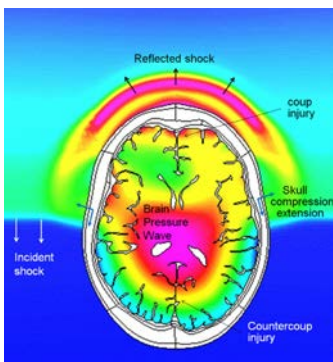
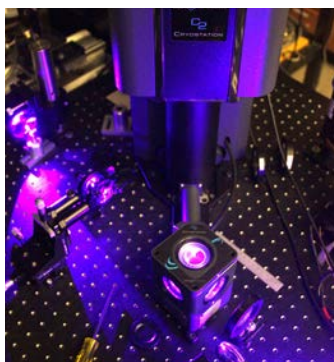


MREDI Montana Research & Economic Development Initiative



MUS RESEARCH TOUR • SEPTEMBER 2016



MONTANA
UNIVERSITY SYSTEM

The MUS received an appropriation of \$15M in state funds from the 2015 Montana Legislature to serve as seed money to leverage university-based research into strategic advancements for Montana's economy. The fundamental purpose of this research initiative is 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.

The Commissioner of Higher Education administered competitive grants to researchers on the basis of each project's potential for private-sector job creation, commercialization, and economic return on investment for the State of Montana. Areas of emphasis include agriculture, natural resources and energy, materials and manufacturing, health and biomedical sciences, and technology and computer science.

Funded projects:

- **Optics and Photonics** · \$2.5 M · *Optics and Photonics Research for Montana Economic Development*
- **Agricultural Profitability** · \$2.3 M · *Increasing Profitability by Improving Efficiency of Montana's Farm and Ranch Lands*
- **Traumatic Brain Injury** · \$2.2 M · *Translational Science at the Neural Injury Center: Expanding Clinical Services, Establishing Diagnostic Testing, and Developing Novel Therapeutic Interventions for Traumatic Brain Injury Survivors*
- **One Medicine** · \$1.5 M · *Reducing the Impacts of Inflammatory and Infectious Diseases on Animal and Human Health*
- **Mental Health** · \$1.4 M · *Synergistic Improvement in the Diagnosis and Treatment of Mental Illness, Dementia, and Chronic Pain*
- **Water Quality Monitoring** · \$1.3 M · *Development and Commercialization of Autonomous Chemical and Biological Instrumentation for Water Quality Monitoring*
- **Energy Technology** · \$1.2 M · *Enhancing Montana's Energy Resources: Research in Support of the State of Montana Energy Policy Goals*
- **DroneFire** · \$900,00 · *Autonomous Aerial Systems for Wildfire Management in Montana*
- **Bio-Based Fuels** · \$800,000 · *Advancing Bio-Based Chemicals and Next-Generation Fuels from Montana's Agricultural Crops*
- **Metal Recovery** · \$495,000 · *Recovery of Metal Contaminants from Industrial Wastewaters with Magnetic NanoComposites in a Novel Continuous Flow Process System*
- **Remediation Technology** · \$263,000 · *Remediation Technology for Chlorinated Pollutants Based on Natural Product from Soil Bacteria*

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OPTICS AND PHOTONICS

Optics and Photonics Research for Montana Economic Development

Principal Investigator:

- Joseph Shaw · Optical Technology Center · Montana State University

Funding Amount: \$2,500,000

Brief:

This research expands core competencies developed through previous investments in optics and photonics to make important contributions to new, high-value Montana problems in agriculture, health and biomedical sciences, energy, materials and manufacturing, and information technology. New commercial products enabled by this research will range from compact optical sensors for precision agriculture to advanced imaging and laser systems for detecting skin cancer and monitoring cell growth. This research also will position MSU and partnering companies to compete strongly in the multi-billion-dollar markets of defense and commercial markets involving optical waveguides and integrated photonic circuits.

Objectives and Progress:

1. Ultra-compact spectral imagers for precision agriculture and mapping of wildfires and natural resources:
 - A. Ongoing development of ultra-compact imaging and laser systems for weed mapping in precision agriculture, UAV mapping of wildfires, and a wide variety of ground-based and airborne remote sensing.
2. High-performance, real-time image processing for hyperspectral imaging:
 - A. Designs underway on a high-speed hyperspectral waterfall sorting system to fuse object edge information with hyperspectral data to sort agricultural products quickly and efficiently using Resonon's Hyperspectral Imagers and remove rejected items via air jets.
3. Remote sensing algorithms for precision agriculture:
 - A. Methodology in development for using hyperspectral imagery for determining optimal narrow spectral band combinations for identifying targeted invasive weeds in specific crops.
4. Machine vision algorithms for precision agriculture:
 - A. Machine vision algorithms for weed detection and food sorting using spectral imaging data in development.
5. Microcavity sensors for hyperspectral imaging:
 - A. Technological advancements in MSU/Advanced Microcavity Sensors LLC (AMS) are focused on imaging sensors towards commercial applications in agriculture and engineering tests to determine feasibility of mountain sensor technology on UAV; secondary objective solving Montana problems in agriculture and skin cancer detection.

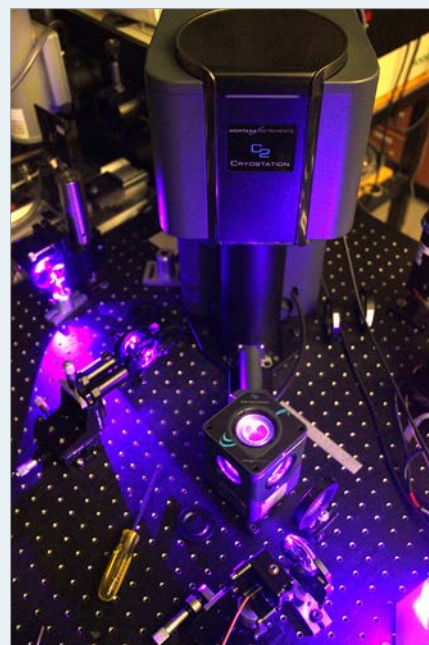


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6. Hyperspectral imaging for monitoring cell growth:
 - A. Designs underway for a hyperspectral imaging system for monitoring the metabolic state of live cells in culture. Applications to stem cells for understanding disease mechanisms in individuals, drug testing in cells from individuals, and potentially optimize personal nutrition.
7. Translational research to commercialize micro-mirror technology:
 - A. Ongoing work to translate MSU-developed deformable mirror technology to a commercially sustainable product.
8. Active waveguides and integrated optical circuits:
 - A. Researchers are integrating Montana products, expertise and capabilities to improve marketability, performance and enable additional products: Building interdisciplinary connections among MUS and Montana optics industries to integrate (a) optical crystals by FLIR/Scientific Materials Corp. (SMC); (b) waveguide photonic components of AdvR, Inc.; (c) Montana Instruments (MI) cryogenic systems; and (d) S2 Corp. (S2C) signal processing devices.
9. Optical parametric oscillator for tunable lasers:
 - A. Investigations underway for optical parametric oscillator performance in support of characterizing large aperture periodically poled non-linear optical crystals and in support of continued development of large area methane detection.
10. Nonlinear optical detection of surface contaminants:
 - A. A new method for detecting organic contaminants that accumulate on the surface of water based on nonlinear vibrational overtone spectroscopy (NVOS) is in development.

Return on Investment:

- **Jobs**
 - 13 faculty
 - 6 research engineers/research scientists
 - 12 graduate students
 - 5 undergraduate students
 - 2 non-MSU people starting new companies
- **Leverage—additional grant funds received:**
 - \$4,275,332 in 13 grants awarded as of 4th quarter
 - \$3M in related NSF grant
- **Output**
 - Up to nine new commercial products in progress for Montana companies; two new companies.
- **Connections—private sector partnerships:**
 - Advanced Microcavity Sensors LLC—Bozeman
 - AdvR, Inc—Bozeman
 - Flat Earth, Inc.—Bozeman
 - FLIR/Scientific Materials Corp.—Bozeman
 - Montana Instruments—Bozeman
 - Meridian Flying Services—Sidney
 - Freeman Farms—Fairfield
 - Nugent Farms—Fairfield
 - Montana Photonics Industry Alliance
 - NWB Sensors, Inc.—Bozeman
 - Resonon, Inc.—Bozeman
 - Revibro—Bozeman
 - S2 Corp.—Bozeman



AGRICULTURAL PROFITABILITY

Increasing Profitability by Improving Efficiency of Montana's Farm and Ranch Lands

Principal Investigator:

- Barry Jacobsen · MSU College of Agriculture and Montana Agricultural Experiment Station, Montana State University

Funding Amount: \$2,276,734

Economic Impacts:

In a year of research, built on multiple years of previous research, this project has focused on replacing 3.38 million acres of Montana land currently left fallow with pulse or cover crop mixes. Initial data analysis generated statewide indicates a projected increased gross income for rural Montana of \$90 million if 25% of previously fallow land is cropped to cover crop mixes, \$101 million if cropped to peas, and \$253 million if cropped to lentils. Precision agriculture technologies have proven to increase profitability by 25–30%. Additionally, new optics-based technologies have been developed and demonstrated to identify herbicide-resistant weeds and reduce herbicide use by >30%.

This project focuses on improving the economic and environmental sustainability of crop and livestock agriculture, Montana's highest-grossing industry, by intensifying pulse and cover crop production on 4.6 million acres of Montana land traditionally left fallow. Information derived from this project will help give farmers confidence as they change cropping practices. All data will be used for professional economic analysis by MSU agricultural economist faculty. Additional objectives:

- Optimize profit potentials for new and improved crops that fit localized needs statewide.
- Develop new markets and offer opportunities for value-added processing. Data on pea protein content will support business plans for a pea protein fractionation plant in Montana. Durum wheat production, marketing, and processing will be supported by better durum varieties.
- Develop new products, including optical sensor-based nozzles for the precision spraying of weeds, and increase the adoption of precision ag technologies by helping farmers access and process data to provide optimal prescriptions for variety selection, fertility, weed management, and re-plant decisions via an automated on-farm precision experimentation system.

Objectives and Progress:

1. Improve income from lands previously fallowed.

The research on cover crop mixes, pulse crops (pea, lentil and chickpea) has been conducted statewide utilizing the seven MAES Research Centers, in addition to MSU's research center in Bozeman. This research identified specific pulse varieties that are best-adapted to each region of Montana and include data tailored for regional profit potential from different cover crop mixes, soil water use, pea protein content, soil microbiology effects



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and better wheat stem sawfly control by parasites supported by flowering plants in the landscape, and weed control strategies that will safely allow pulse crop production in wheat rotations. An important output of this work is the statewide agricultural expertise and experience with these new cropping systems. In addition, the hay production from cover crop mixes has the potential to replace hay supplies now provided in times of drought by the Conservation Reserve Program (CRP) which is being phased out as a producer option.

2. Develop new, improved or quality differentiated products or crops.

A Montana-focused durum variety development program was initiated in a partnership between MSU and Northern Seed. New and promising lines with high yield, high quality and low cadmium content have been identified that will fit traditional durum production areas of Montana as well as the “Golden Triangle Region”. Microbial inoculants to combat nitrate poisoning in livestock have been researched and optical sensors have been developed for the detection of herbicide resistant weeds and precision weed control methods have been identified. A bacterium that can fix nitrogen on a wide range of crops and new bacterial strains associated with peas has also been identified.

3. Develop on-farm precision agriculture tools and technologies.

OFPE (On-Farm Precision Experiments) have been planted and harvested with accompanying data on optimal fertility relative to yield, grain protein and weed management. This data will be used in an economic analysis and in the development of computer software to ultimately develop predictive, and optimal, economic and sustainable recommendations for crop fallow and continuous crop scenarios. In support of this effort, a weather and soil moisture network has been developed and linked to the University of Montana Climate Center in an effort to develop better predictions on soil moisture content for re-cropping, and fertility modeling for predictive yield and protein models. Finally, a research network comprised of producers, suppliers, Extension educators and MUS researchers has been created to evaluate this project and to address constraints for wider adoption by producers.

Return on Investment:

• Jobs

- Research scientists & technicians: 19 faculty (2.6 FTE), 9 technicians (5.0 FTE)
- Undergraduate and Graduate Assistants: 17
- Postdoctoral scholars: 1
- Private industry: 3 FTE

• Connections—private sector partnerships:

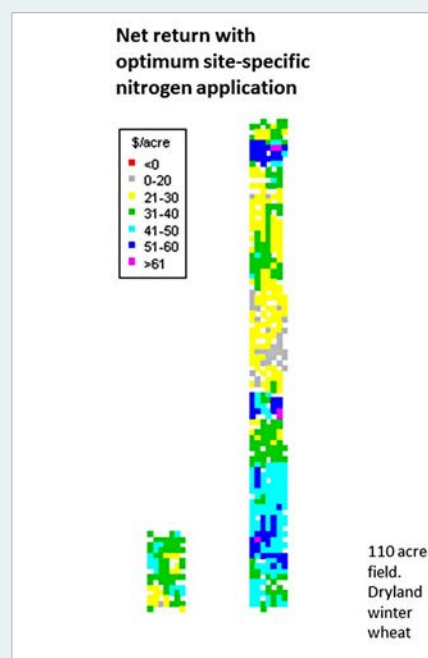
- Northern Seed LLC—Great Falls
- NWB Sensors Inc.—Bozeman
- Salish & Kootenai Electronics—Ronan

• Leverage

- \$4.6 million in grants submitted and >\$1.1 million in grants funded

• Output

- Patentable technologies have been identified for hyperspectral optics to identify herbicide resistant weeds and weeds in crop canopies, nitrogen fixing bacteria that can be used in grain crops, and new software for precision agriculture. In addition, the work in precision agriculture will result in new crop consultant job opportunities in the private sector.



TRAUMATIC BRAIN INJURY

Translational Science at the Neural Injury Center: Expanding Clinical Services, Establishing Diagnostic Testing, and Developing Novel Therapeutic Interventions for Traumatic Brain Injury Survivors

Principal Investigators:

- Sarjubhai Patel · College of Biomedical and Pharmaceutical Sciences · UM
- Thomas Rau · College of Biomedical and Pharmaceutical Sciences · UM
- Alex Santos · Motor Control Laboratory · UM

Funding Amount: \$2,234,834

Brief:

Traumatic brain injury (TBI) affects 13% of Montana's adult population and costs Montana an estimated \$1.4 billion per year. One of the primary issues affecting TBI survivors is proper diagnosis and accurate assessment of injury severity. This project expands scientific research and technology to develop rapid, accurate diagnosis of brain injury. The four objectives focus on blood-based biomarkers for hospital lab testing, molecular techniques to develop new therapeutic inhibitors, a computer-based cognitive training system for TBI subjects that suffer from permanent brain damage, and a deep-learning computer analysis program to analyze brain waves and detect epilepsy before it develops in TBI subjects.

Objectives and Progress:

1. Expand clinical services for TBI survivors and veterans at the UM Neural Injury Center:
 - A. The NIC has screened and provided follow-up services for 119 TBI survivors, and has provided neuropsychological testing to those individuals with lasting brain damage that affects academic performance.
2. Develop a comprehensive panel of tests to diagnose mild TBI:
 - A. TBI survivors and non-injured controls have been assessed using the following newly developed technologies: Synergy Applied Medical Research BalanceLab, cognitive fatigue testing, VAST divergent thinking assessment, FYR diagnostics blood based biomarker testing, and Neurokinetics I-portal assessments. Combined together, they provide a comprehensive overview of brain damage after TBI.
3. Develop micro RNA inhibitors to reduce nerve damage after TBI:
 - A. microRNA inhibitors have been developed and are being validated in laboratory testing prior to use in the animal model.
 - B. A neuroprotective drug, owned by UM and discovered by Dr. Rau, has been tested and has significant therapeutic potential for victims of TBI.

continued



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4. Develop a computer-based cognitive training system for TBI subjects:
 - A. VAST has completed testing individuals with the divergent thinking technology and has followed up with the development of a novel virtual reality platform to incorporate new cognitive testing.
5. Complete development and testing of post-traumatic epilepsy diagnostic analysis program:
 - A. N-SITE has incorporated all of the TBI electroencephalogram (EEG) data from Massachusetts General Hospital. The data is currently being processed through the deep-thinking program to extract variables of interest that can be assessed as biomarkers of epilepsy.

Return on Investment:

• Jobs

- Clinical trials coordinator—Neural Injury Center
- Research specialist
- Post-doctoral fellow
- Computer programmers (2)—VAST & N-Site
- Research technicians (2)
- Biostatistician
- Molecular Biologist
- Neuropsychologist-Neural Injury Center

• Connections – Private sector partnerships:

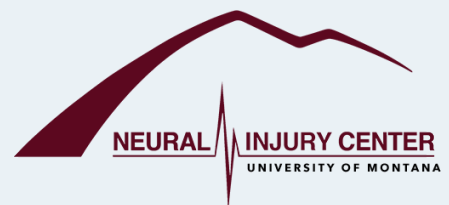
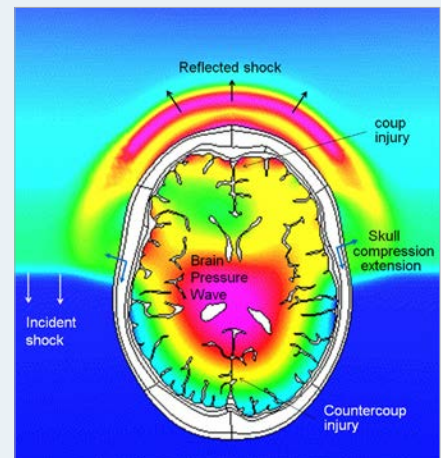
- **VAST-Missoula:** Mobile virtual reality testing goggles and rehabilitation program developed for rapid assessment of TBI.
- **N-SITE-Missoula:** Deep learning program developed to assess EEG brain wave activity and decipher patterns indicative of epilepsy before seizures occur.
- **Glia Diagnostics:** Clinical trial blood collection conducted through the DataPharm program.
- A recent partnership with Dr. Stephanie McCalla of MSU formed to develop new technology for rapid molecular detection of blood-based biomarkers to assess severity of injury and recovery duration.

• Leverage—Additional grant funds received:

- GE/NFL grant: \$500,000
- Match funding from N-SITE: \$350,000
- Match funding from VAST: \$65,500
- CTR-IN grant: \$65,000
- BARDA grant submission pending

• Output

- The following MREDI funded technology expanded into private spinoff companies in Missoula, Montana:
 - **FYR Diagnostics:** Formed in August 2016, FYR is licensing the technology from UM to take small molecule microRNA into a commercial platform for rapid diagnosis of TBI. They are currently in discussion with an angel group for seed funding of \$500,000–\$1M.
 - **Synergy Applied Medical Research:** Synergy was formed in July 2016 and is currently licensing the BalanceLab technology from UM. A fully viable product is ready for commercialization and further computer technology development is ongoing.



ONE MEDICINE

Reducing the Impacts of Inflammatory and Infectious Diseases on Animal and Human Health

Principal Investigators:

- Jovanka Voyich · Microbiology & Immunology, WWAMI · MSU
- Mark Jutila · Microbiology & Immunology, WWAMI, WIMU · MSU
- Mark Quinn · Microbiology & Immunology, WIMU · MSU

Funding Amount: \$1,500,000

Brief:

Inflammatory disorders, including those caused by infectious diseases, negatively impact both humans and animals and contribute significantly to their morbidity and mortality. The goal of One Medicine is to decrease and prevent disease in humans and animals. Funding supports studies to understand regulation of immune responses during inflammation and to discover and improve existing therapies to reduce antibiotic use. Projects are investigating drug resistant bacteria (including MRSA), zoonotic pathogens, scours and inflammatory diseases (rheumatoid arthritis).

Objectives and Progress:

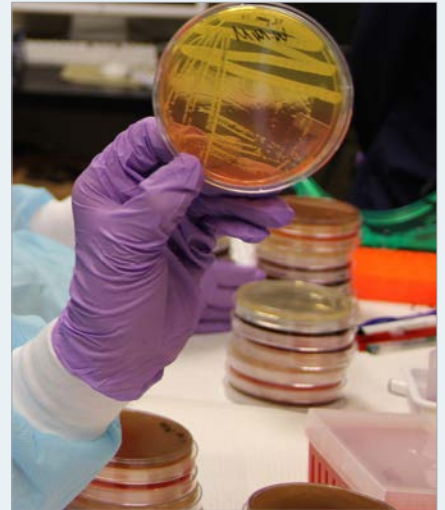
1. Develop therapeutics that induce a favorable immune response toward infectious diseases and chronic inflammation or autoimmunity:
 - A. Basic science results are directing translational research opportunities. Host and pathogen targets have been identified and will be pursued for potential as therapeutics and vaccines.
2. Transfer basic science to the private sector in Montana:
 - A. Collaboration with SAJE Pharma to develop and test new anti-inflammatory treatments for rheumatoid arthritis.
 - B. Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) submissions in progress with Totem BioSciences, Victor Montana.
3. Create sustainable employment and training opportunities for students and research professionals:
 - A. Data collected from experiments made possible by state funding is supporting grant applications that will continue employment.
 - B. Laboratories accepted additional graduate students for basic and translational research opportunities.
 - C. Undergraduate internships were created to stimulate interest in basic and translational research to encourage students to pursue biomedical research.



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Return on Investment:

- **Jobs**
 - Research scientists & technicians: 8 FTE
 - Research associate & assistants: 3 (hourly)
 - Undergrad & Graduate Assistants: 11 students
 - Postdoctoral scholars: 2.5 FTE
- **Connections—private sector partnerships:**
 - SAJE Pharma—Kalispell
 - Totem BioSciences—Victor
- **Leverage—additional grant funds received:**
 - Federal and industry grants awarded to date: \$2,580,740
- **Output**
 - 11 Publications in press or published citing MT State Initiative
 - 12 Additional Grants Pending



MENTAL HEALTH

Synergistic Improvement in the Diagnosis and Treatment of Mental Illness, Dementia, and Chronic Pain

Principal Investigator:

- Matt Byerly · Center for Mental Health Research & Recovery · MSU

Funding Amount: \$1,462,158

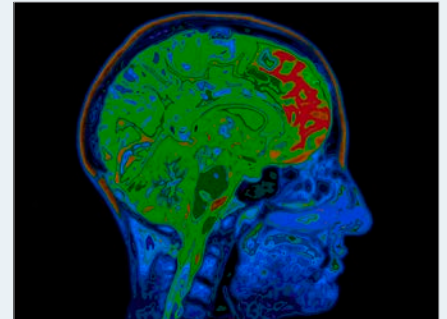
Brief:

Montana has the highest suicide rate in the country, and currently over 18,000 Montanans live with Alzheimer's. Mental health conditions such as major depression, bipolar disorder, schizophrenia, Alzheimer's, chronic pain, PTSD, and substance abuse can be better understood and overcome through research that clarifies the underlying neuroscience of the conditions and tests emerging interventions to meet our mental health challenges. The research aims to ensure that Montanans with mental illness can get the right diagnosis, as early as possible, and receive the most appropriate preventive and treatment interventions.

Objectives and Progress:

1. Develop a brain function analysis tool that improves speed & accuracy of clinical diagnostic process for anxiety and depressive disorder:
 - A. Using brain measures to make mental illness diagnosing more objective.
2. Conduct a breakthrough study on the use of Deep TMS (Transcranial Magnetic Stimulation) for treatment of Alzheimer's:
 - A. Combining brain measures to identify "biosignatures" that identify which people with Alzheimer's disease will benefit from the promising new TMS treatment.
3. Chronic pain research: Collaborate with SiteOne Therapeutics to develop non-opioid treatment for chronic pain:
 - A. Identifying an effective non-opioid treatment for chronic pain that could change the landscape of pain treatment, including reducing the deaths due to opioid overdose.
4. Suicide prevention in high school students: Adapt European-developed intervention program to rural Montana setting (Youth Aware of Mental Health—YAM):
 - A. We are the first research team in the U.S., in collaboration with a Texas partner, to test the feasibility and acceptability of the most promising youth mental health resiliency/suicide prevention program.

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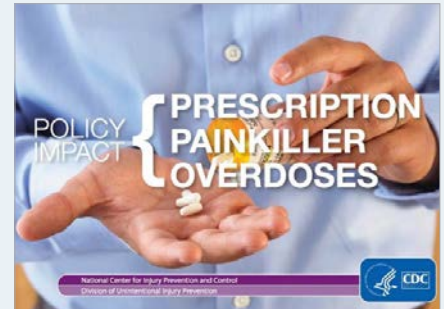


Matt Byerly

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Return on Investment:

- **Jobs**
 - Research Scientists: 3 (.2 FTE)
 - Research Manager: 0.15 FTE
 - Business Manager: 0.15 FTE
 - YAM facilitators: 12 facilitators for total of 1 FTE
 - YAM facilitator assistants: 24 assistants for a total of 1 FTE
 - Undergrad & Graduate Assistants: 5 undergrads for a total of 1 FTE
- **Connections—private sector partnerships:**
 - Western Montana Mental Health Center—Butte
 - SiteOne Therapeutics—Bozeman
 - Neuralynx Inc.—Bozeman
- **Leverage – additional grant funds received:**
 - \$1.5M NIH grant received by SiteOne to refine the chemistry of their non-opioid pain medication
 - \$359,000 MSU Extension/CMHRR collaborative USDA grant to evaluate YAM when delivered by MSU Extension faculty
- **Output**
 - YAM program will be delivered in 8–10 Montana schools beginning in September. Confirmed high schools include Gardiner, Capital (Helena), Helena, Miles City, Terry, Browning, St. Labre, and Pryor.
 - A research infrastructure has been established at the Western Montana Mental Health Center in Butte. A new neuropsychiatric treatment technology (TMS) is now available for the first time in southwestern Montana.
 - Promising non-opioid pain medication candidates have been identified in pre-clinical research models.
 - New technologies are being used to make depression and anxiety disorder diagnosing more objective.



WATER QUALITY MONITORING

Development and Commercialization of Autonomous Chemical and Biological Instrumentation for Water Quality Monitoring

Principal Investigators:

- Christopher Palmer · Department of Chemistry and Biochemistry · UM
- Michael DeGrandpre · Department of Chemistry and Biochemistry · UM
- Orion Berryman · Department of Chemistry and Biochemistry · UM
- Steve Amish · Montana Conservation Genetics Laboratory · UM
- Gordon Luikart · Flathead Lake Biological Station · UM

Funding Amount: \$1,292,398

Brief:

Approximately 50 percent of all U.S. streams, lakes and groundwater are impacted by human pollution and development. The aim of this research team is to develop and commercialize a suite of autonomous environmental measurement and sampling systems for monitoring Montana's water resources. The specific objectives are 1) develop an arsenic sensor for groundwater; 2) build a portable analyzer to detect undesirable nutrients and organic pollutants; 3) apply cutting edge environmental DNA (eDNA) testing for early detection of aquatic invasive species and 4) develop and commercialize an autonomous water quality monitoring system for stream alkalinity and pH.

Objectives and Progress:

1. A selective compound for arsenate has been synthesized and assessment of arsenate binding is currently underway.
2. A sensitive method for analysis of anionic nutrients has been developed and the components for a portable nutrient analyzer have been assembled.
3. Refinement of an eDNA extraction process and a comparison of large and small volume manual sampling techniques have been completed. A field assessment of manual collection techniques for rare/threatened species is currently underway.
4. A system for measuring stream alkalinity has been built and is currently being tested.

Return on Investment:

- **Jobs (FTE)**
 - 4 research scientists & technicians
 - 6 graduate students
 - 4 undergraduate students
 - 1.5 postdoctoral researchers



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continued

- **Connections – private sector partnerships:**

- Sunburst Sensors—Missoula
- Big Sky Machining—Superior
- Vintage Lab Tech, LLC—Missoula
- S&K Electronics—Ronan

- **Leverage – additional grant funds received:**

- Sunburst Sensors’ two XPRIZE awards (\$1.5M)
- Berryman NSF CAREER award (\$675K)
- DeGrandpre Murdock Commercialization Grant (\$120K)

- **Output**

- Patents

- Berryman—1 new application
- DeGrandpre—1 to be issued in November

- Publications from the grant support

- Berryman—3
- DeGrandpre—1
- Palmer—1

- Educational Outreach

- Berryman: spectrUM chemistry camp lab tours; “Building with Biology” spectrUM event
- DeGrandpre: STEMfest 2015, State Science Fair keynote speaker, Three Forks High School demonstration day



ENERGY TECHNOLOGY

Enhancing Montana's Energy Resources: Research in Support of the State of Montana Energy Policy Goals

Principal Investigator:

- Lee Spangler · Energy Research Institute, Montana State University

Funding Amount: \$1,200,000

Brief:

Research focuses on overcoming regulatory and environmental hurdles to access Montana's vast oil and coal reserves. The team is developing new well sealing technology, addressing leakage regulations for coal storage ponds, assessing air capture of CO₂ for algae growth for value added byproducts, and investigating use of potential coal related byproducts to enhance oil and gas recovery.

Objectives and Progress:

1. Create mineral seals for leaky wells at greater depths and higher temperatures than current biomineralization technology:
 - A. Control growth of new rock to plug small pathway leaks in seeping wells.
2. Test use of microbially induced calcite precipitation to remediate fly ash storage to comply with a new federal regulation (40 CFR Parts 257 and 261 Hazardous and Solid Waste Management):
 - A. Use mineralization to solidify fly ash and reduce or eliminate heavy metal leaching.
3. Use bacterially driven mineral formation for removal of heavy metals (cadmium, arsenic, selenite) from water produced by mining and / or energy operations.
4. Assess potential to use CO₂ emissions from Colstrip to increase oil recovery in depleted Montana oil fields.
5. Investigate growth of algae and cyanobacteria in coal bed methane waters to air capture CO₂ and produce byproducts such as fertilizer.
6. Stimulate repeated methane production in coal bed methane (CBM) projects using algal extract.

Return on Investment:

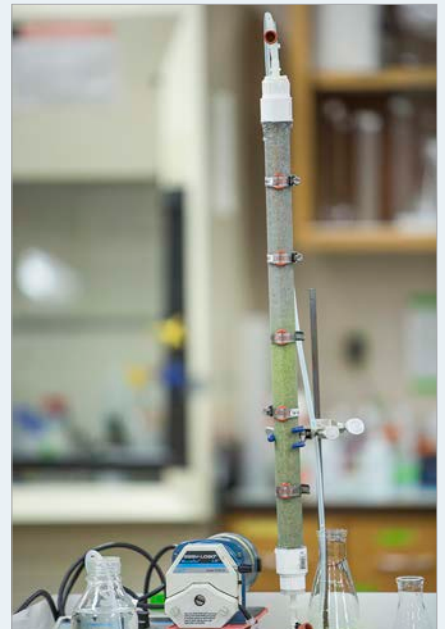
- **Jobs**
 - Undergrad & Graduate Assistants: 13 (9.75 FTE)
 - Researchers/faculty: 15 (4.76 FTE)
- **Connections – private sector partnerships:**
 - Montana Emergent Technologies—Butte
 - Talen Energy—Colstrip
 - Southern Company—Georgia



Lee Spangler

Energy Research Institute & Big Sky
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- **Leverage – additional grant funds received:**
 - \$2M Department of Energy grant for well sealing
 - \$650k Department of Energy grant for using algae to enhance coal bed methane
 - \$160k Department of Energy grant to build mobile well sealing unit
- **Output**
 - Tests of biominerals show similar strength to cement.
 - Initial biomineralization work on Colstrip fly ash shows promise for reducing water use and potential for dry storage—more work needed.
 - Tests of fertilizer properties of algae grown in coal bed methane water show that wheat plants given algae produced more grains per stem than wheat with commercial fertilizer or just water.
 - Montana Emergent Technologies downhole sampler partially developed with MREDI funds.



DRONEFIRE

Autonomous Aerial Systems for Wildfire Management in Montana

Principal Investigators:

- Carl Seielstad · Department of Forest Management, UM
- Lloyd Queen · National Center for Landscape Fire Analysis, UM
- Jennifer Fowler · Autonomous Aerial Systems Office, UM

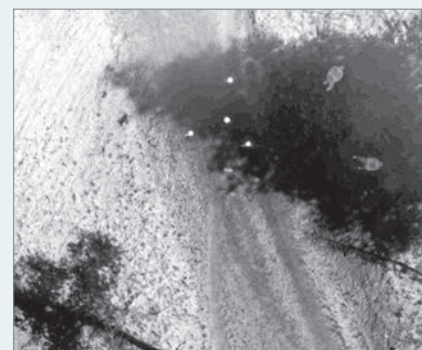
Funding Amount: \$900,000

Brief:

Wildfires in Montana have blackened 62,000 acres of forest and rangeland and cost taxpayers \$32 million so far in 2016. Threats to natural resources, communities, and firefighters are mitigated by reducing fuels and changing forest structure before fires occur. The UM research team has partnered with Montana's Unmanned Aircraft System (UAS) entrepreneurs to design and test instruments and techniques for providing measurements of fires, forests, and fuels—work that will ultimately lead to adoption of UAS in natural resource management at large. DroneFire is accelerating UAS technology development in Montana and creating opportunities for private enterprise by strategically connecting land managers, researchers, and private companies to natural resource challenges, by streamlining FAA and business procedures, and by teaching and training a UAS workforce.

Objectives and Progress:

1. Establish permanent UAS R&D field laboratory to test new platforms, sensors, and technology:
 - A. Droneport now operational at Lubrecht Experimental Forest; 11 missions flown and seven electro-optical camera systems tested.
 - B. National Certificate of Authority secured for Class G airspace below 400 feet—enhances abilities of researchers and companies to perform missions.
 - C. Five UM UAS are operational to complement private-sector capacity.
2. Cultivate science cadre to develop and test field-usable data products:
 - A. 12 faculty are engaged in UAS research on fire behavior, fuel measurements, weather forecasting, forest growth and yield, watershed assessment, and forest health.
 - B. Contracts exist with 8 Montana companies to provide access to 21 different drone platforms, 22 sensors (Electro-Optical and Thermal IR) and 12 processing streams.
 - C. Have conducted site visits to ten companies and institutions in six states and scheduled two winter field campaigns in SE U.S.—ensuring national reach and relevance.



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3. Build workforce and grow emerging field of UAS applications research:
 - A. 22 UM and MT Tech undergraduates trained in UAS operations and data processing.
 - B. One UM course in UAS mapping offered in Spring 2016. Two additional UM class are in development for training pilots and processing imagery.
 - C. Two UM graduate students have proposed to the Barrett Foundation Business Challenge to develop a drone-based wildfire defensible space technology company.

Return on Investment:

- **Jobs:**
 - Seven graduate students funded to use UAS in research
 - Eight technical staff hired to develop techniques for acquiring and processing UAS data
 - Three faculty funded to develop UAS applications
 - Five companies under contract (\$100K) for data services, platform development, sensor integration, and system evaluation and testing
- **Connections:**
 - Skyfish—Missoula (testing made-in-Montana quadcopter, gimbal, and software)
 - SUATS—Kalispell (integrating thermal and meteorological sensors)
 - Commander Navigation—Hamilton (prototyping multispectral cameras)
 - Big Sky UAV—Helena (grant proposal support)
 - ADAVSO—Boise (acquiring forest and terrain data with fixed wing platform)
 - Tesla Foundation—Global (developing training curricula)
 - The Nature Conservancy—Georgia (measuring active prescribed fires)
 - USFS Rocky Mountain Research Station—Missoula (high-speed videography of fire behavior)
 - Trout Unlimited—Missoula (post-restoration watershed assessment)
- **Leverage – additional grant funds received:**
 - Fire and Smoke Model Evaluation Experiment, Joint Fire Sciences Program: \$199K
 - USFS Rocky Mountain Research Station monitoring active fires: \$50K
 - National Fire Plan, Active Fire Remote Sensing: \$145K
 - PENDING: National Science Foundation: Sediment connectivity and its morphologic and vegetative controls: \$511K
 - PENDING: National Science Foundation: Biophysics of plant-insect interactions: \$887K
- **Output:**
 - 29 UM faculty, staff, and students in eight departments are working in UAS R&D.
 - Team is engaged in five private partnerships and four public partnerships to connect UAS technology to management needs, with missions underway in fire monitoring, forest inventory and health, and watershed restoration.
 - Team has overcome regulatory constraints, are expanding opportunities to operate UAS in Montana, and are now conducting 2-4 missions per week.
 - UM's Autonomous Aerial Systems Office has been established to provide a permanent institutional home for UAS operations at project end.



BIO-BASED FUELS

Advancing Bio-Based Chemicals and Next-Generation Fuels from Montana's Agricultural Crops

Principal Investigators:

- Randy Maglinao · Advanced Fuels Center · MSU Northern
- Eleazer Resurreccion · Civil Engineering Technology · MSU Northern
- Andrew Sullivan · Process Plant Technology · MSU Billings City College

Funding Amount: \$800,000

Brief:

Although camelina, a rotational cover crop, grows well in the “Golden Triangle” and does not interfere with wheat production, it currently has no market. The Advanced Fuels Center and MSU Billings City College are creating a fuel additive from Montana-grown camelina to replace lead in aviation gasoline, the only fuel still allowed by the U.S. Environmental Protection Agency to use lead. This project will ultimately create a market for camelina as well as a “green-collar” industry in the Hi-line region.

Objectives and Progress:

1. Analyze economic feasibility as well as renewability of production process:
 - A. Preliminary life cycle analysis data has been collected and is being presented at the American Center for Life Cycle Assessment Conference in Charleston, SC.
2. Create efficient methods for production of aviation gasoline additive from camelina:
 - A. Mechanism validated through experiments and results were presented at the 106th American Oil Chemists' Society Annual Meeting in Salt Lake City, UT.
 - B. Proposals were submitted to National Science Foundation and U.S. Department of Agriculture.
3. Develop efficient green manufacturing processes to lower the cost of production:
 - A. Proposed method for creation of a catalyst is close to confirmation.
4. Create a marketable byproduct from manufacturing side products:
 - A. Small scale pelletization plant to upgrade byproduct has been commissioned at City College and automation techniques are in development.

continued



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Return on Investment:

- **Jobs**
 - Research scientists: 3 (1.0 FTE)
 - Research technicians: 2 (0.25 FTE)
 - Research associate & assistants: 1 (1.0 FTE)
 - Undergrad & Graduate Assistants: 15
- **Connections—private sector partnerships:**
 - Calumet Refining—Great Falls
 - Elevance Renewable Sciences, Inc.—Illinois
 - Omega Grains, LLC—Bigfork
 - Old Dominion University—Virginia
- **Leverage—additional grant funds received:**
 - In progress
- **Output**
 - Successfully produced high octane hydrocarbons from camelina oil.
 - A pilot-scale pelletizing plant with a capacity of 3,600 lbs/day was commissioned.
 - Patent applications are in progress.



METAL RECOVERY

Recovery of Metal Contaminants from Industrial Wastewaters with Magnetic NanoComposites in a Novel Continuous Flow Process System

Principal Investigators:

- Jerome Downey · Department of Metallurgical and Materials Engineering · Montana Tech
- Ed Rosenberg · Department of Chemistry & Biochemistry · University of Montana

Funding Amount: \$495,127

Brief:

Acid rock drainage (ARD) is a serious environmental issue that requires remediation at over 300 identified sites in Montana. To address this imminent need, researchers are leveraging ion exchange synthesis technology under development at UM with a transport reactor system under development at MT Tech. The novel magnetic nanoparticles created at UM will be utilized in the transport reactor system to clean wastewater by extracting and concentrating heavy metal contaminants in a form that is amenable to recovery of marketable high-purity metals such as copper, manganese, and zinc:

Objectives and Progress:

1. Wastewater characterization: fifteen local surface water sites and nine flooded underground mine complexes have been sampled and analyzed for water quality to provide specific chemical targets and mixtures for treatment in the flow reactor.
 - A. Copper, manganese, and zinc were selected as the initial target metals for the pilot transport reactor system.
2. Synthesis of iron-magnetic nanoparticles modified for metal ion capture:
 - A. Demonstrated that metals are efficiently recovered following adsorption by the magnetic nanoparticles and the nanoparticles are reusable after recovery.
 - B. Demonstrated that the magnetic nanoparticles capture metal at rates 50 times faster than previously reported for 300 micron composite particles with similar metal ion capacities.
 - C. Scaled up the synthesis process from 1-5 g to 25 g, which is sufficient for use in the pilot pipeline reactor and is a strong indicator that further scale up will not be a problem.
3. Continuous flow reactor design, construction, commissioning, and operation:
 - A. Completed design and construction of the 4-inch-diameter continuous flow reactor.
 - B. Routinely attain particle capture efficiencies in excess of 98% using a single in-line electromagnet.



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continued

- C. Commissioned an electrowinning cell to evaluate metal reduction from the strip solutions; secured parameters for independently producing copper and zinc cathodes.
- 4. Secure fundamental aqueous processing data and generate process models:
 - A. Developed a wastewater parameter database which will be used to guide experimental design and interpret experimental results.

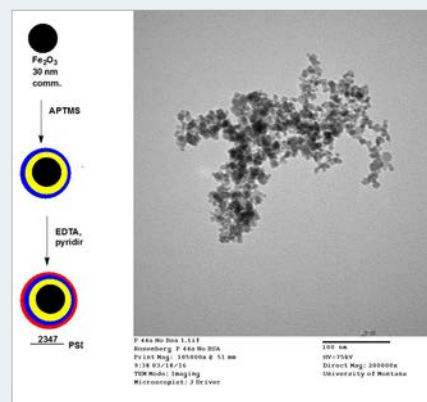
Return on Investment:

- **Jobs:**
 - 0.33 faculty
 - 1 postdoctoral scholar
 - 2.25 graduate research assistants (Ph.D. or M.S. students)
 - 2 undergraduate research assistants
 - 1 technician
- **Connections—private sector partnerships:**
 - Water and Environmental Technologies, a local environmental engineering firm, expressed interest in the technology for recovering selenium from wastewater.
 - A representative from Barrick Golden Sunlight expressed interest in technology to address a copper contamination issue they are experiencing with an intermediate process stream.
- **Leverage—additional grant funds received:**
 - Submitted on August 2, 2016, the NSF EPSCoR Track-1 RII proposal for the Montana Restoration and Environmental Materials Initiative includes research intended to assess another application of the magnetic nanoparticle/pipeline reactor technology. The total funding request of \$20,000,000 includes approximately \$100,000 for the reactor study.
 - Water and Environmental Technologies, which has a proven STTR track record, has agreed to partner on a National Science Foundation Small Business Technology Transfer (NSF-STTR) proposal focusing on the recovery of selenium from wastewater generated during coal production and processing. Proposal submission is targeted for December, 2016. The ceiling for Phase I funding is \$225,000.
- **Output:**

UM's success in establishing the requisite magnetic core and silica coating dimensions and their demonstration of high metal capture rates, stripping, and reuse have provided essential data that is being used to optimize the reactor design and operation.

MT has constructed a fully operational pilot-scale reactor and performance testing is underway. Results to date have shown that, with just a single in-line electromagnet, the magnetic particle capture is extremely efficient, thus eliminating the most serious concern relative to reactor design and scale-up.

For eventual industrial acceptance and commercial development, it is mandatory to demonstrate that the particle synthesis process and the reactor can be scaled up. Highly favorable results obtained with both the scale-up of the magnetic nanoparticle synthesis process at UM and the particle capture efficiency in the pilot-scale transport reactor at MTech provide a strong indication that further scale-up should not be a problem.



REMEDIATION TECHNOLOGY

Remediation Technology for Chlorinated Pollutants Based on Natural Product from Soil Bacteria

Principal Investigators:

- Thomas Lewis, Department of Biological and Physical Sciences · MSU-Billings
- Matthew Queen, Department of Biological and Physical Sciences · MSU-Billings

Funding Amount: \$262,731

Brief:

Carbon tetrachloride is a carcinogenic pollutant that has contaminated groundwater beneath former grain storage and industrial sites. Researchers are addressing a nationwide pollution issue by developing molecules based on a bacterial product to clean up sites contaminated by carbon tetrachloride. The new technology allows pollution to be treated on-site rather than current methods of moving the hazard to the surface. Pyridine di-thiocarboxylic acid (PDTC) is a small molecule natural product that leads to complete dechlorination of carbon tetrachloride pollution. The goal is to synthesize PDTC derivatives for improved performance in field application and conduct analytical work to assess the performance of the new derivatives.

Objectives and Progress:

1. Identify verified, chemically pure PDTC sulfonate, polymer-linked PDTC and their copper complexes, with the goal of improving water solubility of the active molecule and enabling modification of other properties such as density.
2. Develop data regarding solubility and dechlorination rates for new derivatives of PDTC.
3. Assess toxicology of simulated remediation mixtures and refine dechlorination data to include other solvents.

Return on Investment:

- **Jobs**
 - Research scientists & technicians = 1.5
 - Undergrad & Graduate Assistants = 1
- **Output**
 - The team has established baseline data for carbon tetrachloride removal rates by the natural product (PDTC). This data can be used by engineers designing remediation technologies and will be used by us to evaluate synthetic derivatives.
 - Continued study of remediation techniques is enhanced by the inclusion on a statewide NSF (EPSCoR) proposal to study basic aspects of the underlying chemistry of carbon tetrachloride destruction.



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www.mus.edu/research_initiative.asp



