To Build a Fire

The Alaska Science and Technology Plan

The Alaska State Committee for Research

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Approved and accepted by the Alaska State Committee on Research

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Executive Summary

Alaska's economy is based on knowledge. Research – the expansion of knowledge – can improve the state's resilience and competitiveness and contribute to human progress. While Alaska's vast size, extreme climate, and scattered population present challenges for science and technology development, the state also offers many advantages: a rich resource base, a unique Arctic location, an educated populace and increasingly well-regarded university system, and a landscape ideally suited for the study of human and natural systems undergoing climatic and social change.

This report presents a road map for the future of Alaskan science and technology (S&T) development. Improving Alaskan S&T requires a collaborative effort between the state, the University of Alaska (UA), federal agencies, communities, and the private sector. The state has a limited ability to broadly fund research, especially in lean financial times. Its role is rather to help provide infrastructure and basic research; education and training; incentives for industrial development; cost matching and focused funding; and research oversight and coordination. By adopting in-state innovations, the state can also leverage and validate Alaskan research. It is also incumbent on the state to refine research efforts to help industry to develop the state economy, and to foster relationships with communities and businesses to better leverage state funds.

To offer an analogy, the state seeks to build a fire under research. The "spark" is education and incentives for innovation. The "tinder" is infrastructure and capacity. The "fuel" is match funding and other support, and the "bellows" represents long-term planning and coordination by the State Committee for Research (SCoR) and other bodies.

Alaska's unique characteristics lend themselves to seven specific S&T research arenas, as detailed in this report. These arenas take advantage of Alaska's natural and human assets and address research questions crucial to the state's economy, ecology and society:

1. ***Community Resilience and Sustainability.*** Communities' capacity to adapt to change; arts and culture; and preservation and revitalization of Alaska Native languages, culture and knowledge.
2. ***Resource Extraction.*** Technology and processes for safe and efficient exploration, extraction, transportation and use of oil, gas, coal and minerals, including rare earths.
3. ***Energy Solutions.*** Alternative energy sources for northern communities, and cold climate housing and technology.
4. ***Renewable Resources.*** Innovations and strategies to effectively harness the state's renewables, including fisheries, aquaculture, timber, and agriculture.
5. ***Environmental Monitoring and Management.*** Monitoring and mitigation of environmental change, mapping and remote sensing, fire prevention and response, and geophysical research.
6. ***Human Health.*** Delivering effective physical and behavioral health care in the Arctic and subarctic.
7. ***Transport, Communications and Information.*** Land transport, shipping, aviation, aerospace, telecommunications and information technology in northern environments.

An additional section of this report addresses kindergarten through twelfth grade (K-12) and university education, with a focus on science, technology, engineering and math (STEM) instruction. It concludes with a discussion of the ways state entities can assist private industry.

Introduction

Developing Alaska's science and technology capabilities is critical to the state. Research is widely recognized as the most significant engine of economic growth, and also constitutes an economically significant "industry" in its own right: the University of Alaska, for example, conducted $151 million in sponsored research in 2014-15, including $124 million at the Fairbanks campus, $14 million in Anchorage, and more than $1 million in Juneau. This research activity generates over 2,000 jobs, attracts talent from around the nation and the world, and improves our ability to "grow our own" and to keep our best and brightest in Alaska.

The other reason S&T is important in Alaska is the state's unparalleled richness of human and natural resources. A common saying is, "If we can solve it in Alaska, we can solve it anywhere." Our goal is S&T that enables us to affordably and sustainably meet socioeconomic needs while preserving the health of our environment and improving our quality of life. These results are exportable as well: better solutions for basic needs such as clean water, green energy and remote health care are needed around the world.

Challenges. Alaska offers unique S&T challenges. The state's vast size, scattered population, extreme climate and limited transport infrastructure complicate logistics and increase costs. Another hurdle stems from land ownership: Research questions don't respect the jurisdictional boundaries of the various federal, state, and Native organizations which own 99% of land in Alaska, complicating the process of obtaining permits and approvals. A further consideration is the significant research conducted on Alaska Native-owned lands, or involving Native communities or populations, which requires special attention to ethics and to intellectual property issues concerning the use of traditional local knowledge.

Opportunities. At the same time, the Great Land has abundant potential for S&T development. The state's wilderness and coastline, Arctic location, abundance of traditional local knowledge, and position at the forefront of climate change all make it a natural laboratory for innovation in environmental monitoring and management. Its isolated rural communities are ideal sites for social and economic research addressing cultural preservation, migration, and community sustainability, and for testing alternative energy technologies and solutions.

Perhaps most of all, Alaska offers motivation: nowhere else in the U.S. presents a more pressing need for innovation in areas like energy production and adaptation. And never before has there been such intense interest in the North, as factors such as climate change, resource potential, and new shipping lanes focus attention on the eight Arctic nations. As America's only Arctic state, Alaska offers strong opportunities for national and international research, stakeholder collaboration, energy development, and governance initiatives.

Other Segments of the State Economy

Several other Alaskan industries are worth noting due to their contributions to the state, though they are not generally foci of scientific research.

- **Tourism**: Tourism has an economic impact of $3.9 billion a year. 1.93 million people visited the state in 2013-4 (half by cruise ship) and around 46,000 people were employed in tourism jobs during peak season.
- **Military**: Alaska is home to about 23,000 active-duty military personnel, and veterans comprise 10% of the state population, the highest per capita in the nation. The University of Alaska increased cooperation with the military in 2013 by signing an agreement with the multi-services Joint Task Force-Alaska to share information in areas like energy, engineering and communications initiatives. Among other developments, this led to an Arctic Collaborative Workshop in 2014 that drew civilian and military Arctic experts from five countries.
- **Advanced Business Services**: Alaska houses numerous firms that provide customized problem-solving to other businesses, such as consulting and research companies.

The Role of the State. Alaska's unique economic structure and research needs foster a climate dominated by state and federal agencies and the University of Alaska: in 2011 only 22% of Alaskan research and development (R&D) came from industry, versus a national average of 69%. The function of the state is thus to conduct appropriate research through the UA and state agencies; to bolster research taking place at the federal and local levels, and to identify ways to facilitate increased research by private industry. There are five roles the State of Alaska can play in the development of science and technology:

1. Education and training. Through the Department of Education and the UA, the state takes a lead role in educating tomorrow's innovators. In addition to state efforts, tax credits and other support mechanisms can promote private education programs.

2. Incentives for commercial S&T development. Alaska seeks to expand private-sector participation in S&T to spur economic growth. Tax incentives, direct financial support, and purchasing and early adoption of innovations contribute to this goal. Industry and government can also share the costs of research and exploration to identify opportunities and to improve feasibility.

3. Infrastructure and basic research. Adequate laboratory space at the University of Alaska is critical to science and technology development, as are cyberinfrastructure, faculty retention and recruitment, and independent research by state entities. The state can also support and conduct the basic research that undergirds all applied science efforts, but that is unlikely to attract private funds.

4. Cost matching. Many federal programs require a cost match; to the degree that the state seeks to attract such funds, it must provide the needed resources. Similarly, the state bears the burden of building capacity and maintaining excellence in areas where it wishes to attract federal support and private investment.

5. Oversight and coordination. It is incumbent upon the state to pull together various elements of S&T by developing a thorough understanding of what is already occurring and the mechanisms by which it occurs, including economic factors. The state can then suggest priorities, encourage partnerships, provide incentives, and improve the S&T climate.

To Build a Fire

"Building a fire" under research is critical if the state is to diversify and grow its economy.

Education and incentives are the **spark**.

Infrastructure, basic research and capacity-building provide **tinder**.

The **fuel** is cost-matching, as well as other financial support and guidance to help new technology to leave the laboratory.

The **bellows** represents coordination and long-term planning by the State Committee for Research and other state bodies to foster continued development.

Once the state has lit a fire under S&T, it will take the continued development and application of sound policy to **keep the blaze going**.

Research Arena 1: Community Resilience and Sustainability

Introduction. More than two-thirds of Alaska's 737,000 residents live in or near the principal cities of Anchorage, Fairbanks and Juneau, while many of the remainder occupy remote "mixed-subsistence" villages, in which residents obtain food from the land but also participate in the cash economy. In recent years there has been a slow migration of village residents toward population centers, driven by jobs, schooling, health facilities, and increasing reliance upon modern technology. The continued viability of these isolated communities is dependent on numerous local and global variables, from wildlife migration patterns to the price of gasoline. Understanding these variables and ways to respond to them is thus critical to preserving the rural Alaskan way of life.

Research Initiatives. **Community Resilience.** A focus of Alaskan research is the study of adaptive capacity: the ability of communities to effectively respond to environmental and social changes. One key question is how communities and institutions can proactively address major climate-driven landscape changes. Such shifts can profoundly impact food webs and hence resource availability, and can also impact safety by altering chracteristics of natural hazards such as forest fires.

Alaska NSF EPSCoR (National Science Foundation Experimental Program to Stimulate Competitive Research) is implementing a "Track-1" award to create and refine adaptive capacity indices, which highlight the specific elements that enable communities to weather change. Another initiative for adaptation research is the Resilience and Adaptation Program (RAP), an interdisciplinary graduate-level sustainability science program at UAF. RAP students engage in coursework, internships and other training in resilience and vulnerability to prepare them for leadership positions in academia, government, organizations, and education. UAF is also home of the Center for Global Change and Arctic System Research, a network for interdisciplinary research and education. UAA hosts the Alaska Center for Conservation Science, which fosters research and education on northern biological conservation and natural resource management.

Social Research. Many of the challenges facing rural Alaska are rooted in economics. The Institute of Social and Economic Research (ISER) at UAA conducts research into subsistence, rural-urban migration, sustainable communities, risk perception, and other aspects of social, economic and cultural change. The UAA Justice Center also conducts basic and applied research into pressing issues of crime, justice and law that impact community resilience.

Arts, Language and Culture. There is a growing global awareness of the importance of traditional local knowledge, especially in regards to a changing climate – but as Alaskan elders age, important knowledge is in danger of being lost to history. Culture, language and the arts in general are important facets of resilience and identity, and also contribute to the economy through tourism.



Alaska Native Medical Center art displays

The State Committee for Research was actively involved in crafting the Alaska NSF EPSCoR Track-1 proposal, and provides oversight and coordination to the program's various elements. The state also provides an award match. With SCoR oversight, Alaska NSF EPSCoR regularly submits funding proposals for other activities that address community sustainability and contribute to local capacities to respond constructively to change. SCoR has also approved a new Track-1 proposal for 2017-22, which will focus on planning for large-scale landscape shifts in fire-prone boreal forests and coastal marine ecosystems. NSF EPSCoR also works to enhance community sustainability by providing decision support through high-resolution visualization facilities, including upgrading the UAA Planetarium and Visualization Theater and building a new "Decision Theater North" facility at UAF.

The state increased its role in language preservation and revitalization in 2012 by establishing the Alaska Native Language Preservation and Advisory Council, which advises the governor and legislators on language projects and policy. The council released its second biennial report in 2016, offering a number of recommendations in areas of information security, regional disparities, education, reconciliation, technology, and funding. The state took a major step toward acknowledging the importance of Native languages in 2014, when legislators recognized 20 Alaska Native tongues (alongside English) as the official languages of the state. Another ongoing contribution to historic preservation is a new $140 million facility to house the state library, archives and museum, which opened in June 2016.

High on UAF's priority list is a planned $25 million Alaska Native Studies Building and accompanying park. An Alaska Native Art and Culture Building is on the drawing board at UAA, as is a Cultural Arts and Research Center at Kenai Peninsula College that would center on Native ethnography.

The Alaska State Council on the Arts provides assistance and services to artists, art organizations and arts supporters across the state. Since its inception, the council has provided over 4,000 grants totaling more than $42 million, including direct support for artists and a variety of programs to bring artists and art curricula to schools. The Council's strategic plan calls for the organization to cultivate awareness of arts and culture; to promote equitable, accessible high-quality arts education; to expand Alaska's artistic vitality; to build vibrant communities through the arts; and to strengthen the council's governance and administrative capacity. The nonprofit Rasmuson Foundation also provides major funding and support to Alaskan artists. The state contributed direct financial support to the UAA Justice Center in 2015 to compile, analyze and report justice data for policymakers and practitioners, part of a plan to reduce recidivism.

Examples of Alaska Native Language and Culture Preservation Efforts

- The **UAF Oral History Program** preserves more than 11,000 audio and video recordings about Alaska's history and people, many of which are available online.
- The **UAF Alaska Native Language Center** researches and documents Alaska's 20-plus Native languages and raises public awareness of language loss.
- UAF is partnering with Google in the **Endangered Languages Project**, which enables people worldwide to find and share information about endangered languages.
- UAA's **Kenai Peninsula College** operates a major grant-funded research center for language documentation.
- The **Alaska Native Science Commission**, formed by the Alaska Federation of Natives, works to integrate Native knowledge into research.
- The **First Alaskans Institute** is a non-profit organization that helps to develop the capacities of Alaska Native people; its efforts include a Native policy think tank and leadership development programs.
- The **Sealaska Heritage Institute** is a non-profit organization that works to preserve and enhance Southeast Alaska Native cultures.

Introduction. Oil has been the linchpin of Alaska's economy for four decades, but Alaskan production is down by about three-quarters from its 1988 peak. It is estimated that more than 43 billion barrels of technically recoverable oil remain in Alaska's North Slope, Cook Inlet, beneath the Chukchi and Beaufort seas, and in other areas. The state contains an estimated 255 trillion cubic feet of technically recoverable natural gas, which is largely stranded far from major markets. Alaska is home to significant viscous and heavy oil, shale oil, natural gas hydrates and coal deposits, as well as strategic minerals, which have as yet seen minimal development. The state works to provide innovative solutions to extractive industries to help them improve efficiency, especially during financially tough times.

Research Initiatives. **Oil and Gas**. One state research goal is to use technology and improved data to refine oil permitting to be more efficient and scientifically sound. This includes improving understanding of the impacts of development on wildlife and of climate change on infrastructure, vegetation and wildlife. Alaska also facilitates oil development by gathering geologic and engineering information for potential oil and gas basins. ISER can offer insights into economies of oil production, including appropriate levels of public versus private investment.

The state also seeks to collaborate with oil and gas multinationals to help develop and implement advanced exploration and production technology, such as directional drilling techniques, 3-D seismic surveys, and reinjection techniques to improve recovery. It is incumbent on the state and industry to identify and "design out" potential environmental problems before development takes place. One key area is production techniques for viscous and heavy oil - which constitute a huge, largely untapped reserve - and for oil shale. The potential for increased Arctic Ocean exploration and drilling means the state must develop and implement better methods for offshore oil spill prevention and response, including research into skimmers and treatment technology.

Alaska can also facilitate natural gas research. High priorities include arctic engineering; cold-climate propane transportation and delivery; resource and reservoir identification studies focused on coal bed methane, natural gas hydrates, and conventional natural gas; gas-to-liquids engineering; and public policy issues. New technologies hold the potential to unlock vast reserves of coalbed methane and hydrates in particular.

Minerals. Alaska has deposits of gold, silver, lead and zinc mined at an industrial scale and potentially commercial quantities of more than a dozen strategic minerals. This includes abundant rare earth elements, which have been found in more than 70 different deposits across the state. A major goal of the state is to make informed mineral permitting decisions that minimize harmful effects on the environment. Other goals are to assess public lands for mineral potential, to construct ore deposit models, to develop new techniques to explore for mineral deposits, and to conduct research into mine ventilation, remediation, tailings handling, systems engineering and technologies. Alaska has the potential to further profit from its mineral resources through in-state processing and use.

Coal. It is estimated Alaska contains half of total U.S. coal reserves, but little is currently economically recoverable; exceptions are the Usibelli Coal Mine and the proposed Chuitna Coal Project. Although most known deposits are not of the scale to merit development for export, many regions could be developed for local use. For example, natural gas generated from coal in Tertiary basins as well as coal suitable for surface mining have been identified in regions that rely primarily on imported diesel for heat and electricity. Clean coal, coal gasification, tight reservoir gas production and other emerging technologies could be developed for application in these regions. Further delineation of deposits, in combination with development of technologies for extraction and generation, is needed in these areas.

Disruptive Innovation. It is incumbent on the state to position itself to develop, serve as a proving ground for, and take advantage of disruptive technologies, which displace earlier technology and create entirely new markets. Advanced oil and gas exploration and recovery techniques, clean energy storage systems, carbon sequestration, and automated mining are all areas with high potential for disruptive developments in the near future.

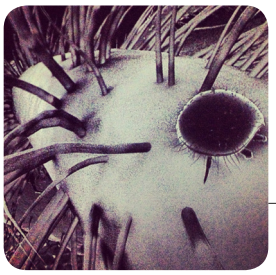
Strategies

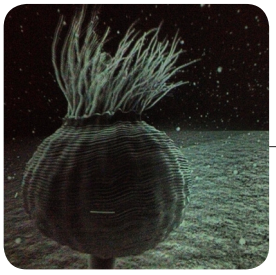
The Institute of Northern Engineering at UAF hosts Petroleum Development and Mineral Industry Research laboratories. Some other key analytical labs at the UA are listed below. The state's greatest recent contribution to improving resources research is the funding of a $123 million engineering building at UAA and partial funding of a similar facility at UAF, concurrent with a highly successful push to increase UA engineering student numbers. UAF is currently preparing a bond package to complete its engineering building, as state capital investment has dropped in the wake of low oil prices.

The state contributed direct funds in 2015 for UAF hydrocarbon research, focused on heavy and viscous oil, shale oil and gas, and enhanced oil recovery. State oil and gas exploration efforts combine detailed stratigraphic and structural outcrop studies, surface geologic mapping, and subsurface well and geophysical interpretation. Recent and current projects have focused on the North Slope foothills and Colville foreland basin, the Alaska Peninsula back-arc basin, and the Mesozoic to Cenozoic evolution of the Cook Inlet forearc basin and adjoining Susitna basin. Additional studies are planned in Alaska's Interior. Another recent project provides new geologic and environmental data on the potential for shale oil.

In 2012 Alaska adopted a five-part plan to develop rare earths, including mineral assessments, industry incentives, permitting changes, coordination with stakeholders, and an information campaign. The Alaska State Geological Survey is collaborating with the U.S. Geological Survey and UAF's Hyperspectral Imaging Laboratory on the "Alaska Strategic and Critical Minerals Evaluation," which seeks to identify the regions of highest potential for rare earths and other strategic and critical minerals in Alaska. The state is also funding a new Geologic Materials Center facility to archive Alaska's legacy collection of geologic samples and data. UAF has asked for state funding support for a planned Critical Minerals Resources Research Center.

Improving oil spill response through better mapping, communications, cooperation and investment is a key recommendation of Alaska's Arctic policy as crafted in 2015 by a state panel, the Alaska Arctic Policy Commission (AAPC). Research into oil spill prevention and mitigation is headed up by the Oil Spill Recovery Institute, a federally-funded research facility in Cordova. UA is exploring partnerships with the federal Bureau of Safety and Environmental Enforcement, Alaska Department of Environmental Conservation, other agencies, and oil companies to study arctic oil spill response in laboratory conditions. The state has also provided support for joint surveys of the marine life and habitats in the Bering and Chukchi seas in advance of potential offshore oil drilling.





Images from UAA Planetarium and Visualization Theater showing of "Nanocam"

Examples of UA Laboratory Facilities

UA has more than 455,000 square feet of space assigned to organized research, including almost 400,000 square feet at UAF and more than 50,000 at UAA.

- The **UAF Advanced Instrumentation Laboratory** specializes in surface and elemental analysis and electron microscopy, and also houses sample preparation facilities.
- The **Alaska Stable Isotope Facility** at UAF and the **Stable Isotope Laboratory** at UAA analyze a wide range of isotope samples.
- The **UAA Applied Science, Engineering and Technology Laboratory** serves researchers studying health, safety, welfare and climate change issues, including toxic substances and chemical environmental changes resulting from glacier and permafrost thaw.
- **Research Computing Systems** at the UAF Geophysical Institute provides advanced computing, storage, data sharing solutions and research information technology support to University of Alaska research communities, collaborators and supporters.
- The **Southeast Alaska Geospatial Environmental Analysis Lab** at UAS provides educational and analytical research capacity in the geospatial sciences, while the **UAS Spatial Ecosystem Analysis Lab** enables the analysis of inorganic and organic samples that are harbingers of socio-ecological and biophysical change.

Research Arena 3: Energy Solutions

Introduction. Energy prices in parts of Alaska, especially rural Alaska, are astronomical; more cost-effective methods of energy production and distribution are crucial to ensuring the future of the state's remote communities. In addition to conventional energy resources (see Arena 2), the state's landscape holds significant potential for alternative energy; the challenge lies in making its use affordable, efficient, and dependable in extreme weather. Alaskan research into cold climate technology also aids in energy conservation.

Research Initiatives. **Renewable Energy.** Alaska contains abundant fossil fuel alternatives, including more than 50% of the nation's wave energy resources and over 90% of its river current and tidal energy resources. Renewable energy possibilities for Alaska include the use of shrubs and trees or waste to power small biomass generators (see Arena 4); wind turbines; seasonal solar power; geothermal power generation (including low-temperature geothermal); and hydropower from dams and from river, wave and tidal generators. Alaska is increasingly viewed by the nation as an ideal test bed for remote power microgrids.

Many options for renewable generation in Alaska have been identified and mapped, but further identification of resources and optimal sites for power generation is needed. Even more important will be continued research into power transmission, in order to bridge the long distances between resources and communities. Improvements in energy storage are needed to increase the feasibility of renewables and to lower their cost. One innovation being studied in Alaska is the use of ammonia as an energy storage medium. Hydrogen and nanocellular carbon are other storage media of interest in Alaska.

Another major challenge for renewables lies in Alaska's climate, which can devastate equipment built for milder weather. Alaskan scientists are continuing research into materials and their performance under arctic conditions, including wind power systems backed up by diesel generators. Research is also needed into the potential for using abundant clean energy resources as an incentive to attract energy-intensive industries to the state.

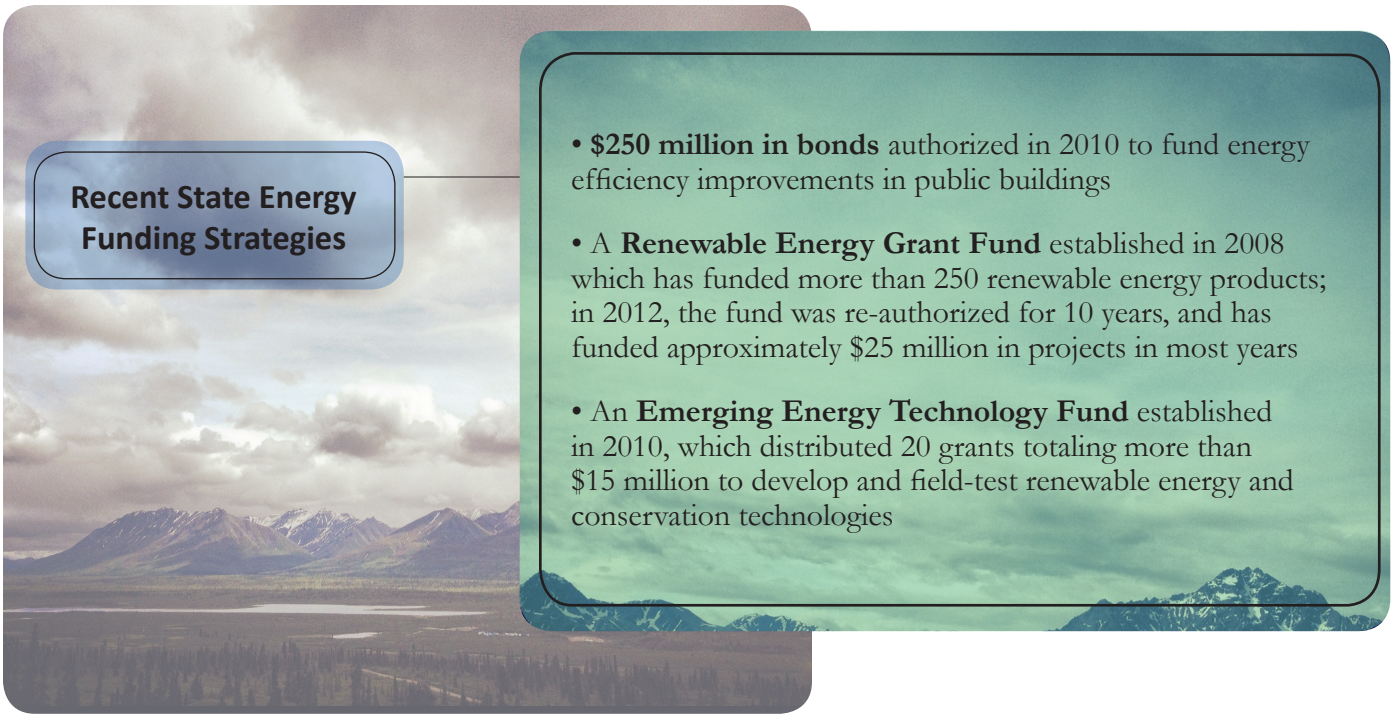
Economics. A significant dimension of alternative energy is its affordability and its acceptance by the public. State research into developing and implementing alternative energy must take into account the socioeconomic factors involved in developing and delivering renewable energy sources.

Cold Climate Housing and Technology. The other side to the Alaskan energy challenge is conservation. Reducing power and heating costs in rural Alaska was recognized as a priority by the AAPC in 2015. The state leader in home energy-efficiency research is the Cold Climate Housing Research Center (CCHRC), a university-industry partnership which develops facility designs, materials, and construction techniques for the subarctic and Arctic. One aspect of housing technology being explored in Alaska is the use of nanofluids to enhance convective heat transfer and thus improve home heating.

In 2010 the Alaska Energy Authority (AEA) - an organization charged with coordinating state energy priorities - produced Energy Pathway, a master document for use in planning and developing local and regional energy projects. The AEA is currently working with multiple partners to develop the Alaska Affordable Energy Strategy, which will outline ways to deliver cost-effective energy to areas of the state without access to a proposed gas pipeline from the North Slope, should one be built. In recent years, various state funds have been used for widespread biomass, geothermal, wind, hydropower, waste heat recovery and energy efficiency projects. In the private sector, more than 100 small businesses in Alaska are working on microgrid energy solutions. In total there are more than 200 microgrid energy projects in progress across the state, and the state and federal governments have invested nearly a billion dollars in microgrid technology in Alaska over the past decade.

The focal point of Alaskan energy S&T is the UA. The Alaska Center for Energy and Power (ACEP) was founded in 2008 to conduct energy research, and operates under an innovative private sector business model within the UA system. ACEP researches alternative energy sources as well as more efficient use of nonrenewables. ACEP facilities include a power systems integration lab, a wind-diesel generator testbed, and a river generator test site. Current projects run the gamut of energy sources, from solar power in Galena and the Northwest Arctic, to geothermal exploration on the Seward Peninsula, to biomass, wave, wind and riverine energy studies. ACEP recently concluded a $3 million Department of Energy EPSCoR grant to develop and test wind-diesel technology in remote villages, and in 2015 received $500,000 in federal funds to found an Alaska Center for Microgrid Technologies Commercialization. ACEP is slated to move into improved space in the UAF Engineering Building once the structure is completed.

CCHRC was founded in 2006 and has completed dozens of research projects to improve energy efficiency and to incorporate alternative energy into home designs. CCHRC has worked closely with other agencies like the Alaska Housing Finance Corporation, including jointly producing a 2008 review (updated in 2012) of state energy efficiency policies and programs, which led to a number of new initiatives. The CCHRC has also built the first phase of a student-occupied "sustainable village" of experimental housing at UAF (and has garnered state support to expand the project), as well as building prototype energy-efficient homes in numerous remote Alaska villages.



Research Arena 4: Renewable Resources

Introduction. Alaska's fisheries are among the most productive in the country, and fishing employs more people in Alaskan than any other industry. Monitoring and managing the state's waters and fisheries is crucial, as climate change and increased human use influence ocean circulation and ecosystem dynamics, impacting biological productivity, marine mammals and fish stocks. Timber and agriculture are other areas where S&T can help increase renewable resource use.

Research Initiatives. **Fisheries and Marine Life.** Alaska contains commercial, subsistence, and sport fisheries. Precise regulation of commercial fisheries is necessary to assure sustainable harvests, and it is imperative that the state collaborate with industry to develop better science-based management of fish and shellfish stocks. There is great potential within the seafood industry for product use and processing to increase the share of seafood processed locally and in-state.

A focal point of state research is the impact of climate change on coastal and oceanic food webs and the fisheries they support. These include potential large-scale shifts in coastal food webs due to glacial retreat. Ocean acidification is another major cause for concern in Alaska; habitat studies (see Arena 5) are key to charting the effects of acidification and climate change on fisheries and marine mammals. Other research priorities include species-specific assessment and modeling for salmon, sablefish, pollock, halibut and other species. Challenges include in situ and spatial data collection, data management, and habitat mapping. One key research area is the decline of Bering Sea pollock fisheries, which have been linked to higher water temperatures, and of Chinook salmon populations, which have been declining statewide.

New technology could have major application in fisheries. Areas of interest include advances in processing, refrigeration, dehydration, genetics and acoustics, spatial information software, and value-added processes, as well as ways to minimize or mitigate bycatch and to use fish waste.

Another key area for research is the potential for increased mariculture and aquaculture, including the production of oysters, mussels, clams and kelp, and salmon ranching. State legislators have passed several acts designed to help the industry, and research could help pinpoint other methods to encourage growth. This includes reducing shellfish maturation times and up-front investments, improving sources of oyster seed, decreasing otter predation of mussels, and commercializing abalone and other underutilized species.

Timber and Forestry. Alaska's timber industry is constrained by changing market conditions and by the small amount of commercial-quality old-growth hardwoods available for harvest. The state can contribute to the industry through innovations: for example, the Ketchikan Wood Technology Center, a government-industry collaboration, developed new strength values for Alaska softwoods, earning them recognition for their aesthetic and structural properties. Market research can also help in the development of value-added products. The state also works to facilitate wood energy, including the use of low-grade timber, wood waste and wood pellets for biomass projects. Field trials of alternative systems, including bailers, forwarders, and in-field chipping systems, could help reduce biomass harvest and transportation costs.

Agriculture. Alaska's short but highly productive growing season has strong potential for large-scale agriculture, but less than 1 million acres statewide are used for farming. There are also economic opportunities in certain high-value agricultural products for which Alaska's high latitude is an advantage, such as reindeer antlers, peonies, and golden root. Alaska's isolation and climate make it extremely "food-insecure:" it is estimated that less than five percent of food eaten in Alaska is produced in the state. Research into bolstering local food production and improving food security is thus critical to the state as a whole, as is continued study of the nexus of food, energy and water.

In 2015, the UAF School of Fisheries and Ocean Sciences (SFOS) took delivery of the R/V Sikuliaq, a global-class ice-capable research vessel that enables up to 26 scientists and students per cruise to conduct multi-disciplinary ocean research. A new Juneau SFOS facility and National Oceanic and Atmospheric Administraiton (NOAA) lab were also recently completed. UAF established an Ocean Acidification Research Center in 2010, and in 2012, the state appropriated $2.7 million to expand oceanic sensor networks in order to track acidification and its effects on fisheries. Alaska NSF EPSCoR has submitted a five-year research proposal which focuses on large-scale climate-driven landscape shifts, including research into the impacts of deglaciation on coastal marine food webs.

The UA Fisheries, Seafood and Maritime Initiative (FSMI) collaborates with industry to research sustainable fisheries and to develop a skilled workforce. Through the program, in 2014-15 eight UA campuses offered 115 maritime classes to 1,121 students across 23 communities. The Alaska Department of Fish and Game has partnered with FSMI and other agencies since 2013 in a $21 million project to study the decline in Alaska's king salmon stocks. A state-UA-federal study is also mapping the ecosystem of the Bering and Chukchi seas.

The UAF/NOAA Alaska Sea Grant Marine Advisory Program conducts fisheries and aquaculture research, with current projects studying predation on salmon, shoreline erosion around Bristol Bay, whale watching in Juneau, environmental change in Cordova, salmon growth in response to climate change on Kodiak Island, state-federal pollock fisheries management policies, and many other subjects. ISER has been a center for research on the economic impact and future of fisheries and other natural resources, including allocation impacts. Alaska NSF EPSCoR is studying aspects of the effects of glacial melt on coastal and estuarine ecosystems and food webs in Southeast and Southcentral Alaska.

Through initiatives such as an Alaska Wood Energy Development Task Group, the state is supporting new timber and resource roads and working to coordinate timber sales with biomass power projects funded through the Renewable Energy Grant Fund (see Arena 3.)

UAF runs experimental farms in Fairbanks and Palmer, and the UA Cooperative Extension Service has taken the lead at the university level in researching and advocating local food production. A state organization, the Alaska Food Policy Council, is operating under a strategic plan for improving Alaska's food systems, including expanding school-based programs to provide healthy, local foods; strengthening enforcement of a statute requiring state agencies and school districts to purchase Alaskan food products; advocating for emergency food plans; and supporting local food security initiatives. The Council works in concert with the Alaska Food Resource Working Group, a panel tasked by state legislators with identifying methods to increase local food production.

Examples of Alaskan Aquatic Research

Alaska is home to multiple ocean research efforts undertaken at the state, federal, industry and university levels.

- **Alaska Sealife Center** (located in Seward)
- **UAF School of Fisheries and Ocean Sciences** (Fairbanks)
- **Kachemak Bay National Estuarine Research Reserve** (Homer)
- **Kodiak Fisheries Research Center**
- **UAF/NOAA Alaska Sea Grant College Program** (Fairbanks)
- **Barrow Arctic Research Center**
- **Gulf of Alaska Ecosystem Monitoring Program** (Anchorage)
- **NOAA Alaska Fisheries Science Center** (Juneau)
- **Prince William Sound Science Center** (Cordova)
- **Alaska Department of Environmental Conservation** (Juneau)
- **Alaska Fisheries Development Foundation** (Anchorage)
- **Alaska Department of Fish and Game** (Juneau and Fairbanks)
- **North Pacific Research Board** (Anchorage)
- **Sitka Sound Science Center**

Research Arena 4: Environmental Monitoring and Management

Introduction. Alaska's 586,412 square miles encompass a wide array of terrestrial and marine ecosystems, which support diverse wildlife and abundant commercial, recreational, and subsistence resources. The Alaskan environment, to a large extent, defines the people of Alaska, and ensuring the health and sustainability of this environment is crucial to the state as a whole.

Research Initiatives. **Fire and Earth Science.** Wildfires are growing in importance as a research focus: mammoth fire years in 2004, 2005 and 2015 burned millions of acres, and evidence is mounting that temperature and precipitation changes are impacting fire frequency and severity and altering forest composition. Research is needed to improve community capacity to model and anticipate forest fires and to take preventative measures. Increased earth science research in general can enable more accurate predictions of changing environmental conditions that contribute to permafrost thaw, flooding, and coastal erosion. This will enhance monitoring and response strategies to emergency situations as well as realistic analyses of their socioeconomic impacts.

Monitoring Environmental Change. High-quality climate observations over extended periods are the only way for researchers to tease out natural versus human-induced change, a necessary element of understanding and predicting climate patterns. The state seeks to facilitate this effort by coordinating an environmental land and ocean monitoring network consisting of linked in situ and remote sensing nodes with a common data portal, building on and coordinating existing monitoring by state and federal agencies. The system would track terrestrial conditions as well as water quality, quantity and availability, glacier and ice extent, and ocean water quality and productivity. This improved information stream would enable enhanced environmental models and forecasts for use in adaptive resource management and refined decision-support tools.

Habitat and Wildlife. The state manages wildlife to support diverse populations and to enable hunting, fishing and viewing. Research into basic biology and ecology, habitat and population mapping, monitoring, and modeling is important to track wildlife information and to understand how climate change affects flora and fauna. Another goal is to identify means to incorporate local and traditional knowledge into resource management. The state must also take a lead role in preventing and, when practicable, eradicating invasive species. Long-term monitoring, process studies, and models of fish and their habitats are a priority, as are research into marine ecosystem structure and processes; endangered and stressed species; contaminants; effects of water system changes on aquatic communities; and marine mammal management.

Mapping, Sensing and Unmanned Aerial Systems. Only a few areas of Alaska have been charted to the high resolutions of 1-5 meters needed for land use planning and many resource applications. An Alaska Geospatial Council brings together the UA, state agencies and numerous stakeholders to improve Alaska's mapping and Geographic Information Systems (GIS) capabilities. A major UA focus is remote sensing: agencies like the Alaska Satellite Facility, the Geographic Information Network of Alaska (GINA), and the UAF Hyperspectral Imaging Laboratory are ideally located to acquire, process, archive and distribute remote sensing data. Many engineering challenges presented by remote sensing open the door for new Alaska industries in sensors and space-based engineering, including the development and launch of small CubeSAT-type satellites.

One key innovation under continued development at the UA is unmanned aerial systems (UAS), which are especially useful for observations in Alaska's harsh conditions. UAF is an international leader in UAS research and was designated by the Federal Aviation Administration (FAA) as one of six official UAS test centers nationwide. Areas of UAS study at UAF include advanced approaches to in situ environmental monitoring, resource assessment, autonomous underwater vehicles and small satellites.

The state can collaborate on environmental sensing with existing initiatives like the National Ecological Observatory Network, the Arctic Observing Network, the Alaska Ocean Observing System and the Alaska Corps of Social Observers. The Alaska Native Tribal Health Consortium's Local Environmental Observation Program recruits citizen scientists to report unusual plants and wildlife, flooding, wildfires and more. The Barrow-based interagency North Slope Science Initiative collects and disseminates Arctic ecosystem information, and the federal Alaska Climate Science Center and Landscape Conservation Cooperatives collaborate in climate efforts. The UAF Cooperative Extension Service has organized a statewide Invasive Species Working Group.

Alaska NSF EPSCoR has installed or reactivated integrated sensors and sponsored LiDAR and aerial photography. EPSCoR data portals implemented by GINA provide access to sensor and mapping data and facilitate model development. EPSCoR-funded improvements to UA cyberinfrastructure have improved statewide capacity to store and process data. An Alaska Geospatial Strategic Plan crafted in 2011 sets overall state mapping and sensing goals.

Fire research in Alaska is spearheaded by the Alaska Fire Science Consortium, an interagency group headquartered at UAF's International Arctic Research Center. The mission of the consortium is to coordinate fire science delivery efforts and to facilitate communication between scientists and resource managers. A proposed NSF EPSCoR project will examine regime change in fire-prone Alaskan boreal forests, with a goal of improving Alaskans' ability to predict fire behavior and proactively respond to it.

The UAF Geophysical Institute (GI) studies earth science phenomena, including space physics and aeronomy, atmospheric sciences, snow, ice, and permafrost, seismology, volcanology, and tectonics and sedimentation. The State Division of Geological and Geophysical Surveys partners with the GI, the U.S. Geological Survey (USGS) and NOAA in earthquake, tsunami and volcano research and monitoring, and works to maintain, expand and upgrade those networks. Alaska recently benefited from the federal EarthScope program, which is operating 260 seismic sensors in a grid across the state; UAF is currently seeking state and other funding to maintain the array after federal support concludes in 2019.

Space research is organized by the Alaska Space Grant Program and by Alaska NASA EPSCoR, which awards research grants in the areas of earth system science, technologies for space and extreme environments, and aeronautics. In 2012, UAF established the Alaska Center for Unmanned Aircraft Systems Integration (ACUASI) to coordinate and oversee UAS efforts. A $5 million state grant supported joint development of UAS by UAF's Poker Flat Research Range and the U.S. Air Force, and in 2015 the state contributed $1.9 million more to continue ACUASI development. In 2014 a state task force on UAS use made a number of recommendations, which included encouraging expanded UAS training in the state and working to spur the growth of UAS as an Alaskan industry.

Examples of UA Biology Research Units

- The UAF **Institute of Arctic Biology** advances basic and applied knowledge of high-latitude biological systems.
- The **Alaska Cooperative Fish and Wildlife Research Unit** at UAF is part of a nationwide cooperative university-state-federal program to promote research and training in the ecology and management of fish, wildlife and their habitats.
- The UAA **Environment and Natural Resources Institute** researches arctic tundra, boreal forest and coastal rainforest regions, including environmental contaminants, geochemical resources, and terrestrial-marine ecosystem linkages.
- The UAF-affiliated **Arctic and Bonanza Creek Long-Term Ecological Research** stations support research into the consequences of changing climate and disturbance regimes on tundra and boreal forest ecosystems, respectively.
- The UAF **Agricultural and Forestry Experiment Station** focuses on natural and manipulated ecosystems, sustainable soil productivity, food safety, plant genetics, enhanced livestock production, economic and legal aspects of resource use, silviculture and forest management.
- The **Alaska Coastal Rainforest Center** at UAS is a university-agency effort to research coastal temperate rainforests.
- The UAF **Toolik Field Station** provides housing, meals, laboratories and support services for arctic research and education to scientists and students from universities, institutions, and agencies from throughout the US and the world.
- The UAF **Large Animal Research Station** conducts research, education and outreach in high-latitude biology and provides facilities for and expertise in maintaining colonies of large animals.

Research Arena 6: Human Health

Introduction. Alaska presents health care challenges as well as opportunities for research and innovation. Environmental contaminants and infectious diseases are health issues, as are chronic maladies like heart disease, cancer, and diabetes, and preventable conditions like obesity and substance abuse. Other issues include behavioral and mental health problems (such as suicide, fetal alcohol syndrome, and violence) and the challenge of providing services to a dispersed population. Further, there are glaring health disparities between Alaska Natives and other Alaskans.

Research Initiatives. **Basic, Translational, and Clinical Research.** UA has growing expertise in biomedical and population health fields, including cell biology, neuroscience, physiology, immunology, genetics and computational bioinformatics.

Environmental Health. Disease, parasite and virus vectors are major issues in Alaska. Hepatitis and other STDs, tuberculosis, pneumonia, and *Helicobacter pylori* bacteria are public health concerns. Unusual epizootic diseases erupt in rural villages where people are exposed to feral animals. Severe and catastrophic weather events can render animals and people susceptible to opportunistic infections. Climate change causes new animal migration patterns and human-animal interactions that may increase the incidence of zoonotic diseases such as West Nile virus. Bioterrorism threats present unique challenges in Alaska because of the distances and isolation. Melting and receding glaciers could unleash new types of pathogens.

Other important environmental health-related topics in Alaska include the impact of contaminants on food safety and security; improved infrastructure for water supplies, sewage and waste disposal; air quality; maternal and child health; and occupational health and safety. Also important are ecosystem and human health ties including toxicology, zoonotic diseases and other infectious agents, and methods for monitoring food and water safety.

Rural Health Delivery. Places where S&T research can make significant contributions to rural health care include epidemiology in sparse populations and in harsh winter conditions; emergency treatment in the wilderness; seasonal syndromes and cold-induced injuries; health care and social services delivery to remote regions; and advances in telemedicine, including telepsychology.

Behavioral Health. Alaska has staggering rates of suicide, child abuse, alcoholism, substance abuse, sexual assault and violence. Yet some communities in Alaska are virtually free of these problems. Alaska researchers must parse out what makes these communities resilient compared to their neighbors, and identify effective methods blending cultural values and traditional Western concepts. Since many significant disparities among segments of Alaska's population are in the areas of behavioral health, the intersection of indigenous and Western beliefs and practices are important issues. The Alaska Native health community continues to make essential contributions to these issues, and the people themselves must partner with researchers in their efforts.

Alaska Native Health. Alaska Natives, who make up 15% of the state population, have a unique set of health needs. In addition to behavioral health challenges, Natives are subject to heightened levels of chronic disease due to rapid environmental, social, and economic change. Rural-urban migration, in particular, can have profound health ramifications. Alaska's unique tribal health system, with its university and community partners, serves as a laboratory for testing innovative solutions to these health challenges, and is well-suited for collaborative, translational health research projects. UA also focuses on public health and social services, including studies of rural-urban health disparities.

Veterans. Alaska has a large veteran population, and must further research veterans' needs, including physical and psychological therapies for traumas and stresses. This includes the development and refinement of prosthetic devices for veterans. These research goals may be best met through university partnerships with military agencies.

Strategies

Biomedical research in Alaska is spearheaded by the NIH INBRE program, which is administering a 5-year award focused on health and disease as impacted by interactions among the environment, animals and human behavior. Research topics include influenza and other viral infectious diseases, environmental contaminants, and molecular processes associated with cardiac and metabolic health. INBRE also works to reduce health challenges associated with tobacco, environmental changes, and infectious diseases. UAF's NIH-funded Bioinformatics Core provides computational services to UA life science researchers.

Nursing enrollment at UAA has skyrocketed, and in 2011 UAA expanded the College of Health and dedicated a 66,000-foot health sciences building, the first phase of a new health complex. The expanded program builds capacity for further health initiatives in the state, such as a full medical school, a pharmacy school and a graduate program in biomedical research. The College of Health operates under a 2014-18 Strategic Plan, which includes research partnerships and infrastructure among its priorities. UAA has expanded partnerships to enable students to complete half of their physician's training in Alaska through the UAA WWAMI School of Medical Education, and an entire Doctor of Pharmacy degree in Alaska through Idaho State University.

Major players in Native and rural health are the Alaska Center for Rural Health at UAA and the Center for Alaska Native Health Research (CANHR) at UAF. CANHR operates under a 5-year, $5.3 million NIH grant to conduct research into Native nutrition and obesity, genetics, environmental contaminants, behavioral issues, and other topics. The state Department of Environmental Conservation sponsors the Alaska Water and Sewer Challenge, which organizes teams to brainstorm and build innovative rural sewage treatment systems. One promising line of UA research is studying Alaskan bog blueberries as the basis for human central nervous system therapy.

The UAA Justice Center engages in research on violence and substance abuse. The statewide Alaska Network on Domestic Violence and Sexual Assault evaluates and tests innovative practices, and suicide prevention efforts are stewarded by a state panel, the Alaska Suicide Prevention Council. A state virology lab constructed in 2009 at UAF greatly increased the state's capacity to track viruses and disease vectors, while UAF is conducting a joint program in veterinary medicine with Colorado State University, which includes links between zoonotic disease and human health. A major initiative partners UAF with several North Pacific universities to study childhood obesity. A direct state appropriation in 2015 is funding a pilot community intervention program to reduce levels of fetal alcohol syndrome.

Examples of UAA Health Research Efforts

- The **Biomedical Interdisciplinary Group** in the Office of Research and Graduate Studies works to increase interdisciplinary biomedical research.
- The **Institute for Circumpolar Health Studies** researches health problems throughout the world's northern regions, including current studies of inhalant abuse prevention, HIV interventions, and supportive housing for the homeless.
- The **Center for Behavioral Health Research and Services** is undertaking several studies, including examining aspects of fetal alcohol syndrome, diabetes, and sex offender treatment.
- The **Alaska Center for Rural Health** helps to strengthen systems to deliver comprehensive and culturally relevant health care to rural Alaskans.
- The **Center for Addressing Health Disparities through Research and Education** informs students and faculty about health disparities in Alaska and encourages students from underrepresented groups to pursue health careers.
- The **Center for Human Development** conducts research, education and service in the field of developmental disabilities.

Research Arena 7: Transport and Communications

Introduction. Alaska has less transport and communication infrastructure than any other state. The state has potential for pioneering approaches to land and sea transport, aviation, aerospace, and information technology. In addition, improved telecommunications through the Arctic would place Alaska at the crossroads of global telecommunications, data, and financial networks and position the state for economic growth and new technology industries.

Research Initiatives. **Shipping.** Alaska will be heavily involved in addressing safety, environmental and security concerns engendered by increased Arctic shipping. One research focus is feasibility studies of expanded shipping and related construction of ports and infrastructure. Other shipping S&T includes engineering studies to improve port design and operations and integration of marine transportation into intermodal systems. Research is also needed into global supply chain logistics to decrease the amount of perishables spoiled or damaged en route to Alaskan communities.

Land Transport. Areas for development include intermodal operations; maintenance methods, construction techniques, engines and fuels for extreme weather; improvement of road traction in snow and ice; and engineering practices to reduce road maintenance and improve longevity.

Aviation. Alaska's remote areas with minimal surface infrastructure, varied terrain, severe weather, mix of aircraft, low density of air traffic, contained airspace, and areas of minimal flight restrictions make the state ideal for development of both civilian and military aviation S&T. Research supports Alaska's domestic aviation needs by providing safer and more efficient technology, and can also identify ways to better export goods and services to global customers. An increasing amount of research is also being conducted into the feasibility of using next-generation airships for cargo transport in Alaska. Alaska is also a center for UAS research (see Arena 5.)

Aerospace. Aerospace S&T initiatives in Alaska include the launch of sounding rockets for auroral and atmospheric research, a low earth-orbit launch complex at Kodiak, and study of the physical and electrical properties of the ionosphere. Alaska's sophisticated radars and other ground- and satellite-support instrumentation, the research capabilities of UAF's Geophysical Institute, and the state's geographic advantage for accessing polar satellites affords it considerable potential for expanded aerospace S&T research.

Telecommunications and Information Technology. One state telecommunications priority is increasing wide-bandwidth connectivity to support data and computer operations of NASA, the Department of Defense, NOAA, and the university, as well as other state and federal agencies. Another need is to improve the state's ability to serve rural communities through remote delivery of healthcare, education, and governmental services, as well as to enable universal personal internet use in rural areas to combat the "digital divide." Another need arises from the establishment of integrated long-term monitoring networks across the state (see Arena 5); each group that currently takes remote observations is on its own for communications, resulting in inefficiency, high costs, and considerable interference. Scalable wireless networks taking advantage of satellite connectivity and technologies offer opportunities for coordinated statewide monitoring.

Also key are upgrades to low-earth orbiting satellite services such as Iridium to enable realistic data service speeds in unpopulated areas. Incremental improvements to remote satellite communications would benefit multiple user groups, from fire crews to field researchers. The state must also improve techniques for laying fiber-optic cable in hostile Alaskan environments, such as river crossings and permafrost soil. Also important is improving microwave technology so that the backbone network used in rural Alaska can provide needed high-speed service.

Strategies

A major facet of the Alaska Arctic Policy Commission's 2015 report setting state Arctic priorities was promoting economic and resource development, including facilitating new port systems. The report also recommends improving marine infrastructure to strengthen Alaska's capacity to respond to marine accidents and emergencies. In 2015 UAA opened the Department of Homeland Security-funded Arctic Domain Awareness Center, which works with 16 partners to conduct research in maritime domain awareness, situational awareness and response support, technology research, and integrated education. Alaska has funded Arctic vessel tracking system upgrades, digital mapping, and an Arctic deep-water port study.

The Alaska University Transportation Center at UAF hosts about $7 million in funded research annually. Anchorage-based Peak Civil Technologies is pioneering a new soil stabilizer that could vastly improve foundations for transport infrastructure, and the CCHRC recently studied geopolymer concrete. The UA was central to developing the revolutionary NextGen air traffic control system and is one of four founding FAA Centers of Excellence for General Aviation. NASA recently held a series of workshops in Alaska on the potential for airship testing and use.

The Alaska Aerospace Corporation operates the Pacific Spaceport Complex, a state-of-the-industry launch site on Kodiak Island that provides access to planetary orbital space for commercial and government interests. The state-owned corporation is in the process of potentially converting to a public-private partnership. In 2014 the corporation started negotiating a $21 million incentive plan with Lockheed Martin to use the facility for Lockheed's Athena II S-6 medium-sized rocket. Sounding rocket and UAS testing takes place at UAF's Poker Flat Research Range. UAF recently took possession of the High-Frequency Active Auroral Research Program (HAARP), a former Air Force operation used to study the ionosphere.

One major recent expansion of broadband has come via Terra, a federally-supported project by General Communications Inc. that has linked up more than 49,000 residents in 72 rural communities in western Alaska and plans to expand farther into the state's west and north. The Arctic Fibre company is also planning a subsea cable network connecting Asia to Europe that would link to Alaska's north and west coasts, bringing broadband to more than 26,500 rural Alaskans. The Arctic Slope Regional Corporation is heavily invested in the effort. The Tlingit and Haida Central Council is working to implement a broadband strategic plan for rural Southeast Alaska.

The Alaska Satellite Facility in Fairbanks

Education

Introduction. The most significant way for the state of Alaska to contribute to S&T innovation is through ensuring quality K-12 and university educations, especially in science, technology, engineering and math (STEM) fields. The contributions that engineers, scientists, and other STEM workers make to the state are multifaceted, as they solve problems and bolster the economy.

Research Initiatives. **K-12 Education.** Alaska's biggest educational challenge is K-12 teacher retention, especially in rural areas. At issue is not just retention in general, but the need for teachers with expertise in given areas, such as math, science and special education. A closely related issue is professional certification for teacher aides, and methods to transition these aides – who are often the most stable element in their schools - into teaching.

Distance Delivery. Distance delivery of education is essential in Alaska, both because of its size and dispersed population, and because of the need for students to accommodate other endeavors – such as subsistence activities and jobs - while learning. Challenges for distance delivery include communications systems, teaching methods, faculty proficiency, integration of distance and traditional programs, and cultural relevance and acceptability.

STEM. Guiding students into STEM careers begins at the K-12 level. Many different state, university and private programs work to increase STEM awareness in Alaska through a variety of methods, including incorporating STEM research into instruction and increasing STEM identity among students. (See boxes, below.)

University of Alaska. About 75 percent of STEM workers need a bachelor's or graduate degree for their positions, compared to only 20 percent of non-STEM workers. The UA, with more than 31,000 students statewide, is crucially important to the state as a STEM teaching institution. The UA in recent years has concentrated on training Alaskans for high-demand jobs in engineering, health, biomedicine, teaching and workforce development, which strongly correlate to STEM fields. The university has recently focused resources on engineering and health disciplines, with strong results: the number of engineering degrees awarded increased 25 percent from 2009-13 and health degrees 20 percent in the same period. UA awards about 50 doctorates per year, of which more than half are in STEM disciplines. Students themselves are also key conductors of research at the UA. One goal for the state is to improve the enrollment and retention of disadvantaged (i.e. minority, low-income or first-generation) students in STEM majors.

Another state goal is to gauge the success of specific programs at the UA, such as the Alaska Native Science and Engineering Program, the Alaska Summer Research Academy, the Rural Alaska Honors Institute, the Della Keats Health Sciences Summer Program, the Alaska Upward Bound Program, and the federally-supported TRIO programs, and work to optimize their impact on STEM students and others.

Examples of Alaska STEM education efforts

- The **Juneau Economic Development Council** conducts STEM programs in fields like robotics, underwater remotely operated vehicles, and environmental science.
- The **Alaska Native Science and Engineering Program** (ANSEP) at UAA (with UAF and UAS units as well) supports Native students from sixth grade through grad school, including academies, academic support, professional development, and financial aid for college students.
- **GeoFORCE Alaska** is a UAF program to excite high-schoolers about Earth science through a series of events which culminate in annual weeklong field trips to sites across the country.
- **Alaska GLOBE**, based at UAF, instructs K-12 teachers on how to run classroom-based research projects into the environment and climate to teach students about science.
- The **Modern Blanket Toss** is an effort by Alaska EPSCoR and the Alaska Upward Bound program to excite rural high school students about STEM fields through experiments with UAS.

Strategies

Recent innovations by the state include Alaska Performance Scholarships for high-performing students to attend in-state college or training, and rigorous new K-12 academic standards. The Alaska Commission on Postsecondary Education spearheads an Alaska Postsecondary Access and Completion Network, which aims to increase the percentage of Alaska's adult population with a postsecondary credential and/or degrees from 47% to 65% by 2025 through synergy among service providers, professional development, public outreach, and research.

Improving teacher retention is the main goal of the Alaska Statewide Mentor Project, which mentors instructors and administrators in 70 percent of Alaska's public schools. The UA has adopted several programs to improve teacher training, including a new UAF bachelor's degree in Secondary Education that qualifies students for teaching jobs without post-degree training, a UAF graduate certificate in science teaching and outreach, and a UAS master's program in science education. UAS also offers two new teacher endorsement programs via distance delivery.

Alaska's Learning Network offers a number of remote core courses across the state's school districts. A state-funded Alaska Digital Teaching Initiative pilot program is improving student access to distance education in four school districts. UAF's eLearning and Distance Education Office offers 129 distance programs.

The state has invested heavily in UA science infrastructure recently, including engineering buildings at UAA and UAF, health and integrated sciences buildings at UAA, the Murie Life Sciences Facility at UAF, and a NOAA-UAF fisheries facility in Juneau. The state has also provided targeted funding for UA students in critical S&T areas: health; oil, gas and mining; engineering; education; and fishing, seafood processing and maritime fields. The Consolidated Alaska Mining Initiative is collaborating with industry to build a state-of-the-art Juneau mine training center.

UA also improves infrastructure through collaborating with federal programs: the current Alaska NSF EPSCoR award includes STEM education programs and funding for six new faculty hires, and EPSCoR's 2017-22 proposal includes five more hires. The proposed program also includes research into first-generation students and values-affirmation and education-difference interventions, proven ways to improve achievement by underprivileged students. The NIH Biomedical Learning and Student Training (BLaST) program offers funding opportunities and programs for undergraduate and graduate UA students in biomedical fields, with a focus on rural Alaskans. Both of these programs emphasize research by students, which is an important element of the UA research enterprise.

UA recently concluded a public input process called "Shaping Alaska's Future 2017," which centered on improving student achievement and attainment, fostering research and development for economic growth, providing accountability to the state, and partnering with schools, agencies and industries. Recommendations from that process have been used to shape university management policies, budget requests, and other university governance.

Examples of Alaska STEM education efforts

- NASA's **Challenger Learning Center of Alaska** provides space science-oriented camps, custom programs and workshops to K-8 students.
- The UAF-based **Alaska Summer Research Academy** offers 2-week STEM learning academies for middle- and high-schoolers and a year-round Saturday program.
- Alaska NSF EPSCoR and GINA have built three interactive **augmented-reality sandboxes** which are used to teach students across the state about topography, hydrology, and related topics.
- UAF's "**Girls on Ice**" program engages diverse groups of high-school-aged girls in field science and STEM activities through extended field trips to glaciers. Alaska NSF EPSCoR has proposed expanding the program to also incorporate trips to Kachemak Bay and Interior Alaskan forests.

A Note on Direct Business Engagement

Improving Alaska's S&T landscape requires cooperation between leaders in government, academia, research groups, business, and organizations. Perhaps the most important way state and local agencies can foster increased S&T development is to provide entrepreneurs with the support they need to cross the "valley of death," the challenging step between developing a product and actually producing and marketing it. This support can take the form of instruction and business connections, or the more direct form of venture capital. Several programs already exist in Alaska that provide financial support and other services to inventors hoping to establish a market for their innovations.

At UAA, the Business Enterprise Institute links economic development programs across the UA system. These include the Alaska Technology Research and Development Center (TREND), which provides workshops, one-on-counseling, and grant assistance to small businesses attempting to garner federal Small Business Innovation Research and Small Business Technology Transfer grants, which can be used to bring technology to market. The UAA Office of Research and Graduate Studies has formed a commercialization infrastructure that includes the Seawolf Venture Fund, LP, a for-profit private equity fund which provides early-stage funding for start-up companies based on research from UAA and the community. UAA also established Seawolf Holdings to oversee the fund and to provide a corporate interface between the university and its enterprise companies. This investment infrastructure created its first start-up in 2013, specializing in battery-free long-lifespan remote sensors, and other UAA-patented technologies have ranged from educational software to biomedical devices.

The UAF Office of Intellectual Property and Commercialization works with UAF faculty, staff and student inventors to guide them through the process of intellectual property licensing and protection. It also works with industry partners interested in sponsoring research, licensing technology, or forming startups around UAF innovations. A partner organization, the Nanook Innovation Corporation, is responsible for licensing UAF intellectual property, and owns a majority share of Nanook Tech Ventures, Inc., a for-profit corporation that works with UAF faculty, staff, and students to create startup companies and viable businesses based on their research. The firm's first two spinoff startups build software for UAS, and tools to manage airborne particulate risk from volcanic eruptions and other events.

The Municipality of Anchorage's 49th State Angel Fund was started in 2012 with $13.2 million from the U.S. Treasury's State Small Business Credit Initiative. This was split into four partner funds which began awarding grants to startups in 2014, with a goal of providing capital to Anchorage entrepreneurs to spur economic development.

The Alaska Marketplace is an annual competition sponsored by the Alaska Federation of Natives to identify innovations with the potential to create jobs and to stimulate state and local economies. Winners receive substantial grant funding as well as entrepreneurial training to refine their concepts. The UAF School of Management hosts an annual Arctic Innovation Competition with similar aims.

Also worth noting is the Alaska Higher Education Income Tax Credit, which encourages private industry to support university research and education by tying donations to tax credits. A similar credit exists for K-12 education as well.

Aurora over the UAF campus

Appendix 1: Drafting Process and SCoR Membership

Drafting Process. "To Build a Fire" is based on "Alaska Research and Development," a statewide R&D plan written in 2003. In 2011 the State Committee for Research authorized a redraft of the plan. An initial outline was prepared in early 2012 by then-SCoR co-chairs Mark Myers and Mead Treadwell. The plan was then written and laid out by Alaska NSF EPSCoR staff. Drafts of that plan were presented to the full SCoR, which recommended changes which were implemented in November 2012.

The November 2012 draft was presented at public meetings held in Fairbanks, Anchorage and Juneau in March and April 2013. Comments from these meetings were incorporated by EPSCoR staff into a new draft presented to SCoR in October 2013. Recommendations from this meeting were incorporated into a final draft and presented at a SCoR meeting in January 2014. The document was updated by NSF EPSCoR staff under SCoR direction in December 2015-April 2016, and approved by the full SCoR in May 2016.

SCoR Membership

1. Byron Mallott, Committee Co-Chair Lieutenant Governor, State of Alaska	12. Alex Hills Distinguished Service Professor, Carnegie Mellon University
2. Dan White, Committee Co-Chair UA Vice-President for Academic Affairs and Research	13. Larry Hinzman UAF Vice-Chancellor for Research
3. Sarah Barton President, ConsultNorth	14. Brian Holst Executive Director, Juneau Economic Development Council
4. Aimee Devaris Alaska Regional Director, U.S. Geological Survey	15. Karl Kowalski UA Chief Information Technology Officer
5. Craig Fleener Arctic Policy Advisor, State of Alaska	16. Mark Myers Former Commissioner, Alaska Department of Natural Resources
6. Samuel Gingerich UAA Provost and Vice-Chancellor for Academic Affairs	17. Anupma Prakash Principal Investigator, Alaska NSF EPSCoR
7. Richard Glenn Executive Vice-President for Lands and Natural Resources, Arctic Slope Regional Corporation	18. Karen Schmitt UAS Vice-Provost for Research and Sponsored Programs
8. Steve Gray Director, Alaska Climate Science Center	19. Mead Treadwell President, Pt Capital, LLC
9. Larry Hartig Commissioner, Alaska Department of Environmental Conservation	20. Fran Ulmer (ex officio member) Chair, U.S. Arctic Research Commission
10. James Hemsath Director of Project Development and Asset Management, Alaska Industrial Development and Port Authority	21. Brian Barnes (ex officio member) Director, UAF Institute of Arctic Biology
11. Susan Henrichs UAF Provost and Executive Vice-Chancellor for Academic Affairs	22. Denise Thorsen (ex officio member) Director, Alaska NASA EPSCoR

Appendix 2: Acronyms

AAPC	Alaska Arctic Policy Commission
ACEP	Alaska Center for Energy and Power
ACUASI	Alaska Center for Unmanned Aircraft Systems Integration
AEA	Alaska Energy Authority
ANSEP	Alaska Native Science and Engineering Program
ASET	Applied Science, Engineering and Technology
BLaST	Biomedical Learning and Student Training
CANHR	Center for Alaska Native Health Research
CCHRC	Cold Climate Housing Research Center
EPSCoR	Experimental Program to Stimulate Competitive Research
FAA	Federal Aviation Administration
FSMI	Fisheries, Seafood and Maritime Initiative
GI	Geophysical Institute
GINA	Geographic Information Network of Alaska
GIS	Geographic Information Systems
GLOBE	Global Learning and Observations to Benefit the Environment
HAARP	High Frequency Active Auroral Research Program
ISER	Institute for Social and Economic Research
K-12	Kindergarten through 12th Grade
NASA	National Aeronautics and Space Administration
NIH INBRE	National Institutes of Health IDeA Network of Biomedical Research Excellence
NOAA	National Oceanic and Atmospheric Administration
NPRB	North Pacific Research Board
NSF	National Science Foundation
RAP	Resilience and Adaptation Program
R&D	Research and Development
R/V	Research Vessel
S&T	Science and Technology
SCoR	Alaska State Committee for Research
SFOS	School of Fisheries and Ocean Sciences
STEM	Science, Technology, Engineering and Math
TREND	Technology Research and Development Center
UA	University of Alaska
UAA	University of Alaska Anchorage
UAF	University of Alaska Fairbanks
UAS	University of Alaska Southeast
UAS	Unmanned Aerial Systems
USGS	United States Geological Survey
WWAMI	Washington, Wyoming, Alaska, Montana and Idaho