Final Reports as of August 2006 - #02 Projects

#02-01 Advanced Materials for Metal Processing, Recovery and Remediation
Edward Rosenberg, University of Montana, Missoula
$180,307
Final report approved: August 2004
Summary:
MBRCT support has resulted in:

- Development of two new resins
  - One for the selective removal of ferric ion from transition metal mixtures and from lanthanides – to be piloted at a company in South Africa in June 2003
  - One for the selective removal of gallium from aluminum, zinc and iron
- Development of a process that separates precious metals from transition metals – to be refined and further developed during the continuation project (#04-03) in collaboration with Montana Tech using leaches from the Stillwater Mine at Columbus.
- Development of a single multistage ion exchange separation and concentration process for acid mine drainage streams, which does not involve any precipitation or liming and yields salable pure metal slats as the final product.
- Construction of a pilot scale demonstration unit to bring the technology to the end user for on site testing.
- Preliminary results (which will be expanded in the #04-03 continuation project) to support the approach to synthesize new materials and procedures for the removal of arsenic and selenium from industrial and mining wastes.

Commercialization Plan:
Product description: Metal selective ***r***esins and treatment protocols that form the basis for a viable process for mine waste recovery.
Advantages of Purity System, Inc. composite resins over polystyrene resins:

1. No shrink-swell in load-strip-regenerate cycles. Ideal for up or down flow fixed beds
2. Faster capture kinetics allows use of shallower beds.
3. Available in four particle sizes
4. Faster operational flow rates at higher capacities than conventional resins.
5. More porous structure gives lower pressure drops at comparable particle sizes.
6. Longer usable lifetimes due to more rigid structure and higher resistance to strong acids
7. Shipped dry compared with water for polystyrene.
8. Higher maximum operating temperature compared with polystyrene.
9. More stable to radiolytic decomposition.
10. Stable over a wide range of alkalinities and acidities

Production or manufacturing plan: The Luoyang, China, factory has a production capacity of 100 metric tons and is anticipating additional orders based on upcoming pilots. Following attainment of a revenue stream from sales, manufacturing will be set up in Montana.
New businesses created or expanded: PSI has expanded as evidenced in increase in employment levels, sales revenues and relocation to the MonTEC facility in Missoula.

Increase in employment levels: PSI has created two full-time and two part-time positions during the period of this grant.
Sales generated: PSI has had sales over the past year from pilot scale quantities of the resins developed. The first major order of approximately 12 metric tons of Ni capture has been received from Columbus Stainless Steel in South Africa. A second order is anticipated, for a combined order of $4 million, of which UM will receive 2% of gross adjusted PSI sales.
Patents applied for or granted: One new patent has been exclusively licensed to PSI during this grant period and two additional submissions for patents are planned in the next year.
Acquisition of investment capital: Ammtec (a mining testing company in Perth, Australia) has purchased 25% of PSI stock and will continue to help with distribution and market development. PSI has a distribution agreement with Ammtec.

#02-02 Biological Decontamination of Human Wastes by "Mycofumigation"
Gary Strobel, Montana State University
$265,520
Final report approved: August 2004
Summary:
The *Muscador albus* organism was discovered and characterized by the PI and colleagues at Montana State University. This endophytic fungus has the ability to inhibit and kill pathogenic fungi and bacteria by virtue of volatile antibiotics that it produces. Extensive testing began under this grant to determine if this organism could be developed as a product for Phillips Environmental Products Company of Belgrade. Experimentation showed that the organism could be grown on human liquid wastes, but no growth resulted when both solid and liquid wastes were combined. By controlling the pH of the wastes, growth and gas production resumed. Another endophytic microbe, *Fusarium culmorum*, which degraded wastes and grows in the presence of *M. albus*, was discovered. Both organisms can be effectively used in the Phillips product line to treat human wastes, a concept which is totally novel and extremely useful and important.

Commercialization Plan:
Upon receipt of EPA permits anticipated in late 2004, both Phillips Environmental Products and Agraquest will be offering *M. albus* as part of their product lines.

Product description: Endophytic fungus, called *Muscodor albus (M. albus)*, an organism that can effectively be used to treat human wastes.
Production or manufacturing plan: It is anticipated that initially Phillips Environmental Products (PEP) will make its own *M. albus* preparations in the lab at its facility and gradually acquire materials from Agraquest.

Economic Impacts:

Patents: At least five patents have been filed relevant to the project: (1) The original *M. albus* provisional patent; (2) and (3) two patents filed on *M. albus* via Agraquest for agricultural applications; (4 and (5)) a full patent and one CIP filed by PEP on the use of *M. albus;* (6) other intellectual property is pending submission.
Acquisition of investment capital: Additional investment capital is being sought.
Other: Bill Phillips, PEP, was designed Entrepreneur of the Year 2003 by Governor Martz in February 2004; Gary Strobel was presented the Technology/Science Award by MSU in early

May 2004, was awarded a NSF grant to prepare a Discover Channel quality production on *M. albus* and other microbes, and was elected to the American Academy of Microbiology for his work on *M. albus* and other microbes.
Eighteen (18) undergraduates have worked on the project and two tech and two post-doctoral people have also been involved.

Unique Features/success stories/news clippings, brochures/other information:

News clippings: Numerous news clippings were attached to the Final Report, including feature stories in the Bozeman Daily Chronicle, Science Magazine, CNN, Times of London, BBC Microbiology, Microbes and Infection.

Documentary film: The NSF funded a $70,000 project for the MSU Film Making in Science department to make a documentary film, "Jewels of the Jungle," about the endophyte project being done in the Strobel lab. The film is expected to be completed by November 2004 and the *M. albus* story will be part of the film. MBRCT will be acknowledged for its support of the research.

#02-03 Material Processing for Optimizing the Performance of an Embedded Bragg Grating
Philip Battle, AdvR, Inc., Bozeman
$200,000
Final report approved: March 2004

Summary:
The MBRCT grant, in conjunction with funding from NSF Phase II SBIR grant, was used to advance state-of-the-art waveguide fabrication technology in order to improve yields and lower manufacturing costs. AdvR, recognizing the need to improve understanding of processing and manufacturing controls prior to commercialization, continues to focus on waveguide Research and Development while making a limited entry into the commercial market. AdvR R&D revenues have grown and are expected to continue to climb. Staff has grown from three employees to 15. The growth can be attributed in part to funding support from MBRCT where its value is doubled and tripled as AdvR competes for R&D funding within the highly competitive US and worldwide marketplace.

Commercialization Plan:
Product description: KTP waveguides and waveguide expertise with applications requiring precise line width control as a complement to diode, solid state and fiber lasers that are robust, have small footprints, and long life cycles.
Target market: Waveguide technology marketing can be divided into three target groups:
(1) A diode based replacement for argon-ion and HeCd laser; (2) Specialty lasers; (3) Filters and switching devices.
Marketing strategy: Since no major market driver dominates the industry, an agile flexible marketing strategy is necessary. Strategic alliances with a limited number of large and smaller laser companies will be forged to establish sales of waveguide structures into high volume, well-established markets. AdvR will build a reputation as a supplier of high-quality waveguide

structures and specialty lasers through cost-effective marketing including publications, trade shows, and the Internet.
Production or manufacturing plan: It is anticipated that within five years, AdvR will have integrated waveguides into devices. However, it may also be possible to supply only waveguide components to some market segments.
Business risk assessment: Competitors can be segmented into three categories: in-kind, not in-kind, and customers and suppliers. The major threat will come from competitors with significantly different approaches that provide the same or similar characteristics for end-users. AdvR will compete on the basis of superior product performance at lower price. For all of the segments, AdvR will ultimately strive to drive down price while increasing product performance.

Economic Impacts:

Increase in employment levels: Number of employees increased 25% from 2002 to 2003, and plans are to add at least one engineer during the first six months of 2004.
Sales generated: Revenues have increased over 300% since the company was founded in 1999. Commercialization efforts include a new laser source for the Navy's Virginia Class submarine, lasers to assist NASA with lidar projects, development contract with Northrop Grumman to provide engineered materials to its lab, and contract with Stanford University to develop waveguides in KTP for a gravity sensing program.
Patents applied for or granted: The AdvR patent estate includes 12 patents licensed from DuPont and Altos Inc.
Other: AdvR has collaborated with Montana State University in Bozeman to support four undergraduate students as part of a Research Experience for Undergraduates (REU) program as well as authoring publications and conference presentations. AdvR has also established relations with other national and international research institutions including collaboration on various articles with the University of Sofia in Bulgaria, the University of Saint Andrews in the United Kingdom and the University of Oxford through Cornell online. These types of publication collaborations play a significant role in the long-term marketing strategy for moving AdvR's KTP waveguide technology from R&D to commercial applications.

#02-08 Weed-Resistant Small Grain Varieties for Montana

Robert Stougaard, Northwestern Agricultural Research Center, Montana State University

$194,352

Final report approved: March 2004

Summary:
The purpose of the project was to select and breed for competitive spring wheat cultivars that aid in reducing weed growth and seed production. To this end, two objectives were identified.

Objective 1. Initiate a breeding program to incorporate large seed size into new spring wheat varieties for use in Montana.
Research Results: More than 30 breeding populations have been generated and are available to start a selection program for competitiveness based on large seed size.
Assessment of Achievements: Development of a large stock of large-seeded materials and gathered insights into genetic basis and heritability for large seed size.

Objective 2. Identify competitive plant traits to be incorporated into spring wheat.
Research Results: Demonstrated that plants derived from large seed simultaneously display several attributes associated with crop competitive ability, the most important of which are associated with seedling vigor attributes and water and nitrogen uptake.
Assessment of Achievements: Confirmation that breeding for large seeded spring wheats will provide benefits in terms of weed control. Other competitive plant traits were also identified.

Commercialization Plan:
Assessment of Commercialization Potential:
Large-seeded spring wheats would improve weed control and minimize detrimental effects of abiotic stress on grain yield. The materials must be evaluated throughout the state to select the most promising lines and quantify the extent to which weed control, yields, and end-use quality are improved.

While the efforts made have provided the initial framework for successful development of large-seeded wheat varieties, additional research is needed before products can be delivered to the target market. Without additional funding to reach that stage, the project will have to be terminated at the present stage of development.

The route to commercialization of weed-resistant wheat varieties will utilize the established channels within the MSU system. This is a collaborative effort between the MSU wheat breeding programs, the Foundation Seed program and the Montana Seed Growers. The commercialization will proceed on two fronts, the seed industry and the baking industry.

Product description: Large-seeded, weed-resistant varieties
Target market: Target markets are the seed industry and the baking industry. A conservative estimate of market potential assumes acquisition of 5% of the current spring wheat acreage in Montana.
Marketing strategy: Promotion and marketing of the higher quality product will proceed with the cooperation of the Montana Wheat and Barley Committee.
Estimate of sales revenues for five-year period into the future: Total farm gate dollar value generated from spring wheat in 2001 was $200 million. 5% market share would equate to $10 million.

Economic Impacts:
In addition to the commercialization potential of the research, the efforts to breed for increased seed size in spring wheat appears to have numerous benefits for Montana producers, including weed control benefits and the ability to minimize the negative effects of drought and other abiotic stress factors. The extent to which weed control is improved, dockage reduced and end-use quality improved ultimately contributes to economic returns and the adoption rate of the technology. Until these factors can be quantified and assessed throughout the state, the total economic impact of this project is yet to be determined.

#02-11 Conversion of Coal Bed Methane Waste Water to a Beneficial Water Resource: Strengthening Southeast Montana's Forage and Livestock Industry using Phytoremediation
James Bauder – Montana State University - $330,046
Final report approved June 2006

Summary:
The objective of this project was to conduct laboratory, greenhouse, and field investigations, which would potentially lead toward development of commercially available plant varieties and cropping system methodologies that could be complimented or supported by coal bed methane gas production water. It was believed that achievement of this objective could serve to strengthen, expand, and add stability to the livestock industry based in a significant portion of eastern Montana. The conclusion is that CBM product water, as the principal source of water, will not support sustained or enhanced livestock forage production under the conditions prevalent in southeastern Montana. Commercialization of CBM product water does not appear to be a reasonable scenario unless blended with other water supplies or used under conditions of intensive management.

Commercialization Plan:
Because of political, legal and environmental regulatory constraints and uncertainties, an immediate opportunity for commercialization of coal bed methane production water in Montana is not likely.

Product description: Hay barley production for livestock consumption **is** a viable use for coal bed methane production water although yield and quality are compromised relative to production based on conventional irrigation water sources.

Economic Impacts:
Data [from other investigations] suggest that economic impacts of long-term irrigation with coal bed methane production water can have significant **negative** economic impacts, i.e. long-term reduced soil productivity, extensive management and soil reclamation costs, and significant reductions in long-term soil productivity.

Under conditions of already altered surface water quality, restricted availability to good quality surface water supplies, or extended drought, coal bed methane production water can serve a valuable purpose in supporting the livestock forage industry in southeast Montana.

#02-13 Lasers Stabilized to Spectral Holes in Rare Earth Doped Crystals
Rufus Cone - $200,000
Final report approved February 2006

Summary:
Lasers, extraordinary sources of intense light beams of very pure color, with ultra-stable output colors or wavelengths or frequencies are required in many high technology applications. Providing that stability was the focus of this project. This research developed ultra-stable lasers

with purity and stability to **13-digit accuracy**. Special rare earth crystal frequency references were developed and the crystals were grown by Scientific Materials Corporation (S2). The crystals were used to make the **most** accurate measurements **ever** recorded of light absorption frequencies in **any** crystal of **any** kind by **any** laboratory, thus adding value to S2 Corporation.

Work related to mode locked lasers is leading to new applications and new measurement techniques and provides Spectrum Lab and S2 Corporation with capabilities at the 1.5micron communication bands. Areas of application for ultra stable lasers include: compact stable continuous wave lasers for S2CHIP and S2 devices – precision vibrometers, gravimeters, and other metrology devices; secondary optical frequency standards using persistent holes as references; compact stable mode locked lasers that can provide periodic trains of optical pulses and optical clocks; mode locked lasers shown to have new uses in material characterization and system development.

Commercialization plan:
Product description
Continuous wave and mode locked stable laser systems and new spectral hole burning materials that act as frequency references and enable new applications of spatial-spectral holography. Product applications developed by a partnership of S2 Corporation, Spectrum Lab and the PI's group and funded by DARPA (Defense Advanced Research Projects Agency) and other DoD agencies and corporations. These include: S2CHIP system, LIDAR remote sensing applications including some Coherent Technologies, analog optical signal processing, and arbitrary optical waveform generation

New businesses created or expanded
Spin-off company from Scientific Materials – S2 Corporation

Sales generated
S2 Corporation has made a sale of a complete stabilized laser system to a major aerospace corporation.

Patents applied for or granted
Much of the laser and crystal technology has been patented and licensed to Scientific Materials Corporation. Three licenses are owned by the spin-off company, S2 Corporation, which was formed to commercialize the S2CHIP and related technologies**.**

Development of intellectual property
Transfer of laser stabilization techniques and frequency reference crystals has enabled a new Phase I and Phase II SBIR award at Scientific Materials/S2 Corporation with aerospace and military applications**.**

Acquisition of investment capital
Sale of Scientific Materials for to FLIR Corporation of Portland, Oregon – monetizing equity of original owners. Scientific Materials will remain in Bozeman**.**

#02-17 Improving Productivity and Value of Wheat for Montana
Michael Giroux - $300,000
Final report approved September 2004

Summary:
The project encompassed three objectives and involved five faculty members in the department of Plant Sciences. Objective one, to examine ways to increase yield of wheat, resulted in the ability to select for increased starch biosynthetic rates and yield without compromising protein content or quality. Objective two, to accelerate the pace of Clearfield winter wheat development, resulted in identification of nine elite Clearfield selections, which are being evaluated for commercial release potential. Objective three examined the usefulness of altered starch properties upon milling and baking quality. It was found that milling and baking qualities can be increased by selecting for desirable starch biosynthetic and puroindoline gene combinations.

Commercialization plan:
Commercialization progress for Objective 1:
The gene mainly responsibly for yield enhancements was crossed into germplasm, which may finally be released as a new commercial variety/varieties in Montana. Increasing yield by only 15 would translate into ~$2 million per year and preliminary data indicate that several -% increases may become possible. The best of the new lines will be released as a public variety to Montana growers and will follow established channels of seed increase and purification, similar to other successful variety releases.

Commercialization progress for Objective 2:
The Montana Agricultural Experiment Station entered a contractual agreement with WestBred to increase seed of MTCL01159 even though adequate data for release is not yet available. MAES is cooperating with WestBred to develop adequate performance, end-use quality, and crop tolerance data during the 2004 season to make a decision regarding its release.

Commercialization progress for Objective 3:
The work describing the added benefit to milling and baking quality of puroindoline b mutation has been adopted by Montana, U.S. and international wheat breeders. The puroindoline b mutation that confers increased milling yield and baking quality is being selected for inclusion into new varieties to enhance quality of new varieties. The new varieties will be released by the Montana Agricultural Experiment Station.

#02-20 Value-Added Crop Development for Irrigated and Dryland Production in Eastern Montana
Joyce Eckhoff, Eastern Agricultural Research Station, Montana State University
$150,000
Final report approved: May 2004

Summary:
The project accomplished its objective, which was to develop value-added qualities in crops that are currently grown under irrigated and dryland production in eastern Montana, through parietal improvement, management practices, and identity preservation. Extensive research has resulted in the development of value-added qualities in crops, production technologies, management practices and identity preservation that will help growers to be more efficient and productive. The MonDak region appears to be positioned to put the results to use with new industries, such as the semolina and pasta production, certified seed production and safflower oil processing industries, springing up. Increasing numbers of malt barley acres and safflower acres are under

contract and jobs are being created as a result. Effort is ongoing to inform and educate the public about the research, results and potential for the MonDak area.

Commercialization plan:
Product and target market:

- Dakota Growers Pasta, expanding pasta companies in Montana and North Dakota, will provide markets for Montana Durum.
- Research results and information will attract management and marketing companies and end users such as Pillsbury, General Mills, Nabisco, Montola Growers, Inc., and Safflower Technologies International to produce and market identity-preserved spring wheats and safflowers from this region.
- New and expanding domestic and international markets will strengthen the position of the safflower oil processing plant in Culbertson and allow the expansion of an alternative broadleaf crop in mono-culture wheat and barley.

Marketing strategy: Efforts are underway to develop best management technologies and new varieties to assure acceptable malt barley under both dryland and irrigated conditions.
Production or manufacturing plan: Production technologies are under development to insure a high percentage of the barley produced is acceptable for malting purposes.

Economic Impacts:
Develop improved durum and malt barley germplasm and production technologies

- Busch Agricultural Resources, Inc. (BARI) increased contracted malt barley acres in the region.
- BARI built a malt barley storage and handling facility at Sidney
- Cargill and Coors are competing with Anheuser-Busch for irrigated and dryland malt barley acres in the area.
- Increased value of barley for area producers
- Jobs created at the BARI storage and handling facility
- Companion businesses of barley transportation, seed cleaning and storage, and certified seed production

Develop improved production technologies and an identity-preserved production system for uniform quality small grain and safflower

- Research at EARC has demonstrated the high quality of hard red spring wheat produced in this region.
- Montola Growers, Inc. and Safflower Technologies International have contracted acres of safflower in this region for identity preserved production.
- Interest exists for identity preserved specialty wheat and safflower products from the region.

Develop improved varieties of safflower for human consumption, bio-fuel, bird food, and livestock feeding to enhance meat quality.

- Montola Growers, Inc. (Culbertson) and Safflower Technologies International (Sidney) are currently marketing Montana developed safflower varieties for end-use markets for human consumption, beauty care products and bird food.

#02-21 High-Value Crop Research and Demonstration Projects to Promote Irrigation Development in Eastern Montana
Jerry Bergman, Eastern Agricultural Research Station, Montana State University
$150,000
Final report approved: May 2004

Summary:
This project identified production management technologies that will result in the highest quality of sugar beets, potatoes and other high value crops. Demonstration of high yield and premium quality of various high value crops will help attract food processing plants, i.e. French fry processors, onion dehydration plant, new dairies, cheese plant, alfalfa processors, and will expand the sugarbeet industry. Research was conducted under flood and sprinkler irrigation systems. Use of low-pressure overhead sprinkler systems demonstrated that it is more efficient to use irrigation water than the flood irrigation commonly used in the lower Yellowstone River Valley. This project has developed production management technologies for high value crop production under sprinkler pivot systems as well as under flood irrigation. The high-value crops of potatoes, sugar beets, alfalfa, corn, onions and dry edible beans were successfully grown at the EARC as well as off-station. The importance of the research is evident from such investments as new dairy and alfalfa processing operations, a new startup certified potato seed operation, early conversion of many dryland acres to overhead sprinkler systems and the start up of commercial onion operations. The research team is committed to conveying the results of the research in terms of best management practices and production technologies to those who will best use it.

Commercialization plan:

Improve irrigation and production management technologies for high quality sugar beets and alfalfa.

- The high value crop research supports the growing and integrated pest and fertility management of sugar beets.
- The high value crop research has expanded production of high quality alfalfa for the dairy operations (Bostana Dairy at Sidney and Northwestern Dairy in Parshall, ND) and a new alfalfa processing plant (Northwest Alfalfa Products) built in 2003 in Tioga, ND.

Develop irrigation production and management technologies for potatoes and other high value crops, such as onions and cabbage.

- The high value crop research has promoted the production of 1,500 acres of commercial potatoes for the French fry market.
- The high value crop research has promoted the establishment of a new certified potato seed operation near Westby started in 2003 by Tom and Corrie Enander.

- The high value crop research has promoted the production of 20 acres of commercial onion production in the Glendive/Sidney, MT and Williston, ND area.

Economic Impacts:

Improve irrigation and production management technologies for high quality sugar beets and alfalfa.

- The high value crop research has supported the development and conversion of 5,000 to 8,000 dryland acres to overhead sprinkler irrigation acres per year.
- The high value crop research has supported the recently established Bostana Dairy in Sidney, the Northwestern Dairy in Parshall, ND, and a new alfalfa processing plant at Tioga, ND.
- The sugarbeet research has resulted in the development of an improved integrated pest and nutrient management program.
- The sugarbeet research has resulted in the identification and recommendation of improved beet varieties for sugarbeet producers to reduce input costs and improve beet yields and quality.

Develop irrigation production and management technologies for potatoes and other high value crops, such as onions and cabbage.

- The onion research has supported the startup of commercial production of onions by several irrigated growers with plans to continue onion production and marketing in 2004.
- The potato research has resulted in the commercial production of 1,500 acres of French fry potatoes.
- The potato research has resulted in the startup of a new certified potato seed operation near Westby by Tom and Corrie Enander.

#02-23 Specialty Mushroom Farming in Montana: New Technology, New Agricultural Products, Economic Diversification, Adding Value to Agricultural Wastes – Cathy Cripps, Montana State University
$149,420
Final report approved: February 2005

Summary:
The primary goal of the project was to develop new technologies, expertise, and resources that can benefit the Specialty Mushroom industry in Montana. Goals were accomplished on several fronts and led to new products, new technology, economic development, and a model for research and commercialization of mushroom production in the state. Garden City Fungi is becoming a model business at the forefront of this development. New technology developed at MSU is now employed by Garden City Fungi. The company is seeing increased productivity and anticipates expanding production, increasing its work force; and, possibly expanding to satellite production centers in the state.

Commercialization Plan:
***Product description*:** Improved mushroom production and development of new products

Major parts of this research have already been applied to commercial production by Garden City Fungi.

- 25% of Garden City Fungi's wholesale production of shiitake mushrooms consists of new strains developed through this research. This percentage is expected to increase.
- These new strains are of high value because they fruit at least 33% faster than original strains. This results in faster turnover and a higher production capacity in a limited space.
- According to GCF, "The new strain provides quality organic shiitake mushrooms that are flavorful and accepted by chefs throughout the northwest".
- Other new strains of shiitake developed through this research are being produced on a limited scale at GCF and are considered valuable for various marketable qualities.
- GCF has debuted a 5 lb mixed box of specialty mushrooms being offered by Food Service Companies and available throughout Montana and North Central parts of the USA.
- GCF mushroom kits are available nationwide through Carolina Biological Supply. The kits include educational material for teachers and use mushroom strains developed through this project.
- An invitation to GCF to attend the International Mushroom Growers Conference in Florida recognizes organic mushroom production in Montana on a national level. "Organic mushroom growing" is of high interest in the United States.
- Orson Miller, a prominent mycologist, has visited the GCF farm and given GCF his endorsement.

Economic Impact:

New businesses created or expanded
During the last few months, Garden City Fungi has undergone a complete expansion of its mushroom farm. They have applied technology developed through this grant and purchased their own equipment, which has enabled them to produce 2-3 times as many mushrooms as in the past. The expansion includes a new substrate preparation facility and new improved laboratory space to accommodate multiple workstations. GCF has also increased incubation space to accommodate a higher number of substrate blocks and has redesigned the growing rooms to be more space efficient.

Increase in employment levels
GCF has hired one new employee and expects to hire additional employees in the future.

Other
- Production is expected to increase 5-fold.
- GCF has initiated workshops to help other growers with production techniques.
- The project serves as a model for how research at Montana's universities can move directly into commercialization by partnering with Montana companies.
- Research on edible mushrooms has been initiated at MSU and which will continue – this will serve the people of the state of Montana.

#02-24 Novel and Sustainable Technology for Pulping of Agricultural By-Products in Montana

Richard Talley/Richard Williams - $500,000

Final report approved February 2006

Summary:

This MBRCT grant was supported by grants from DOE and USDA. An environmentally friendly straw pulping process has been developed. Selection of a continuous soda-oxygen based process as the pulping technology – a chlorine and sulfur free process capable of producing high-value pulp from wheat straw at a competitive price. A pilot plant capable of processing 2.5 tons of pulp per day was designed, constructed, and operated in Butte. Demonstrations were completed for interested parties and potential investors. The new technology demonstrates there are economic alternatives based on readily renewable resources. The business model for wheat straw pulp plants is based on small-scale conversion of cereal straw into high-quality pulp primarily for high-quality paper. A wheat straw plant can provide local high paying manufacturing jobs to revitalize rural communities. Local collection and use of wheat straw will permit conversion of 125,000 tons of wheat straw into 50,000 tons of pulp per year, in a tree-free, chlorine-free, sustainable manner, providing substantial environmental, economic and marketing benefits.

Commercialization plan:

Basic Business Concept

Wheat straw pulp business concept is based on a technology using a total chlorine free chemical process to convert straw for use in fine writing and printing papers. The proposed business will initially operate small pulp plants centered in cereal producing regions of the Pacific Northwest and possibly expand to cereal producing regions of Europe. Each plant will convert 125,000 tons of straw to 50,000 tons of pulp yearly. Printing and writing papers are target market. It will appear to environmental sensitivity because the product is environmental friendly in its chlorine free attribute. Implementation of the Federal Biobased Initiative requiring the Federal Government to purchase biobased products when reasonably available is imminent.

Commercialization Activities

Entities expressing interest throughout the project include: Northern Cheyenne Tribe, Potlatch Corporation, Second Harvest Project, the Alberta Research Council, and Brix-Berg Company. Due to financial constraints, the tribe did not move forward with further development nor did Potlatch materialize. Discussions continue with Second Harvest and Brix-Berg.

Conclusion

The result of the effort brings Resodyn to the edge of being a viable business concept. An important first step is to solve the black liquor problem. A key issue is the amount of chemicals that can be recycled out of the effluent of the pulping process. A demonstration pilot plant has been designed, constructed and operated. There are beginnings of a market that values the advantages that wheat straw pulp can provide. There are large-scale trends that are supportive and others that are not. There are positive steps that need to be taken to make wheat straw pulp more viable, i.e. finding a strategic partner in a position to help move the technology to market, doing the additional research to improve the economic efficiency of the process to make the pulp more cost competitive with wood pulp and recycled paper.

#02-31 Microbial Enhanced Oil Recovery Using Starved Bacteria
Randy Hiebert, MSE Technology Applications, Inc., Butte
Year 1 - $141,685
Final report approved August 2006

Summary:
The objective of this project was to fill in research gaps that have been slowing commercialization of MSE's Microbial Enhanced Oil Recovery Technology and to then perform a pilot-scale field demonstration in a Montana oil field. The laboratory research portion (to test Biofilm Barrier Technology to enhance the recovery of oil from a Montana oil field) was accomplished successfully at Montana Tech. However, many delays (and three extension requests) occurred in performing the pilot-scale field demonstration of the technology in an oil field. The field injection was finally achieved in August 2005. Although it went well, at the time of this report, field results are inconclusive. Final impact of the injection may not be known for several more months because transport in the deep subsurface is very slow. MSE will continue to monitor the field progress and report any significant findings to MBRCT.

Commercialization plan:
Product:
MEOR (Microbial Enhanced Oil Recovery) - The use of very small, starved bacteria to penetrate deeply and selectively into the zones of high permeability. Proposed products and services are:

- Site investigation services
- Bacteria production
- Field application services
- Field monitoring services

Target market including size:

- Customers include oil companies and oil service companies, first in the US and Canada and, later, international
- According to DOE, for every barrel of oil produced to date, two barrels have been left behind, leaving some 350 billion barrels as the target of improved oil technologies.

Marketing strategy:

- Pursuit of multi-pronged marketing approach.
- MSE may align with a partner, likely an oil company or an oil field service company.
- Once proven, the technology will sell itself. To successfully market the technology, field data is imperative.
- Focus on technology benefits that differentiate MSE from the competition, including economical increased production, no H2S production, removable barrier, natural solution, and decreased costs.
- MSE will sell novel MEOR technology to oil companies by presenting at conferences and trade shows and by direct contact with the oil company.

Production or manufacturing plan:

- MSE has license for basic patents and is considering three additional patent filings.
- MSE has the necessary equipment for isolating the bacteria needed to form barriers.

- MSE has facilities that could be readily modified to produce large quantities of bacteria if needed.
- MSE has personnel with extensive experience in all facets of the technology.
- MSE has the infrastructure to support the business line.
- MSE has access to more sophisticated equipment at MSU.
- MSE's partner, CBE, is a research facility at MSU and is primarily supported by NSF.

Business risk assessment:

- **Technical risks** include the plugging bacteria could be used as a food source by other microorganisms, pathogenic bacteria are stimulated by the nutrient injection, and subsurface conditions are not conducive to barrier formation. These risks have been mitigated.
- **Acceptance risk** that corporations are wary of new technologies is overcome because this is an approach that is relatively easy to understand. MSE must prove the technology is technically sound, and economically more attractive over conventional methods.
- **Regulatory risk** that regulatory agencies will not allow subsurface injection of microorganisms should be overcome by proper preparation.

Economic Impacts:
Economic impacts are difficult to predict because field injections to date have not yielded positive results. However, if and when the technology proves itself and becomes a commercial product, increased oil production would result in increased employment for Montana businesses, including such technology development companies as MSE and the Center for Innovation. Oil companies would benefit from increased production and greater employment, generating additional tax revenues for Montana from higher incomes and royalties from the increased oil production.

#02-32 Ultraclean Transportation Fuels Technology: A Sorbent-Based Approach
Douglas Rosholt, MSE Technology Applications, Inc., Butte
Year 1 - $35,331
Final report approved November 2003

Summary:
The project objective of investigating a promising sulfur removal technology, known as adsorption, was met. MSE believes this to be a good technology, but the strength of the adsorbent needs to be increased and costs need to be reduced to make it truly competitive. Technological advances occur regularly in the chemical adsorbent market as new adsorbents are constantly under development. When suitable advancements are developed, MSE intends to propose modifications to the research based on those advancements.

Commercialization plan:
Product:
Sulfur removal technology, known as adsorption, suitable for use in petroleum refining processes. This approach to removing organic sulfur from motor fuels, if viable, will enable refiners to meet the 2006 fuel sulfur regulations and provide a lower cost means of removing sulfur than presently available.

Target market:
The principal market is the worldwide refining industry, which processes approximately 24 billion barrels of crude oil per year. The domestic market for clean transportation fuels is currently about 12 million barrels per day, or $184 billion per year. As other nations develop increasingly stringent sulfur regulations, customers for sulfur removal technology will ultimately include refiners from around the globe.

Commercialization strategy:
MSE's commercialization strategy is built around seven principles: (1) Determine if the technology is sufficiently mature and economically viable; (2) Identify potential markets and estimated market size; (3) Identify potential users: (4) Communicate with potential user and understand the user's specific needs; (5) Know the timeliness of the commercialization; (6) Make the product available to the customer at an attractive and affordable price; (7) Identify and bring on an industrial partner early during the pre-commercial stage of the technology development.

Risk assessment:
The technical risk is that no suitable adsorbent to make the system work properly can be found or developed. This situation would cancel the whole program, or severely delay it when timing is crucial. The market risk is that the need for the product may disappear, which is not very likely because changes in the regularly environment are likely to get more stringent regarding sulfur emissions.

Economic Impact:
A royalty for sulfur removal licensing fees would produce a net income to the process patent holder (MSE) if all domestic refiners used the process.

#02-33 PCAP Spray Forming of Invar – Ronald Glovan, MSE Technology Applications, Inc., Butte
Year 1 - $21,723
Final report approved November 2003

Summary:
The purpose of the project was to evaluate whether or not the PCAP thermal spray process had commercial value as a process for the spray forming of Invar for use in products that require a high degree of dimensional stability, such as waveguides, advanced thermostatic controls, and molds for composite aviation components. The result has demonstrated the feasibility of using the PCAP thermal spray system to fabricate Invar 36 in composite fabricating tooling applications. However, since this project was initiated, MSE has abandoned its advanced materials business, and its only commercialization activity will be to find a licensee for the patented technology.

Commercialization plan:
MSE has abandoned its advanced materials business and, since MSE is the owner of the PCAP patent, the only commercialization work that will take place will be an effort to license the technology to another party.

Conclusion and recommendations:

After conducting the individual tests, the PI offered the following conclusions and recommendations:

- The project was successful in determining the feasibility of thermally spraying Invar 36 with the PCAP thermal spray system.
- Additional testing aimed at improving the amount of Invar that can be sprayed, and lowering the porosity in the deposits, will be required.
- Any future testing should include evaluation of the mechanical properties of the PCAP sprayed deposits.
- Development work will also be required to improve the high temperature performance of the PCAP nozzle and tundish.

#02-35 Montana's NSF EPSCoR Infrastructure 2001: Cross-Sectional Partnership Building for the Future – Mark Young, MSU/UM

Year 1 - $1,505,604

Final report approved January 2005

Summary:

The governing strategy of this grant is to identify and enhance the science and technology capacity, and directly stimulate Montana's economic development. The overall goals include: (1) develop three target areas to serve as a science and technology foundation to economic development (Integrative Analysis of Complex Biological Systems, Nanotechnology and Biomolecular Structure and Function); (2) provide a highly skilled science and technology workforce involved in each of the three target areas; (3) establish new initiatives in education outreach that have a significant regional and national impact: (4) expand, in the long term, the science and technology capacity of MSU and UM; (5) expand the positive economic influence of MSU and UM to the entire State of Montana.

Commercialization Plan and Economic Impacts:

Montana's EPSCoR program has laid a foundation of excellence in research and technology and will work with the state to build on this new foundation to define a niche market for Montana's companies and graduates.

- Instrumental in growing MUS G&C expenditures from less than $10 million to over $100 million since its inception twenty years ago and, in the future, could be the mechanism to continue to launch and enhance growth in the private sector as well.
- Instrumental in funding researchers who have collaborated with, and helped to "home grow" about nine laser optics companies in Montana, which have become quite successful with markets that extend internationally and have used a work force trained in the MUS.
- Funding initially directed to Plant Sciences has paved the way for the biotechnology effort in the state.
- Continued federal and state funding for the EPSCoR program have included definitive outcomes including:
    - An increased level of economic development in Montana with a significant increase in clean technology industries
    - A College of Agriculture major in the new "hot" biotechnology area
    - Collaborations with numerous companies surrounding the universities as well as elsewhere in the state
    - Development of high paying jobs for Montana graduates in Montana companies

    - Seed funding for over 35 Montana based companies for assistance in developing proposals for large federal and private funding grants
    - Broader education and research opportunities for undergraduates
    - An overall increased quality of life for Montana residents
- Increase in multi-investigator awards within the MUS.
    - 2001-present, UM and MSU have been awarded 14 multi-investigator research grants, including IGERT, NIRT, PPG, STC and COBRE.
    - UM was recently awarded a new building grant for $3 million for construction of a new research facility linked to the School of Pharmacy.
    - Extramural funding at UM and MSU has achieved record highs exceeding $130 million.
- Montana has responded to emerging initiatives involving diversity, tribal colleges, education and outreach, governance and program guidelines and increased economic development.
- Expansion of Phase 0 SBIR program to include Phase 1.5 and The Partnership Development program, helping small businesses move toward Phase 2 awards, as well as co-support of SBIR Phase 0 awards with Montana SBIR program and MSU TechLink.
- Montana Tech and six Montana tribal colleges will become partners in the 2004-2007application.

#02-37 Investigation of Electron Transfer Based Photonic and Electro-Optic Materials and Devices – Jerry Bromenshenk, University of Montana, Missoula
Year 1 - $200,000; Year 2 - $200,000
Final report approved December 2004

Summary:
The project provided funding for two years matched by a three-year Implementation Award from the DOE EPSCOR, the most immediate outcome of which was successful competition and award of an additional three years of support from DOE totaling $1.2 million (which will be raised to $1.9 million pending restoration of full funding to the national program).

DOE Implementation Awards have a goal of building research infrastructure in energy sciences and, for MBRCT, this means the overall program builds infrastructure, expertise and synergy among Montana colleges and businesses rather than development and commercialization of a single technology.

Because of the multiple technologies involved, commercial development has occurred via multiple routes and has been highly successful in meeting milestones of producing new electron transfer materials that have applicability in a wide variety of devices:

- Chemical components show advantages over many other competing technologies.
- Incorporation of multiple chemical agents into dendritic structures enhances activity.
- Inter-campus characterization facilities give exceptional information about how well materials and devices work and the mechanisms by which they function.
- Characterization data is fed back into the materials synthesis process and into computation modeling.
- Modeling leads to more effective and rapid material development.

- The team has engineers who have the ability to incorporate these materials into devices and provide feedback on other improvements needed for compatibility with implementation devices.

A real synergy has developed across three campuses, The University of Montana, Montana State University and Montana Tech. In the third year review of the program, DOE scientists and program directors concluded that this project already has "demonstrated an exceptional integration of a program to transfer fundamental studies to practical applications that hold promise for very significant economic and technical benefit". This interaction has produced funded cooperative projects totaling several million dollars, resulted in several patent applications and played a role in the spin-off of four new businesses in Bozeman and Missoula as well as a new academic/business technology center at Montana Tech in Butte.

Commercialization plan:
The PI states, "DOE recognizes that research science is a major form of economic development, producing new knowledge, new materials and devices, and breakthroughs in basic and applied science. At the same time, both in the classroom and especially in their laboratories, these investigators are developing critical knowledge and training the next generation of scientists and engineers needed in a world that has become increasingly complex and information rich; where high technology companies and employment are key ingredients to a strong and growing economy. These well-paid, high technology jobs are sorely needed in Montana, whose average income now competes with states like Mississippi for being the lowest in the nation."

This project has already significantly affected Montana's economy in several ways:

- Recruitment and training of under-represented groups for careers in science and engineering, including 5 Native American College and pre-college teachers, 8 high school students, 4 Native American graduate students, 5 Native American undergraduate and high school students, and 20 women.
- Faculty development, collaborations and submission of many funded proposals and projects in the focus area and related activities.
- Initially three team members (Rebane, Spangler and Yakymyshyn) were engaged in spinning off two companies. Ed Rosenberg at UM has spun off a business in Missoula. Richard Donovan at Montana Tech formed the RAVE technical development center in Butte.
  Jerry Bromenshenk and five partners formed a technology transition operation in Missoula and have already published two patents.
- Wavelength Electronics, Bozeman, is working with three team members to develop a new material that has much improved properties for use in the feedback element in feedback control. Wavelength is working with TechRanch to spin off a new company to commercialize feedback control apparatus based on this material.
- Stated another way, 8 of 14 investigators are, or will soon be, engaged in new technology based businesses in Montana.

Details regarding the intellectual properties component are discussed in the Final Report under "MUS Commercialization Plan for these projects leading to a distributed, state-wide system of photonics, optics, and sensor-based businesses".

Economic Impacts:
Information dissemination, public and business awareness, and reputation are key ingredients to success, according to the PI, and the following numbers provide evidence that investigators, their

professional staffs and students are productively working toward establishing themselves as national and international leaders in the field. (A list of publications and presentations is attached to the Final Report.)

- **Publications and presentations**
    - 138 total publications, including those directly and indirectly related to the project
    - 102 total presentations, including those directly and indirectly related to the project
- **Table of Impacts** – Lists millions of dollars in currently funded and pending proposals from federal agencies and private companies for the faculty of the research team. Examples, which address the importance of collaborative research and dispel the myth that Montana investigators and separate research campuses do not work together, include:
    - Dr. Michele McGuirl, UM – awarded more than $540,000 by DOE and DoD as well as recipient of a five-year, $500,000 CAREER award, and a highly competitive award from NSF to promising young scientists. She credits this project for helping her successfully compete for this award.
    - Dr. Spangler, MSU - received $1,022,500 in awards related to this effort. In addition, networking at the Rotunda Session in Helena resulted in new collaborations at UM.
        - The networking resulted in formation of an alliance between UM, MSU, S&K Electronics, and Sandia National Laboratories (DOE) and, six months later, proved that bees and LIDAR could be used to map landmines.
        - This story has received national and international attention and has tremendous potential because the system could reduce the time required to clear existing mine fields and could mean hundreds of jobs and millions of dollars in revenue per year to Montana companies.
    - Work done under the direction of Dr. Richard Donovan using computerized learning systems (Artificial Neural Networks) was important to winning a contract to network security sensors at the Helena airport and the Bert Mooney airport. In addition, Montana Tech received two of 16 awards made nationally by the Transportation Security Administration, totaling $2million of the $20 million awarded nationally.
- **Spin-off companies and technical development centers**
    - Rebane, C. Spangler and Yakymyshyn were engaged in spinning off **two companies**.
    - Rosenberg spun off a **business**.
    - Donovan formed the **RAVE technical development center** at Montana Tech.
    - Bromenshenk and five partners formed a **technology transition business** in Missoula and have already published two patents. One objective of the business is to facilitate the movement of new and emerging technologies from research laboratories into the commercial sector.
- **Other activities**
    - Schmidt, L. Spangler, Abbott are developing a new material with improved properties for use in the feedback element in feedback control in cooperation with Wavelength, which is working with TechRanch to spin off

a new company to commercialize feedback control apparatus based on this material.

- Through collaboration with C. Spangler, activities with the University of Florida and the University of Alabama show promise for producing photovoltaic devices with potential for commercialization through MPA Technologies in Bozeman.
- Work by Rebane and C. Spangler has produced new highly branched organic materials that exhibit the largest multi-photon absorption yet measured and are being studied for applications in photo-medicine, ultra-fast optical memory and photovoltaic devices based on extremely efficient electron transfer.
- The Dickensheets' group is patenting fast focus control systems using a deformable mirror. Two patents have been filed and licensed for this technology.
- Equipment support to establish a microfabrication capability for Montana and by end of summer 2004 a new cleanroom housing micro-device fabrication tools will be in operation at MSU. This will provide Montana researchers and small companies access to important specialized capabilities.
- The Access Grid system is envisioned to provide full, multi-media, two-way communications among university investigators and their students, tribal colleges and Montana businesses.
- Bromenshenk worked closely with State Legislator Richard Heines in providing justification for a 2001 House Bill to remove impediments and encourage University professors to pursue commercialization of technology.

Summary:
The success of the core DOE/EPSCOR Implementation program in electron-transfer based materials and devices is evidenced by:

- Successful completion of an additional three-year DOE award
- Large number and value of related federal, state, and private industry awards and contracts to team members
- Outcomes and success of collaborations with other investigators and joint submissions to other agencies and programs

The PI concludes that, overall more businesses are expected to emerge as a result of this synergy and dynamics. Changes in Montana law removing barriers to faculty holding equity in businesses, the example set by four newly formed companies, and the ability of founders of these companies to assist their colleagues to start their own companies show considerable potential for return on the MBRCT investment.

#02-40 Enhancement of Applied Research in Biomedical Technology
Richard Bridges - $400,000
Final report approved February 2006

Summary:
This project represents a 3-year performance period of a five-year effort to establish the NIH Center for Biomedical Research Excellence (COBRE) for the purposes of increasing critical mass of researchers and providing necessary infrastructure to increase the competitiveness of biomedical research efforts in Montana. Collaborators on the project

include St. Patrick Hospital and Health Sciences Center and the Montana Neuroscience Institute in Missoula as well as other emerging Montana biotech companies.

Significant progress has been made to extend the COBRE funding and enhance applied biomedical research efforts in Montana - Increasing research productivity and funding; supporting shared instrumentation; training students; increasing opportunities for private sector collaboration and IP commercialization (SBIR awards, university-private sector collaborations).

Significant accomplishments toward these original goals include leveraging COBRE and MBRCT funds to attract additional federal research dollars. These federal research contract dollars contribute to the salaries of more than 70 employees, including 30 students, which represent new dollars coming into Montana. Clinical research trials at the Montana Neuroscience Institute have reached a record 25 projects. CSFN investigators continue to build collaborative ties with emerging Montana Biotech companies, including NanoMed Technologies, Bozeman. A new PhD program has been initiated in the Neurosciences in collaboration with MSU.

Commercialization plan:
Given that the emphasis of the project is long term, University-based and directed to enhancing the infrastructure needed to enhance translational and applied biomedical research, there are no plans to commercialize a specific product. However, commercialization of technology is an overall goal of this project that has been accomplished through strategic collaboration with private sector companies, such as BioPred and Neurocrine Biosciences, with funding via SBIR and STTR grants. With the progress CSFN investigators have now had in developing intellectual property (IP), these efforts have been expanded to include the development of spin-off companies through which to commercialize the IP. The results so far include one new provisional patent by David Poulsen and colleagues and the subsequent creation of Big Sky Biotechnologies.

Economic Impacts:
The MBRCT award has had a significant impact in terms of leveraging additional federal grants, the creation of research-based jobs, and increasing the expertise and resources available to regional biomedical/biotech companies. Annual federal research contract funding within the ***CSFN*** is currently about $7,000,000, with total funding committed to CSFN researchers over the next five years approaching $20,000,000. These federal research contract dollars contribute to the salaries of more than 70 employees, including about 30 students. These dollars came from federal research contracts and represent new dollars coming into Montana. Lastly, the investment in translational and applied research is beginning to pay off with the generation of intellectual property. This award period marked the first submission of a provisional patent by CSFN investigators (D. Poulsen and colleagues) and, in turn, formed a basis for the creation of a new spin-off company, Big Sky Biotechnologies.