporting a changing Arctic in the decades ahead?

In this report, a panel of 14 Arctic researchers synthesizes its reflections on the future of Arctic research, drawing on foresight methods explained below. This process surfaced cross-cutting considerations for future research, alongside a deeper exploration of three provocative and compelling research programs. The report concludes with highlighting the necessary shift from interdisciplinary to transdisciplinary research to support environmental, economic, institutional, and socio-cultural prosperity in the region.

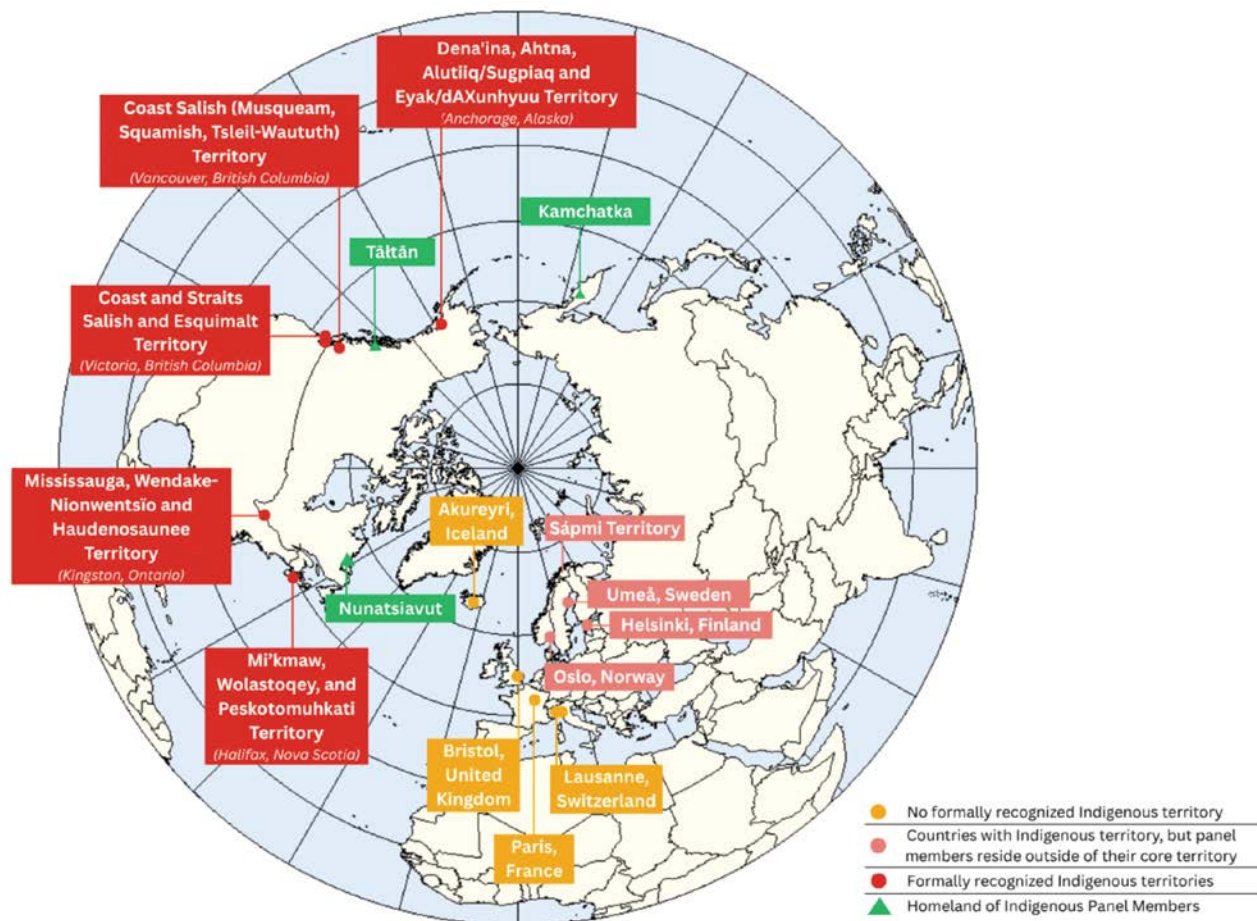


## Discovery Panel Positioning

This report is informed by a panel of 14 interdisciplinary Arctic experts (see Appendix I for full names and affiliations). Their areas of expertise include fisheries governance, food security, oceanography, geology, hydrology, remote sensing, climate studies, extreme environments, polar governance, law, economics, Indigenous Knowledge Systems, Indigenous arts, and speculative fiction. While the panel reflects considerable disciplinary breadth, we recognize that its collective perspective is shaped by its composition: 11 women and 3 men, a predominantly academic professional background, 3 Indigenous members, and a geographic concentration in North America and Europe. All proceedings were conducted in English.

Recognizing that many voices were not in the room, we spoke about what Ta'an Kwäch'än Council Elder Copper Joe Jack calls "No Voice" — a responsibility to account for those not present in the discussion including ancestors, future generations, and non-human kin. While we tried to hold No Voice in our hearts and minds, we acknowledged that our discussions were inevitably shaped by those in the room.

The geographic distribution of panel members is shown in a map below. While standard maps often peripheralize the Arctic, the circumpolar projection centralizes it, more accurately reflecting its significance in our panel discussions. (see Figure 1).



**Figure 1.** Geographic distribution of panel members, represented by dots, on a circumpolar map projection. Dot colours indicate the extent to which Indigenous territories are officially recognized in each region. Green triangles represent Indigenous panel members' homelands.

## Panel Values

Given the panel's diversity, the real consequences of Arctic research, and the spirit and intent of interdisciplinary work as care, we share below the values that guided our conversations and work.

### Generosity

We approach this conversation with generosity by assuming good intent, listening to understand before responding, and sharing our knowledge and time openly. We make space for perspectives that differ from our own and resist zero-sum thinking, recognizing that collaboration expands possibility.

### Vulnerability

We allow ourselves to speak honestly about uncertainty, limits, and lived experience. We acknowledge what we do not know, where we have made mistakes, and where our institutions or countries may carry responsibility — understanding that trust grows when we are willing to be real with one another.

### Gratitude

We enter with gratitude for the people, places, and knowledge systems that make this dialogue possible — especially Indigenous communities whose homelands and futures are central to the Arctic story. We actively name and appreciate contributions in the room, recognizing that collaboration is a gift, not an entitlement.

### Humility

We hold our expertise lightly, recognizing that no single discipline, nation, or worldview can define the Arctic's future alone. We remain open to being changed by what we hear and commit to centering those most affected in shaping decisions.

### Joy

We notice and name moments of possibility, connection, and progress — even amid complexity. We allow ourselves to celebrate shared insights, cultural richness, and the privilege of working together toward something that matters.

### Creativity

We remain open to new combinations of knowledge, disciplines, and worldviews. We experiment with ideas, ask “what if,” and make space for approaches that may not fit traditional policy or academic frames.



## Methods

CIFAR Discovery Panels bring together a small, international, interdisciplinary group of researchers to explore future research priorities on a given topic. For clarity, the term discovery refers here to the identification of interdisciplinary research opportunities within the Arctic domain, and not to the Arctic itself, which has long been home to Indigenous communities. CIFAR facilitates this exploration through a number of structured exercises, including foresight methods, to support panel members in identifying emerging trends that are likely to be significant but remain poorly recognized (“critical uncertainties”), as well as opportunities for interdisciplinary knowledge sharing and research. The goal is not to produce an exhaustive list of research priorities, but rather to signal potentially transformative new research directions over the next 20 years on a topic of critical importance to science and humanity.

CIFAR identified 14 disciplinary diverse Arctic experts from North America and Europe to participate in the panel. The panel convened several times over a six-week period. Two initial sessions were conducted virtually, followed by two and a half days of in-person meetings in Geneva, Switzerland.

To identify research areas warranting further exploration by CIFAR, members engaged in iterative cycles of exploratory brainstorming and synthesis. These cycles featured foresight activities, including an impact-versus-uncertainty matrix and scenario-based engagement (see Appendix II). The insights generated through these activities form the basis of this report.

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## Context for Future Research

Conducting research in the Arctic takes many forms. For some, research in the Arctic is conducted within their homelands and territories, with kinship networks, and on topics rooted in lived experience. For others, Arctic research is undertaken using remote-sensing technologies that amass and combine vast quantities of data on oceanic and atmospheric conditions. Some researchers are based at southern institutions and travel north to do community- or government-partnered work, while others conduct their work from vessels at sea, sometimes spending months on the water collecting samples and studying life in some of the coldest and most remote parts of the world. Still others work and reside at permanent academic and research stations across the Arctic.

Regardless of the research paradigm or approach one takes, it is increasingly impossible to ignore that this work is being conducted in someone’s homelands, that it has implications for current and future generations, and that the funding accompanying research programs can either perpetuate research inequities or contribute to regional and local research capacity and sovereignty. With this in mind, the panel synthesized several important cross-cutting considerations for conducting research in the Arctic, summarized below. These are, of course, not the only considerations, but they are the ones the panel engaged with most deeply and felt were particularly worthy of inclusion here. Each cross-cutting theme is accompanied by illustrative questions raised by the panel. These are offered as food for thought for those who, like us, are grappling with what it means to do Arctic research.

### Change and Preparedness

The Arctic is often characterized as undergoing rapid change, and that change is often described as unprecedented or disproportionate. Importantly, however, change is not new for those who have called the Arctic home for hundreds or thousands of years. What is different is the sustained rate of change occurring now. Multiple interconnected systems are expressing non-linear, abrupt, and overlapping transformations. Cumulative impacts and compound events are increasing the risk of deeply uncertain futures. Both in this contemporary context and looking to Arctic futures, research needs to set the table for adaptation in all its forms—extreme and not extreme. Of central importance is to identify what we are preparing for, and why, and how we, as researchers, are meeting or moving with these changes.

**Example questions:** *How should irreversibility be defined in Arctic systems where recovery may or may not be possible? Can compound events in the Arctic be meaningfully separated into categories (fire, permafrost thaw, flooding), or are they fundamentally inseparable?*

### Care

The Arctic is a place, and contemporary colonial conceptualizations of place often involve property. One might therefore ask: To whom does the Arctic belong? But other ontologies do not subscribe to land ownership in that way, and so we challenge researchers to think

instead in terms of: To whom does the Arctic pertain? Who cares for the Arctic, and who cares about the Arctic? For researchers, these questions raise the issue of what it means to take on an ethic of care in their work. We use care broadly here, noting that Collective Benefit, Authority to Control, Responsibility, Ethics (CARE) Principles<sup>1</sup> related to Indigenous data sovereignty may be relevant to Arctic research, and that there is also a rich body of scholarship on care as speculative ethics<sup>2</sup>.

**Example questions:** *What futures of governance, well-being, and sustainability become imaginable if care and relationality guide how we plan, build, and maintain a diverse Arctic? If we imagine the Arctic as a diverse, self-determining, knowledge-producing region, how might we also foresee the ways in which it is connected to the rest of the planet through care?*

## Ice, Snow and Permafrost

The land–water interface that may appear more absolute in other research contexts is not universally experienced as such in the Arctic. Sea, lake, and river ice are extensions of land and can function like highway infrastructure that supports mobility and existence. Permafrost is the foundation — both for engineered infrastructure and ecological systems — of many Arctic regions, and it is being rapidly lost and at dramatic and disproportionately high rates. Thawing permafrost is releasing carbon stored for thousands of years, contributing to rising greenhouse gas emissions and accelerating climate change. This can set off cascades of interconnected impacts, whereby the reactivation of long-dormant microbial communities accelerates the decomposition of previously frozen organic matter, releasing substantial amounts of greenhouse gases such as CO<sub>2</sub> and CH<sub>4</sub>. These can in turn amplify warming and further destabilize permafrost systems. It is therefore important that understandings of homeland and territory be broad enough to encompass Indigenous sovereignties and the realities of what constitutes the entirety of homelands.

**Example questions:** *What are the implications of a summer ice-free Arctic Ocean? How does the loss of permafrost reshape connectivity in the Arctic — in terms of access to traditional places and community connection, and in terms of growing pressures for infrastructure development?*

## Science for Society

All research proceeds with assumptions and is, in its own ways, implicitly or explicitly biased. Furthermore, research inevitably serves different interests, whether researchers reckon with that truth or not. Researchers working in the Arctic should ask themselves: In service of whom is this work? In what ways can and should research be undertaken to ensure it is impactful and supportive of societal goals? Who is society? And, returning to earlier questions of who cares for and about the Arctic, whose goals matter? The increasing flow of money into the Arctic — the Arctic research economy — offers an additional lens through which to think about science for society. When research is undertaken through genuine, meaningful, and long-term partnerships, and with attention to the power dynamics inherent in contemporary research practice, money can support capacity and self-determination.

**Example questions:** *In what ways can international research collaboration model pathways for enhanced multi-level government and community cooperation? What might a return-on-investment model look like for the Arctic research economy?*

## Resilience, Rupture and Renewal

Some of today's research is conducted to address the system as it currently exists — the Earth system, the social-ecological system, and the geopolitical system. It recognizes change, perturbation and positive feedback loops, possibly leading to ecological and cultural tipping points. This thinking aligns with resilience paradigms: how to manage for change and prepare for disruption. But some research may also investigate rupture, or a fundamental shift away from the current system. Arctic researchers may therefore find themselves asking what an entirely different system might look like, and what forms of renewal might follow rupture.

**Example questions:** *Is an Arctic transformation inevitable? If so, is that transformation toward a new way, or a restoration of previous ways? When do we prioritize resilience vs rupture? Who decides on those priorities?*

These cross-cutting themes were approached differently by panel members, without clear consensus on how they should be viewed or incorporated into research. There was, however, broad agreement that leaning into these tensions will likely be necessary for future Arctic research.

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<sup>1</sup>Carroll, S. R., Garba, I., Figueroa-Rodríguez, O. L., Holbrook, J., Lovett, R., Materechera, S., ... & Hudson, M. (2020). The CARE Principles for Indigenous Data Governance. *Data Science Journal*, 19(1), 43. DOI: 10.5334/dsj-2020-043

<sup>2</sup>Puig de la Bellacasa, M. (2017). *Matters of care: Speculative ethics in more than human worlds*. University of Minnesota Press.

# Emerging Research Ideas

Through iterative brainstorming and synthesis, the panel refined three interdisciplinary and transdisciplinary research themes. While not comprehensive, these themes are offered as examples of transformative research that necessarily draws on multiple ways of knowing and being, and that the panel felt were compelling and provocative enough to sustain long-term programs of work. Importantly, these ideas represent only a few days of conversation among a specific group of people and should not be taken as limiting the scope of intellectual creativity needed from Arctic researchers.

Each of the three ideas is presented first through a narrative that conveys the theme in plain language. The narratives below offer one possible future that might emerge if the research theme in question were to develop. These are followed by a deeper articulation of the concept, a discussion of its relevance to the Arctic, an explanation of how it might shift existing paradigms, and a set of speculative research questions.

## Theme 1: Mobility as Place in the Arctic

### Possible Future Narrative

*The territorialities, national competitions, climate forcings, geophysical boundaries, and colonial pressures that currently shape the Arctic's imaginary lines are being challenged, broken down, and reconfigured. The concept of human-centred sovereignty and ownership – historically expressed through control and domination – is being unsettled by a multi-centred value system grounded in collective and mutual relations and responsibilities. The collective here encompasses both human and more-than-human beings. Difficulties and tensions remain in 2050, but they are addressed through constructive engagement with representation, responsibility, and recognition of actors without formal political voice. This shift does not eliminate conflict or misunderstanding, but it does reframe them within a mobile and relational Arctic that continually works toward possibilities for multispecies flourishing.*

### Concept

Mobility in the Arctic is a constant and constitutive reality. The Arctic, as place, is constructed through movement: shifting ecoregions, the advancing and retreating of treelines and the thawing and refreezing of permafrost. Movement is in turn made possible by these very places, as human and animal migrations unfold across land and sea. The concept of “mobility as place” fundamentally decentres

the human, opening a non-hierarchical space to recognize multiple intersecting axes of movement in a constantly shifting region. This idea foregrounds a productive tension – an apparent contradiction between movement and place – that offers a more nuanced way to understand the Arctic as a space characterized by contradiction, tension, and the coexistence of dynamic forces.

Applying a mobility as place lens challenges our understanding of existing colonial bordering practices, both horizontally and vertically. Horizontally, through the drawing of state and municipal frontiers, maritime zones, and supposed land–sea divides. Vertically, through distinctions between subsurface, surface, and built structures; between crust, ocean floor, water column, and water surface; and between airspace, atmosphere, and space. Mobility as place forces us to confront the unreality of drawing boundaries across fundamentally mobile spaces, which have historically and presently been driven by domination-based conceptions of human–land–nature relations. Quotas are issued for fish stocks, marine mammals, and refugees as though they can be contained within predetermined spaces. Capital flows freely – until sanctions are imposed.

A critical dimension of mobility as place in the Arctic lies beneath the ocean surface. According to the UN Convention on the Law of the Sea (UNCLOS), horizontal and vertical boundaries are drawn into maritime zones: the surface, where freedom of navigation prevails; territorial seas (up to 12 nautical miles from coastal baselines); exclusive economic zones (EEZs) in the water column (up to 200 nautical miles); and the continental shelf regime for the sea floor and crust, extending beyond 200 nautical miles where geological continuity can be demonstrated. Within these zones, states exercise differentiated bundles of rights—sovereignty in territorial waters; sovereign rights for exploration and exploitation in the EEZ and continental shelf; and specific jurisdictional competences over the

water column, seabed, and subsoil. These are not merely technical legal procedures. They represent shifting subsea territorialities grounded in evolving geological interpretations and scientific evidence presented to the Commission on the Limits of the Continental Shelf. At the same time, the physical geography of the Arctic Ocean is changing through melting sea ice, warming waters, and shifting currents. Ice retreat alters navigation routes, coastal state powers to apply stricter environmental standards, economic viability, and strategic calculation. The seabed itself — mapped, re-mapped, and interpreted through new data — becomes part of a dynamic legal and economic geography that operates through moving legal-geophysical assemblages, not stable territorial containers.

Approaching the Arctic through mobility as place opens possibilities for moving beyond place as a static geographical locale and instead understanding it as a dynamic field of movement, shaped by multiple directions, motivations, and forces. From this perspective, the Arctic becomes a place of constant transformation informed by lived experience rather than a static, remote region. Its borders are not merely lines on a map, but legally contingent, scientifically mediated, and politically negotiated. Mobility as place seeks to capture these fluid conditions in all their fullness.

## Contribution to the Arctic

The Arctic is often approached through static categories: sovereignty, territory, resources, resilience, and stability. Yet Arctic realities are defined by circulation and transformation. Indigenous settlement patterns, colonial expansion, resource extraction, infrastructure development, and military positioning have all occurred in waves. Today, climate change amplifies these processes.

The perspective of mobility as place offers alignment with Indigenous worldviews that will result in transformed stewardship and subsistence practices that prioritize well-being and care for all relations in the Arctic, which are deeply dependent and interconnected. Indigenous borders are not defined by states, but by socio-ecological systems and the movements within them, and by strong bonds between humans and extended networks of non-human relatives (Whale, Salmon, Reindeer, River, and others). Mobility as place can therefore be grounded in Indigenous legal systems, languages, long-term observations, and lived experience, bringing these into the foreground of conversations about the Arctic's past, present, and future.

In Arctic security terms, this reframing matters profoundly. Extended continental shelf mapping, sea-lane openings, resource rushes, and strategic competition all unfold in a region where the geophysical substrate itself is transforming. Security cannot be fully understood without recognizing that territorial place is produced through mobility.

Recognizing the Arctic as constituted by plural mobilities — where human movement is not privileged over ocean currents, migrating species, shifting infrastructures, or moving ice — challenges the assumption that resilience is equivalent to stability. Instead, it centres the constancy of change and forces reconsideration of what is being defended, by whom, and over what timescale.

### Ways in which this shifts the current paradigm

The tension between mobility and place captures a core reality of the Arctic. It enables us to move beyond binary thinking, bridging sciences and the arts, nature and culture, insiders and outsiders, stability and disruption, and challenging simplistic notions of “good” or “bad.” Change is constant. Time operates at multiple scales, from the lifecycle of a species to geological epochs. Agency extends beyond human actors to more-than-human systems. Using a lens of mobility as place also helps bring together subjects that might not ordinarily be connected in Arctic scholarship. A study of an Arctic mine, for example, might trace mobilities into and out of that site. Miners from outside the region may bring traditions of labour unionism that in turn shape embodied relationships — human and more-than-human — that constitute place. Meanwhile, the ore itself is mobilized out of slow geological cycles into global trade, potentially to the detriment of the kin surrounding it.

Similarly, studies of frozen matter — ice, snow, permafrost, frozen air — conducted collaboratively by permafrost scholars, hydrologists, meteorologists, Indigenous knowledge holders, and social scientists become valuable in confronting climate change and informing decision-making. Frozen matter is not static; it is constantly transforming and shaping human mobility practices. A river or lake, for example, may be an abundant source of food in summer and a crucial part of winter infrastructure and mobility in colder months.

Even subsea mapping expeditions that underpin continental shelf submissions to the UN Commission on the Limits of the Continental Shelf are forms of mobility that produce new legal places. Scientific data become territorial argument. Geological formations become claims to sovereign rights.

Mobility studies have explored socio-ecological-technological systems across social, ecological-biophysical, and infrastructural domains. Social scientists have undertaken extensive work on senses of place, relationships among place, space, and power, human migration, and the making of space and belonging. Indigenous studies have examined coloniality, legal practices, stewardship, and governance systems that underlie mobilities and place-making. A focus on mobility as place in the Arctic extends this scholarship through radical interdisciplinarity and a vertical legal-geophysical lens.

By dismantling the dichotomy between fixed place and fluid mobility, this framework encourages — and perhaps requires — interdisciplinary and transdisciplinary scholarship. It could facilitate collaboration among legal scholars and oceanographers, dialogue between climate scientists and political theorists, engagement between security analysts and social scientists, and the integration of Indigenous knowledge systems across disciplines.

Examples might include:

- Atmospheric mobility studied by climate scientists shaping senses of place explored by writers.
- Energy flows analysed by economists affecting military strategy.
- Seabed geology interpreted by scientists becoming the basis of sovereign rights.
- Indigenous-led and Indigenous-engaged research conducted in collaboration with colleagues from multiple disciplines to inform action-oriented and meaningful responses to transforming food systems.

Mobility as place integrates multiple timescales and actors, recognizing that place is constructed over generations through ongoing cycles of movement, knowledge transfer, and reconfiguration. It offers a new lens for Arctic security and well-being by showing that sovereignty, borders, and territorial claims are not stable endpoints, but ongoing processes shaped by geological, climatic, legal, colonial, and political mobilities.

## Speculative Research Questions

- How do we recognize agency — human and more-than-human — in migration? How voluntary are mobilities?
- What does it mean to construct a species or actor as “invasive” in a region defined by mobility?
- In a constantly transforming Arctic, what is worth preserving, and over what timescale?
- How can models and forecasts integrate legal and geophysical mobility (for example, tipping points, maritime boundaries, jurisdiction, and ice retreat)?
- What temporal thresholds define when a system can be considered stationary?
- How does a mobility as place perspective reshape understandings of sovereignty in the Arctic Ocean, particularly in relation to extended continental shelves?
- How do subsea geological formations become political through mobility (mapping expeditions, scientific interpretation, legal submission)?
- What is the relationship between mobility and kinship infrastructures?



## Theme 2: Arctic Kininfrastructures

### Possible Future Narrative

*In 2050, kinship guides decision-making. If a mine is understood as kin, it cannot simply be overtaxed, abandoned, or reduced to a site of extraction. It must be returnable to the land, and throughout its construction and active life it must meet high standards in how it relates to the lands, waters, non-human beings, and human communities in its vicinity, near and far. It must be understood as a past and future home for organisms at multiple scales, deserving of care. In this paradigm, humans carry an expanded responsibility in relation to use, extraction, management, and restoration. We need to think not only about present and future human generations, but about future generations of kin and the ways they may relate to the mine. The goal would move beyond harm reduction toward coexistence and mutual flourishing.*

### Concept

We draw in part on scholars who have identified the ways in which Indigenous thought and science relate to environmental kinship studies. Kanngieser and Todd (2020) remind us that environmental kin studies are about the cultivation of, and attention to, relations. Relationships are connections and interactions among people, environments, and beings through time and space, lived through the body and the senses. In this framing, relationships are foundational to how we understand ourselves as belonging to, and always already entangled with, the Earth. To be in relation is an agreement to, and commitment to, care. It is an intention of reciprocity. We extend this relational framework to challenge conventional notions of development and the privileging of the built environment.

We also bring Indigenous ideas and scholarship about kinship into conversation with the role and significance of infrastructure in climate discourse. The Intergovernmental Panel on Climate Change (IPCC) 1.5°C report emphasized that major infrastructural transformation is needed to avoid catastrophic climate impacts. We are especially interested in the proposition that questions about transforming infrastructure are also questions about what counts as infrastructure. Indigenous communities responding to climate impacts, for example, have shown how forests can be understood as a form of living infrastructure.

Conventionally, infrastructure refers to the physical and organizational structures and facilities needed for the operation of a society or enterprise. Kininfrastructure begins from a different premise: that kinship is foundational to all relations and relational possibilities, and that this should shape the physical and organizational structures needed for the flourishing of a society that includes non-humans as well as humans. Kininfrastructure therefore shifts us from individualism toward collectivism and from a focus on material structures alone toward organizational, ethical, and relational ways of thinking.

The underlying philosophy of this concept is reflected in Lewis et al. (2018), who write in *Making Kin With Machines* that the human is neither the height nor the centre of creation. This principle is central to many Indigenous epistemologies and underpins ways of knowing and speaking that acknowledge kinship networks extending to animals and plants, wind and rocks, mountains and oceans. Indigenous communities worldwide have retained languages and protocols that enable dialogue with non-human kin, creating intelligible relations across differences in materiality, vitality, and genealogy. Kininfrastructure builds on this orientation and asks what might change if such relationality were treated not as metaphor, but as governance logic.

This leads to foundational questions, such as: How might our research change if we related to the Arctic, in all its forms, as kin? What futures of governance, care, and sustainability become imaginable under a regime of kininfrastructures — infrastructure that enables us to do our work in a good way? We find it a compelling question to ask whether reconceptualizing infrastructure as kininfrastructure might offer disruptive pathways toward maintaining a diverse and flourishing Arctic.

### Contribution to the Arctic

The history of colonialism in the Arctic has often involved unchecked industrial development, alongside geopolitical frameworks that prioritize state influence and power while ignoring fundamental vulnerabilities and compound events. A kininfrastructural approach offers another starting point. It recognizes the diversity of knowledge systems rather than privileging only scientific modes of apprehending both stability and change.

In the Arctic, this conceptual shift could contribute by foregrounding Indigenous knowledge in the stewardship of social and ecological systems, building on work by Indigenous scholars who use kinship as a research framework. It could also offer new ways of managing social and ecological systems by centring more-than-human relationships — an especially important intervention in a region that is both vulnerable and contested. It asks what flourishing looks like when community includes lands, waters, human inhabitants, and non-human beings

in relation to one another. It also creates openings for bringing together Indigenous knowledge, environmental science, health, law, social work, and the arts within a shared conceptual frame.

### Ways in which this shifts the current paradigm

A shift to kininfrastructures responds directly to unsustainable ways of perceiving and organizing the world. It can shape how we think about and act across a wide range of decisions, from industrial development and knowledge production to data care and sovereignty, climate response, ethical judgment, and our broader responsibilities toward the more-than-human world.

For example, Inuit approaches to land stewardship, including *Avatittinnik Kamatsiarniq* — respect and care for the land, animals, and the environment — offer one grounding for such a shift. So too does *Ná t'sin t'ra*, a Northern Tutchone phrase often translated as “hold everything up in respect,” which Elders from the Yukon have described as treating the land as one would one’s own mother, keeping water clean for future generations, and understanding that land, water, and all inhabitants are connected through spirit. Among Itelmen in Kamchatka, fish may be understood not simply as a species, but as kin. As panel member Tatiana Degai shared, when the river opens from ice, Itelmen people hold ceremony to thank the river and greet the fish, offering gifts to the river’s spirits in hope of a good season. In Northern Sámi thought, *luonddu oassi*, meaning “a part of nature,” reflects a worldview in which humans are understood as part of nature, not above it, and where this belonging grounds values and traditional knowledge.

Within this paradigm, scientists and scholars would need to account not only for the impacts of their research, but also for the fundamental questions of who benefits from it and how it affects relationships among varied kin. In scholarly terms, this approach could both extend and connect new materialist thought and kinship studies, while providing conceptual scaffolding for sovereignty, self-determination, and the authority of Indigenous and ecological knowledge.

Institutions and governance systems would also need to develop processes that hold proponents of development,

communities, and builders accountable to those with no voice and to others within kinship networks. Indigenous communities would need to be constitutive participants and co-creators in these systems, as well as in the research projects that inform them. Central to this paradigm shift is recognition of the constant nature of change and the importance of maintaining relationships and well-being across kinship networks.

This perspective could also reshape public understanding of the relationship between the built environment and the so-called natural environment. It may help society think more critically about what is built, for whom, who is displaced by it, and toward what ends. It privileges everyday life in the Arctic and attends to lived relations on the ground. As Kanngieser and Todd (2020) note, this is a vital turn in kin-centred studies: at a time when so much attention is given to global collapse, it is easy to forget the everyday ways in which we all live within our surroundings.

### Speculative Research Questions

- If we understood permafrost as kininfrastructure, how might that change our relationship to it and the actions we take?
- If we understood bridges, mines, and buildings as kininfrastructure, how might that alter our approach to civic and industrial development?
- How might kininfrastructure change the way we think about knowledge production and care for data?
- How does kininfrastructure shape ethical decisions about everyday life in the Arctic and responsibilities to future generations?
- In what ways could kininfrastructure account for “No Voice,” and how might it shift our sense of responsibility?
- How can understandings of governance, care, and sustainability be epistemologically and politically reshaped through a shift to kininfrastructure?
- Could this concept open additional possibilities for thinking through a broader expansion of kininfrastructure to include family, culture, and food sovereignty practices as generative aspects of Arctic flourishing?



### Theme 3: Knowledge Integrator — Modeling preparatory governance, systems change and tipping points

#### Possible Future Narrative

*Rapid change across the Arctic environment — and the living conditions of both humans and animals — has opened previously unexplored areas, brought new economic opportunities, and geopolitical interests in the region have continued to intensify. In 2050, these trends are accelerating and in such a rapidly evolving system, decision-making becomes increasingly complex. The Arctic is a tightly interconnected environment in which ecological, economic, social, and geopolitical factors continually influence one another, and yet work in the early part of the twenty-first century continued to model Arctic social-ecological systems as if each sector, place, and problem was isolated. But actions in one domain can quickly affect many others. In this context of accelerating change and deep interdependence, the risks of unintended consequences and poor decisions increased to the point of requiring new and integrated tools. Moving from a reductionist to a holistic modeling paradigm helped to lead the development of tools capable of integrating diverse forms of information — environmental, social, Indigenous, economic, and political. These essential decision-making assets have allowed humankind to navigate complexity, anticipate risks, and support wiser, more resilient choices for the Arctic's future.*

#### Concept

We propose the development of an integrated Arctic system model with the ambition of robustly forecasting possible Arctic futures under accelerating environmental and socio-economic change. The Arctic is undergoing some of the most rapid transformations on Earth, shaped by tightly coupled processes across the climate system, including the cryosphere, ocean and atmosphere, terrestrial ecosystems, and human activity. Change is increasingly compounded and potentially non-linear, with interacting pressures creating the risk of abrupt transitions, cascading impacts, and irreversible pathways. In this context, knowledge preparedness and forecasting are becoming critical prerequisites for effective governance.

The proposed model would integrate diverse spatial observations, combining environmental data — such as climate variables, sea ice and permafrost dynamics, ocean

circulation, atmospheric forcing, land processes, and biosphere responses — with socio-economic information, including demographics, infrastructure, land use, resource pressure, and geopolitical change. By bringing these domains together, the model would enable scenario analysis, risk assessment, and the identification of critical vulnerabilities across multiple spatial and temporal scales. Its design would support interrogation at different levels of granularity, allowing both pan-Arctic synthesis and locally relevant insight.

A central objective is to translate this modelling capacity into an open-access decision-support tool that strengthens evidence-based policymaking and anticipatory governance. The tool could support mitigation and adaptation planning by helping decision-makers navigate trade-offs among development, ecosystem integrity, and carbon storage, while also identifying unintended consequences and system feedbacks. Crucially, it would enable a holistic assessment of how global climate policies and intervention pathways translate into Arctic-specific consequences for ecosystems, infrastructure, livelihoods, and cultural systems. This would provide Arctic nations and communities with a stronger scientific basis—and potentially a clearer voice — in international climate negotiations, where regional risks and thresholds of irreversibility must be more effectively represented.

Given the deep uncertainties inherent in Arctic futures, the modelling framework would need to address uncertainty explicitly through probabilistic methods, including perturbed-parameter ensembles and Bayesian approaches. This would allow systematic exploration of uncertainty ranges, sensitivity to key assumptions, and the robustness of projected trajectories. Particular attention would need to be paid to feedbacks and tipping-point behaviour, where relatively small perturbations may trigger disproportionate system-wide responses.

Beyond forecasting, the model could also serve as a strategic instrument for research prioritization by identifying where data and knowledge gaps most strongly limit predictive skill. Maintaining the framework as a living system — continuously updated with new observations, improved process understanding, and evolving stakeholder needs — would be essential to sustaining its relevance and usefulness over time. Overall, this integrated Arctic digital twin approach offers a timely and potentially transformative foundation for resilient governance in a region at the front line of global change.

#### Contribution to the Arctic

The proposed integrated Arctic system model responds directly to the growing gap between the pace of change in the region and the ability of policies, institutions, and communities to anticipate it. Existing decision frameworks remain insufficiently equipped to address compound risks,

cross-sectoral feedbacks, and the long-term consequences of interventions in a region where small perturbations can generate disproportionate effects. By assimilating diverse environmental and socio-economic observations — including Indigenous knowledge — into a unified modelling architecture, the tool could enable holistic assessment of Arctic futures under multiple scenarios, including those involving tipping points and other non-linear dynamics.

A particularly important contribution would be the model's capacity to evaluate climate interventions and policy choices in an integrated way. The Arctic is both a driver of, and a sensitive recipient of, global climate strategies, yet the regional consequences of mitigation pathways, adaptation measures, and emerging interventions remain poorly quantified. By incorporating climate policy assumptions alongside socio-economic trajectories, the model could clarify how global decisions translate into Arctic-specific impacts on ecosystems, infrastructure, livelihoods, and cultural systems.

This capability could provide Arctic nations and communities with a stronger evidence base and a clearer voice in international climate negotiations. Model outputs could support robust, science-based narratives about what is at stake, which risks are nearing thresholds of irreversibility, and which policy pathways are most supportive of long-term resilience. Beyond forecasting, the project could enable anticipatory governance, strengthen preparedness, reduce maladaptation, and support earlier action in the face of rapid systemic change.

#### **Ways in which this shifts the current paradigm**

This project represents a paradigm shift in Arctic systems research by developing an integrated modelling framework that, unlike many existing approaches, aggregates physical, biogeochemical, ecological, and socio-economic dimensions within a single predictive architecture. Current models typically treat these domains separately, limiting their ability to capture coupled feedbacks, compound risks, and the full societal significance of environmental change. By unifying environmental observations with demographic, geopolitical, infrastructural, and land-use information, the project moves beyond climate-centric projection toward a genuinely socio-ecological Arctic system model.

A key novelty lies in the possibility of using a dynamic frame of reference that follows moving communities and ecosystems — human settlements, migratory species, and shifting resource use — thereby translating change into impacts experienced by people and biodiversity rather than only through fixed geographic grids. This reframing allows for more actionable assessments of vulnerability, resilience, and adaptation pathways.

The project also advances multidimensional and multidisciplinary data assimilation by requiring a fundamentally interdisciplinary approach to uncertainty that spans both natural and social systems. Finally, it addresses a critical knowledge-to-action gap by embedding decision-support and translation mechanisms into the model itself, helping ensure that complex outputs become usable knowledge for policymakers and other stakeholders and, ultimately, support anticipatory governance and timely intervention.

### **Speculative Research Questions**

- How can an Arctic system digital twin integrate heterogeneous forms of knowledge — physical, biogeochemical, ecological, socio-economic, and Indigenous — while also rigorously representing multiple forms of uncertainty?
- What new system behaviours may emerge in an increasingly ice-free Arctic, and how might non-linear feedbacks and tipping points reshape Arctic futures across environment, society, and governance?
- How vulnerable is Arctic infrastructure to abrupt and compound change, and how can quantitative stress-testing frameworks define resilience thresholds under extreme scenarios?
- What hybrid model architectures can responsibly combine mechanistic Earth system models with AI-based emulators while maintaining interpretability, robustness, and trust?
- How can Arctic digital twins be validated and legitimized through co-production with local and Indigenous knowledge systems and with reference data and observations, ensuring credibility for communities living with rapid change?
- Who governs access to, ownership of, and use of Arctic predictive models, and what safeguards are needed to ensure data sovereignty, prevent misuse, and translate outputs into actionable decision support?
- Given the scale of the task, how can such an ambitious modelling effort be advanced step by step, with realistic implementation strategies and iterative increases in ambition? What might a development roadmap look like?
- How can policy be designed, tested, and revised through engagement with a digital twin system?

## Concluding Remarks

The research themes articulated above represent a short but deep dive by panelists who had the space, interdisciplinary mixing, and professional facilitation to dream big. At the same time, we recognize — as noted earlier — that these dreams represent only one small moment among many possible futures Arctic research might imagine. Notably, many not at the table — the plethora of “No Voice” entities — may have other dreams for the future of the Arctic. The panel returned repeatedly to the importance of intentionality in whether Arctic research is conceptualized, funded, and operationalized from the bottom up or the top down. This conversation was inseparable from the reality that the Arctic is first and foremost a homeland inhabited by diverse Indigenous Peoples for thousands of years, even as it is also viewed by some as a site of contestation and competition by external actors.

The panel also discussed the importance not only of interdisciplinary partnerships, but of transdisciplinary ones. Transdisciplinarity is an approach that transcends the academy. It recognizes that research breakthroughs and impact require not only multiple disciplines, but also multiple ways of knowing, including those of rights-holders, stakeholders, and decision-makers. Transdisciplinarity also requires that research be undertaken for the benefit of society — that there be a social driver making the partnership necessary and meaningful. Questions of which society and societies are at the centre of partnerships remain.

Taken together, the reflections in this report point toward an Arctic research future that is less about mastering complexity than learning how to work responsibly within it. Rather than offering a definitive roadmap, the panel has identified a set of tensions, concepts, and research directions that may help scholars ask better questions about change, preparedness, care, mobility, governance, and flourishing in the Arctic. The report therefore offers something more generative than consensus: a framework for transdisciplinary inquiry grounded in humility, creativity, and attentiveness to the multiple worlds that constitute the Arctic. For scholars working across disciplines, sectors, and knowledge systems, our contributions lie in encouraging forms of research that are collaborative, ethical, and capable of engaging the Arctic not as an abstract frontier, but as a lived, contested, and deeply relational region whose futures will be shaped by the quality of the questions we ask and the partnerships through which we confront them.





## Appendix I

### Discovery Panel Members

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Sciences Po, Paris

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**ADRIAN HOWKINS**

Reader in Environmental History  
Bristol University

**LEE HUSKEY**

Unable to attend in-person panel discussions. Provided early input.  
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## Appendix II

### Overview of Foresight Methods

The impact-versus-uncertainty matrix served as the core framework for the second virtual meeting. Panel members participated in a two-hour session to prioritize key signals, trends, and drivers of change related to the Arctic over the next 20 to 30 years. In advance of the workshop, panel members identified emerging changes likely to reshape the region. By collaboratively mapping these factors, the group identified highly impactful and highly uncertain areas warranting deeper exploration. The matrix served as a vital tool for fostering dialogue and surfacing diverse perspectives, ultimately helping the panel build rough consensus on which signals would benefit most from continued exploration.



During the first in-person day, panel members were introduced to two contrasting Arctic scenarios for 2050. Each scenario drew on a subset of the identified critical uncertainties, with one developed as a divergent future, where governance is fragmented and power in the Arctic is increasingly contested, and the other as a convergent future, where strong, collective governance frameworks align actors toward a cooperative Arctic system. These scenarios were developed by the Berlin-based consultancy futurehain. We acknowledge the use of generative AI in developing these scenarios. The scenarios served as a tool to surface a broad set of ideas pointing to potentially transformative research frontiers. Specifically, members were asked to identify challenges and opportunities within each scenario. Discussions then expanded to consider emerging research needs.

Following the two foresight activities, panel members participated in creative role-playing exercises to identify broad themes, uncover novel interdisciplinary opportunities, and surface emerging foundational questions. The insights generated over the course of their time together form the basis of this report.

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