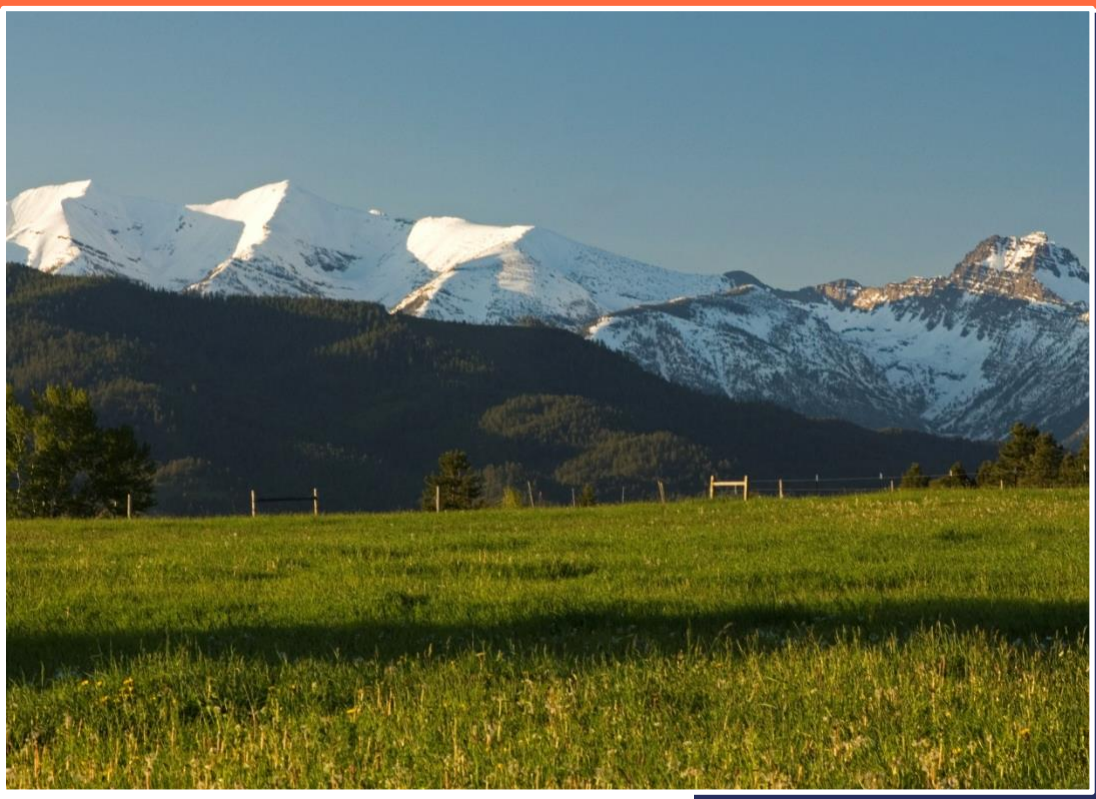
MONTANA UNIVERSITY SYSTEM

2022

Montana's Science & Technology Plan



Montana University System

Last Updated:

August 1, 2022

Table of Contents

Montana University System

Leading the way forward

Five Major Areas of Focus:

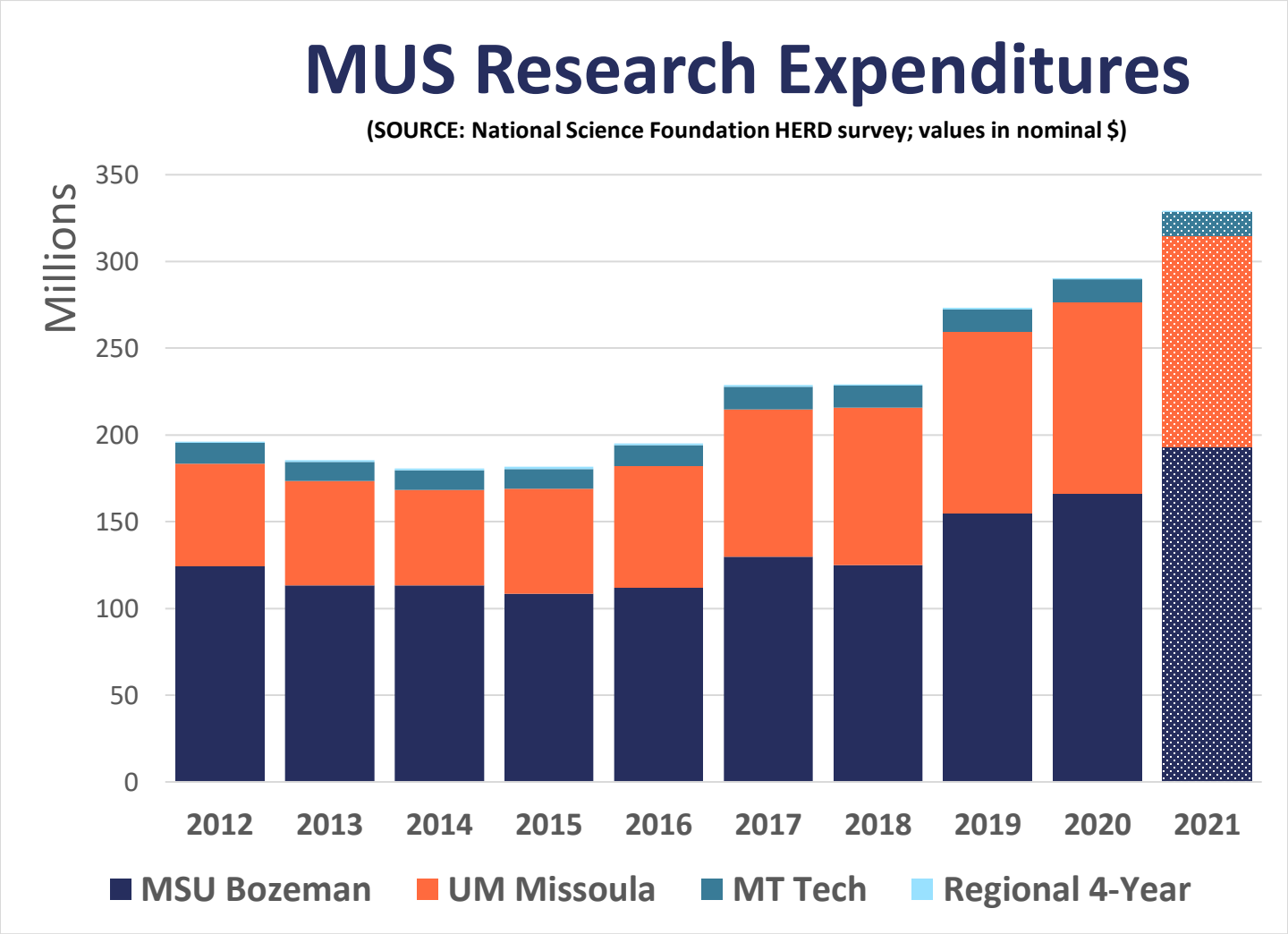
1. HEALTH & BIOMEDICINE
2. AGRICULTURE & NATURAL RESOURCES
3. ENERGY AND THE ENERGY/FOOD/WATER NEXUS
4. MATERIALS & MANUFACTURING
5. COMPUTATION & INFORMATION SCIENCES

Research conducted by the Montana University System (MUS) is a key driver of economic development in the state of Montana. Scientific research conducted in Montana has the potential to solve today's problems in rural health, agriculture and natural resources, materials science, energy and computational and engineering sciences. Research also prepares the next generation of students to innovate, create, and obtain jobs in all sectors. The Science and Technology Plan for 2022 focuses on specific areas of research with significant potential for success in spurring economic development by attracting Federal, State and private investment and spurring the creation of small businesses in Montana.

The MUS Strategic Plan includes a goal for Research and Development: Establish collaborative programs between MUS institutions, the private sector, and the state to expand research, technology transfer, the commercialization of new technologies, and the development of our entrepreneurs. MUS research initiatives are designed to (1) solve Montana problems with Montana solutions; (2) create good Montana private-sector jobs, and/or; (3) grow emerging and important research sectors that contribute to the diversity of Montana's economy.

Education and training in science, technology, engineering & mathematics (STEM) stands as our most important tool for ensuring prosperity across Montana.

In today's world, attracting research dollars for economic development is a highly competitive process. Faculty in the Montana University System (MUS) have proven to be successful in this complex process of winning grant and contract awards from the leading federal funding agencies in the United States with a combined $330 million dollars in research expenditures in FY2021, an increase of over $100 million dollars compared to research expenditures a decade ago. Montana's future prosperity depends on expanding the investment strategies for research while translating these results to increased and diversified economic potential across the state.



Montana State University and the University of Montana are both classified as "Doctoral Universities: Very High Research Activity" by the Carnegie Classification of Institutions of Higher Education. There are only 146 higher education institutions with this classification in the US, and for a small population state like Montana having two universities recognized this way is an impressive accomplishment. Although research is focused at these two flagship campuses, collaborations and partnerships across *all* MUS institutions extend impact of this research into education programs to ensure a workforce that is prepared for today's and tomorrow's needs.

Students who are well prepared for college and careers in Science, Technology, Engineering and Mathematics (STEM fields), represent a foundational human resource for Montana. New graduates of the MUS will shape our future through innovation and invention. This next generation of science and engineering professionals are critical for maintaining Montana's economic competitiveness. The need for high-quality science education with a focus on critical thinking is more essential now than ever before.

In the pages that follow, five specific areas are identified where MUS researchers are poised to make transformative discoveries that advance knowledge and directly address the MUS research and development goal of expanding research strength, spurring technology transfer, commercializing new technologies, and developing a new generation of entrepreneurs.

Health and Biomedicine

Health and biomedical research is a major focus within the MUS, aiming to improve health care for Montanans. Strong outreach and research programs have been developed to address health care disparities in our rural state, while world class biomedical research carried out on MUS campuses is linked with translational research implemented in partnership with Montana's hospitals.

Montana researchers investigate new ways to prevent, detect, and cure a variety of human maladies, including emerging infectious diseases, respiratory illnesses, stroke, cancer, cardiovascular disease, brain injury, mental illness, and others. It is critical that Montana continues to invest in health sciences and biomedical research in broad areas.

Key research initiatives include:

- Advancing research into the most effective means of providing health care to Montana's rural population
- Developing new techniques to improve nutrition, health, employment and participation in community life for people with disabilities living in rural settings
- Researching new avenues for addressing mental illness
- Identifying risk factors for suicide across the state with an emphasis on rural areas
- Exploring new and emerging biotechnologies
- Partnering with Montana hospitals and biomedical researchers to develop new treatments and technologies

Agriculture and Natural Resources

Northern Seed collaborates with scientists and plant breeders in the MUS, sponsors research and licenses technologies from the College of Agriculture at Montana State University.

Montana is in the enviable position of having one of the most pristine environments in the world along with extraordinary agricultural productivity and an abundance of natural resources. Increasingly, however, Montana's agriculture and natural resources have come under threat from hazards such as drought, flooding, and wildland fire and smoke. Understanding and mitigating how these hazards impact agricultural and natural resources as well as economic viability poses a direct and immediate challenge to MUS researchers. The MUS Science and Technology Plan recognizes the need for research to increase agricultural production sustainably and to tailor environmentally sound and safe extraction technologies for the state's mineral, energy, and water resources. These needs must be met while preserving the Montana's ecosystems and natural beauty for the enjoyment of current and future generations of Montanans and visitors.

Key research initiatives include:

Crops, Pests and Diseases

- Breeding plants for greater crop yields and increased resistance to drought, disease and pests
- Researching use of alternative crops for diversification and mitigating risk from climate variability
- Researching marketing and distribution that capitalizes on the premium of Montana quality crops
- Researching bark beetle infestations and impacts on Montana's forest resources

Fire, Water and Minerals

- Researching the role and impact of fire and smoke in natural resource management to mitigate wildfire risks
- Exploring and evaluating naturally occurring mineral resources
- Developing deployable smart field sensors for resource management and land reclamation
- Creating environmentally sound, safe and economically viable tailored resource development strategies
- Researching groundwater and surface water quality, chemistry, and geothermal resources

Natural Resource Social Science

- Identifying and understanding how Montanans engage in adaptive behaviors in response to environmental threats including wildfire, flooding, and air quality
- Quantifying specific and combined influences of social trust, governance processes and social ecological system properties on perceived community resilience.
- Understanding how management officials use real-time information to make decisions about addressing threats posed by natural hazards to Montana communities.

Energy and the Energy/Food/Water Nexus

Decades of unprecedented growth in population and a corresponding global economic expansion have created a demand for new energy production and more efficient and environmentally sustainable energy use. Energy research programs include the goals of improving the efficiency of using carbon-based resources as well as identifying and optimizing new sources of energy. It is also important to recognize the importance of the energy/food/water nexus and understanding of the underlying dynamics, processes, and interactions between these three systems. Researchers use integrated analysis and modeling to develop analytical methods that provide critical information on global and region energy, water and food resources. In addition, MUS researchers investigate advanced materials to optimize energy capture and efficiency and continually improve food (livestock and plant) production with consideration of energy and water usage.

In a research partnership with Montana Tech, the Butte firm, Water & Environmental Technologies (WET) developed an innovative on-site wastewater treatment technology now being marketed statewide by a spinoff company, SepticNET. Founded in 2000 by MTech alumni, WET is now a multi-million dollar engineering firm with 35+ employees, offices in Butte, Anaconda, and Great Falls, and

The nexus between energy/food/water is a key driver of socioeconomic status and challenges in both urban and rural areas in Montana. Basic and applied research that bridges the hydrological, environmental, ecological, geochemical, energy, agricultural, and engineering sciences is essential. MUS researchers incorporate research advancing technologies that allow remote sensing and continual assessment of energy/food/water resources and interactions.

We can guide effective stewardship of state energy resources, focusing on environmentally acceptable development of, and reliable, cost-effective distribution and use of Montana's energy resources, including petroleum, coal, natural gas, solar, biomass, energy dedicated crops, geothermal, wind and water. Research to enhance oil recovery from existing wells in the Williston Basin Bakken, proppant research for increased efficiency of oil and gas recovery and production through hydraulic fracturing are important strategies.

Key research initiatives include:

- Environmentally acceptable deep well stimulation
- Clean coal technologies for power plant retrofits
- Carbon sequestration and innovative ideas to reduce the carbon footprint
- Smart grid technologies for transporting electricity reliably
- Energy storage and efficiency, the key enablers for solar and wind
- Renewables – wind, solar, biomass, biofuels, advanced fuels
- Research to enable restoration of damaged ecosystems
- Policy and regulation advances to foster environmentally acceptable, sustainable energy development
- Development of solid oxide fuels cells
- Modelling of economically sustainable feedstock for alternative fuels and bio-based materials.

Materials Science & Manufacturing

Montana Instruments, based in Bozeman, develops cryogenic tools vital for the manufacture and operation of quantum computing technologies. Their expansion in Bozeman has been boosted by the MonArk Quantum Foundry. This facility, co-led by Montana State University and the University of Arkansas, the National Science Foundation's 2nd major facility investment to accelerate the development of quantum materials and devices.

Montana has significant multi-institutional expertise and economic opportunities centered around new technologies in quantum materials, biomaterials, energy materials, electronic and optical materials and materials processing including extractive metallurgy. Current nanoscale and microscale polymer fabrication research is focused on chemical sensing, targeted drug delivery, functionalized devices, and optical polarization. The design and characterization of nanotechnology materials and devices is of great interest industrially, for national security, and for economic competitiveness. Intellectual property, spin-off or relocated companies, and high-paying jobs flow from materials science, engineering and manufacturing research.

Key Research Initiatives:

- Advancing research into minerals, metals, alloys, glasses, slags, ceramics, polymers, biomaterials, thin films, nanomaterials and composites
- Developing methods to recover high value materials from previously mined sites
- Researching alternative construction materials that require less energy for manufacture, use recycled materials and have greater corrosion resistance
- Enhancing materials to create longer-lasting and less expensive fuel cells
- Discovering and developing *new* materials with greater strength, reduced weight, reduced cost, corrosion resistance, catalytic traits, resistance to temperature extremes for use in biomedicine, aerospace or in combustion engines
- Engineering optical materials, components and systems for applications in imaging for biomedicine to precision agriculture applications
- Researching optical materials for high-bandwidth computation and data processing
- Advancing joining methods, processing, and additive manufacturing technologies

Computational & Information Sciences

Computational science, information science, and engineering are fundamental aspects of research and innovation. All areas identified in Montana's Science and Technology Plan – health and biomedicine; agriculture and natural resources; energy; materials science and manufacturing – rely upon vigorous, agile, and innovative capabilities in all areas of computer and information science. Particular emphasis must focus on emerging opportunities in artificial intelligence (AI) and machine learning (ML) research.

We are establishing a network, the Montana Cloud, to provide necessary infrastructure for the Montana University System, creating an economic advantages for Montana's researchers by enhancing the cumulative capabilities of the campuses.

Key Research Initiatives:

- Advancing AI and ML capabilities to evaluate the "4 V's" of big data (Volume, Velocity, Variety and Veracity) and develop relevant predictive models
- Mining large datasets that exist in health care, manufacturing, agriculture, equipment maintenance for higher safety, better management and cost savings
- Developing simple, inexpensive methods for detecting an attack on a computer network
- Modeling weather, hydrology, and vegetation for management in agriculture, forestry, fire and smoke management, and human health
- Anchoring a cooperative statewide network of research computing and data (RCD) capabilities and associated services with MUS institutional RCD assessments, joint MUS RCD strategic planning, and a statewide RCD working group
- Digitizing Montana's resources and history
- Exploiting 3D visualization, high-performance computing, semantic web, and data capabilities to support research and commerce in Montana
- Modeling of biofuel combustion in industrial engines for emission reduction and improving work place air quality.

Technology Transfer & Economic Development

Business Incubators The spirit of innovation and entrepreneurship in the MUS is emerging across all disciplines and spilling out into communities across Montana. Both MSU and UM have business incubators that facilitate launch of start-up and early-stage companies, provide space to incubate start-up and early-stage companies, provide essentials that include a variety of administrative and facilities services, and provide flexibility in tenant improvements and lease terms. Other MUS campuses must be empowered, funded, and enabled to provide similar services in their communities.

Through their business incubators, MSU and UM provide a suite of services to Montana entrepreneurs and businesses by hosting many support programs aimed at facilitating job and company creation in Montana. Outreach efforts provide faculty, staff, students, and alumni in the MUS with many touch-points along their path to success. An incoming freshman can visit the Blackstone LaunchPad offices at MUS campuses and gain insight into launching a business idea around a passion of skiing or the culinary arts. Businesses looking to expand product and service offerings globally can tap into resources that include those dedicated to providing assistance with government contracts through Procurement and Technical Assistance Program (PTAC) programs, Techlink, or Montana Manufacturing Extension Center (MMEC). In total, the MUS innovation and entrepreneurship programs actively engage with hundreds of businesses and entrepreneurs, with greater than 95% being Montana based.

The ***Technology Transfer Office in the Office of Research and Economic Development at MSU*** has issued almost 300 active licenses, approximately one third of these are shared with Montana companies, including licenses of new wheat varieties that add more than half a billion dollars annually to the Montana economy, and numerous photonics and biomedical technologies. In the past 15 years MSU Technology Transfer Office has facilitated more than 50 startups based on university technology, adding hundreds of high-paying jobs to the Montana economy. These companies also provide internships to our students and employment for our MUS alumni through collaborative research with MSU through SBIR's, STTR's and other grant and contract opportunities. MSU Research has also launched a pilot in-house Gap Fund to assist with funding of early-stage, applied projects to reduce the risk of technology transfer to the private sector.

The ***Technology Transfer Office in the Office of Research and Creative Scholarship at UM*** has captured more than 100 new inventions/ideas in the past five years, with nearly 80% still in some form of active assessment or advancement. Examples on UM inventions include a physiological strain monitor with the potential to reduce human heat related illnesses and death, a portable aquatic cervical traction device for improved treatment of pathological neck injuries, a new topical ointment for treating dermatitis without traditional treatment side effects, novel silica composites with an increased efficiency at removing arsenic from surface water sources, and many, many others.

Workforce Development

Building the talent pool for our state and the companies already here and for those to come requires the development and adoption of benchmarked standards. *Updated science learning standards* prepare students to enter the workforce with enhanced communication, problem-solving and critical thinking skills by encouraging students to understand concepts and content and not just memorize them. There is also a strong need to provide students hands-on training and experiential learning.

Over the past 25 years, there has been a 26% increase in the demand for highly skilled workers proficient in STEM and STEM workers account for over 50% of the nation's sustained economic growth.

The other key to success are students who are well prepared for college and careers in science and STEM fields are vital for shaping our future through innovation and invention, and they are key to maintaining our economic competitiveness. The need for high-quality science education, beginning at the very earliest grades, is more essential now than ever with a focus on critical thinking.

Montana Photonics Industry Alliance

The Montana Photonics Industry Alliance (MPIA) is a hub for Montana's optics and photonics companies, entrepreneurs, laboratories, and universities that will aid in commercializing, nurturing, and sustaining organizations that create photonics-related jobs and associated economic opportunities in the state of Montana. This industry has grown out of the efforts of faculty, staff and students of the MUS. MPIA includes approximately 30 companies in optics/photonics in the Gallatin Valley area alone, employing approximately 500 people around the nucleus of the MSU OpTec and Spectrum Laboratories.

Supporting Components

- **Program development**: University-based research and graduate education are inseparable, and states with vibrant and productive research activity also have thriving masters and doctoral programs. The doctoral degree is a research-based degree, and all graduate students are a mainstay of research productivity in science and technology. A concerted effort to recruit, retain, and graduate the most talented graduate students from the state, region, nation, and world will pay off in research productivity and in long term, economic development – as many of these students – wherever they originated will want to pursue their careers in Montana. At the same time, strategic growth of graduate programming through expanded and new graduate programs will be required to capitalize fully in the five theme areas identified in this plan.
- **Computational Science and Information technology** and quantitative modeling infrastructure and research are seen as fundamental in all five core research areas. Advanced networking, large-scale computationally intensive modeling and visualization are seen as fundamental to all five of the major research areas. The infrastructure needed to support leading research should focus on computation power, connectivity, software and programming expertise, as well as development of modeling tools, algorithms and new statistical, quantitative and computational methods.

- **Partnerships and collaborations –** Public entities (e.g., national laboratories or other research universities), and private, and non-profit organizations perform or support of Montana's research efforts. Partnerships and collaborations within the MUS, with other Montana entities, and beyond our boundaries will leverage and expand the research results and associated benefits to maximize value and return on investment.
- **Technology transfer** allows the MUS to move ideas from the laboratory to the private sector. Many excellent examples of such transfer already exist, but considerable room for growth is evident. The MUS research infrastructure not only should facilitate tech transfer, but it also should encourage researchers to proactively seek opportunities for moving ideas to the marketplace and for employing people in a high- technology economy.
- **Social Sciences** is a necessary component in the research arena as policies and practices increasingly are drawn from scientific discovery. The scientific research community needs to make a concerted effort to engage social science colleagues in cooperative research and in the identification of areas of where research is needed to meet human needs.
- **Ethical conduct** is integral to quality research. Researchers and their students and support staff will engage in formal ethics education opportunities. Additionally, researchers will be honest and transparent regarding any potential conflicts of interest.
- **Communication** will be a high priority for researchers and their students, and they will focus on high quality scientific writing and developing the ability to communicate complex subjects clearly for multiple audiences. Contemporary researchers must communicate effectively not only with other researchers, but also with policy-makers, investors, and the general public. An emphasis will be placed on helping scientists understand the expectations of the public and helping the public understand the implication of scientific discovery.

Strategies for Success

1. **Develop a communication strategy for Montana "Science & Technology" to include**:

    a. Bringing the excitement of discovery to middle school and high school age students across the state through a guest lecture program by faculty researchers
    b. Bringing the excitement and impact of MUS research to communities without MUS campuses.
    c. Hold annual tech transfer and research conferences in Montana to communicate to Montana business and political leaders the opportunities, potential returns, and economic impacts of investment in MUS research
    d. Strengthen and expand MUS research partnerships with Montana businesses, in part by providing support of innovative campus efforts to commercialize research efforts (tech transfer) with Montana partners;

2. **Encourage an entrepreneurial climate in graduate education by:**
    a. Implementing business school entrepreneurial outreach programs for scientists and engineers
    b. Establishing regular forums on tech transfer in Montana to communicate the economic value of research investment in the state
    c. Connecting graduate students with research and innovation needs of Montana firms
    d. Establish a fund for endowed research scholarships (maybe targeting upper-level undergraduate students and graduate students) where private contributions could be matched at some percentage by state funds

3. **Establish a permanent funding mechanism for:**
    a. Establish priorities and funding mechanisms to recruit and retain nationally competitive faculty and researchers to grow the research and development capacity of the state
    b. Funding endowed research scholarships for undergraduate and graduate students
    c. Vouchers to assist Montana businesses to collaborate with university user facilities
    d. Matching requirements for federal dollars