QUANTUM EDUCATION & WORKFORCE DEVELOPMENT

ACTION STEPS FOR MONTANA

NOTES FROM NEW FRONTIERS:
A STATEWIDE CONVENING OCT. 11, 2024

MSU Science Math Resource Center

Montana Work-based Learning Collaborative

Montana Photonics and Quantum Alliance

Montana State University Applied Quantum CORE

with support from the Air Force Research Laboratory

MONTANA
STATE UNIVERSITY

QUANTUM EDUCATION & WORKFORCE DEVELOPMENT: ACTION STEPS FOR MONTANA

Notes from New Frontiers: A statewide convening Oct. 11, 2024

INSIDE:

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www.montana.edu/smrc/quantum/convening/

Montana State University Quantum
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Montana Work-based Learning Collaborative
www.wblmt.org

Montana Photonics and Quantum Alliance
www.mpqa.org

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Photos by Jacob Weber and Lee Spangler.

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MONTANA STATE UNIVERSITY
Science Math Resource Center

Work-based Learning Collaborative MONTANA

MONTANA PHOTONICS & QUANTUM

New possibilities and connections

Whether or not you could join us in person on Oct. 11, 2024, we welcome you now as we recap the speakers, panels and – most importantly – conversations, ideas and brainstorms that took place during New Frontiers: Education and Workforce Development in Quantum and Emerging Technologies.

By design, many of our audience members were invited to the meeting in Bozeman not because they know about quantum mechanics, computers, sensors or networking, but rather for their expertise in workforce and career pathways; K-12, higher and adult education; community development; and how industry, government and non-profits can play a role in advancing economic development in Montana.

Together, we learned about quantum, optics, photonics and other emerging technologies and why they have put Montana on the map as well as the current role that Montana State University and its partners play in advancing the quantum ecosystem and how Montana's rural composition and entrepreneurial spirit can be the driver for transformational change.

Inside you will find recaps of our two outstanding keynote speakers and overviews of our panels on workforce development and rural issues. You will also learn how and why Montana is uniquely positioned right here and right now to take advantage of emerging developments in quantum.

Lastly, you will read a synopsis of YOUR thoughts, questions and ideas as well as concrete action items we can explore to move forward.

We hope you will be energized as you read (or revisit) these ideas. As you do, keep your mind open to new possibilities and connections, and, as Dean Tricia Seifert implored in her opening remarks:

> *Just as light can be both a particle AND a wave, let us shed our 'either/or' mentality moving forward and instead frame our reality as 'both/and'.*

Thank you for your contributions and interest in education and workforce development as we move onward to 2025, the International Year of Quantum! We know you will be both engaged and inspired.

– Suzi Taylor, Director, MSU Science Math Resource Center
Education and Workforce Development Lead, MSU's Applied Quantum CORE

P.S. Special thank you to our partners with the Montana Work-based Learning Initiative. Their insights and connections to workforce development ideas and professionals were invaluable. Additional thank to MSU's vice president for research and economic development, Dr. Alison Harmon, for her opening remarks, overall support and vision for growing MSU's capacity and contributions.

To see video recordings of the keynote speakers and panelists, visit the MSU Quantum Convening website

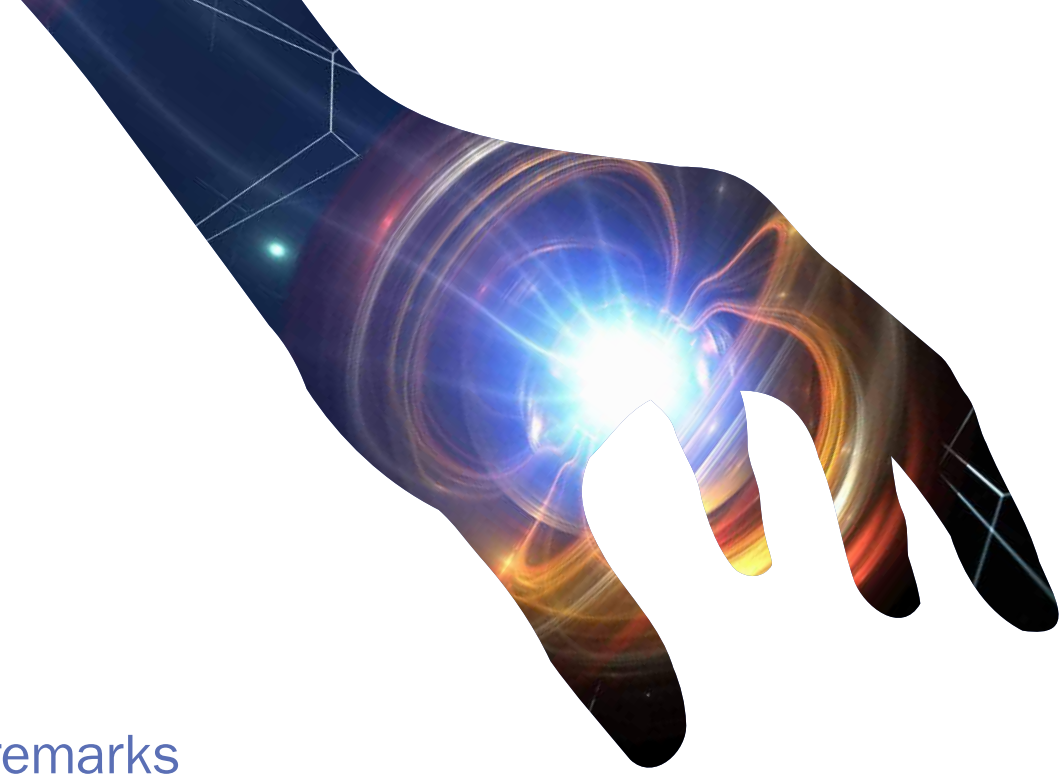
http://bit.ly/Q-convening

What is Quantum?

Everything physical around us is made of matter, from the air we breathe to the water we drink – even our own bodies are made of matter. In its smallest measurable form, matter is made up of atoms. Within atoms are even smaller particles called electrons, protons and neutrons – and protons and neutrons are made of even smaller units of matter called quarks.[1]

At this very small scale, the universe behaves quite differently than the everyday world we observe around us,[2] and materials' properties – such as melting point, electrical conductivity and even color can change significantly from those at larger scales.[3] Quantum scientists and engineers are discovering how to harness these unusual properties to create faster, more sensitive and more precise systems in electronics, including sensors, location systems, computers and medical equipment.[4] Many Montana companies are positioned to provide materials and technologies for – and jobs in – the growing industry.

1. Excerpt from https://www.nasa.gov/directorates/somd/space-communications-navigation-program/world-quantum-day/
2. Excerpt from https://www.livescience.com/33816-quantum-mechanics-explanation.html
3. Paraphrased from https://www.nano.gov/about-nanotechnology/what-is-so-special-about-nano
4. Excerpt from https://www.montana.edu/news/23386/montana-state-receives-26-7-million-grant-for-facility-to-test-and-promote-quantum-technology



Opening remarks

Tricia Seifert

I confess that I do not have a scientist's understanding of quantum mechanics. In fact, the first time I heard the word 'quantum' was the TV show "Quantum Leap." This might have also been your first interaction with the word 'quantum' and its concepts. Yet, our lack of familiarity with the quantum world is not unusual. This has led me to think it is important to demystify quantum – to the extent possible – by highlighting points of connection between quantum theory, how we engage as learners (whether in the K-12 or college classroom or work place), and life.

First, the duality principle of quantum objects – which of course is all things – is particularly interesting. We may think of matter in its concrete/particle form, but it is actually comprised of waves. Only at the point of measurement does the wave 'behave' such that we view it as a particle. The fact that matter is both wave and particle reorients how we think about the nature of things. No longer 'either/or', the wave and particle reality invites us to frame things as 'both/and'. This is an important lesson to share with the people who will be part of the quantum workforce. For example, learning difficult concepts can be both challenging and captivating. It is challenging in its particle nature (measured perhaps at the particular moment of frustration) but it also possesses a wave that is captivating.

The uncertainty principle is refreshing, as a teacher and a learner. Quantum theory holds that we do not simultaneously know exactly where something is and how fast it is going. Said simply, we cannot know position and momentum at the same time. Because of this, nothing can be measured with certainty but rather within a probability. Often students become discouraged because they think (or maybe they have been taught) that there is only one correct/certain answer. There is little recognition that an approach to responding to a question may be optimal within a probability function. As an educator, I want to leverage this quantum principle and invite learners to view uncertainty as the foundation for ideating, and creating. In a world in which we have a false sense of certainty, quantum thinking invites us to develop greater comfort with ambiguity which is actually the centerpiece of our world.

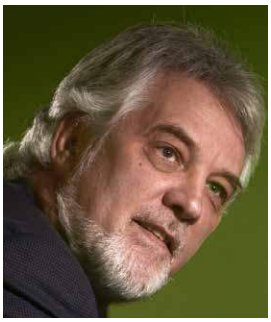
Finally, quantum is like life; it is not simple. There are interference patterns, impermanence, complexity. Recognizing the complicated nature of things makes today's gathering of such enormous value. We sit among diverse groups of people – scientists, educators, designers and artists, workforce trainers – people from institutional contexts that range from industry, to the military to tribal colleges and public two-year and four-year colleges and universities. We may have different approaches and I hypothesize it is these diverse perspectives that will enable us to glimpse the particle of the future and chase its wave forward.

I am extremely excited to learn with and from you in conversation today. Thank you for taking the time to be part of this important convening.

– Tricia Seifert,
Dean, MSU College of Education, Health and Human Development

Setting the scene: Why Montana? Why Now?

Dr. Joe Shaw and Dr. Lee Spangler, Montana State University



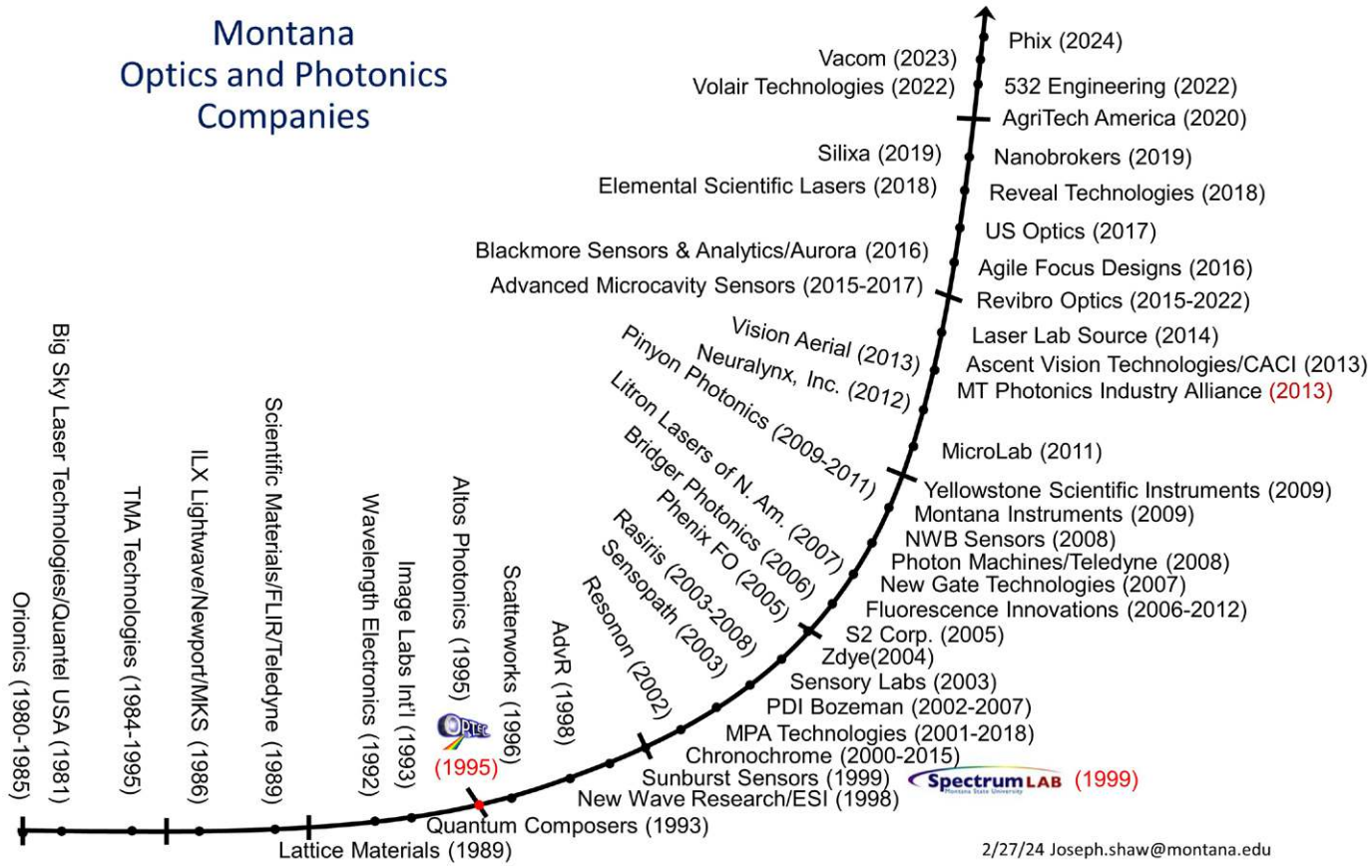
Dr. Joe Shaw

MONTANA'S ROOTS IN QUANTUM AND EMERGING TECHNOLOGIES

Dr. Joe Shaw, director and distinguished professor with MSU's Optical Technology Center, began the day's talks with an overview of Montana's history of success in optics and photonics, the science and technology of light. OpTeC was formed in 1992 and has been promoting research and education in optics and photonics for economic development in the Gallatin Valley ever since. At that time, the emerging photonics cluster consisted of four MSU faculty members (two in physics, one in electrical engineering and one in chemistry) and four companies (Big Sky Laser, ILX Lightwave, Scientific Materials, TMA & Associates). Today, the Gallatin Valley photonics ecosystem consists of more than 20 faculty and more than 40 companies, making the area one of the highest concentrations of optics and photonics companies in the nation. This university-industry ecosystem has seen skyrocketing growth and has put Montana on the map for high-tech capabilities, thus seeding the way for the nascent quantum industry to grow.

One of the most significant recent developments in Montana's optics, photonics and quantum fields is the 2024 designation by the Economic Development Association of a regional technology and innovation hub called the Headwaters Tech Hub. With $41 million from the EDA, the HTH aims to become a global leader in smart, autonomous, photonic remote sensing technologies. The consortium seeks to develop and deploy smart photonic sensing systems coupled with autonomous systems to address critical defense, resource management, and disaster prevention needs.

To ensure that the impacts of these projects benefit the entire region, components of the strategy are led by Tribal and two-year colleges, and activities include providing robust wrap-around services for workforce development participants.



6 Since the early 1980s, the number of optics and photonics companies in Montana has grown to more than 50.

Dr. Lee Spangler

NATIONAL INTEREST IN QUANTUM

Dr. Lee Spangler, MSU associate vice president for research and economic development, gave an overview of national interest in emerging technologies like quantum:

- The pandemic revealed strong dependencies on other countries for critical technologies
- Not all of those countries are friendly to the U.S.
- This resulted in bipartisan legislation – the CHIPS and Science Act in 2022
- The primary goal of this Act is to increase US competitiveness in critical and emerging technologies
- The Act created a new directorate in the National Science Foundation called Technology, Innovations and Partnerships (TIP) with a goal of translating more research into societal benefit
- It also created programs in the US Economic Development Administration, which funded the Montana-based Headwaters Tech Hub

KEY TECHNOLOGY FOCUS AREAS OF NATIONAL IMPORTANCE

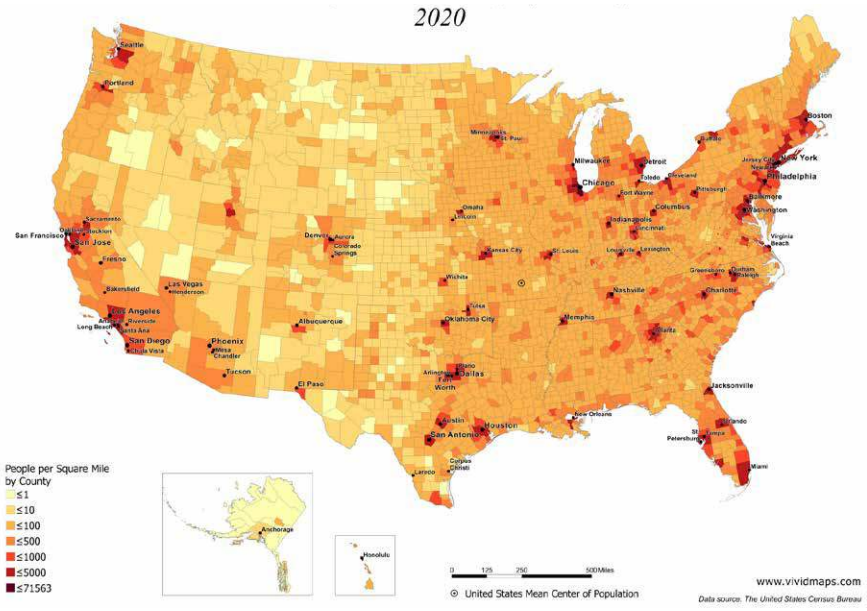
The Notice of Funding Opportunity for Phase 1 Tech Hubs (which funded the Headwaters Tech Hub) included ten key technology areas of focus. Note the emphasis on quantum information science and technology. MSU is a leader in many of these other areas, as well, such as cybersecurity and 2D materials.

1. Artificial intelligence, machine learning, autonomy, and related advances;
2. High performance computing, semiconductors, and advanced computer hardware and software;
3. Quantum information science and technology;
4. Robotics, automation, and advanced manufacturing;
5. Natural and anthropogenic disaster prevention or mitigation;
6. Advanced communications technology and immersive technology;
7. Biotechnology, medical technology, genomics, and synthetic biology;
8. Data storage, data management, distributed ledger technologies, and cybersecurity;
9. Advanced energy technologies, such as batteries and advanced nuclear;
10. Advanced materials science, including composites 2D materials, other next-generation materials, and related manufacturing technologies.

MONTANA'S POSITIONING AS A RURAL STATE

Spangler shared that the National Science Foundation and other funding programs are particularly interested in increasing the nation's latent capacity for innovation by creating new business and economic growth opportunities in regions of America and within untapped populations and under-served communities that have not yet fully participated in the technology boom of the past several decades. This bodes well for Montana:

- Montana is one of the country's most rural states
- Many communities are just now getting broadband
- Lack of reliable high-speed internet has had negative consequences for economic development and education
- This was particularly felt during the pandemic
- One of the best ways not to fall behind is to be a leader



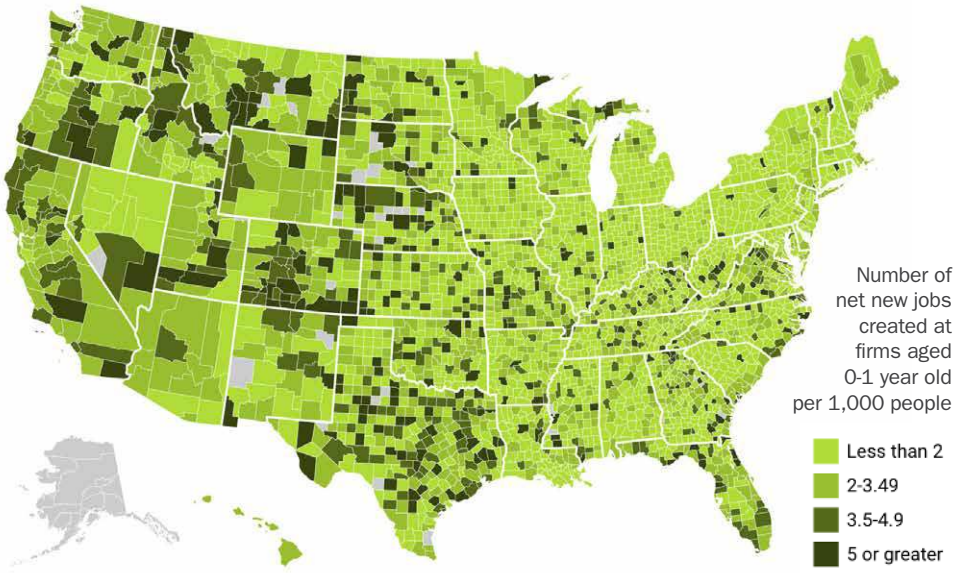
U.S. Population Density by County. *https://vividmaps.com/us-population-density*
Courtesy of VividMaps.com

Spangler noted that interestingly, some of the most rural areas of the country are also the most innovative and entrepreneurial. For instance, the Innovation Intelligence Index (II3) from StatsAmerica provides regional characteristics related to innovation and entrepreneurship to help advance economic development. The calculation takes into account:

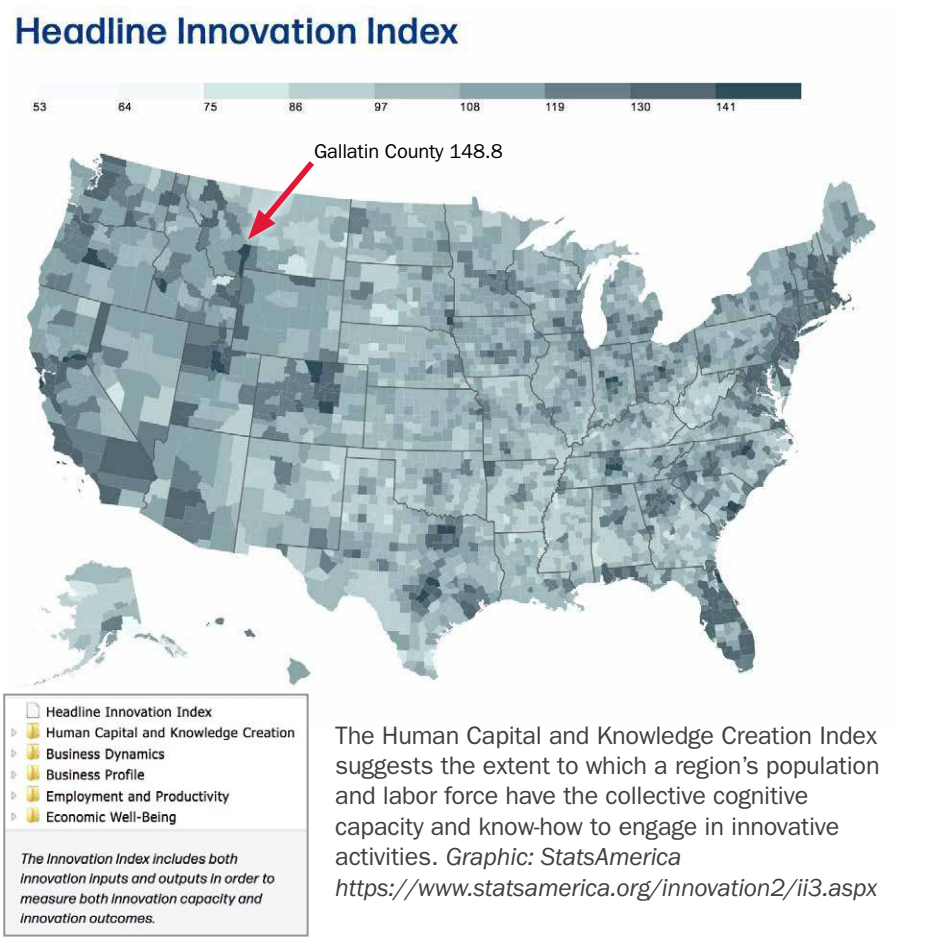
- Human capital and knowledge creation
- Business dynamics
- Business profile
- Employment and productivity
- Economic well-being

Note that several counties in Montana rank quite highly on the most recent index, including Gallatin County (home to Montana State University), which ranks in the highest tier of innovation intelligence in the country.

Gallatin County and other regions in Montana also rank in the highest tiers of entrepreneurial activity. The Kauffman Indicators of Entrepreneurship offers a visualization of the number of net new jobs created at firms aged 0-1 year old per 1,000 people, an indicator of entrepreneurship activity.



Entrepreneurial Jobs Indicators, Job Creation 2020
Graphic: https://indicators.kauffman.org/]



The Human Capital and Knowledge Creation Index suggests the extent to which a region's population and labor force have the collective cognitive capacity and know-how to engage in innovative activities. *Graphic: StatsAmerica https://www.statsamerica.org/innovation2/ii3.aspx*

RURAL ENTREPRENEURSHIP

Data show that rural areas like Montana rank highly for innovation inputs and outcomes, as well as entrepreneurship. Rural counties have more small "mom and pop" businesses and self-employed people than do metropolitan areas. Rural businesses are also more resilient and last longer than those in more urban areas.

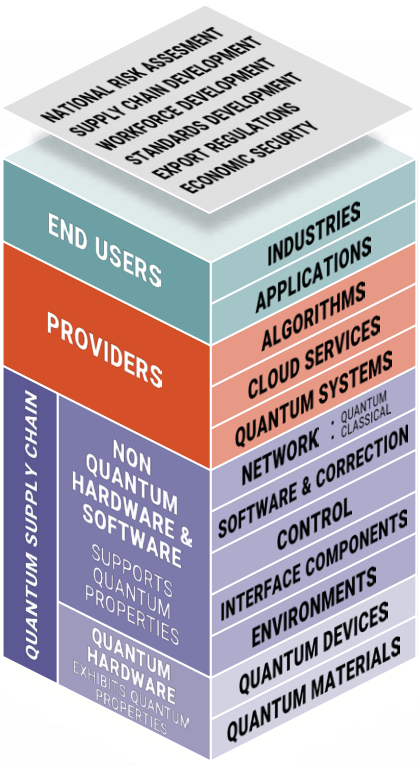
According to The Conversation, "most people mistakenly believe that startups occur overwhelmingly in metropolitan areas. Yet it is in fact rural counties that have higher rates of self-employed business proprietors." A related bar graph shows that rural areas with population less than 2500 people and not adjacent to a metropolitan area have the highest rate of proprietorship (234 per 1,000 people as compared to 131 per 1,000 people for metropolitan areas of 1 million or more). Relatedly, businesses in communities of 2,500 or less have the highest five-year rate of survival (71.6%), despite the economic advantages of more urban areas.

All these factors uniquely position Montana to take advantage of the country's interest in emerging technologies while ensuring equitable distribution of funding opportunities to rural and underserved areas of the country.

Visualizing the Quantum Ecosystem

Borrowing from a common technical visualization technique, the "stack," the Quantum Ecosystem Stack diagram below was developed by the Quantum Economic Development Consortium and the MonArk Quantum Foundry (of which MSU is a partner) to represent the entire quantum ecosystem.

Montana businesses primarily play a key role in the bottom (purple) part of the stack, producing non-quantum hardware and software that support quantum properties and hardware components that exhibit quantum properties. This key element of the quantum ecosystem is considered the quantum supply chain and is critical to providing the systems and components that enable quantum computing.



The Quantum Stack

Policy and Strategy

INDUSTRIES	Communications, Transportation, Aerospace and Defense, Automotive, Finance, Life Sciences, Energy …
APPLICATIONS	Logistics, Simulation, Cybersecurity, Financial modeling, Materials discovery …
ALGORITHMS	Algorithms for applying quantum hardware and software to each applications …
CLOUD SERVICES	Cloud services for delivering quantum technology solutions to customers.
QUANTUM SYSTEMS	Computing, Distributed Computing, Secure Communications, Sensing Network …
NETWORK : QUANTUM CLASSICAL	Protocols, specialty cladding fiber …
SOFTWARE & CORRECTION	SW and FW for controlling quantum hardware necessary for a quantum produces.
CONTROL	Cryogenics CMOS, SFQ, control electronics, stabilized lasers, latest CMOS technology …
INTERFACE COMPONENTS	SNSPDs, QLAs, cryoLNAs, cryoRF, HD connectors and wiring, I/O, AOMs, ion traps, lasers, detector arrays …
ENVIRONMENTS	Cryocoolers, compressors, dilution refrigerators, sorption coolers, ADRs, UHV chambers, thermometry …
QUANTUM DEVICES	Qubits (sc, ion, atom, defect, quantum dot, photonic), transducers, memory, sensors, entangled sources …
QUANTUM MATERIALS	Rare-earth, two dimensional, superconducting, non-linear photonic, thin film, micro-fabricated …

Q-EDC and the MonArk Quantum Foundry

Keynotes

Two keynote speakers were carefully selected for New Frontiers in order to share advances and innovative ideas from around the country on quantum literacy and workforce development.

Dr. Tim Akers represented the National Quantum Literacy Network, and Scott Halliday presented on the Center for Advanced Manufacturing at Navajo Technical University.

Tim Akers is associate provost for academic research and chief research officer in the Office of Academic Research at California State University, San Bernardino. He is also CEO of the National Quantum Literacy Network. Akers presented "Building a Quantum Literacy Ecosystem for Learning and Workforce Development: A Call to Action" and was introduced by Luke Mauritsen, founder of Montana Instruments, who serves on the national board of directors for the NQLN.

Akers' talk included three important questions:

- **WHAT IS NEEDED** by the U.S. as a national science, security, education and economic development imperative?
- **HOW** do we track our progress in quantum literacy education, workforce development and competitiveness?
- **WHERE** do we begin to **RAPIDLY** educate our national workforce, policymakers, program managers, academics and military?

Akers shared that basic understanding of quantum physics is not brand new; in fact, Albert Einstein presented on the topic nearly 100 years ago at Lincoln University. But our rapidly growing understanding of quantum technology is quickly revolutionizing computing and impacting every facet of society from smart phones to healthcare and global communication. Quantum mechanics are everywhere and provide the functioning technology for devices ranging from a microwave oven or smart phone to an MRI machine or nuclear power plant. Quantum technologies lead to faster processing times that transform experiences, as well as more accurate sensors that save countless lives.

However, hackers could use quantum computing to steal data and disrupt

Dr. Tim Akers, National Quantum Literacy Network

society. They could impede military engagements in the air, interfere with strategic objectives on land, and halt protective operations at sea. Quantum power in the wrong hands threatens the safety of our world.

Akers said our geopolitical adversaries are ahead of us in many ways. China invested $18 billion in quantum technologies from 2017-22; the U.S. invested just $2.2 billion during that time period.

But, he said, an interdisciplinary quantum literate workforce can help

Government Jobs!	Industry Jobs!	Education Jobs!	Military Jobs!
Policy Analyst	Quantum Research Scientist/Technician	Quantum Physics Professor/Lab Technician	Quantum Cryptanalyst
Quantum Technology Regulator	Quantum Software Engineer	Quantum Computing Lecturer	Quantum Communications Specialist
Science Advisor	Quantum Hardware Engineer	Quantum Curriculum Developer	Quantum Sensor Engineer/Technician
Quantum Technology Grant Manager	Quantum Algorithm Developer	Quantum Research Lab Manager	Quantum Radar Specialist
Quantum Infrastructure Specialist	Quantum Materials Scientist/Technician	Quantum Technology Outreach Coordinator	Quantum Security Analyst
Quantum Technology Patent Examiner	Quantum Applications Sales Representative	Quantum Education Program Manager	Quantum Warfare Strategist
Quantum Communications Policy Analyst	Quantum Network Architect	Quantum Ethics Researcher	Quantum-based Electronic Warfare Specialist
Quantum Standards and Metrology Specialist	Quantum Machine Learning Researcher	Quantum Science Librarian	Quantum Computing Technician
Quantum Technology Economic Analyst	Quantum Error Correction Specialist	Quantum Technology Career Counselor	Quantum Satellite Systems Engineer/Technician
Quantum Technology Liaison Officer	Quantum Supply Chain Analyst	Quantum Science Journal Editor	Quantum Technologies R&D Coordinator

mitigate these risks, and not everyone needs to be trained as a quantum physicist in order to contribute. Every quantum application: photonics, optics, lasers, cryogenics, sensors, computing, networking, machine learning, has components – its pieces and parts. The industry will need technicians, measurement specialists, evaluators, and more, none of whom have to understand how it all works to play a critical role.

Akers also shared data from the McKinsey Digital Quantum Technology Monitor Reports (see Appendix) showing that the four industries most impacted in the near future by advances in quantum technologies – chemicals, pharmaceuticals, automotive and financial services – have an economic value of nearly $1.3 trillion. But the industry will bring a wide variety of new jobs, not all of which are technical.

According to Akers, quantum workforce opportunities will span nearly all disciplines and all levels of experience: Tribal and community colleges, Historically Black Colleges and Universities (HBCU's), Hispanic-Serving Institutions (HSIs), first generation college students, rural communities – all those who have not traditionally been part of this space. He shared that his own past educational experiences – vocational education, military service and community college – have influenced his view on quantum literacy, and he challenged our nation to embrace all sectors in order to advance the quantum economy.

Akers echoed Montana's positioning as a key piece in the quantum supply chain: all the components that are needed for building quantum computers can be assembled and manufactured here in this state and sold to those who are building quantum computers.

Akers concluded by reiterating that the country needs to invest in quantum literacy at all levels. We should think about how to help people in one career pivot to another, we should consider how neurodiverse people may learn differently and develop strategies for inclusive education, and we need to invest – rapidly and immediately – in quantum literacy for all ages and sectors.

For more information, visit https://quantumliteracy.org/

Scott Halliday is director of the Center for Advanced Manufacturing at Navajo Technical University in Crownpoint, New Mexico.

From taking apart his mom's washing machine (complete with ball bearings all over the floor) to building the center that houses New Mexico's first metal additive manufacturing (AM) machine, Scott Halliday is creating niche opportunities for students on the Navajo Nation in order to catalyze economic development.

Halliday is director of the Center for Advanced Manufacturing (CAM) at Navajo Technical University in Crownpoint, N. Mex. (population 2,823). Though NTU with its 1500 students is the largest of the country's 38 tribal colleges and universities (TCU's), it is still in a very rural area. Overnight visitors to the campus must stay an hour away, and, like other rural communities, the area struggles with access to broadband Internet, roads, electricity, water and essential services like childcare.

When Halliday helped start the CAM, the Navajo Nation had no manufacturing businesses, and Halliday saw a need to create economic opportunities. It has since grown into a hub for research, education, industry partnerships, and economic sustainability.

Believing that tomorrow's researchers may be today's technicians, CAM follows a Technician-to-Engineer-to-Scientist progression, and as early as freshman year, students are operating equipment worth hundreds of thousands of dollars. They learn the metal additive manufacturing (AM) industry from a holistic view: Pre-processing, processing, validation, and post-processing. The whole

Scott Halliday, Center for Advanced Manufacturing at Navajo Technical University

system is under one roof, which is highly unusual. While students in the program can specialize in one area, many have become highly sought after for internships, jobs and advanced degree programs due to their hands-on experiences and holistic knowledge of the industry.

Halliday said TCU's can lead the way in emerging technology industries, and offered these words of advice:

- TCU's are generally agile. They are looking to address local needs and often can create niche programs. Allow them to be experts and contribute to what's going on in the state.
- There is a lot of money for TCU's as well as many opportunities to fund good ideas as long as they are supporting the school. The National Science Foundation's TCUP program is one. However, sustainability can be tough when consistently relying on soft money (grant funding).
- A strategic plan is essential – not just 5 years, but longer. The plan will be critical to getting grants, as you can articulate where you are, where you've been and where you're going. Explain why you need certain pieces of equipment and what you will do with them.
- Be prepared to operate in an "unknown economy:" You may not know who your customers will be or how much product they will buy. You may have to trust the "Build it and they will come" mantra.
- Choose partners carefully. Some may come with a very orchestrated plan

on how it's going to work. Out-of-state partners may be looking to boost counts of minority students. Instead, make partnerships that work for both of you - Both partners need to have skin in the game
- Make multiple partners - Don't put all your eggs in one basket. Multiple partners provide multiple resources
- Keep projects manageable
- Can your project still be successful if partners get busy?
- Prepare for bringing together your partners
- Consider whether your partnerships can expand into larger projects?

What does economic development look like on the Navajo Nation?

- Smaller distributive manufacturing businesses that impact communities that want them.
- Working with Navajo Nation Economic Development Dept to identify those communities
- Working to create infrastructure and advance quality of life.

For more information, visit http://digitaltech.navajotech.edu/ hhalliday@navajotech.edu

Panel: Industry and Workforce Needs

Moderator:
Dr. Stephanie Gray,
Dean of Gallatin College

Panelists

- Luke Mauritsen, Founder of Montana Instruments
- Todd Hawthorne, AdvR
- Jason Yager, Montana Photonics and Quantum Alliance
- Jenni West, Montana Manufacturing Extension Center
- Laura Wessing, Air Force Research Laboratory

The goal for the industry panel was to gather representatives from quantum-related companies and professional associations together with university, state and national level workforce development specialists to discuss ways to promote quantum and quantum–adjacent career pathways and identify successful methods of workforce development around the state of Montana.

What should every high school or 2-year college student be learning right now to prepare themselves for quantum-related occupations?

The panel emphasized the importance of hands-on learning, specifically building, taking apart and fixing things. Robotics programs were mentioned by several panelists as an effective method to enhance student interest in this type of learning

and interaction with electronics, sensors, optics and coding. One panelist pointed out that in rural communities, kids often get this type of experience by fixing tractors and farm equipment. Other skills on which to focus included:

- Learning to communicate effectively – being able to explain what you did, why you did it and, importantly, receive feedback about your work (being able to learn on the job)
- Problem solving – figuring out the next step when things don't work
- Basic math and how to apply it

Finally, panelists discussed passion and excitement as keys to getting students interested in quantum-related topics and career paths.

How do you envision industry in these fields working alongside high schools, 2-year and 4-year institutions across Montana to grow the quantum workforce?

The panel agreed that hands-on apprenticeships, internships and other work-based learning that get students' understanding of the theoretical aligned with the practical are valuable ways for industry and educational institutions to work together.

Specific programs mentioned as good examples of this type of opportunity include:

- Accelerate Montana (online 9-week certificate program with experience embedded in industry)
- Gallatin College Photonics and Laser Technology program founded in 2016 has since had 100 percent placement of graduates

Other programs that encourage crossover between industry and education include:

- EconoQuest Montana – economics-related high school competition with specific focus on photonics and quantum industries
- Spark Photonics – an example of educational programming created by a company in the semiconductor and photonics industry (programs are currently being implemented in Glendive and Billings, Montana). Spark is now also developing curriculum on quantum.

Panelists also placed importance on industry representatives sitting on educational advisory boards and vice versa. Finally, the industry representatives agreed that taking the time to have visits and conversations with other companies from around the world has led to many new ideas and opportunities capitalizing on the Montana photonics and quantum industry.

Can you speak to the photonics/optics/quantum-adjacent occupation opportunities?

Occupations adjacent to and supporting these fields include jobs like machining and welding. The focus of the conversation became the importance of both a hands-on workforce and increased automation (both to address the workforce shortage of the last several years). The panelists stressed the importance of workforce development in those hands-on fields but also the growing career opportunities in programming, data analysis and CNC (computer numerical control) machining – creating automation to solve the need for as many workers and creating more efficient manufacturing processes.

What advice would you give to educators about how they should be changing their classrooms?

The general message conveyed by the panelists was that we must start thinking about classrooms being everywhere. In essence, the workplace is a classroom. Panelists emphasized the importance of creating the space and time for students and educators to go off campus and visit labs and industries. Examples of structured opportunities to do this in Montana included:

- Montana Instruments' High Tech Apprenticeship program, which allowed high school and college students to get paid hands-on summer experience, but was costly both financially and in terms of time commitment
- Work-based Learning Collaborative Montana

To address the issues that living and working in a state as large, remote and geographically diverse as Montana presents, the panel suggested solutions that might lead to accessibility and scalability. Panelists stated that we have to find ways for students to be able to learn where they are. For example, while classroom visits from researchers or industry representatives might be feasible in urban areas, visiting distant schools is not always possible. Potential solutions included:

- Virtual tours, such as a 360 virtual tour of the Air Force Research Laboratory accessible for free, online.
- A mobile technology demonstration unit, or "lab in a van" is in production at Montana Manufacturing Extension Center (MMEC) through funding from the Department of Energy to be able to both show manufacturing facilities what automation might be appropriate for their companies and share these technologies with students
- Events and public tours related to Manufacturing Day (each year in October)
- Resources such as Discovery Education, described as a "Netflix for teachers" providing programs for students followed by potential virtual visits from volunteer industry representatives
- Externships for high school teachers through the Work-based Learning Collaborative

Final questions and Ideas from the audience

- Consider how to inform school administrators/boards on the importance of hands-on programs like robotics so that they increase the priority of these programs in schools across the state.
- Think about how do engage our communities so that qualified parents and others can volunteer to help with this
- Note that while Career and Technical Education (CTE) teachers and classes as well as robotics programs are beneficial and potentially key, many rural schools in Montana don't have these teachers or programs

Audience Reflections

During the convening, attendees engaged in "table talk" discussions to reflect on the panel presentations and explore actionable insights. These discussions were facilitated by convening leaders and structured around key questions related to advancing quantum literacy, education and workforce development. Participants documented their thoughts on sticky notes, posters and personal notebooks.

REFLECTIONS AFTER THE INDUSTRY PANEL

Following the industry panel, attendees discussed four guiding questions:

What additional information would you like to have?

Many of the audience members had little prior knowledge about quantum and sought resources, such as free and accessible materials for educators and the public, to further educate themselves. Attendees specifically referenced the McKinsey Digital Quantum Technology Monitor Reports (which Tim Akers referenced in his keynote address) as valuable resources but noted that they are difficult to "translate." Additionally, guests were interested in hearing how employers in the field could be incentivized to better support youth and adult learners. They understood that businesses still need to be profitable, and opportunities need to be convenient to entice industry partners.

What opportunities do you see within your community or sector to support quantum literacy, education and workforce development?

Several ideas emerged on how our audience members could see themselves supporting quantum in their sector, including:

- Expanding outreach infrastructure, such as distributing quantum activity kits to teachers and students in rural areas. The Science Math Resource Center (SMRC) at MSU already does this, but including more partners could improve awareness and reach.
- Enhancing communication strategies to meaningfully engage students in elementary and middle schools, homeschool settings, students at two-year and tribal institutions, and lifelong learners.
- Offering more learning and teaching opportunities for students and teachers. Potential opportunities include externships where educators visit companies, or sabbaticals for learning and exploration.
- Supporting people with disabilities through vocational rehabilitation programs and disability-focused employment initiatives in the field.
- Collaborating with employers to create impactful activities for younger students and developing programs for non-college-bound learners.
- Funding dual-enrollment classes introducing quantum concepts.

Additionally, some groups explored the potential of VR/AR (virtual reality and augmented reality) and AI (artificial intelligence) as educational tools but emphasized the need to address bias in AI datasets by including cultural insights from Tribal elders.

What obstacles might present barriers to training more individuals in Montana for quantum and emerging technology fields?

A lot of the table conversations revolved around how teachers are incentivized to teach in Montana. Despite opportunities to be a part of or even create meaningful programs, there are shortages of teachers across Montana, particularly in tribal and rural communities. Participants specifically highlighted the need to support low-income and first-generation students in pursuing careers not only in quantum and emerging technology but also in education. That way future educators will be better able to support future students facing similar challenges.

Can you envision any initial action steps?

From these conversations, participants proposed actions such as:

- Partnering with organizations like Montana State University, the University of Montana, Montana Digital Academy, Accelerate MT, Micron Technology, qBraid, and Department of Energy national labs to create educational curriculum and work-based learning opportunities (e.g., job shadowing, internships, apprenticeships). Additionally, participants suggested that the state government has an important role and is in a unique position to support and further the initiatives.
- Engaging with industry HR departments and recruiters to prioritize diversity in hiring.
- Creating quantum-specific curricula for educators and policymakers, as well as expanding professional development opportunities for educators.

Panel: Emerging Opportunities in Rural Contexts

Moderator:

Dr. Jayne Morrow, National Institutes of Standards and Technology (NIST); currently serving as CEO of Montana State University's Applied Quantum CORE

Panelists:

- Scott Halliday, Digital Technology Center Coordinator, Navajo Technical University
- Dr. Rita Kratky, Vice President of Academic Affairs, Miles Community College
- Kortny Rolston-Duce, Director of Ecosystem Development, Quantinuum
- Dr. Lori Stiglitz, Workforce Development Lead, US Navy Joint Hypersonics Transition Office
- Jim Swan, Chief Executive Officer, RJS & Associates

The goal of the panel was to learn about challenges and opportunities related to emerging technologies and their impact on Montana's rural and tribal communities. Much of the development in Montana's photonics and optics industry has thus far been in the Gallatin Valley; how can we think "beyond Bozeman" as we consider jobs, education and opportunities for all people in Montana?

Based on your experiences, how have rural and tribal places been left behind during historical shifts in the economy, and what can we learn from these past experiences that may benefit us as we are looking at emerging technology today?

Panelists described multiple challenges related to why rural and tribal places have been left behind, including the absence of broadband Internet, and, in particular, how that lack of access impacted students during COVID. Panelists also noted that communities fear "brain drain" – people needing to move away in order to find work when many rural people would rather stay in their communities. And, although small rural businesses are already serving clients around the country and the world, many new tech businesses may not see the return on investment for locating in rural areas. Suggestions included:

- Make sure rural and tribal community leaders are included in discussions and opportunities early on, not AFTER getting a grant
- Community colleges and community organizations can partner to bring technologies into rural areas
- Diversity of thought is highly desired – people from different places, races and socio-economic status bring innovative thinking
- Encourage employers to include rural and Native talent in their workforce
- Expose all Montana students to opportunities and the encouragement that the opportunities can exist for them – they are not just for people in cities.
- We need to embrace the shift from a natural resources economy to an information technology economy.

How can we lean in and take actions to help position rural and tribal communities for potential transformative shifts and the changes in society that will result? What do we need to be doing now?

Panelists encouraged the audience to share with students that they should be open to a growth mindset throughout their careers, which are no longer a single line (e.g., my dad was a barber). Careers are now less like a ladder and more like a jungle gym – we need to be open to more connections. They also encouraged short- and long-term strategic planning with concrete, measurable goals.

Audience question: In many small communities, teachers are not properly prepared – they are teaching on an emergency authorization or provisional license. What can we do?

- Pay teachers more
- Provide affordable housing for teachers
- Pay teachers for professional learning and give them opportunities to collaborate
- Online is great, but we need to provide in-person experiences
- Encourage new ways of learning – there's more than one way to get to an answer
- Give kids opportunities to learn from industries throughout the state.

Panelists also suggested that partnerships need to be more than one-off opportunities. We need resources to support long-term relationships for education but also industry. If we want industry to do longer-term projects, or help kids see what careers are possible, they need support, too.

We are on the cusp of a truly transformative and exciting time in history. Quantum systems are grounded in who we are fundamentally as humans, and we don't often talk about that. Can you share ideas and opportunities that have developed today?

The panelists were enthusiastic and encouraging when it came to outcomes from the day's conversations. Comments included engaging rural communities to inspire kids and support parents, connecting and providing free resources to them, outreaching to rural and tribal students with opportunities, and collaborating with organizations such as FFA and 4-H to expand awareness.

But panelists also noted the challenges – it's harder to share opportunities with young people when they don't see them nearby or know people in the industry. It's even tougher for first-generation students... how can we support their parents?

Ideas included:

- For institutions that have resources, don't come in too strong – listen first to what a community needs
- Show students all the areas they can go into
- Find ways to send students to internships in other counties across the state
- Utilize Zoom or Teams to put students in labs and companies, even if just for a day
- Get high schoolers engaged in conversations like these
- Could we form mini-ecosystems (like the people on this panel) to develop a national model?

Final questions and ideas

- Technicians are so valuable! We can't operate high-tech equipment if we don't have anyone to fix it when it breaks down
- The global supply chain is critical – if we are dependent on lasers from the European Union or helium from Qatar (for cooling high-tech systems), we are vulnerable to supply chain breakdowns
- Industry needs to step up and say what they need. As we move from research to a manufacturing state, we need to talk realistically about what businesses are needed

The bottom line at the end of the panel was "sourcing and supply chain challenges in quantum can and should be met by Montanans. Let's work together to make this happen."

Audience Reflections

REFLECTIONS AFTER THE RURAL PANEL

Following the rural panel, discussions focused on how to expand access to quantum and emerging technologies for Montana's youth and workforce.

How can you and your organization support access to quantum and emerging technologies?

Guests highlighted the importance of engaging with respective Nations and tribal colleges early on in the conversation, particularly in the grant proposal process. Participants emphasized the importance of modernizing materials and using inclusive language to foster understanding. Creative approaches, such as integrating art into quantum education, were also highlighted.

Do you see statewide or local needs that should be addressed?

Attendees identified the following needs that should be addressed:

- Support non-traditional learners who may not pursue four-year college pathways.
- Provide additional support (e.g., higher pay, summer employment, and affordable and accessible continuing education) for teachers, especially those in tribal communities.
- Support students in tribal communities. Many people face homelessness and housing shortages that prevent them from receiving equitable access to STEM opportunities.

What collaborative actions could address these needs?

Participants recognized that we need to build a "community of practice" to foster cross-sector collaboration. Additionally, we are more able to engage Tribal partners through compelling and culturally relevant hooks. Suggestions included:

- Hosting additional educator conferences and experiential learning opportunities for students.
- Educating policymakers and journalists to better support STEM and quantum initiatives.
- Sharing Indigenous stories.
- Addressing misconceptions about career opportunities in the state and the diverse credentials available.

Can you envision any action steps that you might take?

Attendees highlighted the need for legislative efforts to support quantum education, including the creation of quantum-specific curricula for legislators to better understand the field themselves. Participants explained that if they are working with tribal communities, they need to ensure the individuals in the communities are identifying and sharing what help and support they need, rather than identifying these for them. This will help better support sustainable partnerships where all parties benefit from the work. Across all discussions, participants agreed on the importance of *"meeting communities where they are"* to promote inclusivity in quantum education and workforce development.

Facilitated Discussion

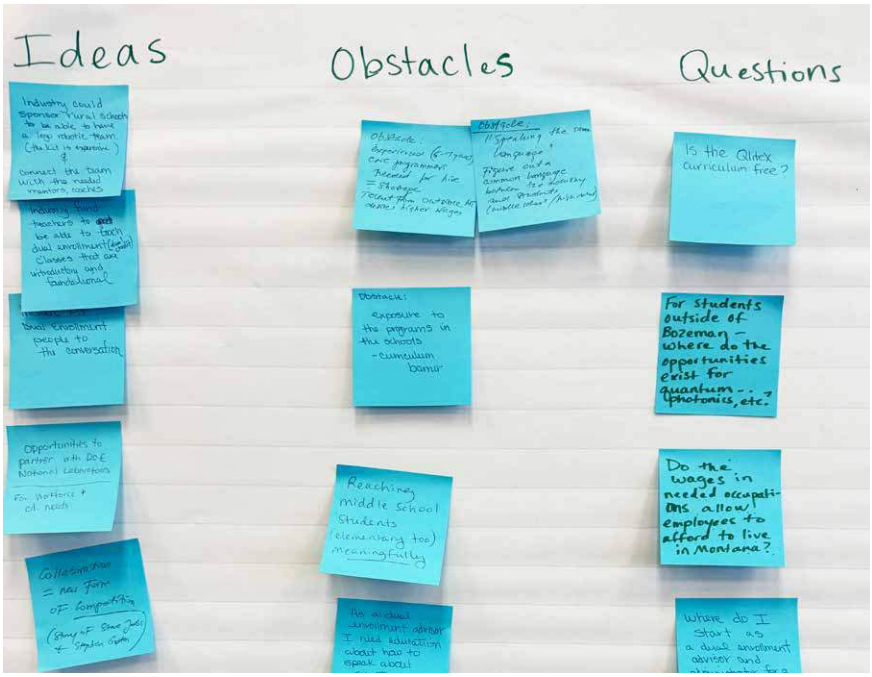
The quantum convening final session included facilitated discussions on four key topics: quantum and emerging technologies for rural communities, higher education, quantum literacy in K-12 and informal learning, and career pathways. These conversations brought participants from similar sectors together to capture the final thoughts of the day. The aim was to encourage attendees to develop action steps in areas most relevant to their work.

RURAL PATHWAYS

Rural community member and experts in rural education attended the rural pathways session. A key take-away from the session: to meet rural communities where they are and to encourage inclusion. The attendees discussed continuing to distribute a quantum science activity kit to rural and tribal students as well as encourage TRIO students to become teachers, as a robust educational ecosystem attracts industry. (Students who qualify for the federal TRIO program are first generation, low income, and/or students with a disability.) Many comments spoke to the need for exposure to quantum and emerging technologies by talking about current applications already in place (e.g., cell phones) as well as providing affordable and accessible continuing education training for rural teachers.

HIGHER EDUCATION

The higher education session engaged attendees from some of Montana's four-year universities and two-year colleges in Montana and Wyoming. These individuals discussed the need to continue to engage in conversations with both employers and K-12 school systems. Additionally, they expressed interest in further reports on the future quantum workforce, particularly here in the Rocky Mountain West.



QUANTUM LITERACY

Attendees at this session included both classroom and out of classroom educators. The key takeaways included a need for more classroom materials and resources and connections to quantum careers. We need to help students understand their secondary education options, whether that is four-year college, community college or options like Montana Conservation Corps. Most students in high school will not attend college, but schools are oriented towards colleges. Students are often set in their ways before they can choose what they want.

Several individuals shared STEM resources that could be used when engaging in quantum literacy and outreach events (see Appendix).

CAREER PATHWAYS

The attendees at the career pathways session included individuals who work in emerging industries and those involved in workforce development. These individuals shared thoughts on incentivizing more internship opportunities to allow additional career explorations and to remove barriers in offering and accessing internships in quantum and quantum-related careers.

KEY THEMES AND TAKEAWAYS

Across all discussions, participants agreed on the importance of listening to what communities need and promoting inclusivity in quantum education and workforce development. There was a strong consensus that career awareness, specifically understanding the diversity of opportunities in the field, is a critical first step towards improving quantum literacy and supporting education and workforce development. Guests remarked that "there is a large ecosystem around quantum, and you don't have to be an engineer or physicist to participate." Particularly in this field, the need for compelling spokespeople, communicators, and educators is essential to fostering a supportive ecosystem and driving meaningful change.

"We want quantum translators who will speak to a wide range of individual interests and abilities."

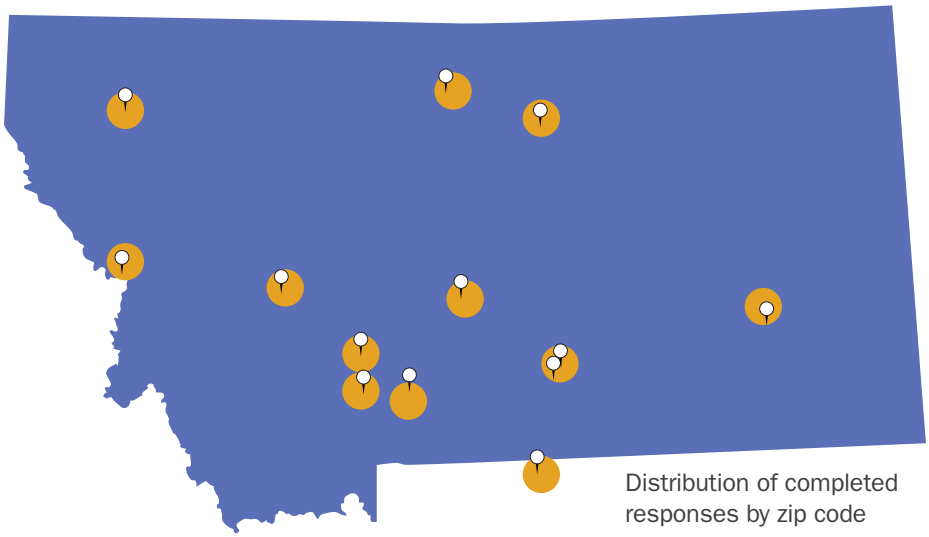
"We want more visualizations of "who" is quantum– like an "I am Quantum" poster series or a collection of visuals of everyday objects that use quantum."

Post Convening Feedback

What new knowledge did you gain at today's convening?

- That there are many different areas related to quantum and many different ways to learn about them.
- Different examples of what Quantum is
- Quantum specifics and opportunities, services / programs in MT
- Quantum opportunities
- How diverse the quantum industry is
- The quantum supply chain is crucial
- An overview of Quantum Technology and how it can be incorporated into our nonprofit programs: Tourism, Language Revitalization, Food Sovereignty and Youth Leadership. The many opportunities in quantum technology for tribal communities, tribal/rural schools & colleges, nonprofit organizations.
- Needs of the quantum workforce.
- Breadth of opportunity in the quantum arena, how widespread, urgent, and multifaceted the need is, and that there are many ways to get involved.
- A better understanding of quantum and how deep it goes in manufacturing. Great information.
- So much!
- Lots of good connections, knowledge of internship dynamics and opportunities to improve this for the quantum industry
- Opportunities on the Fort Belknap Indian reservation
- I learned a lot more about the numerous pathways available in the quantum industry in Montana and beyond.
- The community is ready to hear about these opportunities
- Overall, not to be afraid to learn things you might not understand. Also, there are other perspectives of learning and adapting in the workforce.
- Insights into what Montana is focusing on in quantum and their look forward on how this will expand
- Quantum Literacy resources, as well as an unrealized enthusiasm for industry to be involved in K-12 education with regards to quantum and photonics!

"This convening was just outstanding. The more industry (any industry) and education can work together the more relevant learning is for our students. I believe Quantum and Photonics here in Montana has the opportunity to be not just an industry leader, but a model for how business and education can work together!"



Distribution of completed responses by zip code

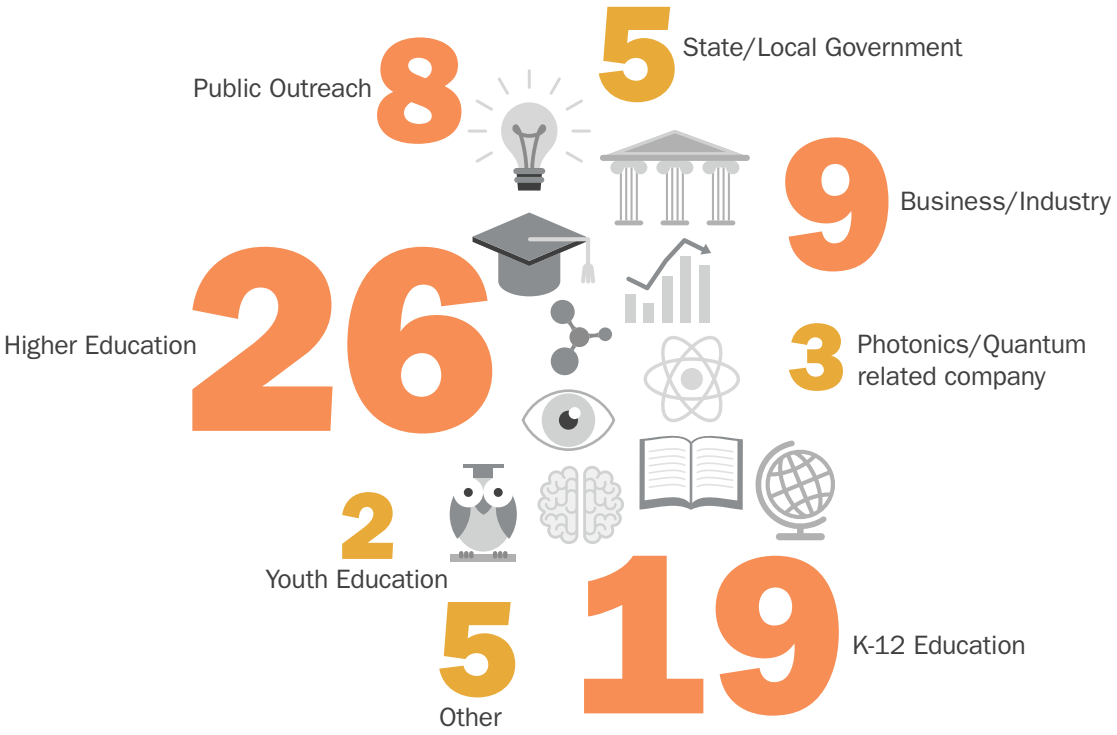
What action steps will you take?

- Create new projects within the organization
- Specific examples: "creating a new career pathway" and "new summer programming" from K-12 education and youth outreach members.
- Sharing of information/report out to the organization
- Connecting with attendees through email
- Setting up meetings with attendees
- Reaching out to community partners
- Reading research reports from the meeting

Whose voices should have been included but were not present at the convening?

Several people commented that the mix of individuals present was appreciated. However, others reported wanting to hear from:

- More tribal college educators/tribal leaders
- K-12 personnel explaining education in Montana today
- State representatives
- Local high school superintendents, principals, educators, school board members, nonprofit boards, for profit boards, tribal college professors, tribal MSU Extension staff, high school and college students.
- TCUs (Tribal colleges and universities), but understand why they weren't here.



Quantum Convening Participation by Professional Role

- Montana College Attainment Network. MT Dept. of Labor.
- The economic development people in our community.
- I can't think of any! The inclusion of rural and Tribal voices was essential and appreciated.
- Solutions providers to bridge the gap between technology and students
- OPI, educators, counselors, CTE teachers, administrators
- It would have been helpful to hear about additional emerging technologies.
- I would have loved some high school and college student representation to gain their perspective regarding barriers to entry and journeys

What additional information would you like or what questions do you still have?

- More specific examples of what Quantum is and where it is being used
- More about opportunities
- Curricula for a quantum course
- To learn more about how quantum technology can be incorporated into our nonprofit programs, for profit corporations, tribal council, directors, tribal colleges, high schools. What additional educational quantum technology workshops.
- So many questions!!! Can I get modules? Can I get more collaborations?
- More specifics on what we can make in our communities.
- This was good for a first conversation but in the future I hope we can have more focus on particular issues or goals
- Would like to start a process with partnering and see how we can be helpful
- I recommend developing a one-page document of essential information that we can easily distribute to our students. A lot of great information was shared at the conference, but I would appreciate help with distilling that into impactful, bite-sized chunks for high school students.
- I'd love to know more about the role of software engineering in this realm

Anything else we should know?

- Networking with tribal MSU Extension staff to help start the introduction of sharing quantum technology with tribal program directors, tribal colleges, tribal schools, nonprofits and for profits. Also, a fabulous quantum tech workshop. I learned lots.
- Tribal participation at Navajo Technical University!
- This was one of the best conferences I've been to. I was skeptical at first, but learned so much and came out with great ideas.
- That this was wonderful, and I hope we do this again!
- Thank you for providing this cool forum! This type of work must continue across our state to empower the next generation. The Montana College Attainment Network is a great resource with this purpose.
- This convening was just outstanding. The more industry (any industry) and education can work together the more relevant learning is for our students. I believe Quantum and Photonics here in Montana has the opportunity to be not just an industry leader, but a model for how business and education can work together!

Convening summary

This convening sought to bring together diverse thought partners from across the state, region and nation to address critical questions and barriers as Montana moves toward what could be a transformative quantum economy.

Many questions were answered, but many more remain, and we hope future conversations can shed more light on our path forward.

The growing quantum, photonics and other high-tech industries in Montana face challenges related to education and workforce development. High-tech businesses are primarily located in Bozeman and the corridor that extends to Missoula and up to Kalispell. How could this reach other areas, where people want to stay and support their communities? And, for the critical entry-level non-technical jobs in Bozeman and other larger areas, how can we address high housing costs and affordable childcare? How can we better learn or predict the needs of national high-tech companies, so small businesses in Montana can produce the components they need? And, do we even have enough workers to fill these new jobs if they came?

Educators and administrators understand the importance of this new wave of technologies but need resources: cohesive language around new technologies and greater exposure for students. For instance, how could K-12 students engage with industry early on while earning dual credit and/or overcoming age restrictions that limit job shadowing and internships? How could community college students be placed in internships in other Montana counties?

To support these educational initiatives, industry is encouraged to form partnerships with schools, offering resources and expertise while promoting mentorship programs and community engagement. Ideally these experiences would be for prolonged periods of time rather than one-offs, for which industry may need additional support. Addressing the shortage of STEM and CTE (Career and Technical Education) teachers is crucial, particularly in rural areas, where localized education programs can help bridge the gap. Sabbaticals or externships in industry settings can also empower K-12 and community college educators to bring real-world applications into the classroom, enhancing student learning and interest in these fields.

We also need to spread the word to policymakers and citizens that a growing quantum industry won't necessarily replace an existing one – we can actually have *"both, and."* For example, Dr. Lee Spangler shared that in the early days of Montana's photonics industry, a presentation to the Montana Legislature outlined that Montana photonics revenue is the same as winter wheat production, but with no change to winter wheat revenue. *Montana can have both viable industries.*

Even small steps can be meaningful. In a small community, a machine shop with twenty good paying jobs can make a significant difference – creating and maintaining community vitality.

Looking ahead, Montana needs to prioritize funding for education, particularly in STEM and CTE programs, and develop curricula that encompass a wider range of skills beyond robotics. By fostering early exposure to non-traditional manufacturing and technology careers, expanding apprenticeships, and ensuring ongoing support for students, the state can cultivate a skilled workforce ready to meet the demands of the quantum and photonics industries. Collaborating closely with local communities will be essential to align educational efforts with workforce needs and support economic growth in both urban and rural areas.

FINAL TAKEAWAYS INCLUDE:

- Montana's strong photonics and optics ecosystem positions our state well to support and supply the emerging quantum industry
- While Montana's rurality has some challenges, we view this as an asset:
  - Rural places rank highly for entrepreneurship and innovation
  - Rural kids grow up with hands-on skills and resourcefulness
  - Federal funding is available for rural communities
  - "Mom and pop" businesses are well-positioned to make high-value, low-volume components critical to the quantum supply chain. Even a small number of new jobs can make a big difference in a small town
- The quantum industry will need all types of jobs and skills levels, from trained technicians to PhDs
- NOW is the time to build partnerships and support quantum literacy at all levels

Exhibitors

During our morning breakfast, the following groups engaged with attendees and presented resources and information about their organizations:

American Computer & Robotics Museum

Jake Chipps—The American Computer & Robotics Museum, located in Bozeman, Montana, inspires visitors of all ages to explore the past and imagine the future of the Information Age through thought-provoking exhibits, innovative storytelling, and the bold exchange of ideas. **acrmuseum.org**

Montana Afterschool Alliance / Montana STEM Ecosystem

Heather Jameson—MTAA serves as the champion for afterschool and out-of-school-time programming and extended learning opportunities in Montana. MTAA also leads the Montana STEM Ecosystem, a network of organizations, institutions, industries and individuals working to expand STEM (science, technology, engineering, and math) learning opportunities across the big sky. **mtafterschoolalliance.org/stem-ecosystem**

Montana Photonics & Quantum Alliance

Jason Yager and Dana Terry—The Montana Photonics and Quantum Alliance serves as a hub for Montana's optics, photonics, and quantum companies, entrepreneurs, laboratories, and universities to commercialize, grow and sustain globally leading organizations that create high quality jobs and economic opportunity in Montana. **www.mpqa.org**

Montana State University School of Art

Bruce Barnhart—Assistant Teaching Professor Bruce Barnhart brought together students and faculty from MSU's School of Art, Stone Child College, and the University of Washington for a program to work with botanists and quantum physicists while creating unique works of art called cyanotypes or "sun prints." **art.montana.edu**

Reach Higher Montana Work-Based Learning Collaborative

Gabrielle Rowley—The Montana Work-Based Learning Collaborative works to promote belonging, meaning, well-being, and purpose for all young Montanans by building capacity for high-quality work-based learning opportunities. **wblmt.org**

WHAT IS THE SCIENCE MATH RESOURCE CENTER DOING NEXT?

The Science Math Resource Center is a STEM outreach center in the Department of Education at Montana State University. The Center leads education and workforce development efforts for MSU's Applied Quantum CORE.

- April 2025 – World Quantum Day outreach activities
- Summer 2025 – Quantum Camps for students AND teachers

WHAT ARE NEXT STEPS YOU CAN TAKE?

1. Subscribe to our Quantum **newsletter** to receive updates. **bit.ly/MSUquantum-info**
2. Read the ***Quantum Under the Big Sky: Education and Workforce Development Report.***
3. Visit the **Science Math Resource Center website** to see our future work.

Works Cited

Tech hubs notice of funding opportunity (NOFO). (2023). Economic Development Administration.
https://www.eda.gov/sites/default/files/2023-05/Tech_Hubs_NOFO.pdf

Innovation intelligence user guide. (n.d.) StatsAmerica.
https://www.statsamerica.org/innovation/reports/Innovation%20Intelligence%20User%20Guide_final.pdf

Appendix

Accelerate Montana:
https://www.acceleratemt.com/

Air Force Research Quantum Laboratory 360 Tour:
https://dafstem.us/afrl-quantum-lab-360-tour/

EconoQuest Montana:
https://www.montanaworldaffairs.org/econoquest

Gallatin College Photonics and Laser Technology program:
https://gallatin.montana.edu/academics/photonics-laser-technology/

McKinsey Digital Quantum Technology Monitor Reports:
https://www.mckinsey.com/~/media/mckinsey/business%20functions/mckinsey%20digital/our%20insights/quantum%20technology%20sees%20record%20investments%20progress%20on%20talent%20gap/quantum-technology-monitor-april-2023.pdf

Montana State University Science Math Resource Center:
https://www.montana.edu/smrc/quantum/

Quantum Newsletter for education and info
https://bit.ly/MSUquantum-info

Quantum Under the Big Sky: Education and Workforce Development Report:
https://www.montana.edu/quantum/QuantumEducation-WFD-MT24.pdf

Spark Photonics:
https://www.sparkphotonics.org/

Work-based Learning Collaborative Montana:
https://wblmt.org/