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Workshop Outcomes Report: 1st International Workshop on Seismic Resilience of Arctic Infrastructure and Social Systems

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1st International Workshop on Seismic Resilience of Arctic Infrastructure and Social Systems

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1. Workshop Objectives

The overarching goal of the workshop was to build capacity for investigating the resilience of Arctic infrastructure and social systems in response to seismic events in light of a changing climate. Specific objectives were to:

1. Foster collaboration among the diverse group of participants.
2. Identify, define, and prioritize research needs and ideas.
3. Propose strategies for outreach to Indigenous communities and best practices for co-production of knowledge.

Seismic infrastructure response in the Arctic region considers the dynamic response of frozen ground, earthquake-induced soil-structure interaction, seismic response of structural and non-structural systems, and effect of permafrost condition and changes on seismic ground response. Interdependence of Arctic infrastructure systems and a network of lifeline systems and their effects on seismic resilience and adaptation strategies for future planning and design guidelines. Questions remain concerning the role of changing climate on the performance of civil infrastructure under earthquake loads. In addition, there are institutional challenges to strengthening science-decision engagement for resilient infrastructure-social systems, and a need to further identify strategies to overcome these before, during, and after earthquakes.

Specific questions used to kick off this workshop addressed:

1. How do we model and evaluate the infrastructure system response and the damage states due to earthquakes in the Arctic?
2. How can the interdependencies among infrastructure systems be modeled and how much system redundancy is needed to ensure network functionality in case of infrastructure failure?
3. How can we integrate substantive understanding of social decision processes and institutional context into these models?
4. How can the models accommodate discrepancies between physical and social science understandings of functionality, resilience, and adaptiveness with respect to Arctic infrastructure systems?
5. How can integration of resilience-based earthquake engineering and institutional analysis enable safer, more sustainable, and adaptive infrastructure.

Workshop outcomes will ultimately contribute toward identifying and evaluating potential metrics to integrate natural, built, and social systems.

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2. Workshop Scope

The event was designed to promote the convergence of ideas and strategies from diverse disciplines and sectors. Bryan Fisher, Director at Alaska Division of Homeland Security and Emergency Management, delivered the opening talk. He emphasized the robust earthquake preparation and response structure within the state of Alaska, yet acknowledged the need to better include the effects of climate change.

Plenary sessions provided short talks from workshop participants on the following themes: 1) State of Alaska's Seismic Practice and Vision, 2) Lessons learned from past Earthquakes, 3) Community Resilience and Disaster Management, 4) Earthquakes and Infrastructure Response, 5) Arctic Seismicity; Climate Change Adaptation, 6) Effects of Permafrost Thawing and Climate impacts on Soils and Seismic Response, 7) Infrastructure Resilience; 8) and Sensing, Monitoring, and Climatic Impacts.

Participatory activities were interspersed throughout these sessions, including audience surveys and "write the room" activities using sticky notes to identify and share priorities on flip charts. participants identified concerns as they relate to seismic resilience of Arctic and Sub-Arctic built infrastructure, natural systems, and social systems as well as links with climate change. Outcomes are described below.

After the final speaker session, participants gathered in small teams to collaboratively develop ideas for convergence research projects based on the information presented throughout the workshop. Each team was tasked to develop a research concept that combines a high priority infrastructure concern with a high priority social system issue, taking into account links with the changing climate. Project ideas are presented below.

3. Participants

Participants and speakers joined the workshop either in-person or remotely through the Zoom platform. The names of all participants are listed in Appendix A. In total there were 51 participants including 27 in-person and 24 remote attendees. There were 31 technical presentations provided in this hybrid format from speakers from different disciplines (engineers, physical scientists, and social scientists), different sectors (government, academic, industry, and community outreach), and different geographic locations (Alaska residents, other US states, Iceland, Greenland, and Japan). In addition, the workshop's opening speaker was Brian Fischer, the director of Alaska Division of homeland security and emergency management. We were also privileged to have three members of the Alaskan indigenous community speak at the workshop. The workshop's detailed agenda is presented in Appendix B.

4. Outcomes

4.1. Participant response to workshop themes and structure

The structure of the workshop was designed to foster collaborations among a diverse community, striving toward the convergence of discipline-specific ideas to address the compelling societal problems related to Arctic seismic events. While this report presents highlights, it does not capture the numerous side discussions of synergistic links and potential collaborations during the activities and workshop breaks, both among in-person attendees as well as on Zoom for virtual attendees. Many participants noted the unique experience of such a wide variety of ideas from multiple disciplines and sectors focused on the common concern of Arctic seismic resilience.

Workshop participants marked the uniqueness and importance of bringing together a variety of disciplines and sectors. Participants from the seismic community in Alaska noted that EERI (The Earthquake Engineering Research Institute) hosts multi-disciplinary meetings, these are focused on California and other Western US states, and it is refreshing to have a workshop entirely focused on Alaska and other Arctic regions. Many of the social science, climate, and hazards Arctic scholars noted that these types of multidisciplinary workshops are increasing, especially through NSF NNA grants, providing an entry into new disciplines and a foothold for early career researchers to engage with impactful research that addresses societal problems.

While the workshop aimed to be international in scope, due to COVID-19 and the workshop location in Anchorage, much of the discussions focused on the Alaska region. There was a strong desire for follow-up workshops to broadening participation not only across Arctic regions but also to geoscience hazards beyond earthquakes, for example landslides in Greenland and Iceland or tsunamis that evoke similar discussions in resilience. This and future workshops will better establish link of local geohazards to global perspectives, learning about what is happening in other regions and the connection with climate change.

In general, participants were pleased with the hybrid format of the event and the pivot resulting limited travel during the pandemic. Challenges included accommodating all participants into the schedule, as organizers felt that it was important to honor both in-person and virtual participants by providing oral presentations to all who were interested. Participants noted the desire to have more discussion time following each session as well as more facilitated group discussion prior to participatory “write-the-room” activities. More opportunities for discussion internally among the virtual participants on Zoom would have also been valuable, especially during breaks and at the end of the meeting (making sure microphones and video were muted to avoid broadcasting to the conference room).

Another recommendation concerned the value of pre-workshop surveys of Arctic and sub-Arctic communities in order to bring local issues and concerns of end users to the forefront of the workshop discussions. PI Ghayoomi noted that while the original plan was to have meetings to gather insight from local communities and conduct a survey at UAF, there was concern about having survey too early without first conducting expert interviews. One participant acknowledged this approach but suggested that even if only 10 out of 100 people responds to an initial broad survey, it would likely bring new and highly relevant ideas into workshop discourse.

There was strong interest in follow-up activities or events to continue to keep the group connected. Ideally, future annual workshops could be hosted by other Arctic nations, but an NSF Workshop proposal might also be a path to continue to build on the initial momentum. Participants would like to also see broader international participation, with time to work in specialty break-out groups. For example, representatives from the Greenland emergency management would benefit greatly from speaking with Alaska’s emergency management, particularly as issues in Greenland are very new. Current participants could help further expand this circle. There was a request to compile key research questions and aims from each speaker in order to help promote synergies going forward (with the website used as a source to review workshop content, upload slides from the talks). Finally, participants expressed a need to have a concrete product from the workshop beyond this report, such as a white paper or funding opportunity.

The post-event survey also reflected mostly the above mentioned recommendations. Example feedbacks from the participants are quoted here:

- Climate-driven landslides, tsunamis, social vulnerability of the Indigenous communities and the resource allocation, port facilities in seismic areas, influence of climate change on liquefaction susceptibility, combined effects of climate change and earthquakes on hydrological hazards in cold regions, and influence of sub-zero temperature on material and structural response were among the topics that participants expressed their desire for further study.
- The participants would like to see more community training, scenario exercises, more focus on port facilities, more focus on damage assessment and impacts on social systems, the vulnerability of other Arctic regions, and outburst floods from glacier dammed lakes and thermokarst lakes.
- The participants were mostly satisfied with the workshop, and all satisfied with the organization with climate change discussion, permafrost thawing impacts, and group discussions received the highest marks.
- COVID certainly impacted the interaction level. Longer talks could have provided more time for presenters to go in-depth.
- It was recommended that the second workshop be in Greenland and probably during the Greenland Science Week in Nuuk.

4.2. Local Community and Indigenous Engagement

During the workshop, three Indigenous speakers provided insight into historical and current challenges of Alaskan Tribal communities along with the importance of taking the time to develop the trusting relationships needed to successfully conduct outreach and engagement necessary for co-produce knowledge. Wilson Justin from the ANCSA Corporation emphasized the importance of making our language more understandable to communities, especially given the constraints of the English language with its cultural values. Victoria Hykes Steere, an Inupiaq from Unalakleet and Assistant Professor of Alaskan Native Studies at Alaska Pacific University, provided a moving picture of how climate change has impacted her community. As we plan our response and adaptation strategies, she also encouraged us to consider adaptation strategies that not only respond to destructive aspects of climate change and seismic events but also that bring joy and beauty to humanity. Michelle Davis, EPA Tribal Coordinator, discussed more practical aspects of outreach and engagement with communities, including the importance of consistent communication with appropriate Tribal liaisons, appropriate times to reach out and engage communities, and sharing our work with the Tribal youth. These presentations ensured that these Indigenous concerns informed our small group discussions of convergent research ideas.

It was also recommended that on a local level, while addressing infrastructure resilient to seismic events, it is also important to recognize costs and capacity for construction and maintenance within small communities with very few jobs. As snow patterns change, access to clean water will become more of an issue and there are increasing concerns over storing and purifying water that contains pollutants such as heavy metals and microplastics. An additional example is that composting toilets often make more sense than sewage lagoons, especially as the diesel needed to heat the pipes to keep wastewater infrastructure working in the winter.

Plenary discussions on the final day of the workshop included considerations of strategies for reaching out to local and Indigenous communities in the Arctic and sub-Arctic. There was an acknowledgement that engagement of these Arctic residents is critical but challenging, especially in some areas of Alaska where recent NSF NNA and other funding opportunities have led to a saturation of science projects. There is clearly a need to know what is directly relevant to communities, landowners, etc. beyond merely providing financial compensation, such as funding training opportunities or fellowships to enhance capacity and support the type of tracking and monitoring work proposed during this workshop. While NNA-CO office members were unable to attend the workshop (due to pandemic travel and other last-minute circumstances), this project intends to engage this office in future plans.

The NSF NNA project supporting this workshop plans to return to Alaska in 2022 and host several community meetings, currently planned for Healy, Anchorage, and Valdez. Recommendations are to reach out to the ANSEP program at the University of Alaska moving forward, in order to involve students in these and future activities. The Alaska Division of Homeland Security and Emergency Management (through Lead Planner, Community Resilience, James Benzschawel) also expressed an interest in collaborating with this project to help reach out to communities.

The group also considered best practices for reaching out to communities in Arctic regions outside of Alaska. Trine Dahl-Jensen offered to identify participants from Greenland. Sólveig Thorvaldsdóttir noted that engaging communities in Iceland is easy IF you are doing something they see as worthwhile are willing to follow up and sustained the relationship and not perpetuate past mistakes of researchers. There are a lot of EU earthquake projects in Iceland requiring the need to be protective of community liaisons, so they are not overburdened with requests and needs of scientists.

4.3. Participant feedback through quantitative surveys

Brief surveys were conducted three times throughout the workshop to generate a baseline understanding of workshop attendees' demographics, priorities, and concerns. Surveys were conducted using Slido live-polling software, with participants responding using mobile devices or personal computers. A total of sixteen questions were developed for the survey, composed entirely of multiple-choice and rating scale questions. Participants were asked mainly about their experiences during past earthquakes or opinions on seismic resilience improvement methods (considering both adoption and implementation), and their familiarity and concern with climate-induced impacts on infrastructure and social systems. Survey questions were developed from a series of key informant interviews performed by student research assistants prior to the workshop. Results from the survey can be seen in Appendix C.

Survey responses were then presented, inspiring a vibrant discussion on how the needs of individual communities can be better met within "mainstream" goals – essentially asking "What are the top priorities for your community's future?" and "What do you and your community need to be more resilient to seismic hazards?" While we cannot predict earthquakes, many people still do not understand the strides we can still make, especially through educating communities about consequences, preparedness, and response. There is also a need to learn what communities know or do not know about areas vulnerable to seismic activity, including asking questions to demonstrate the appreciation of the hazard within different communities. “What is a seismic hazard? Do you know what liquefaction is? Surface rupture?” Seismic experts often go into communities assuming people do not know about these issues, but they may indeed already know a lot.

The workshop included an optional field trip to Earthquake Park in Anchorage. There were comments on how this park holds a lot more opportunities for information sharing and education about earthquakes. It was suggested that the municipality of Anchorage has an interest in not promoting landslides for economic reasons, continuing to build in regions vulnerable to landslides. Indeed the workshop venue, the Hotel Captain Cook, is located on land that could be “an extension of Earthquake Park.”

4.4. Top 10 concerns related to seismic resilience of Arctic and Sub-Arctic built infrastructure.

Top 10 concerns with regards to built infrastructure and natural systems under earthquake loads were identified by summarizing the ideas from the group activities on Day 1. During this activity each participant shared their top 3 concerns. The data were tallied and categorized under 10 themes with highest priority and then presented to workshop participants on Day 3 to refine and identify “What is missing?” These priority concerns will inform follow-on activities:

1. Permafrost thawing and soil liquefaction (soil properties)
2. Access to and redundancy in lifeline infrastructure (power, communication, water, sewage, etc.)
3. Cascading effects (tsunamis, landslides, etc.)
4. Transportation infrastructure
5. Ports, harbors, and shipping routes
6. Development in known hazard zones
7. Revised and enforcing zoning and building codes
8. Infrastructure monitoring systems
9. Supply chain
10. Pipelines

During the summary discussions, participants reiterated specific concerns related to these categories important to consider in future research efforts. Regarding lifeline infrastructure (#2), robust sub-maritime infrastructure such as fiber-optic cables that connect communities is crucial for tele communication. If communities lose Internet connections, they “lose all communication with the outside world” during an emergency. Maritime infrastructure involving ports, harbors, and shipping routes (#5) are especially vulnerable in Alaska given that their locations through the Aleutian Island chain coincide with regions of high seismic risk. The risk of shipping routes shutting down following seismic events affects economic resilience throughout Alaska, for example inhibiting the transport of oil to refineries.

Development within known hazard zones (#6) and the enforcement of zoning and building codes (#7) intersects with equity and social marginalization. In Alaska, the state defers to local governments instead of providing an overarching “No” went allowing development within known hazard areas.

Property rights enable the building of homes in hazard zones. Sometimes these are wealthy homes built along coastlines where owners accept the risk knowing they will receive insurance and federal bailout following an emergency. In contrast, less expensive housing built on permafrost zones incentivize lower income communities to live in risk zones, aggravating conditions of poverty and marginalization. This is an example of where infrastructure affected by biophysical vulnerability interests with social systems.

4.5. Top 10 concerns related to seismic resilience of Arctic and Sub-Arctic social systems.

Top 10 concerns with regards to social systems under earthquake events were identified. After the group activities performed by the participants on the first day, the ideas have been summarized to multi-category concerns. During this activity each participant picked their top 3 concerns. The data were tallied and the notes written by the participants were categorized under 10 themes with highest priority. These priority concerns formed the follow-on discussion and activities; and they are listed below:

1. Resource distribution and access (especially of funds)
2. Hazards education, understanding, and prediction (lessons learned from historical events/social memory/place-based connections)
3. Institutional engagement of communities in preparation, response, and recovery
4. Information and resource access inequality
5. Code enforcement challenges (Earthquake response and reopening buildings, rapid-response and inspection of buildings)
6. Multi-hazard access distribution and interconnected environmental stressors
7. Integration of indigenous knowledge
8. Risk perception
9. Food Security

Discussions involving all 10 of these social systems stressed the *capacity of small/local/indigenous communities for disaster preparedness, response, and mitigation.* Local understanding about seismic hazards is important to planning. Consider the history of what community knows or does not know about the hazard (#2). Given colonial resettlement, if people moved or migrated from another area, the local risks are not necessarily known to them. It is important to also recognize the trauma associated with the local knowledge from historical lessons of a given community. While some communities have a deep understanding of local hazards, others fail to grasp the details of seismic risk and recovery, especially the non-structural damages that can require years to recover. Scenarios can help explore the step-by-step details of what could happen in a disaster beyond immediate destruction, including building the knowledge and capacity to access funds both pre and post disaster. And once we understand the details of the problem the solutions often make themselves known. Risk perception (#9) is fundamental to getting people prepared and motivated enough to take action before a disaster. Further, community response is very important on multiple timescales, including opening up buildings in small communities after an event.

It is important to honor the local knowledge and oral history from communities, especially Indigenous groups that have long-term relationships with their local environments (#8). The social memory of past events needs to be respected and not treated as an "add on" to Western science. Tacit information from communities can be brought together with implicit information from the laboratory, ideally developing a shared vocabulary at the interface between engineering and communities. While heterogeneity among Indigenous knowledge systems make seismic resilience unique in each location, multiple groups can speak through one voice in order to promote the interests of sovereign nations.

There are also ethical concerns toward information sharing and public outreach, especially because of mistrust regarding government programs developed from past experiences. It is important to work upstream in building capacity and trust in order to have a more successful downstream relationship. Engaging communities from an early stage when developing a proposal for a project, establishing community members as partners and part of the leadership team, and integrating Indigenous communities into the data collection and implementation of a project can enable knowledge transfer and buy-in.

Alaska is unique in that there have been many significant potentially tsunamigenic earthquakes in recent memory. While agencies have had much success generating awareness all over the state, some people are becoming complacent given that the most recent seismic events have resulted in very little damage compared to the devastation that we know is possible. Many Anchorage residents that weathered the 2018 7.1 earthquake consider themselves prepared for the next earthquake, without considering that infrastructure in Anchorage as a whole was weakened. They also do not realize the difference between intraplate earthquake potential versus megathrust earthquake potential. While landslides and even tsunamigenic landslides are on everyone's mind right now because of several deaths over the past decade, low-probability but devastating events like a megathrust earthquakes and tsunami's exemplified by the 9.2 earthquake of 1964 are just a few too many decades to remain on people's radar.

Seismic disaster preparedness, response, mitigation also extends beyond individual states and nations. What does seismic risk mean for international communities? Who are vulnerable communities across the Arctic? How do perceptions and realities differ across the Arctic? These are some of the questions that need to be addressed.

4.6. Top three concerns related to the seismic resilience of Arctic and Sub-Arctic built infrastructure most impacted by climate change

Using the "top 10" infrastructure concerns listed in section §4.4, each participant picked two that they considered most affected by a changing climate. The data were tallied and the top three were identified. These three concerns were used as themes to drive the final activity of proposing specific and compelling convergent research questions. The following items were chosen as the items playing a crucial role in improving the seismic resilience of Arctic and sub-arctic regions with regards to built infrastructure amid changing climate:

1. Permafrost thawing and soil properties (liquefaction)
2. Redundancy in lifeline infrastructure (power, roadways, communication, etc.)
3. Cascading effects (tsunami, landslide, etc.)

4.7. Top three concerns related to the seismic resilience of Arctic and Sub-Arctic social systems most impacted by climate change

Among the "top 10" social systems concerns listed in section §4.5, each participant once again picked two that they considered most affected by a changing climate. The data were tallied and the top three were identified as themes for the final activity of proposing compelling convergent research questions. The following items were chosen as the items playing a crucial role in improving the seismic resilience of Arctic and sub-arctic regions with regards to social systems amid changing climate:

1. Capacity of small/local/Indigenous communities
2. Resource Distribution
3. Information and resource access inequality

4.8. Drafting strategic questions

During the group activity on the afternoon of Day 2, participants were grouped around different tables in-person and within break-out rooms online. Each group was assigned either an infrastructure or social system from the "top 3" listed in sections §4.6 and §4.7 and were asked to discuss and answer the following questions:

1. What is the built infrastructure/social system assigned to your group?
2. Discuss the current seismic resilience of that system across Arctic and sub-Arctic regions.
3. How will a changing climate affect this system?
4. If this is an infrastructure system, propose a research plan or strategy to integrate it with one or more social systems. If this is a social system, propose a research plan or strategy to integrate it with one or more infrastructure systems.
5. Propose an outreach or engagement activity related to the research plan from the previous question.

The goal was for each group to come up with a convergent research idea or research need. A summary of these ideas is listed below; with more detailed presentation of the notes provided in Appendix D-H.

4.8.a. Effect of permafrost thaw and soil liquefaction (soil properties) on seismic resilience of built infrastructure and social systems.

Properly engineered systems within the zone of continuous permafrost regions (Arctic) currently are resilient to seismic loads. At the same time, the zone of discontinuous permafrost (Subarctic) has a reduced level of resilience and increases the probability of the liquefaction and other mechanisms of soil instability during seismic events. Warming climate will decrease the seismic resilience of any built infrastructure due to changes of elastic and mechanical properties of frozen soil reaching the temperature range of phase transition of soil water/ice. In order to fully understand how these changes to permafrost will affect Arctic livelihoods and infrastructure, it will be crucial to interact with local residents and stakeholders and conduct a social vulnerability analysis that integrates local knowledge and identifies concerns. For example, seismic-induced damage to lands with discontinuous permafrost will make it more difficult for caribou migration and hunting, disrupting the food security of some Indigenous Alaskan communities. The research idea establishes a collaboration among scientists, engineering, local stakeholders, and communities to better understand how climate change will affect the water balance in soils, what this changing water balance means to liquefaction and other soil mechanics during seismic events, and how humans and societal activities will be affected by these changes.

4.8.b. Cascading effects of earthquake on built infrastructure and natural systems

Landslides and tsunamis are emphasized in this convergent research question. Landslides can be, and are frequently, triggered by earthquakes or other causes. Arctic nations deal with this hazard as it relates to earthquake response. However, there is little to no meaningful monitoring of precursory and in-progress landslides. Tsunamis are mainly triggered by subduction zone earthquakes and the submarine landslides are considered a major threat to Arctic infrastructure; for example, during the M9.2 earthquake in Alaska in 1964. Climate change can increase the frequency of landslides due to thawing permafrost in fjord walls and natural slopes as well as through the projected increase in precipitation intensity and river flow. It is important to understand how combinations of climate induced drivers and earthquakes will impact on frequency and magnitude of landslides and to identify the most vulnerable areas. Weather events such as rainfall events can continually open a wound from an earthquake.

Although tsunamis driven by coastal landslides are expected to increase, ‘normal’ tectonic earthquakes should be relatively not affected by climate change. However, the consequence of such tectonic landslides and tsunamis may be significant for communities impacted by climate change. To integrate the effects of tsunamis in particular on social systems, new and improved communication pathways are needed to deliver timely and critical information to communities, including providing warning systems through redundant pathways. Education campaigns play an important role in this work, teaching communities about the growing risks from these hazards as a result of climate change and practicing how to respond when they receive a warning. School programs, working with community leaders, and user-friendly accessible materials are essential to the success of such educational campaigns. Engaging communities early in the process is essential to to understand the communities’ priorities and concerns as well as obtain historical local knowledge from past events and understand the local knowledge of architecture and landscape change. This research question also provides an opportunity to enhance the ongoing work of agencies and institutions to bring in more convergent collaborations, for example within the United States organizations such as the Alaska Division of Homeland Security and Emergency Management and Alaska Earthquake Center already have synergistic programs related to this theme.

4.8.c. The significance of redundancy in lifeline infrastructure (power, communication, etc.) under the conditions of climate changes.

Well-developed oil infrastructure already has significant redundancy, given their economic value, but other critical infrastructure often has little to no redundancy challenging recovery following a seismic event. Following the 1964 earthquake in Alaska, the closure of the Eagle River Bridge and Seward Highway made it difficult to get people and goods to Anchorage. Infrastructure resilience investments are not always focused on risk and consequences of failure but rather on economic value. For example, in the Alaskan North Slope, consortiums of oil companies own and operate entire towns (Deadhorse/Prudhoe Bay) and invest heavily in their lifeline infrastructure with substantial redundancy. This investment is not seen in other Alaskan communities.

In addition, many communities have an influx of seasonal workers or tourists but are not able to support this influx of people during a disaster. While residents may have the information and capacity to respond during disasters, visitors will likely not know what to do during a hazard to remain safe. Even if there is redundancy within lifeline infrastructure in these communities, it does not always address the seasonal influx of populations. For example, communities need to be prepared to absorb tourists left on shore by cruise ships during a disaster. Rural communities first need to have a conversation about current infrastructure, followed by conversations about redundancy and risk perception. Risk perception is subjective, often differing among the public and policymakers. Studies of the cost and benefits of building redundancy will enable comparison with alternative options. However, change will only be possible when people recognize the gravity of what could potentially happen (as in the 1964 Alaskan earthquake). This convergent research idea is using a multidisciplinary approach to develop an assessment procedure that will help local authorities improve the risk perception and plans to retrofit infrastructure while considering the importance of redundancy.

4.8.d. The effects of small, local, and indigenous community capacity on seismic resilience of arctic systems

Small, local, and Indigenous communities have strong social networks, social memory, and relationships that make them resilient to environmental shocks. Traditional response and recovery programs may have not been necessarily designed for small communities and their seismic vulnerabilities, so fewer resources are allocated to these groups. Providing resources for communities to be active agents in their futures is critical when developing of redundancy of lifeline infrastructure, transportation infrastructure, supplies, and information. By relying mostly on local knowledge and existing relationships and cultures, communities can embrace the ingenuity that often arises in most difficult circumstances while avoiding replicated past systems of inequality. The place-based connections, ancestral connections, and reciprocal relationships with the land bring intangible aspects of resilience beyond the traditional redundancy of lifeline infrastructure. Climate change and global warming, however, can make traditional approaches in ways of living difficult and may challenge existing community capacity to prepare and respond to seismic direct and cascading effects. This convergent research topic proposes to engage communities in developing areas of concern, communicating with people from different age brackets, asking communities about their need, perception of resiliency, and vulnerabilities, and integrating communities into research. Engaging students in this process is as particularly effective, as children are likely to pass on knowledge to their parents.

4.8.e. Effects of resources distribution on seismic resilience of arctic systems

Three major social issues were identified as affecting resource distribution including inhibition of resources, public health resources, and access hurdles. These social issues relate to several infrastructure and natural systems either through resources and goods or accessibility. Some examples include disaster assistance and community services, transportation infrastructure, ground subsidence, road failures, river movements, infrastructure redundancy, telecommunications, and ports. Economic incentives can be provided to build community capacity and private investment, for example public health resources that allow doctors to practice in rural areas to forgive student debt. Climate change effects can vary among resources; thus, adaptation strategies, community input, and feasibility of engineering problems must be considered accordingly. For example, identifying areas of increased avalanche risk might enable communities to better prepare for avalanches that block access to communities for weeks of months. It is also important to take into consideration resource distributions over time, both throughout history and into the short-term and long-term future. This convergence research project focuses on outreach activities to enhance resource distribution including participatory mapping and vision building activities, improving community capacity, increasing self-sufficiency within the communities, providing incentives for investments, and developing support systems for existing capacities.

4.8.f. Effect of inequality in access to information and resources on seismic resilience of arctic systems

Low population density and unevenness of urbanization along with limited transportation infrastructure in the Arctic creates problems with access to crucial information related to seismic events (earthquakes and tsunamis), public safety and education as well as general resources such as fuel, energy, food etc. Climatic impacts might aggravate these issues and increase inequalities. The proposed convergent research project posed aims at promoting redundancy of communication systems and reinforcement of supply lines. Developing regional infrastructure inventories and generating Indigenous and local communities' long-term and short-term needs are crucial in enhancing resource access equality. There are also great opportunities in citizen science for integrating residents in knowledge transfer and data collection.

5. Acknowledgements:

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Appendix A. Participant Names and Affiliations

#	Name	Position	Affiliation
1	Elham Ajorlou	Visiting Researcher	California State University - LA
2	Michael Baker	Seismologist	Sandia National Laboratories
3	Sam Bass	Member	Alaska Seismic Hazards Safety Commission (ASHSC)
4	James Benzschawel	Planning Specialist, Community Resilience	Alaska Division of Homeland Security and Emergency Management
5	Dennis Berry	President	BBFM Engineers, Inc.
6	Kevin Bjella	Research Civil Engineer	Cold Regions Research and Engineering Laboratory - USACE
7	Jennifer Brewer	Associate Professor	University of New Hampshire
8	Guangqing Chi	Professor of Rural Sociology and Demography	Pennsylvania State University
9	Trine Dahl-Jensen	Senior researcher	Geological Survey of Denmark and Greenland
10	Michelle Davis	Tribal Coordinator	EPA Region 10 - Alaska Department Office
11	Robert Doehl	Building Official	Municipality of Anchorage
12	Katharine Duderstadt	Research Scientist	University of New Hampshire
13	Yashar Eftekhar Azam	Assistant Professor	University of New Hampshire
14	Jessica Feenstra	Project Geologist/Geophysicist	Golder Associates
15	Thomas Fenoseff	Senior Director, Capital Planning & Construction	Anchorage School District
16	Lea Gardine	seismologist, Cartographer, Outreach	Alaska Earthquake Center

#	Name	Position	Affiliation
17	Majid Ghayoomi	Associate Professor	University of New Hampshire
18	Beth Grassi	Science Communications Specialist	Alaska Earthquake Center
19	Peter Haeussler	Research Geologist	U.S. Geological Survey
20	William Homka	Planning Director	City of Unalaska
21	Victoria Hykes Steere	Alaska Native Governance Program Director	Alaska Pacific University - Native Village of Unalakleet
22	Matthew Jull	Associate Professor	Arctic Design Group / School of Architecture/ University of Virginia
23	Wilson Justin	Representative	ANCSA Corporation
24	Alexander Kholodov	Research Assistant Professor	University of Alaska
25	Rich Koehler	Associate Professor	Nevada Bureau of Mines and Geology, University of Nevada Reno
26	Colin Maynard	Principal	BBFM Engineers Inc.
27	Heather McFarlin	Data Specialist	Alaska Earthquake Center
28	Qing Miao	Assistant Professor in Public Policy	Rochester Institute of Technology
29	Elise Miller-Hooks	Professor and Bill & Eleanor Hazel Endowed Chair	George Mason University
30	Ramin Motamed	Associate Professor	University of Nevada Reno
31	Nicholas Murray	Bridge Engineer	Alaska Department of Transportation
32	Masamitsu Onishi	Associate Professor	Kyoto University
33	Shahriar Quayyum	Assistant Professor	Manhattan College
34	Michelle Ritchie	Assistant Professor	Institute for Disaster Management, University of Georgia

#	Name	Position	Affiliation
35	Verónica Rodríguez Tribaldos	Research Scientist	Lawrence Berkeley National Laboratory
36	Barrett Salisbury	Earthquake Geologist	Alaska Division of Geological & Geophysical Surveys, ASHSC
37	Siamak Sattar	Research Structural Engineer	National Institute of Standards and Technology (NIST)
38	Alexander Shiklomanov	Research Assistant Professor	University of New Hampshire
39	Amanda Siok	Earthquake Program Manager	FEMA Region 10
40	Jeremy Spoon	Professor of Anthropology	Portland State University
41	Logan Stolpe	Emergency Management Specialist	Alaska Division of Homeland Security and Emergency Management
42	Sterling Strait	Earthquake Engineer	Alyeska Pipeline Service Company
43	John Thornley	Geotechnical Engineer	Golder Associates Inc.
44	Sólveig Thorvaldsdóttir	Free Lance	Rainrace consultancy, University of Iceland, Árnessýsla Fire Department
45	Matthew Turner	PhD Candidate	University of New Hampshire
46	Karli Tyance Hassell	Indigenous Engagement Coordinator	Alaska Pacific University
47	Ryosuke Uzuoka	Professor	Kyoto University
48	Kaylan Wade	Transportation Assistant Director	Chickaloon Native Village
49	Michael West	Research Professor, State Seismologist	Alaska Earthquake Center, University of Alaska Fairbanks
50	Brian Winnestaffer	Transportation Director	Chickaloon Native Village
51	Zhaohui Joey Yang	Professor	University of Alaska Anchorage

Appendix B. Workshop Agenda

1ST INTERNATIONAL WORKSHOP ON SEISMIC RESILIENCE OF ARCTIC INFRASTRUCTURE AND SOCIAL SYSTEMS

Monday September 20, 2021

(all times in AKDT)

0730 Breakfast and Check-in

0830 Welcome, Background, and Logistics (**Majid Ghayoomi**)

0845 Workshop scope and goals (**Katharine Duderstadt**)

0900 Day 1 Opening Speaker (**Bryan Fisher**–Director of the State Office of Emergency Management)

0915 Participant introductions

0945 Plenary Presentation: State of Alaska's Seismic Practice and Vision

- 0945 An Overview of the Earthquake Hazards in Alaska (**Peter Haeussler**)
- 1000 Perspectives on Seismic Resilience in Alaska (**Michael West**)

1015 Morning *Break*

1035 Plenary Presentation: Lessons Learned from Past Earthquakes

- 1035 Lessons Learned from 2018 Anchorage Earthquake (**Sterling Strait**)
- 1050 Rapid Earthquake Reconnaissance: Helping to Better Understand the Distribution of Hazards and Improving Resiliency (**Rich D. Koehler**)
- 1105 Liquefaction-Induced Large Ground Deformations in Port Facilities and Lessons Learned from the 1964 Alaska Earthquake (**Ramin Motamed**)
- 1120 Anchorage School District Earthquake Recovery and Lessons Learned (**Thomas Fenoseff**)

1135 Group Activity – Session 1

- 1135 Introduction/Survey
- 1145 Write the room with your priorities – Preliminary Round (*Identify your top three concerns as they relate to seismic resilience of Arctic and Sub-Arctic built infrastructure.)*

1200 *Lunch*

1300 Plenary Presentation: Community Resilience and Disaster Management- State of Practice

- 1300 State Emergency Management Resources for Seismic Resilience (**James Benzschawel**)
- 1315 Disaster-Related Management Systems. Example: Earthquake Repair and Reconstruction Timeline Modelling (**Sólveig Thorvaldsdóttir**)
- 1330 Functional Recovery of the Built Environment (**Siamak Sattar**)

1345 Plenary Presentation: Community Resilience and Disaster Management- Indigenous Communities

- 1345 Contextualizing Indigenous and Rural Disaster Recoveries: Lessons Learned from Nepal (**Jeremy Spoon**)

1400 Group Activity – Session 2

- 1400 Day 1 – Survey
- 1410 Write the room with your priorities – Preliminary Round (*Identify your top three concerns as they relate to seismic resilience of Arctic and Sub-Arctic social systems.)*

1425 Break

1445 Plenary Presentation: Earthquakes and Infrastructure Response

- 1445 Frozen Soil Impact on the Bridge Foundations during Seismic Events (**Zhaohui Joey Yang**)
- 1500 Influence of Welding on the Seismic Performance of Moment Resisting Connections (**Shahriar Quayyum**)
- 1515 Seepage and Deformation of Unsaturated Slopes during Post-Shaking Rainfall (**Ryosuke Uzuoka**)

1545 Day 1 Wrap up

1600 Adjourn

Tuesday September 21, 2021

(all times in AKDT)

0730 Breakfast

0830 Regroup and Announcement (**Majid Ghayoomi**)

0845 Political Ecology (**Jennifer Brewer**)

0900 UNH Survey Data (**Matthew Turner**)

0915 Plenary Presentation: Arctic Seismicity

- 0915 A Review of Northern Alaska Seismicity (**Heather McFarlin)**
- 0930 Seismicity and Landslide Hazards in Greenland (**Trine Dahl-Jensen**)

0945 Plenary Presentation: Climate Change Adaptation (1)

0945 Social-Ecological Influences on Household Adaptation Response to Climate Change Risks (**Michelle Ritchie**)

1000 Risks of Natural Hazards and Climate Change in Alaska and Adaptation Response (**Qing Miao**)

1015 Morning *Break*

1035 Plenary Presentation: Effects of Permafrost Thawing and Climate impacts on Soils and Seismic Response

1035 Permafrost in Alaska: Current State and Future Fate (**Alex Kholodov**)

1050 Permafrost Engineering and Climate Change (**Kevin Bjella**)

1105 Increases in Liquefaction Susceptibility Due to Thawing Permafrost: The Challenges with Characterization of the Hazard (**John Thornley**)

1120 Projected Climate Impacts on Permafrost Soils (**Jessica Feenstra**)

1135 Group Activity – Session 3

1135 Day 2 - Survey

1145 Write the room with your priorities (*Identify your top three concerns as they relate to seismic resilience of Arctic and Sub-Arctic built infrastructure and social systems - among the list compiled from Monday- that will be mostly impacted by climate change.)*

1200 *Lunch*

1300 Plenary Presentation: Climate Change Adaptation (2)

1300 Adaptation, Mitigation, and Resiliency strategies (**Wilson Justin, Victoria Hykes Steere, Michelle Davis**)

1315 The Design of the Built Environment in the Extreme and Changing Arctic (**Matthew Jull**)

1330 Plenary Presentation: Infrastructure Resilience

1330 POLARIS: Pursuing Opportunities for Long-term Arctic Resilience for Infrastructure and Society (**Guangqing Chi**)

1345 Concepts of Resilience and their Application for the Arctic (**Elise Miller-Hooks**)

1400 Infrastructure Resilience Framework and its Application to Seismic Resilience (**Masamitsu Onishi**)

1415 Break

1435 Plenary Presentation: Sensing, Monitoring, and Climatic Impacts

1435 Landslides and catastrophic lake drainage in cold regions under the climate change (**Alex Shiklomanov**)

1450 Distributed acoustic sensing of seasonally variable environmental processes in the Beaufort Sea, Alaska (**Michael Baker**)

1505 Using Distributed Acoustic Sensing (DAS) for subsurface imaging and process monitoring (**Verónica Rodríguez Tribaldos**)

1520 Group Activity – Session 4

1520 Topic Tables – Draft strategic questions

Task: Each table will write a 1-page description of a specific and compelling convergent research question on the top three climate-impacted priority topics identified under both infrastructure resilience and social systems; although it might include multiple task items.

1620 Day 2 Wrap up

1630 Adjourn

Wednesday September 22, 2021

(all times in AKDT)

0730 Breakfast

0830 Regroup and Announcement (**Majid Ghayoomi**)

0900 Group Activity – Session 5

0945 Workshop outcome draft reading and comments by the attendees

1015 Morning *Break*

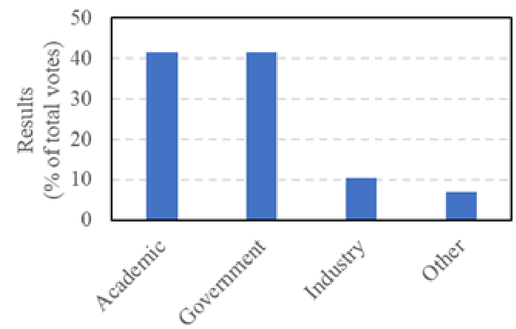
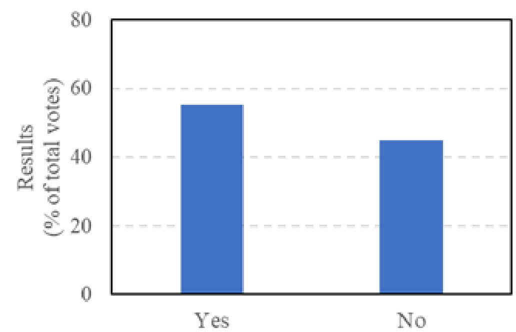
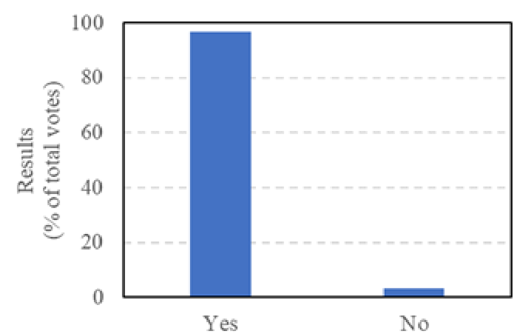
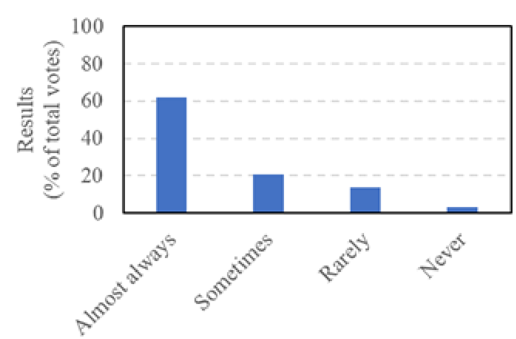
1045 Group Activity – Session 6

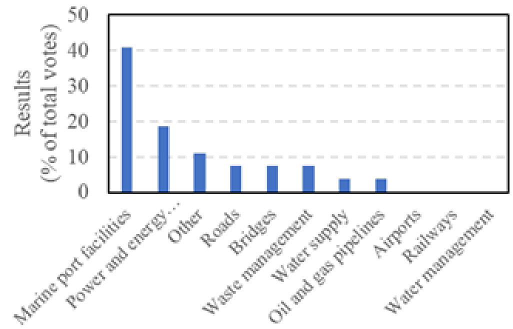
1045 Workshop outcome draft review and finalize

1145 Final Remarks and Good bye (**Majid Ghayoomi**)

1200 *Lunch*

Appendix C. Quantitative survey outcome

Question	Results
How would you describe your primary job type?	
Are you a resident of an Arctic or sub-Arctic community?	
Have you ever felt an earthquake?	
How often does your work involve familiarity or concern with seismic resilience including earthquake impacts on built infrastructure, soil liquefaction, mass movement of soil, rock, or ice, tsunamis, and other earthquake-induced hazards?	

<table>
<tr>
<td>Considering the current capacities for seismic resilience, please indicate the top two Arctic and sub-Arctic infrastructure systems, from the following list, which require the most improvement.</td>
<td>
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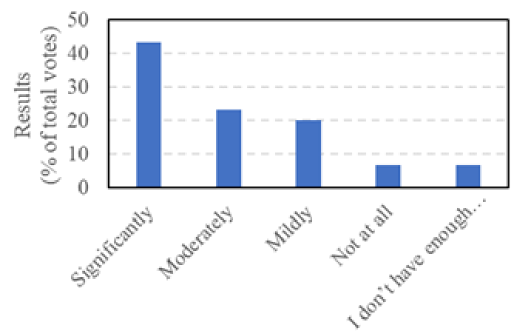
<tr>
<td>Considering the uncertainty, complexity, and high cost of seismic early warning systems, to what extent do you believe they would impact Arctic and sub-Arctic seismic resilience?</td>
<td>
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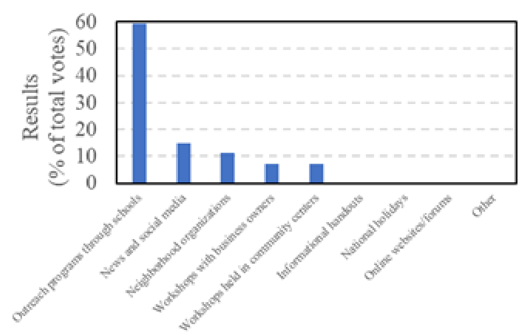
<tr>
<td>From the following list, which method do you think is the most effective way to educate a community about seismic resilience.</td>
<td>
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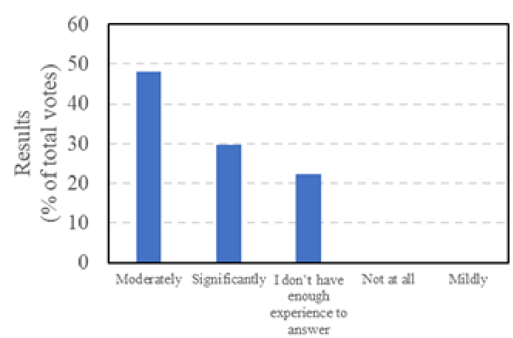
<tr>
<td>To what extent do you think Arctic and sub-Arctic communities need to improve the system cooperation and responsiveness during the post-event phase of a seismic event?</td>
<td>
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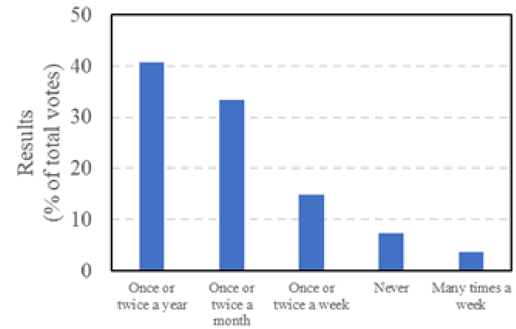
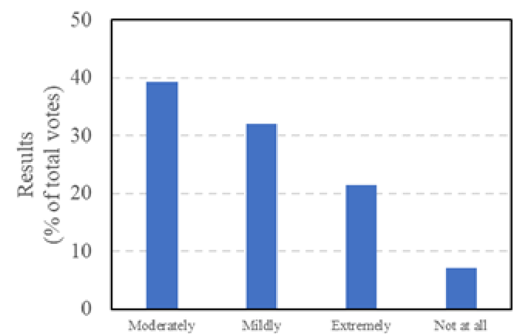
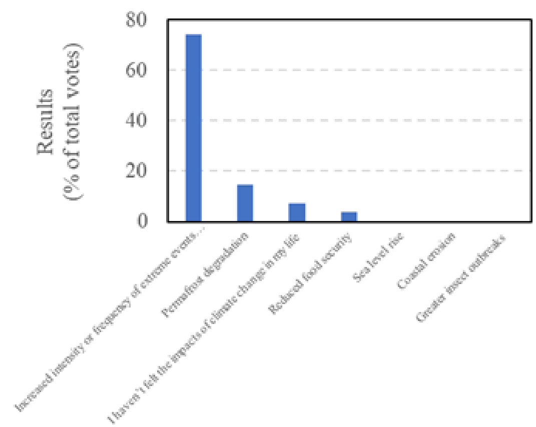
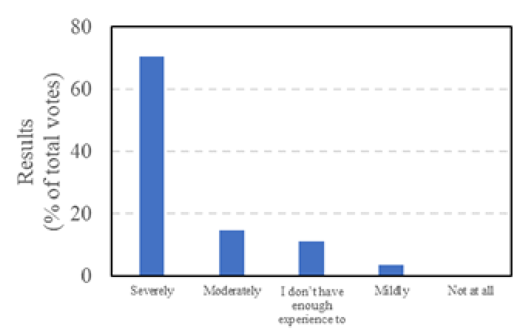
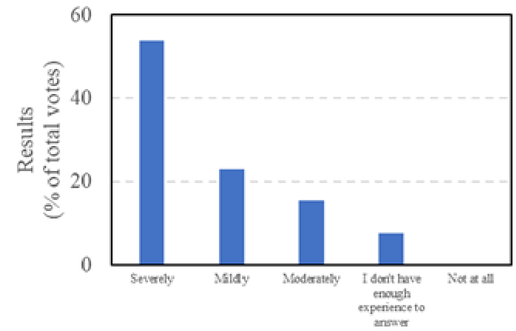
How often do you talk with your family, friends, or close communities, who are not familiar with seismic resilience, in order to let them know how to be prepared and react to a disruptive seismic event? For example: less vulnerable and more resilient.	
How familiar are you with organizations and resources that relate to emergency management and response in Arctic and sub-Arctic regions?	
Considering the following climate change-induced impacts and events, which one has affected your life the most?	
To what extent will a changing climate impact the seismic resilience of Arctic and sub-Arctic built infrastructure?	

<table>
<tr>
<td>To what extent will a changing climate impact the seismic resilience of Arctic and sub-Arctic social systems?</td>
<td>
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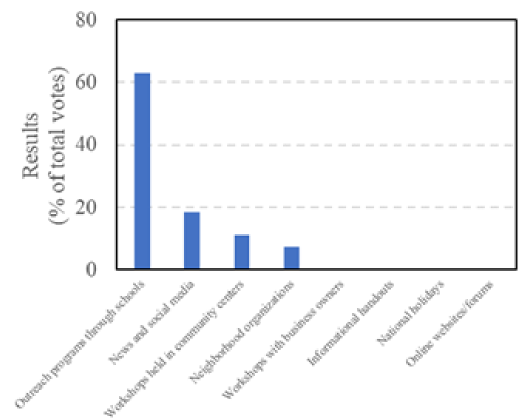
<tr>
<td>From the following list, which method do you think is the most effective way to educate a community about climate change?</td>
<td>
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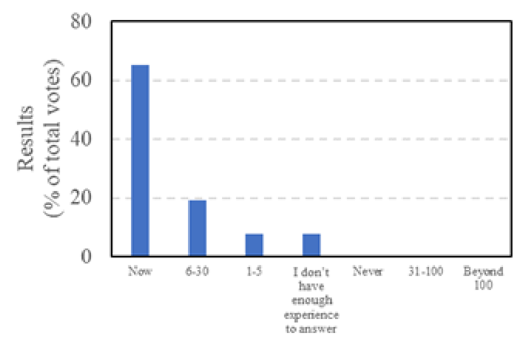
<tr>
<td>Within how many years will climate change impact the seismic resilience of Arctic and sub-Arctic built infrastructure and social systems?</td>
<td>
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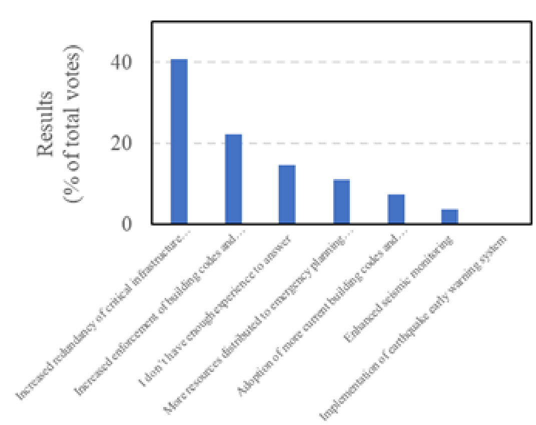
<tr>
<td>Which climate change-induced seismic resilience measure is most critical for climate change adaptation of Arctic and sub-Arctic communities?</td>
<td>
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Appendix D. Participant concerns as they relate to seismic resilience of Arctic and Sub-Arctic built infrastructure

Priority 1

- Food security (food security)
- Limited capacity in rural human resources: leaders wear many hats, limited time; transient
- Increasing soil liquefaction on climate change (soil properties – permafrost thawing and soil liquefaction)
- Vulnerability of the object of power/energy systems and oils and gas pipelines (pipelines) (power infrastructure)
- Buildings/building codes (building codes)
- Ports and road rails (ports) (transportation))
- Because Alaska's population is small the state is sometimes overlooked in the national level (underrepresented nationally)
- Building on thawing permafrost (soil properties – permafrost thawing and soil liquefaction)
- Development in known hazard zones like Tsunami inundation; landslide failure; active faults (Development in known hazard zones
- Resiliency of supply change/transportation facilities (transportation))
- Food and essential goods infrastructures, currently no backup on secondary infrastructure (food security) transportation)) (supply chain)
- Lack of redundancy for lifelines; too many single points of failure (redundancy in lifeline infrastructure)
- Transportation infrastructure transportation))
- Timely adoption and enforcement of building codes building codes)
- Realize a critical aspect of infrastructure to small rural communities. If a part is damaged it could lead to a collapse of small town forever.
- Uncontrolled growth Alaska already has development in hazard areas. Will we allow the build environment to continue like it was in places where fires, flooding, mudslides, hurricane happen? Government ballots for FEMA are not sustainable. Development in known hazard zones
- Develop liquification susceptibility maps soil properties – permafrost thawing and soil liquefaction)
- Current condition of the port of Alaska (port)
- Redundancy and resiliency of lifeline infrastructure (Redundancy and resiliency of lifeline infrastructure
- Port facilities and liquefaction effects (port)
- Building code inspections (building codes)
- The potential growth of exposure. (Development in known hazard zones
- Improved monitoring and research, including collaboration on and availability of this data (need for monitoring systems)
- The future of structures that were built in permafrost assuming that permafrost would always be there. soil properties – permafrost thawing and soil liquefaction
- Thinking holistically in terms of the built and natural environment Development in known hazard zones
- The future of structures that were built in permafrost assuming that permafrost would always be there.
- How Indigenous knowledge and traditions related to the built environment are integrated into disaster relief and recovery planning.
- Prioritizing indigenous knowledge/input in future resilience strategies.
- The connection between seismic hazards and related cascading hazards, such as landslides and tsunamis. Cascading effects
- Integrating Social and Cultural priorities into the design of the built environment

- Building on thawing permafrost soil properties – permafrost thawing and soil liquefaction
- Avoiding "solving problems" by focusing only on engineering concerns.

Priority 2

- Seismic resilience for ports (Port)
- Alaska Building codes (building codes)
- Identifying and mitigating nonstructural hazards in schools (nonstructural components) (Sensitive structures)
- Communications infrastructure
- Promote better avenues for seismic hazard information to be integrated into policy
- Pipelines
- Building at high elevation in areas prone to Tsunami treats (and how the rise or drop in sea level changes the regions that are vulnerable) Cascading effects
- Organizing response for rapid visual inspection after major earthquakes (damage assessment)
- Community response and preparedness (need for monitoring systems)
- Mitigation strategies for seismic resiliency at port facilities (ports)
- Vulnerable power grid or telecom structures Communications infrastructure
- Banks are defector enforces of building codes
- Lack of building codes and enforcement building codes)
- Combination of wetter arctic and earthquakes may lead to more catastrophic landslides Cascading effects
- Encouragement of individuals to prepare themselves/families for seismic events
- State/federal assistance to small rural towns to help with hazard mitigation planning for infrastructure
- The consequences of secondary effect from earthquake can be huge. Consider for example the impact of a power outage at -20c Cascading effects
- Under representation of the seismic hazards in the regulations of building constructions building codes)
- What are sewer management is missing in half of Alaska communities. How do we develop this risk then with severe seismic activities
- Electrical and redundancy (power infrastructure)
- Improve behavior of nonstructural elements to earthquakes to improve resiliency (nonstructural components)
- The lack of construction (and design?) monitoring (monitoring)
- Improved risk communication, including modeling for public awareness and for community input
- Climate change resulting in wetter storms causing more landslides in previously stable areas Cascading effects
- Avoiding "one size fits all" solutions
- The connection between seismic hazards and related cascading hazards, such as landslides and tsunamis. Cascading effects
- Identifying what elevations to build. (What areas are prone to tsunami?) Cascading effects

Priority 3

- Seismic resiliency for roads and railroads (transportation)
- Construction of individual building needs better control in terms of sustainability to earthquake (building codes)
- What is the plan to address the growing movement of nonscience believers; it won't happen
- Combination between different levels of government in planning earthquake response
- Working relationship od fed/state/local/NGO enhancement

- Fragility of power/road/ marine infrastructure (transportation) (ports)
- Alaska and the arctic in general have issues that fall outside the scope of many national programs (underrepresented nationally)
- Hazard management program requirement for NIST money (underrepresented nationally)
- Inability for small rural towns to receive help from outside sources in a timely manner to rebuild infrastructure (supply chain)
- Building code enforcement of ‘’home facts’’ transparent (building codes)
- Aging public school buildings (sensitive infrastructure)
- Use of earthquake instrumentation to monitor port facilities during shakings (monitoring system)
- Lack of understanding of consequences of seismic events under the changing climate Cascading effects
- Seismic resilient construction to retrofit (damage assessment)
- Communications, cell, internet, radio (communication infrastructure)
- Bridges (transportation)
- Fuel and chemical storage and potential for environmental pollution air and water following an seismic event Cascading effects
- Lifeline infrastructure preparedness due to climate change (lifelines)
- Continued funding for research of seismic sources (monitoring systems)
- Government resources for preparing and responding to earthquake
- The increased risk during the freezing and thawing period. (soil properties – permafrost thawing and soil liquefaction)
- Fuel and Chemical storage and air/water pollution from seismic event Cascading effects
- The relationships between the built environment and social/spatial inequalities.
- Fresh water supply quality monitoring, storage and distribution, moving sources (lakes/glacial outflow no longer viable), and consumption Cascading effects

Appendix E. Participant concerns as they relate to seismic resilience of Arctic and Sub-Arctic social systems

Priority 1

- Small villages / leaders wear many hats with limited bandwidth
- Problems with remote access to information resources for isolated rural communities
- Adequate resources for response and recovery
- The ability of small, local/rural governments' ability to utilize outside aide
- Mis/dis-information on social media
- Enforcers of seismic codes need to not have an economic stake in the game, I.e., Alaska building inspectors are hired by real-estate agents prior to the sale. If the agent did not get the answer they want, the inspector is not used.
- Food security post disaster
- Improve notification of local/Indigenous communities about geohazards to improve their resilience
- Rapid spread of misinformation
- How to make inspection and repair assistance accessible and understandable for rural communities
- Information to understanding divide
- Balance between regulation and individualism
- It can be difficult to dispel existing but incorrect knowledge at the community level
- Inability to communicate the hazards and risks to community
- #1 concern is the demand for public resources as a result of poor planning or growth of private sector without regard for potential disasters
- How serious do people WANT to be prepared for earthquakes?
- The lack of awareness of Indigenous relationships with the land and previous experience with hazards
- Indigenous perspectives, including how science/gov can decolonize their disaster practices
- Risk perception and solutions / public awareness
- Understanding the feedback structure in the FEMA programs. 2 Understanding systems for identifying lessons from experience and implementing change. 3. Understanding how functional functional recovery is addressed.

Priority 2

- Loss of cultural significance
- Community impact when schools are closed
- Communication-people don't conceptualize how seismic hazards with influence them
- Communications infrastructure – phone and internet down – no good way to get/receive/send info
- Supply chain planning
- That another seismic event will occur prior to developing faster, accurate prediction models
- Emergency housing post disaster
- The ability of healthcare / first-responders ability to respond given the current climate of COVID burnout
- Challenges can arise when societal best practice conflicts with tradition use. Not all traditional approaches are necessarily good.
- Impacts of resilience and rural communities with few resources
- How to help communities understand how to assess which members are most vulnerable and how to assist them prepare
- Over confidence in resilience w/o enough understanding. "It was just an earthquake."
- Supply chain

- Resources from governments from federal to state and local levels
- Recovery indicators only include the built environment
- The disproportionate and "out of sight" climate impacts on Arctic peoples - science communication

Priority 3

- Short memory – forgetting what has happened and that it can happen again.
- Displacement following a large seismic event leading to loss of placed based connection.
- Outreach activities in schools not reaching adults. Parents not believing / listening to what kids have learned.
- Access to resources blocked by damage
- Too few people to carry the message. Hard to penetrate some communities
- Framework of response between urban and rural communities
- Earthquake recovery planning
- How to work with tribal organizations to increase preparedness resources
- Power infrastructure
- Resources
- How to ship resources (food and other stuff) during the recovery stage before the transportation infrastructure is restored.
- Issues with Indigenous communities accessing funds
- Support for ethical and long-term involvement of communities in research as collaborators not participants

Appendix F. Strategic Convergent Research Questions

a. Effect of permafrost thaw and soil liquefaction (soil properties) on seismic resilience of built infrastructure and social systems.

1) Assigned Topic: Permafrost Thawing and Soil Liquefaction (Soil Properties)

2) Current seismic resilience: This will depend on the type of permafrost being considered. With a properly engineered system, continuous permafrost regions (Arctic) are highly resilient to seismic loads. Discontinuous permafrost regions (sub-arctic) have a reduced level of resilience as the soil strength is lower and the likelihood of liquefaction is increased.

3) How impacted by Climate? Warming climate is seeing continuous permafrost regions transition to discontinuous, and discontinuous regions becoming ice-free. This decreases the seismic resilience of any built infrastructure installed on a permafrost region.

4) Research plan or strategy to tie to social system
    a. Propose changes to the building code that addresses potential impacts of thawing permafrost
    b. Engage with Arctic stakeholders to identify what their current risk perception with regard to thawing permafrost
    c. Map areas of liquefaction vs the distribution of lifeline infrastructure (ie. Power, oil, roads, bridges)
        i. Evaluate the fragility and vulnerability of existing infrastructure
    d. Conduct water balance studies to evaluate how the changes to permafrost may impact liquefaction hazards

5) Proposed outreach or engagement activity
    a. Public & stakeholder meetings to explain strategy, how it will impact their lives, gather their input, present results
        i. Stakeholders to include industry (Oil & Gas), military, utilities, DOT, local governments, engineers, contractors, and builders
    b. Present results to professional organizations:
        i. Engineers (American Society of Civil Engineers, Structural Engineers Association of Alaska)
        ii. Contractors (Association of General Contractors, Alaska Homebuilders)
    c. Engage local and indigenous communities to assist in collecting data

b. Cascading effects of earthquake on built infrastructure and natural systems

1. What is the built infrastructure/social system assigned to your group?
Cascading effects.

2. Discuss the current seismic resilience across the Arctic
There are numerous cascading impacts in the natural environment. We chose here to focus on one well-identified cascading effect that has recently been recognized to have a clear climate connection.

- **Landslides**: It is well-established that landslides can be, and frequently are, triggered by earthquakes. Landslides also occur spontaneously without an earthquake trigger. But the monitoring of landslides is relatively independent from earthquakes. Landslides are monitored on three different time scales: long-term (years), precursory (hours to months), and in-progress crisis (seconds). Greenland, the US, and other Arctic nations have some ad hoc approaches to identifying long-term landslide hazards that might be seismically triggered. There is little to no meaningful monitoring of precursory and in-progress landslides with the possible exception of Norway where they have established science teams, instrumentation, and communications lines.
- **Tsunamis** (from different types of sources) can impact most Arctic nations. In the US, the main tsunami threat is from subduction zone earthquakes and the submarine landslides they trigger. It is worth noting the triple cascade of events here (earthquake -> submarine landslide -> tsunami). This mechanism was the primary cause of casualties during the M9.2 earthquake in Alaska in 1964. The US has a tsunami warning system operated by the NOAA National Weather Service. However, this system is entirely premised on tectonic earthquakes. The system has few provisions to account for submarine landslide-drive tsunamis.

3. How will changing climate affect this system?

- Current science suggests (but is perhaps not yet conclusive) that coastal landslide activity will increase as the climate warms. The reasons for this are that (1) thawing permafrost has been shown to loosen the unconsolidated materials in fjord walls and (2) glaciers that once buttressed fjord walls have retreated leaving the wall unstable.
- Tsunamis driven by coastal landslides are expected to increase (see paragraph above). ‘Normal’ tectonic earthquakes should be relatively unimpacted by climate change. It is possible that tectonics tsunamis could be more impactful in the communities themselves were destabilized by climate change.

continued…)

4. Propose a research plan to integrate this with one or more social systems

1. For the purposes of this exercise, we are going to focus solely on the emerging threat of tsunamis caused by landslides (which can be triggered by earthquakes)

   Inventory questionable coastal slopes and fjord walls from remote sensing.

   DEM differencing over years; LiDAR; and aerial photography; …
2. *Conduct field investigation to identify greatest hazards*
3. *Create geophysical monitoring systems to identify precursors and in-progress slopes failures*

   Geodetic; seismic; laser-ranging; tide guages;

   considerable software development and testing will be needed to make this work

   This needs to be fully automatic. There is little room for humans in the process
4. *Build communication pathways to push critical information to coastal communities*

   aka, build a warning system. This is a <u>massive</u> task. It involves some combination of redundant pathways including radio, internet, cellphone, etc.

5. Propose an outreach or engagement activity

- In order for this research plan to be useful at all, it must be combined with a major education and outreach campaign. This campaign should teach people (1) about the growing risks from this hazard as a function of climate change and (2) how to respond when they receive a warning.
- This campaign can include low-hanging fruit like radio and internet ads. However, the more impactful efforts will be conducted in-community. Engaging communities early in the process is essential to learn about past relevant events in the community (past landslides and tsunamis that may only be recorded in oral traditions, for example). These meetings are also valuable for understanding the communities' priorities and concerns. School programs over the course of years are essential to getting information into families. Work with community leaders is critical but more straightforward. To be successful, user-friendly accessible materials are needed in order to translate the science into actions by the public.

c. The significance of redundancy in lifeline infrastructure (power, communication, etc.) under the conditions of climate changes.

1. What is the built infrastructure/social system assigned to your group?
    - Redundancy in lifeline infrastructure (power, communication, etc.)
2. Discuss the current seismic resilience of that system across Arctic and sub-Arctic regions.
    - Well-developed oil infrastructure, probably with a lot of redundancy, given the economic value of the resources there.
    - In other areas of Arctic Alaska, there is little to no redundancy.
    - These areas may respond differently and recover differently from a seismic event.
    - Infrastructure resilience investments may not be focused on the component's or system's risk of failure, but rather on its economic value.
    - Minimally built, minimally connected, little to no redundancies, and possible lack of access to needed elements/resources/materials/products required for bouncing back/repairing/restoration.
    - Minimal emergency response capacity affects ability to cope with and recover from an event.
    - On the other hand, the residents have emergency kits and practice with evacuation.
    - In terms of seismic events (and tsunamis), the people of some communities in South Central and Southeast Alaska and other coastal communities may have high emergency responder turnover, so retraining is required.
    - Many locations will have two governments in the same town, one local and the other tribal, making coordination in emergency planning and response very important.
    - Many coastal areas in Alaska are at risk of tsunamis. The risk perception for this hazard is way too low and their moving is not realistic. Greater awareness is needed.
    - Seasonal, transitory population who may not be familiar with the hazards, procedures, options. Tourists may also require special treatment. In an earthquake, a cruise ship might leave its thousands of tourists in a town that cannot absorb them and head out to sea to protect the ship. What if a tsunami were to occur during that period? There is no capacity to absorb such a large population so suddenly, and to do so without excess resources is unrealistic. Are the tourists accounted for in extreme event planning? And what if there is no access for the ship post-event to reconnect with its passengers?
3. How will a change in climate affect this system? (we thought about this some in (2))
4. If this is an infrastructure system, propose a research plan or strategy to integrate it with one or more social systems. If this is a social system, propose a research plan or strategy to integrate it with one or more infrastructure systems.
    - We often consider only the supply-aspect of the infrastructure system or its components. Adaptability (self-aid) of the community is equally important. System of systems approach is important.
    - How culture plays a role in adaptability, perspectives on planning, and capabilities, and how this impacts community resilience.
    - How does a distribution of wealth (investment funds) toward economically valuable infrastructure affect resilience across the area?
    - Role of self-sufficiency in community resilience.
    - Indices/mapping of critical infrastructure across the Arctic and Sub-Arctic needed.
    - Joint venture with Google to map the infrastructure!

5. Propose an outreach or engagement activity related to the research plan from the previous question.
    - Activity to better understand the indigenous perspective
    - Climate change is endangering the indigenous people even more than people living in highly built communities, like Anchorage. They may not have the same resources for coping. What more can we be doing to watch out for a people who are put at risk by our actions? Easy to get funding to protect expensive oil pipelines, but difficult to get many to protect the smaller communities or at-risk communities.
    - Many studies on things like how much more CO_2 is released from thawing permafrost, but we have few studies to really understand or make a difference to the everyday concerns of the indigenous populations in smaller communities. An engagement activity might be organized around understanding the perspectives of and issues for these communities.
    - Many research groups approach the indigenous communities to try to understand their issues, but nothing changes. It is difficult to really understand the issues without really living in the community. It is not enough to just visit. Need a long-term relationship with the community.
    - Insufficiency in engineering approach that does not consider the contribution of the community. Consideration of the engineered system as a socio- technical system.

d. The effects of small, local, and indigenous community capacity on seismic resilience of arctic systems

1. The built infrastructure/social system
    - Capacity of small/local/indigenous communities
2. The current seismic resilience of the system
    - Social network and ties are strong, making them particular resilient to environmental shocks.
    - FEMA or other similar programs may not have been designed for these small communities. And they have fewer resources to access the resources available through these programs.
    - These communities are vulnerable in terms of redundancy in lifeline infrastructure (power, communication, medical, food, clean water, building materials, etc).
    - These communities are more vulnerable in terms of transportation than regional hubs and big cities. After a disaster, they need food/goods and medicine to be shipped in quickly. And they also need telecommunication to reach to outside world, and fuel to power electricity. If electricity is gone for a week, the food they prepared for the winter will go spoil.
3. How will a changing climate affect this system?
    - Warming makes the traditional way of freezing food underground difficult.
    - Warming leads to more precipitation and permafrost erosion, both increasing landslide in terms of both frequency and magnitude.
    - Climate change increases wildfires, which burns vegetation, leading to landslide.
    - Tsunami caused by earthquakes could swamp a community away.
4. Research plan or strategy
    - Scenario-based approach: based on their biggest concerns, design a few scenarios. AND we provide a list of scenarios and let them pick a few.
    - Ask students to think about the scenarios, which might be different from their parents' perspectives.
    - These scenarios will help identify the problems.
    - Interviews with local communities about how they think about their vulnerability and resilience, and what they need.
    - Preparedness: increase human capacity by training them.
5. Outreach/engagement activity
    - Train their students with the preparedness. This is an effective approach as children are more interested in science and can get the researchers to their parents.

e. Effects of resources distribution on seismic resilience of arctic systems

Big issues

1. continued impacts to critical infrastructure, including the inhibition of resource distribution and operation of critical functions
2. need for improved social resilience (as measured by broad and local indicators), such as health care and water systems, in efforts of resilience
3. Decreased access to natural areas, such as salmon runs, caribou migrations

Sectors/Reach of big issues

- *transportation infrastructure* (roads, ports, airports)
    - ground subsidence, road failures, river movements
- maintaining open routes (river)
- infrastructure redundancy, such as oil pipeline
- telecommunications
- goods limited to port/barge transportation (Port of Alaska, Port of Seattle)
- *stakeholders across scales and capacities*: government, such as by state operations, distribution management plan, disaster assistance programs; HUB communities
- need people to work at schools, health facilities, emergency management positions
- S&R done by National Guard and state troopers, volunteer rescue groups

Research plan

- review adaptation strategies, such as stockpiling supplies when able, reusable energy
- survey with residents across the state to identify infrastructure capacities and needs
- review and feasibility assessments of engineering projects
- bring top strategies back to communities to see what they would like to see

Outreach or engagement activity

- community goals/visions of the future in a participatory mapping and vision-building activity in their then-to-be more resilient communities

- survey to develop metric on community capacities and their view of needs for elsewhere
- improving self-sufficiency
- incentives for investments (people power, economic)
- how to support existing capacities

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Influence of Climate Change on these issues:

Drinking water → no influence or not making it any better

Transportation infrastructure → worsens

f. Effect of inequality in access to information and resources on seismic resilience of arctic systems

1. What is the built infrastructure system?
   - Information and resource access inequality
2. Discuss current seismic resilience of the system
   - Lack of understanding of information related to earthquakes
   - Access to information can be expensive
   - Data (internet) access is expensive, poor quality, hard to track
   - Cell access is limited, repeater sites may be vulnerable and/or not evenly distributed
   - Lack of communication redundancy
   - News is often anecdotal
   - Price of services
   - Public safety access is limited
   - Health care is limited
   - Education resources are limited
3. How would changing climate affect
   - Could see more shipping
   - more people in coastal communities could increase quality
   - Fishing seasons changing, decreasing community resources to afford resources and population
   - Migration patterns change
   - Gardening
   - Access to fuel and resources can be limited if the haul road (ice road) is damaged
   - If permafrost or other factors impact runways, supply deliveries could be impacted
   - Increases in forest fires preventing access to communities that aren't road accessible
   - Impacts to the port of Anchorage limiting resources, would the limited resources be distributed evenly
   - Rising cost of food due to shipping issues due to storms
   - Permafrost changes affect monitoring efforts that would trickle down to information availability and/or increased inaccuracy
   - Weather effects on power systems and data systems to provide information
   - Information on how and where to build may not reach the communities
   - Rescue workers and public safety may not be able to access the communities following an emergency
   - If communications systems are impacted, 2-way information exchange becomes impossible
   - Water and sewer resources will be impacted
4. Propose a plan to integrate social and infrastructure
   - More research needs to be done to access the actual vs perceived needs
   - Communication redundancy is needed
   - Supply lines need to be reinforced
5. Outreach activity associated with this plan
   - Outreach by region and facilitate an inventory of data issues by region
   - Address indigenous vs migrant issues/needs, long-term vs new-term
   - Showing up and having a face in the community to provide the information
   - Help the community find ways to access information