## Final Reports as of April 2009 - #04 Projects

### #04-03 Advanced Materials for Metal Processing, Recovery and Remediation
**Edward Rosenberg, University of Montana**
***Final report approved May 2006***

**Summary:**
This project has continued to develop new technology allowing extraction of commercially valuable metals from low-grade ores not previously suitable for extraction. The project also is aimed at solving some of the critical environmental problems facing Montana. The project has developed a process for separating platinum group metals from base metals, a new material for the separation of nickel and cobalt, the separation of lanthanides from base metals and innovations in the synthetic design of the composite materials and opened the door to the development of a new class of materials for the recovery and removal of toxic negative ions from contaminated streams and ore leaches.

**Commercialization:**
PSI line of products offers significant advantages over conventional ion exchange resins, the most important being lack of shrink and swell during use and exceptionally sharp separations breaks critical for mining industry applications.

***Product:***
(1) BPAP – selective removal of ferric ions from divalent transition metals and lanthanides
(2) WP-4 – selective removal of ferric ion from divalent metals except copper and gallium separation from aluminum, zinc and iron
(3) BSAM – actinide recovery
(4) IMPACs – removal of low level arsenic and selenium and recovery of other valuable negative ions

***Target market:***
American environmental engineering companies charged with remediation of abandoned mine sties and waste streams from operational mines; growing gallium arsenide, glass and xerography industries; mining industry especially companies using bio-leaching for ore extraction; metal processing industry where recovery of valuable metals from waste streams is important.

**Economic Impacts:**

***Patents applied for or granted:***
PSI has supported development of four patents to date, all assigned to UM with exclusive license to PSI in return for 2% gross adjusted sales.

***Acquisition of investment capital:***
PSI has a distribution arrangement with Ammtec Limited, Balcatta, Western Australia, a minority shareholder in PSI. Production and sales of finished products will be financed with additional private capital.

***Other:***

- ✓ Two invited papers, four contributed papers, five presentations at professional meetings where MBRCT support has been acknowledged.
- ✓ Project Agreement between Montana Manufacturing Extension Center and Purity Systems to develop a feasibility analysis for the operation of a production facility to produce resins
- ✓ General Manufacturing Process for PSI-WP "XXX" Series Ion Exchange Resins
- ✓ Multiple Letters of Support

## #04-05 Deployment of a Real-Time Coal Content/Ore Grade ($C^2OG$) Sensor
**Rand Swanson, Resonon, Inc.**
**$88,578**
***Final report approved April 2005***

**Summary:**
**Research carried out.** The objective of this proposal was to deploy a $C^2OG$ sensor in a working mine. A custom scanning system was installed in the core room of the Stillwater Mine near Nye. Improvements were made in the system, particularly in an improved lighting technique.

**Results.** Primary results generally show a positive correlation with assay results although the system missed the smallest flecks of sulfides.

**Achievement of objectives.** Objectives were achieved with the exception of establishing a maintenance schedule for the hyperspectral imager due to the fact that no breakdowns with the hardware were experienced. This, overall, is good news even though it made it impossible to establish a maintenance schedule.

**Assessment of commercial potential.** For mining applications the commercial assessment is considered fair because it has both strong positive and strong negative features. There is no direct competition and little indirect competition and the mining industry it receptive and tolerant to new technology. However, the mining market is highly volatile and relatively small and highly fractured. Resonon will pursue this application because mining provides a good development platform to new technology. It will do this via an SBIR Phase II to deploy the technology in blast holes and application for a new DoE Mining program to utilize the technology in surface mining with Barretts Minerals. In addition, the advances made under this grant have assisted Resonon in obtaining funding for other applications of hyperspectral imaging, including commercial sales, an NSF STTR Phase I, and DOD SBIR Phase I and II awards. Requests for quotes are coming in nationally and internationally for the systems.

**Commercialization Plan:**
Although commercialization will focus on mining applications, this effort has helped Resonon develop hyperspectral technology in general, which can be applied to a broad range of applications.

**Product description**: The products are hyperspectral imagers for grading ore and may take more than one form, such as a system that will fit in blast holes to evaluate the ore before blasting, or a scanner on a rotating tripod to image the working face of a talc mine to identify high- and low-grade ore before testing the material.

**Target market(s) including size**: Potential markets Include platinum group metals, gold, lead, silver, zinc, copper, and other metallic minerals. Resonon will focus on metallic minerals, primarily platinum/palladium with secondary attention to gold, for its near-term commercialization efforts.

**Marketing strategy:** Initially the technology will be marketed directly to mines, such as Stillwater Mining Company and Barretts Minerals. Additionally, Resonon will take steps toward penetrating the gold mining market as part of the Phase II effort and making arrangements with Mount Sopriss, a leading provider of borehole equipment, to market the down-hole probe.

**Production or manufacturing plan**: Resonon will do the initial manufacturing in-house because of the small volume and specialized training required for assembly and optical alignment procedures.

**Business risk assessment**: Machine vision market for mining is so small and difficult, it is unlikely to attract any large competitors and, thus provides an excellent opportunity for first-entry advantages for a start up. There is some risk the technology will not meet the needs of the mining industry, but real-time potential, low operating costs and low maintenance should lead to important niches.

**Economic Impacts**
The project has helped Resonon to obtain DoE funding, a major source of revenue during the start-up phase of the company. This has helped gain the expertise for Resonon to become more competitive and led to other external funding.

**New businesses created or expanded**: This project has helped Resonon secure SBIR Phase 1 and II funding for the down-hole probe, SBIR Phase I and II funding from DoD, and STTR Phase 1 funding from NSF.

**Increase in employment levels**: Resonon recently hired two new full-time employees and two part-time employees, for a total of five full-time and one-part-time employees.

**Sales generated**: Resonon has made commercial sales to several MSU research groups and has recently supplied quotes to groups in Montana and other areas of the U.S., Taiwan and Germany.

**Patents applied for or granted:** Resonon has applied for a patent on the technology developed under the DoD Phase I and is investigating applying for another patent for the NSF project as well as one for the DoD down-hole probe.

**Development of intellectual property:** Resonon has obtained considerable know-how in near-field hyperspectral, which is the foundation of the company.

## #04-06 Montana Infrastructure via Science and Technology Enhanced Partnerships – INSTEP
**Charles Thompson, University of Montana/Montana State University**
**$3,000,000**
*Final report approved November 2006*

**Summary:**

All of the proposed milestones for this award were either met or exceeded. Projects completed or established include: faculty hire diversity, K-12 and outreach programs aimed at enhancing the science and technology (S&T) infrastructure in Montana including the creation of a Science Learning Complex at UM. The State of Montana EPSCoR co-invested in S&T-based businesses, enhanced Montana's non-PhD granting institutions, research and science education capacity, and generated new research space. Montana invested in local and regional businesses through SBIR Phase 0 and 1.5 awards and new SBIR-based incentives.

**Commercial Potential:**
Montana NSF EPSCoR continues to expand its investment in the research enterprise by assisting inventors and entrepreneurs to become more competitive for federal SIBR awards as well as partnering with the State of Montana SBIR program, offering more competitive funding, providing counseling and promotion of SBIR award and business plan writing, and increasing faculty involvement through seminars and conferences.

## #04-10 Functional Analysis of Genes Controlling Malting Barley Grain Protein Concentration

**Andreas Fischer, Montana State University, Bozeman**

*Final report approved October 2006*
**$176,801**

**Summary:**
Results from this project have been shared with MSU's barley breeding program and knowledge gained will be utilized for the development of superior, new malting varieties with stable GPC <13.5%. Data indicates a trend in the malting industry to purchase increasingly greater quantities of malting barley, representing a potential value of $40-60,000,000 to Montana farmers.

**Project results:**
A number of genes directly important in increasing barley grain protein concentration have been identified. Altering expression of one or several of these genes could conceivably decrease protein content of mature barley kernels, as needed for improving malting quality in Montana's dryland agriculture. Functional analysis of identified genes will continue in MBRCT #06-10. Increased competitiveness with federal granting agencies has also been an outcome of this project, i.e. experience gained with preliminary microarray hybridizations has resulted in a $295,000 USDA-NRI grant.

**Commercialization Plan:**
**Product description:**
The final goal of the project (continued under #06-10) is the application of gained knowledge for breeding superior malting barley varieties with stable GPC under Montana's dryland farming conditions. Results will be incorporated in ongoing barley breed programs through

- Direct use of created germplasm for crosses in ongoing breeding efforts, as appropriate
- Marker-assisted selection for genes/alleles, which are demonstrated to have a major influence on GPC
- Transgenic approaches (to lower expression of genes directly enhancing GPC) if/when this technique becomes acceptable to the end user

**Target market including size:**

Malting industry is increasing purchase of barley and prices for malting barley have increased from $3.29 per bushel in May 2006 to $3.42 per bushel in June 2006. Malting barley represents a value of $40-60,000,000 to Montana farmers, depending on yield and price fluctuations.

**Marketing strategy:**
Physical presence of a new malting barley plant in Great Falls is expected to lead to an overall increase of Montana's malting acreage. The plant has contracts with about 130 grain growers and employs approximately 35 people.

**Production or manufacturing plan:**
Resulting experimental lines will be tested and interesting germplasm released through MSU's established Foundation Seed Program.

**Economic Impacts:**
Besides the commercial importance of barley to Montana's economy, the question of N recycling in crops has considerable economic importance besides the narrower implications for GPC. Inability for major annual crops to re-utilize nitrogen would necessitate higher N fertilization rates to maintain present yield (and grain protein) levels. This is undesirable from both economic (fertilizer cost) and ecological reasons (nitrogen runoff from agricultural soils). This project has made a substantial contribution toward solving the long-standing problem modern plant science has faced in not fully understanding the underlying molecular processes which are of crucial importance for providing food for the world's growing population.

## #04-11 Development of New Products for the Field Detection of Bioterrorism Pathogens
**Brenda Spangler, SensoPath Technologies**
**$118,500**
***Final report approved November 2004***

**Summary:**
The grant specifically covered the synthesis and characterization of a water-soluble fluorescent tag for anti-anthrax antibodies. The capture of an anthrax antigen can be supplied in kit form with all necessary reagents and instructions to carry out the detection procedure**.**

**Accomplishments:**
- Synthesis of a licensable fluorescent dye
- Demonstrated use of dye as a tag for proteins
- Demonstrated qualities to be comparable to, or better than, the best commercial products available
- Demonstrated remarkable stability and complete water-solubility considerably superior to currently available fluorescent dyes and tags
- Demonstrated that the dye can be produced at considerably less cost than the most successful stable dye products
- Sent dye to potential licensees and customers as an evaluation sample
- July 27, 2004, a NSF Phase II proposal was submitted.
- August 1, 2004, a NIH Phase I proposal for shipboard detection of Norwalk Virus was submitted.

- Principles have been proposed for development of a novel tether for antibodies or other proteins. The tether has been offered as an NIH Phase I proposal for shipboard detection of Norwalk virus and, if funded, will serve as a model application for field detection of viral pathogens.

**Commercialization Plan:**
**Commercial potential of the research includes:**

- Potential licensing of the fluorescent tag to DNA array and immunodiagnostics companies for use with their products
- Potential licensing agreement with a biotechnology company for use in a variety of applications
- Sales and potential licensing of the kits for detection of Biowarfare Category A bacterial and viral pathogens for a global market
- If developed, the novel heterobifunctional tether will be a major addition to the diagnostic toolkit envisioned for physician offices and hospital laboratories

**Product description:**
Key innovation is a proprietary scientific breakthrough in fluorescent tagging of monoclonal, polyclonal or recombinant antibodies with new proprietary fluorescent chromophores. This will be in the form of a kit that will have the capability of detecting anthrax, plague, botulinum toxin and tularemia in the field of first responders in less than one hour. Extensive market opportunities growing from the fluorophore innovation exist.

**Target market including size:**
Initial target market is first responders to potential bioterror events, which includes nearly 31,000 establishments in these industrial classifications. The total U.S. target market size is believed to be approximately $100 million at saturation for all competitors and should continue to increase at a conservative compound annual rate of 4% per year.

**Marketing strategy:**
Value Proposition – Using Differentiation Strategy, SensoPath will develop and launch innovative bioterror technology testing kits that will be less expensive, easier to use, faster and have significantly increased sensitivity.

Production and Sales – Sophisticated and proprietary means of rapid, low cost production have been established. Sale of fluorophores is beginning a revenue flow that will allow other products to be launched as they are stabilized for the market. Sales are presently being made to individual research institutes and to distributors.

**Production or manufacturing plan:**
Presently sales are being handled by senior management with plans to hire a professional with Marketing, Distribution and Licensing expertise as sales justify growth.

Sales are presently being made a Japanese corporation and a first sale agreement with them to serve as exclusive distributor in Japan is being finalized.

A distribution license is being negotiated to supply SensoPath dithiol tethers.

Non-Disclosure Agreements have been exchanged with several companies

**Economic Impacts:**
***Increase in employment levels:***
Three full-time and four part-time employees in the year since this grant commenced.

***Acquisition of investment capital:***
SBA CapLine for operating capital through a local bank.

***Other:***
- Registered with Central Contractor System
- Trading Partner ID with US Government
- Registered and listed as a supplier of tethers and fluorophores with Pacific Northwest National Laboratory, Pasco, WA

***SBIR Proposals Submitted:***
- NSF Phase II SBIR - $500,000/2 years
- NIH Phase I SBIR - $100,000/6 months

**#04-13 Developing Improved Hay Barley Varieties for Montana**
**Lisa Surber, Montana State University, Bozeman**
**$66,232**
*Final report approved September 2008*

**Summary:**
The main objective of this project was to develop new forage barley varieties with enhanced agronomic performance and nutritional quality for livestock. Approximately 1400 $F_4$ lines are now available for future planting and concurrent selection for plant maturity, forage yield, seed and agronomic characteristics, low ADF and other desirable forage quality traits. The research will provide producers with improved forage barley cultivars to create value-added opportunities in Montana's grain and beef industries. Since a key component of value-added strategies is the integration of crop and livestock systems, the development and release of modern, high-yielding varieties with increased nutritional value will allow producers to utilize on-farm production in cattle feeding and Backgrounding operations. Products from this project could enhance production agriculture by providing sustainable seed and grain markets for regional barley producers and increasing marketing opportunities for livestock producers. Development of new forage barley varieties will improve quality of forage fed to beef cattle and benefit barley producers through improved agronomic traits.

**Commercialization:**
**Product description**
This research will improve the economic value for Montana farmers by providing barley varieties with increased yield and enhanced forage quality. Barley breeders and researchers at MSU recognize a niche market for barley forage varieties with improved feed quality. Release of these varieties will provide value-added opportunities for Montana crop and livestock producers. Development of improved forage quality barley lines will offer a competitive advantage to Montana seed and grain producers by allowing them to market barley specifically for livestock feed. Added feed value could result in a price premium.

**Target market including size**
Of the 1.6 million calves produced in Montana in 2007, only 55,000 were on feed in-state. Use of improved barley forage varieties would expand the use of barley in backgrounding and cattle feeding operations by allowing producers to increase animal performance and efficiency of gain while decreasing feed costs. Currently, the majority of feeder calves produced in Montana are shipped to out-of-state feedlots. Improved feed quality barleys could allow producers to feed their own calves to feedlot weight.

**Marketing strategy**
Improved barley forage varieties will be released and distributed through the Montana Agricultural Experiment Station. Information on new releases is distributed through a news release and the Variety Performance Summary bulletin.

**Production or manufacturing plan**
Development of new varieties is generally expected to take approximately 10 years. However, MSU researchers were able to shorten development time of Valier barley to eight years. This indicates that use of new technology will shorten the length of time required for development of new lines and allow Montana barley growers and livestock producers to recognize benefits as soon as possible.

**Estimate of sales revenues for five-year period into the future**
Increased yield of new lines are estimated to increase revenue substantially for Montana barley producers.

**Economic Impacts:**

- This project provided employment, research, and education opportunities for five undergraduate students. Three have completed, or are completing, their MS degrees and one is applying to PhD programs.

- A 15% increase in energy value to cattle would increase the value of a ton of hay by $5 per ton, from $15 to $20 per ton. Improved forage barley quality will also encourage production.

- This research will benefit livestock producers as well as the seed industry because forage barleys are some of the most marketable products in Montana's seed industry. Screening and selection of the lines developed under this project and possible release of new forage barleys with high grain and forage yield, low nitrate level and good forage quality would benefit Montana livestock and hay producers by increasing production and sales of breeder, foundation, registered and certified seed. It may also result in more hay produced per acre and higher prices for hay with increased forage quality, providing more flexibility, options and higher profit potential for seed, hay and livestock producers.

## #04-14 Value-Added Crops for Irrigated and Dryland Production in Montana
**Joyce Eckhoff, Montana State University, Bozeman/Sidney**

**$150,000**
***Final report approved October 2006***

**Summary:**
The results of seeding rate studies over the two years of the project will provide improved production technologies for durum, barley and hard white winter wheat. Studies were undertaken to determine use of feed barley and rejected malt barley for ethanol production in Montana. New gas liquid chromatography (GLC) equipment was purchased and GLC technology developed to enable identification of triacylglycerols in safflower. This information provided data for identifying superior safflower selections with value-added oil quality characteristics. A paper describing the research was presented at the Sixth International Safflower Conference in June 2005, in Istanbul, Turkey. The project also provides data for feasibility of ethanol production in Montana. Incorporation of value-added oils into new commercial safflower varieties allows expansion of the safflower industry in Montana and will help diversify Montana producers from small grains production.

**Commercialization:**
**Develop improved production technologies durum, barley and hard white spring wheat.**
Demonstration that high quality small grains can be grown consistently in this area on a high percentage of planted acres has already attracted a barley storage facility to this region. A malting facility may also be located in this area. Improved small grain varieties and production management research will help assure a consistent supply of acceptable malt-quality barley and high quality wheat and durum for the malt, pasta and milling industries.

**Develop technology to identify high-amylose durum.**
High-amylose durum may allow a new industry to be established in Montana.

**Identify best barley varieties for ethanol production.**
This project provides data for feasibility of ethanol production from barley and will help develop the industry in Montana, adding value to a crop already in production. Instead of exporting barley from Montana as a raw commodity, and importing corn into Montana for ethanol production, value can be added to a crop already under production for use in the ethanol industry.

**Develop improved varieties of safflower for human consumption, bio-fuel, and livestock feeding to enhance meat quality.**
This project has identified value-added safflower genetic lines for edible oil, bio-fuels/bio-lubricants, and high-end nutritional supplements for feed stocks using new GLC technologies. The safflower variety ***Nutrasaff*** was released for commercial production in 2005 to provide a high-end nutritional supplement to enrich livestock, poultry, fish, bird food, and other pet food diets with high levels of linoleic acid, protein, and oil.

**Improve quality and added value to safflower varieties for human consumption, bio-fuel and livestock feed supplements and added value and improved meat qualities using triacyclglcerol analysis of safflower oils.**
Value-added high-oleic/low-saturate safflower oils and high-linoleic/low-saturate safflower oils were identified using the new GLC analytical equipment purchased for the new triacyclglcerol analysis technology. The incorporation of these value-added oils into new commercial safflower varieties will allow expansion of safflower oil markets as edible health oils, bird food, bio-fuels,

bio-lubricants, livestock feed, nutritional supplements for animal health and value-added meats, as a base oil for beauty care products and pharmaceuticals, and as a source of a high purity oleic or linoleic oil for the chemical industry. The new and expanding domestic and international markets will allow the expansion of the safflower industry in Montana and provide expanded safflower production in Montana to help diversify Montana producers.

**Economic Impacts:**

- Durum and malt barley acres have increased in eastern Montana from 500,000 bushels contracted by Anheuser-Busch in 1999 to 24 million bushels in 2005. A new 1.5 million bushel malt barley handling and storage facility was built by Busch Agricultural Resources, Inc. (BARI) in Sidney and put in operation in 2003.

- Ethanol producers are looking at Montana for construction of ethanol plants and preliminary data from this study has been requested by such companies as Katzen International, Inc., Delta T Corporation, and Broin Companies. Currently there are four known efforts to build ethanol facilities in Montana. One effort is underway by the Fort Peck Water Users Association to build a small-scale barley-based ethanol plant in the Wolf Point area.

- *Nutrasaff*, a non-GMO high oil, high protein, high linoleic safflower line, was exclusively released for 2005 commercial production as a high-end nutritional whole seed product to enrich livestock, poultry, fish, bird food, and pet food diets with high levels of linoleic acid, protein, and oil. New non-GMO high oleic, low saturate safflower oil genetic lines were identified for potential release for the edible oil, cosmetic, bio-fuel/bio-lubricant, and livestock nutritional supplement markets. New non-GMO high linoleic, low saturate safflower oil genetic lines were also identified for potential release for livestock, edible oil, and industrial applications of high linoleic safflower oil. The development of superior safflower varieties will allow the expansion of safflower production as a broadleaf crop to diversify the cropping system from a strict small grain rotation and promote the expansion of the safflower industry in Montana.

## #04-17 Two-Photon Volumetric Re-Writable Optical Memory Material
**Mikhail Drobizhev – Montana State University – Bozeman**
**$120,000**
*Final report approved July 2006*

**Summary:**
The goal of the project was to find a material which could be used for fast two-photon volumetric rewritable optical memory. Comprehensive theoretical and experimental analysis of material parameters has been performed for the first time and has shown that a certain high threshold for two-photon absorption sensitivity exists. Support from the international company, Ciba Specialty Chemicals, is seen as a major success of the project in terms of both research and future commercialization. Several joint applications of US patents involving MSU MPAT and Ciba have been submitted and a SBIR NSF Phase I award was received in 2005.

**Commercialization Plan:**
***Product:*** Material that can be used for fast two-photon volumetric (3D) rewritable optical memory.

***Target market:*** Optical memory market is anticipated at a yearly value of at least $1 billion.

***Marketing strategy:***

- Negotiations began in May 2005 between MSU, MPAT and Ciba SC to co-develop phthalocyanines as potential materials for 3D optical memory.
- Technology licensed by MPAT from MSU and potential license transfer to Ciba SC
- In January 2006 NSF awarded an SBIR Phase I to MPAT for $99,912 to study "Asymmetric Tetraphyrroles for Two-Photon Volumetric Optical Memory", incorporating a subcontract to the PI and team for $33,000.
- The research is underway at MSU and MPAT.
- A Phase II proposal will be submitted in December 2006 for a two-year project of $500,000 each.
- MPAT is negotiating a Research Agreement with Ciba SC (one of the top 50 chemical companies in the world specializing in development of new materials for emerging applications) to be the Phase III Industrial Partner that will commercialize this technology.
- MPAT has obtained a grant from TechLink to provide funds for preliminary marketing assessment of the technology and has been assigned a marketing consultant firm by NSF for help in developing its' NSF Commercialization Plan.

**Economic Impacts:**
***Patents:*** Two provisional patents based on this research were filed at MSU in 2005.

## #04-26 Accelerated Development of Solid-Stemmed Wheat Varieties
**Luther Talbert – Montana State University - Bozeman**
**$150,000**
***Final report approved April 2006***

**Summary:**
The goal of the project - to use modern techniques in molecular biology to develop new wheat genotypes with resistance to the wheat stem sawfly, the major insect pest of wheat in Montana – was achieved. This project resulted in new lines of spring and winter wheat with introgressed solid stem genes ready for a second field-testing summer of 2006. The crosses also enabled identification of a genetic marker for a secondary stem solidness gene, which means additional solidness of the stem and additional sawfly resistance. The project successfully improved the genetic background of solid-stemmed wheat genotypes. Several companies have indicated interest in proceeding with potential release of new varieties following preliminary testing this summer. Most likely, the company would be responsible for seed increase and sales from which MSU would receive a royalty.

**Commercialization Plan:**
New varieties will be commercialized through established protocols, i.e. release of seed to the Foundation Seed Program for increase using Research Center farms, then released to Certified Seed growers for further increase. The resulting seed will be sold by seed dealers to Montana farmers. The varieties will be released to the public with Plant Variety Protection. Private breeding companies own two of the recurrent parents. Company representatives will review field trials in summer of 2006 and data obtained. If they are interested in commercializing, an agreement will be developed for MSU for release. Company representatives have shown interest

in proceeding with potential release. Most likely, the company will be responsible for seed increase and sales, and MSU will receive a royalty.

**Economic Impacts:**

- Availability of superior varieties of wheat with resistance to the wheat stem sawfly
- Enhanced yield on grower fields leading to increased profits, i.e. increase of harvested grain of two bushels per acre on 500,000 acres equals $3 million in increased sales in Montana
- Solid stemmed wheat varieties cause high level of sawfly mortality leading to more sustainable production.

**#04-29 Research Support for the Manufacturing and Marketing of the Drip Flow Biofilm Reactor**
**Darla Goeres**
**$146,606 – Montana State University - Bozeman**

**Summary:**

This project resulted in the development of the Drip flow Biofilm Reactor into a commercial product that BioSurface Technologies Inc. (BST) manufactures and sells. To date, the company has sold reactors and hired two new employees as a result. The research involved developing an apparatus that simulated an environment different from the reactors in the current BST product line, creating a product design that met BST's manufacturing and marketing criteria, and developing a standard operating procedure suitable for use as an official standard method.

**Commercialization Plan:**

BioSurface Technologies, Inc., of Belgrade, was established in 1994 to manufacture and sell biofilm reactor systems and provide biofilm related microbial process evaluation services. Since that time, it has established a market for four biofilm reactor systems (including the DFR) and a line of Imaging Flow Cells. The technologies are licensed from the Center for Biofilm Engineering and have returned royalties of over $50,000 to MSU to date.

***Target Market:***

Proposed markets for the DFR include: EPA Certified Evaluation Laboratories/Certified Biofilm Evaluation Process, Education, Academic Research, Government Research, Chemical Manufacturing and Medical Device Industries, and the Industrial Biofouling market. These markets represent a significant sales volume from current gross revenues.

***Marketing Strategy:***

Through the development of product literature, trade show marketing material, and web site support (www.biofilms.biz), web-based advertising campaign via Google, the DFR can become recognized as a standard laboratory tool that will be used in professional research and academia.

**Economic Impacts:**

***Increase in Employment Levels:***

BST hired two new employees during the past year as a result of increased sales in its biofilm reactors, including the DFR.

***Other:***

- BST uses local companies for parts fabrication, thus providing an indirect economic impact on the local economy. In addition, the salaries funded by the grant, as well as the matching funds benefited the local economy through taxes paid and reinvestment of the money into the local economy for living expenses.
- In addition, the CBE continues to gain recognition as a world leader in biofilm research and this funding demonstrates Montana's support of the CBE.
- This work capitalized on the expertise at MSU and local business, helped to secure a global market for a local company, created manufacturing and technical jobs in Montana, and contributed to the education of three undergraduate students.

**#04-30 Biological Treatment of Animal Wastes by Endophytic Fungi and "Mycofumigation"**
**Gary Strobel - Montana State University – Bozeman**
**$300,000**
*Final Report approved October 2007*

**Summary:**
Results of this research showed that it is possible to find and develop microbes that can be used to treat human and animal wastes. The microbes, *M. Albus* and *F. culmorum*, were found to work with a buffer, either citrate or phosphate, to grow on wastes and begin the processes of decontamination and degradation. Results have been published and three patents have been filed, one of which has been issued and the other two are pending. The issued patent has been licensed from the MSU office of technology transfer to Phillips Environmental Products. Microbial products have been developed to decontaminate human and animal wastes and a patent is pending on these. The EPA and USDA have approved their use. These microbes are being produced at Laverlam in Butte and sold as a new product by Phillips Environmental Products. Other related products are in various stages of development.

**Commercialization:**
**Product description**
Manufacture of *M. albus* and *Fusarium culmorum* on pasteurized barley seed by Laverlam in Butte – small amounts of each of the organisms is placed into the PEP WAG bag and sold as part of its portable toilet system. AgraQuest is also seeking Laverlam for *M. albus* production for ag uses.

**Economic Impacts**
Economic impact has been enormous.

- ✓ Phillips Environmental Products has a new product on the market.
- ✓ Laverlam of Butte is making the product for Phillips to sell.

- ✓ It is anticipated that AgraQuest (California) will use Laverlam to make *M. albus* for its agricultural applications which are part of this project and which will have a major impact on Butte.
- ✓ Four patents have been applied for.
- ✓ One patent has been granted to date.
- ✓ Numerous publications have resulted from this work including reviews, papers and other reports. Each publication has cited the MBRCT for its support.
- ✓ Eleven students and six post doctoral associates have been involved in the project.
- ✓ "Jewels of the Jungle", made by MSU students, is an award-winning documentary, which was on the NSF website, cited by the *Wall Street Journal*, *Inventors Digest* and *Science* magazine.

  - **(New) businesses created or expanded**

  *Phillips Environmental Products, Belgrade, MT; Laverlam, Butte, MT; AgraQuest, Davis, CA*

  - **Increase in employment levels**
  - **Sales generated**

  $4 to $6 million in 2007 alone

  - **Patents applied for or granted**

  4 applied for, one granted, three pending

  - **Development of intellectual property**

  License from MSU to Phillips Environmental Products

  - **Acquisition of investment capital**
  - **Other**

- **Unique features/success stories/news clippings, brochures/other information**

Many articles, presentations and publications are included on DVDs accompanying the Final Report.

**#04-35 Biologically-Based Products for Management of the Wheat Stem Sawfly**
**Wendell Morrill - Montana State University – Bozeman**
**$145,000**
*Final Report approved October 2006*

**Summary:**
Mass-rearing of parasitoids in nursery cages has been demonstrated and may have commercial potential. Two new pathogenic fungal endophyte showing promise as true entomopathogens were isolated. These should not cause crown rot disease. Pheromone lures and traps show promise as tools for monitoring wheat stem sawfly populations. A trap was designed and could be developed for commercial use. Further basic research will be needed to develop a molecular method for determining the sex of immature sawflies. Technical difficulties occurred during this aspect of the project and measurement of the insect sex ratio resulting from mating disruption trials could not be achieved.

**Commercialization:**
**Product description**

- Mass-reared parasitoids for sawfly control
- Wheat stems containing over wintering parasitoids could be packaged and sold.
- Parasitoids could be sold that a company specializing in biological agents. Preliminary discussions with McClay Ecoscience, Sherwood Park, Alberta.
- Fungal endophytes for sawfly control

**Target market including size**
Potential customers are wheat producers in the United States and Canada in areas like Montana, Idaho, North Dakota, South Dakota, Wyoming, Nebraska, Alberta, Manitoba, and Saskatchewan where sawflies are problematic.

**Product description**
The newly-discovered entomopathogens are the only species that might have potential economic value and might be marketed by a company that sells the same species, such as Certis U.S.A.

**Target market including size**
US and Canadian wheat producers from the large area are heavily impacted by the wheat stem sawfly.

**Product description**
Note: The marketable product is based on information, i.e. how many insects it takes to cause how much damage. This information will need to be obtained before further development can proceed.

- Pheromones for sawfly control show promise for use in traps that could be utilized to monitor sawfly populations.
- Pheromone trap that could be used in conjunction with the attractant to capture adult sawflies.

These products could be readily sold through a company that specializes in insect pheromone traps, such as Trece, Inc. or ISCA Technologies.

**Target market including size**
Customers would be agricultural consultants, county agents, and progressive farmers located in the Canadian Prairie provinces and states where sawflies are problematic.

**Marketing strategy**
Marketing plan and costs involved may be developed after a working relationship has been established with a marketing company.

**Economic Impacts:**

- Enhance wheat production profitability in the northern Great Plains

- Development and sales of the products would support several modest Montana-based companies.
- Patents could be requested for the traps, pheromone blends, formulations of the fungi.
- Potential market is based on a target pest that causes approximately $100 million in losses per year in the United States.
- Economic benefits will come from reduces losses and from direct sales of the products, amounting to approximately 5-40% of the total economic loss.

**#04-46 Development of a Novel Tissue Valve for Replacement of Diseased Aortic, Pulmonary, and Vein Valves**
**Carlos Duran/Matt Maxwell – International Heart Institute of Montana Foundation – Missoula**
**$226,040**
***Final Report approved April 2009***

**Summary:**
The focus of this project was the evaluation of a novel, pericardial aortic valve (PAV) invented by Dr Carlos Duran of the International Heart Institute of Montana Foundation. The overall goal of the studies was to improve the design of the original valve and to test this valve within a stent. The *in vitro* and *in vivo* studies focused on the use of this valve as a replacement for the aortic valve. The early studies demonstrated that this design functioned as well as a native valve in terms of hemodynamics. The studies also showed that the design of the stent was important. When compared to standard porcine valves, the PAV was found to be superior to the native valves when used within a collapsible stent. The PAV is also more compressible than a native valve making its use with stents more amenable. *In vivo* studies demonstrated the difficulties with testing the valve in healthy animals. The grant allowed the idea to be tested both *in vitro* and *in vivo*. The studies ultimately showed that a simple valve design can be sewn into a stent and deployed in the aortic valve position of sheep. The valve can also be compressed so it will fit inside a delivery catheter of a small enough bore that it could be delivered percutaneously. The project provided the opportunity for two engineering students from Montana Tech to obtain their Masters in Engineering degrees and two international research fellows to collaborate with these students and gain valuable research experience.

**Commercialization:**
Commercialization potential lies in the patented tissue treatment process, L+D-Hydro™, which could be used for the treatment of bovine pericardial tissue currently used in the manufacture of bioprosthetic heart valves. The treated bovine pericardium could be used as a tubular shaped valve with three anchor points, mimicking the commissures of a native semilunar valve. This design is readily compressible into a metal stent for delivery to either the aortic or pulmonic position for replacement of a diseased valve. Licensing opportunities exist with companies that possess the stent and percutaneous delivery technology.

**Unique features/success stories/news clippings, brochures/other information:**

The results of the *in vitro* study were presented at the biennial meeting of the Society for Heart Valve Disease June 17-20, 2005, in Vancouver, BC.

A paper describing the *in vitro* study, entitled *"In Vitro Study of Percutaneous Aortic Valve Replacement: Selection of a Tissue Valve"* was published in the *Journal of Cardiac Surgery*, a copy of which is appended to the Final Report.

The project supported Master's thesis for two graduate students, John Curry and Brook Brady as well as providing valuable research experience for two international research fellows.

**#04-47 Optimizing KTP Waveguide Performance for Precise Optical Characteristics**
**Elizabeth Noonan – AdvR, Inc. – Bozeman**
**$209,717**
***Final Report approved May 2006***

**Summary:**
The primary goal of the project was to continue development of processing conditions to enable AdvR to accurately design and fabricate high-yield waveguide structures in KTP that produce a specified set of spectral and electro-optic characteristics. Accomplishments as part of this project include:

- Automated equipment to remove processing variables in waveguide manufacturing
- Transfer lithographic techniques to an in-state manufacturing facility at MSU Bozeman
- Refinement and expansion of in-house tracking database
- Maintenance of ties with MSU Bozeman through shared facilities and equipment and continuing discussion in regard to understanding and predicting KTP behavior under various conditions

With this knowledge and these protocols, progress is being made toward:

- Automated manufacturing
- Increasing yields
- Effectively tracking chip performance

**Objectives:**
The objectives of the project were: (1) Upgrade and expand ion exchange appliance from research to manufacturing level; (2) Collaboration with Image and Chemical Analysis Laboratory (ICAL) at Montana State University to evaluate ion exchange characteristics; (3) Implement the new file tracking system for KTP waveguides; (4) Transfer proprietary photolithographic techniques to an in-state nanofabrication facility at MSU; (5) Incorporate a new procedure for measuring ion conductivity KTP.

**Results:**
AdvR successfully created an ion exchange oven, which is robust, automated and easy to use via a computer program, trained personnel on, and used, ICAL's scanning electron microscope, expanded database for documenting KTP characteristics, bean transferring lithographic techniques to MSU nanofabrication facility, and began work on a new procedure for measuring ion conductivity of KTP.

**Commercialization plan:**
The work has provided AdvR with an important building block in its effort to commercialize.

***Product:***
Product lines of specialty wavelength lasers, particularly lasers with a wavelength of 488 nm

***Target market:***
- Focus is on the 488 nm target.
- Embryonic applications provide the basis for continued strong market growth and market entry points.
- Annual worldwide sales in 2005 were $135 million with 20% growth
- 10 mW 488 nm lasers are expected to see in the $4,000 price range.
- 2005 market size of 100 mW488, 473, 532 nm and related lasers estimated at $34,700,000

***Marketing strategy:***
- Selling waveguides to end-users, including university researchers seeking to create specialty lasers and other devices, as well as the Air Force and NASA.
- Strategic alliances with a few laser companies to establish sales of waveguide structures into high volume, well-established markets for rapid market penetration.
- Strategic alliances to develop KTP materials better suited for AdvR waveguide applications.
- Providing waveguides to strategic alliance partners that will facilitate end product developments.
- Selling non-frequency conversion waveguides to strategic partners.
- Building reputation as supplier of components and lasers. Current marketing efforts include the website, free listings and advertisements in trade magazines, technical publications, collaborations, trade booths, collaborations in research magazines and word of mouth.

***Competitive advantage:***
AdvR is seeking to maintain competitive advantage over the long term via its extensive patent estate, continuing product innovation, focus on the less than 10mW output segment, and commitment to maintain competitive price advantages.

***Production or manufacturing plan:***
AdvR will draw on production expertise of its alliance partners when setting up quality control and other production functions. It has recently expanded its facility and workforce, and has purchased a production-level automated dicing saw and a polishing unit. Additional equipment and modifications to existing equipment will be required in order to achieve the 4$^{th}$ year forecasts.

***Business risk assessment:***
AdvR manages the full range of technical, competitive, administrative, financial, and other risk factors, independently to control overall risks to the company and to product commercialization. It is at a risk level appropriate for a well-managed, high-tech start-up company.

**Economic Impacts:**
***Increase in employment levels:***

AdvR revenue generation has resulted in hiring of 18 employees and more than 75% hold degrees from Montana university system. Increasing sales will result in increasing staff involved in high value manufacturing positions for non-degree personnel.

***Other:***
The capabilities of the new Montana MicroFabrication Facility has made it possible for AdvR to conduct much of their lithographic transfer process in Montana rather than out of state, an effort that used to cost $45,000 per year. As more capabilities are available at MMF, AdvR will use it more, benefiting from faster turn-around time, travel savings and access to trained students for full-time local employment.

## #04-52 Transient RF Signals Processors for Pulse Shaping and Arbitrary Waveform Generation

**Wm. Randall Babbitt – Montana State University - Bozeman**
**$45,278**
***Final report approved August 2005***

**Summary:**
The MBRCT funds directly supported work on modeling and demonstrating OCT processing devices and developing techniques and supporting technologies for improved performance of OCT devices. The research team collaborated with Professor Cone's group and Spectrum Lab at MSU and Kelvin Wagner's group at the University of Colorado. In addition, the project had strong ties with local companies, including Scientific Materials and AdvR. An Air Force Office of Scientific Research DEPSCOR grant provided the matching funds for the project. The techniques and supporting device technologies have benefited other programs in Montana working with S2 related technologies, which will be field tested in the next two years.

**Objectives:**
The objectives of the project were: (1) To develop broadband OCT processing techniques with linear frequency chirped laser sources; (2) Design and evaluate linear chirped OCT devices to perform pulse shaping and arbitrary waveform generation; (3) Test the devices for specific design goals.

**Results:**
All milestones were completed with the exception of development and characterization of frequency chirped laser sources up to 10GHz. The original design did not meet the requirements of the OCT devices, which delayed the work and it is now being carried out under another project. Although commercialization of the OCT devices will not occur in the near-term, the project has identified major obstacles to commercialization and has significantly benefited other projects with high commercialization potential.

**Commercialization Plan:**
The major limiting factor in commercialization of broadband OCT devices is the availability of chirped laser sources with sufficient characteristics, i.e. broad tuning range, fast chirp rate, and low laser bandwidth. These requirements are also needed for the S2CHIP devices for radar and spectral analysis; thus, similar technology is being pursued under the S2CHIP projects.

One area in which broadband OCT devices may reach market sooner is the coupling of broadband OCT devices as front ends to S2CHIP devices. A significant demand exists in

military application for the performance afforded by this combination and the option is under review.

**Economic Impact:**
Although commercialization of OCT devices is not near-term, the main impediments to commercialization have been identified. The developments made under this project have had significant impact on other commercialization projects. The chirped laser development, the double sideband chirped optical source techniques, the broadband tapered amplifier, and the techniques for improved chirped pulses have proven useful in the S2CHIP and S2 Spectrum Analysis projects, both of which have high commercial potential. The S2CHIP project is a $15 million program that will produce field-tested prototypes in the next two years. The S2 Spectrum Analyzer is a Phase III DARPA project being carried out by MSU Spectrum Lab, Scientific Materials, the University of Colorado, and Northrop Grumman and that will culminate in field-testing next year. Work on the chirped lasers is providing valuable information to another Montana company, AdvR.