Business Plan for
Montana University System
Collaborative Materials Science Ph.D.

"The World we have created today, as a result of our thinking, thus far has problems which cannot be solved by thinking the way we thought when we created them."
Albert Einstein

1. Summary

The University of Montana-Missoula (UM), Montana Tech of The University of Montana (MTech), and Montana State University-Bozeman (MSU) propose a collaborative Ph.D. program in materials science (MatSci). The program will involve multiple departments, faculty, courses, and research infrastructure from all three campuses. Research specialties will focus in biomaterials; electronic, photonic, and magnetic (EPM) materials; materials for energy storage, conversion, and conservation; and materials synthesis, processing, and fabrication—all areas that are inextricably tied to Montana's economic interests and areas where the three campuses individually or collectively have nationally recognized expertise.

The curriculum will cohesively integrate relevant science and engineering disciplines with a broad range of applications: from health and medicine to nanotechnology to energy, environment, and natural resources. Courses will be coordinated and shared by the three campuses, taking advantage of on-line instructional technologies where appropriate. Students entering the program are expected to have backgrounds in the basic sciences and/or engineering. Each student will complete original, independent research culminating in a doctoral dissertation. Major funding will be obtained from federal agencies, national laboratories, and industrial partners. Graduates will likely find employment with research, development, and manufacturing companies in Montana, the region, and the nation. Academia and government laboratories and agencies are also possible career pathways. State and local economies are expected to benefit significantly from the ensuing increase in material-based entrepreneurial ventures and to gain the ability to attract a diverse range of materials-based private-sector corporations, international entities, and/or start-ups. Program details are described in the Level II submission. This business plan summarizes program features and financial analysis most applicable to the financial/business viability of the program.

2. Mission, Vision, and Core Values

The mission of the MUS MatSci Ph.D. program is to advance knowledge and techniques while preparing the next generation of leaders in materials research, application, and education. The program's vision is to become a top-ranked program, sought after by students, sponsoring agencies, and industry, with high student demand, placement success, and positive impact on Montana's economy. This mission and vision align directly with those of the participating campuses and the MUS, as described in detail in Section 4D of the Level II proposal. Noteworthy contributions are expected to Montana's workforce and economic development, research and development, graduate education capacity and opportunities, and efficiency and effectiveness. In addition, through this program Montanans will have affordable access to the highest level of educational opportunity in materials science and closely related fields.

The proposed program's core values are:

- High standards of academic quality, research originality, and significance
- Integrity
- Interdisciplinarity and collaboration, with administrative processes transparent to the students
- Service and value to Montana, the nation, and world
- Efficiency and effectiveness

This three-campus collaborative Ph.D. program is designed specifically to ensure that the curriculum, courses, mentors, research teams, infrastructure, funding, and governance will sustain its interdisciplinary and collaborative nature; with educational experiences and original research of the highest quality, integrity, significance, and value to Montana; thereby achieving high efficiency and effectiveness while preparing graduates for the workforce and fostering economic development in Montana.

3. Goals and objectives

Given its goals, the MatSci Ph.D. program will contribute significantly to the intellectual climate and research environment on the three campuses. Furthermore, the program aspires to become a top-ranked program in its fields and to serve students superbly by achieving high student retention, timely degree completion, and direct pathways to careers. In terms of value to the campuses and more broadly to the MUS, the program's objectives are to:

- Attract the highest caliber of tenure-track and visiting faculty to Montana, further enriching the environment for students at all levels;
- Foster and increase grant activity and research collaborations within Montana, regionally, nationally, and internationally;
- Enrich the research opportunities and infrastructure on each campus, including those available to undergraduate and master's students in related fields;
- Accelerate implementation of the cost-effective and collaborative graduate-education model being pursued by the Montana University Graduate System (MUGS), and potentially become a cost-effective model nationally, where campuses with complementary strengths collaborate to offer shared degree programs that transcend what would be possible on any one campus alone;
- Bring national recognition to the materials science research enterprise in Montana and the MUS;
- Nucleate start-up companies and attract other firms to relocate or expand to Montana. These entrepreneurial ventures will not only enhance local and state economies, they will increase internship and employment opportunities for students and graduates in Montana;
- Be highly cost-effective, with courses and curriculum coordinated across the three campuses, thereby maximizing course enrollments (including those in existing courses serving graduate programs in the many science and engineering disciplines important to MatSci); and
- "..make more efficient uses of resources and …reach critical masses of faculty and students that cannot be readily attained by individual campuses" (AAAS, August 2012, p. 3).

The MUS MatSci Ph.D. curriculum is designed to be flexible, but still provide students with an exceptionally strong and broad understanding of the theory, experimental techniques, current challenges, and societal/economic impacts of materials science and engineering. The program's learning goals for all students—regardless of specialty—are to understand materials and the full suite of characterization and analysis tools commonly used in materials research. Specific learning goals are for students to understand how classes of materials derive their properties from the atomic to the macroscopic level; be familiar with the growing set of materials fabrication, assembly, processing, and characterization tools and techniques; be aware of and committed to the professional and ethical standards of the field; be knowledgeable about the economic, societal, and other broader impacts of materials and materials research; and to demonstrate through their dissertation research, that they can conceive, plan, design, conduct, analyze, defend, publish, and communicate original and creative research that advances understanding in an area important to MatSci.

4. Market

The market for the proposed MatSci Ph.D. program includes prospective students as the direct market and employers of prospective graduates as an indirect market. With respect to the latter, about one-third of Montana's non-agricultural employment depends strongly on materials, while most of the remaining business/employment sectors are weakly dependent on materials (see Figure 1). Moreover, universities with leading materials R&D capacity and programs tend to both nucleate and attract materials intensive, high-tech commercial enterprises to their communities.

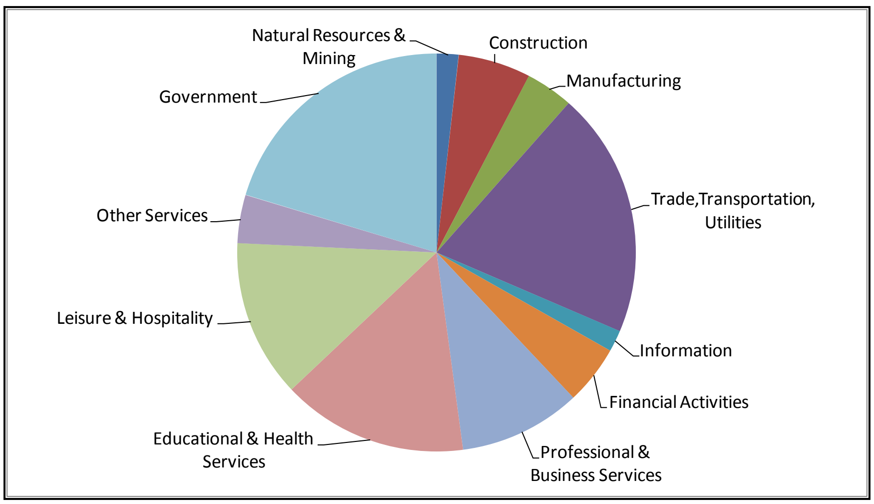

Figure 1. Pie Chart showing the distribution of Montana's non-agricultural workforce of 436 thousand in October 2012 as a function of employment sector. *(Downloaded 29 December 2012 from http://www/ourfactsyourfuture.org/?PAGEID=4&SUBID=155)*

The student market includes bachelor's and master's degree-holders in physics, chemistry, materials science, polymer science, ceramics, mechanical engineering, materials engineering, metallurgy, bioengineering, life sciences, and related fields. Recent graduates from Montana universities, recent graduates from outside Montana (some of whom are Montana residents who left the state to pursue higher education), and individuals already in the workforce, especially those located in Montana, who are seeking professional advancement in materials-related fields are all examples of prospective students. Note that with the core coursework and many electives being available via distance learning, the program may also attract interest from and serve bachelor's/master's degree holders outside the state. Currently there are approximately 100 materials science and/or engineering doctoral programs in the USA and Canada. Only nine of the programs are located in the Pacific Northwest and states bordering Montana, with none in Montana or Wyoming. Materials-focused Ph.D. programs are common among Schools of Mines (being at 11 of the 15 such institutions), and they are available at 32 land-grant institutions, due to the strong base and need associated with the academic expertise and research/service enterprises of those campuses. The proposed MUS program would bring those totals to 12 and 33, respectively, while providing Montanans with affordable access and employment/economic spinoff benefits typical of such programs.

Significant funding has been reserved in Years 1-3 for marketing and recruiting, using approaches in line with the best practices in graduate recruiting. This effort is planned to include a common program web site (linked transparently to all three campus web sites), “name buys,” multi-touch outreach, and strong visibility and recruiting presence in the diverse venues where prospective materials doctoral students can be found (as current undergraduates, current master’s students, and high-potential employees in materials-based firms, for example). In addition, faculty involved in the program will be empowered to recruit vigorously at the professional conferences in their fields and to spread the word whenever and wherever they present seminars at other universities and in Montana. A pre-launch seminar series is planned, to bring influential thought leaders in the field to Montana during Year 1, and the seminar series will continue as the program grows. As these speakers learn about the program and the capabilities and opportunities at the three institutions, they will spread the word when they return home and visit other institutions.

5. Organization and Management

The collaborative MUS Materials Ph.D. program is designed to be organized and managed as a systemwide asset of the MUS. Figure 2 provides the Organization Chart. Additional details are provided in Appendix V of the Level II proposal. This section emphasizes the multi-campus management aspects of the program.

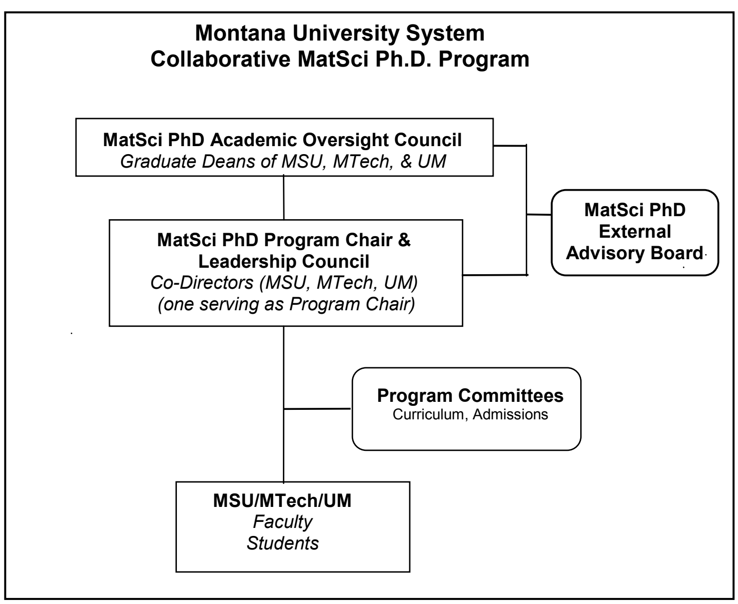

Figure 2. Organization Chart for Proposed MatSci Ph.D. Program

With major participation at Montana State, Bozeman, Montana Tech, and the University of Montana, Missoula, the program will be overseen by the *MatSci Ph.D. Academic Oversight Council*, consisting of the graduate deans of each of the campuses. The Academic Oversight Council and its members resolve issues related to the MatSci Ph.D. program and ensure that the Program complies with MUS and institutional requirements.

Each campus will have a program Co-Director, who is a member of its faculty. The three co-directors together will comprise the *MatSci Leadership Council.* One of the three Co-Directors will be the *MatSci Ph.D. Program Chair.* The Chairperson chairs the *Leadership Council,* while the other two co-chairs each head one of the two standing committees of the program (*The Curriculum Committee* and the *Admissions Committee*). The Program Chair has responsibilities typical of program chairs, including course scheduling across the campuses, advised by the other co-directors. Campus *co-directors* direct the program on their campuses, serve as the primary academic coordinator with the other campuses, and collectively and cooperatively provide leadership for the collaborative program. An *External Advisory Board* will consist of outstanding, nationally recognized, diverse individuals, collectively bringing expertise in the scientific theme areas, from materials industry/employers in Montana, and in graduate education at the Ph.D. level. Members will serve staggered renewable 3-year terms.

Program committees will be established, e.g. for curriculum and admissions, as is typically found in a department or program. Some committees will have student members, as appropriate. Each committee will include faculty member(s) from all three institutions. The *MatSci Ph.D. Program Curriculum Committee's* role is to review/approve new course proposals along with modifications to the curriculum and degree requirements. New core courses and curriculum and degree requirements must be approved through the curriculum review/approval process on all three campuses, while new electives would proceed only through the process on the proposing campus.

The *MatSci Ph.D. Program Admissions Committee* will include faculty members from all three campuses. The Admissions Committee member from each campus is designated as the MatSci Ph.D. program admissions representative on that campus. Students would apply to the MatSci Ph.D. program through the graduate admissions process of any one of the three campuses, ideally the campus where they wish to enroll. Each application would be processed in the normal way by the graduate admissions office and forwarded to the campus' MatSci Ph.D. program admissions representative, who shares it with the Admissions Committee. The Admissions Committee reviews the applicants, including the match between the applicant's interest and preferred campus. Admissions recommendations for the Program will be made as they are for all graduate programs, considering the applicant's quality, the availability of financial support, and the availability of willing mentor(s)/advisor(s). For applicants being admitted, the Admissions Committee would let them know if there is a mismatch between their preferred campus and area of interest and allow them to switch, if appropriate. The Program's recommendation on each applicant would then be forwarded for action to the graduate admissions office on the campus where the student is recommended or waitlisted for admission. In the case of students not recommended for admission, the recommendation is returned to the graduate admissions office of the campus where the student applied. Note that effective summer 2013, all three campuses will be using CollegeNet® for their admissions applications and processing. In addition, MUGS is coordinating the migration of all MUS graduate programs to a common, CollegeNet®-based application system by 2015, which will clearly benefit the proposed program and make integration and handling of applications very straightforward.

Every course offered each term will be listed in the course schedule at each campus, indicating the faculty member(s) and lead campus/location for that course. Courses will be taken "in residence" by all Ph.D. students, with registration, billing, and grading done in accordance with the established MUS mechanism and process for students to enroll in courses at other campuses within MUS. Under this mechanism, students register and pay tuition and fees at their home campus.

Students are subject to the academic progress and good-standing policies of their home campus. Each student will have a committee, chaired by a faculty member (the student's advisor) on the student's home campus. The committee will have at least five members, including at least one faculty member from a collaborating campus and one member appointed by the graduate dean of the home campus. The process for approving and establishing the committee membership follows the process of the student's campus, with the final approval provided by the graduate dean for that campus. The role and responsibility of the committee and the timing for its actions will follow the policies of the student's home campus. Students in good standing at the home institution are accepted as being in good standing at all institutions, and they will be allowed to enroll in any courses identified as part of the Ph.D. program at any of the institutions, providing they have the specific prerequisites for that course. Course grading is subject to the grading standards and policies of the institution offering each course. The dissertation process and format follows the standard for the campus where the student is enrolled. All students in the program and their supervising faculty shall have access to library resources and research equipment on all three campuses, equivalent to the access provided to students and faculty at the campus where the equipment and resources are located. Subject to the approval of their committee and the Program Chair, enrolled students would be permitted to switch home campuses before starting their dissertation. Such a switch would be justified, for instance, if the student's interests change and the preferred Ph.D. advisor is located at one of the other campuses, if the advisor leaves, or if there are more suitable research opportunities with financial support (grant funding) at the other campus. Within the Ph.D. program students would have the same flexibility and options spanning the three campuses, as are typically available to a Ph.D. student in a program on one campus.

The Ph.D. program will agree on and offer a standard total financial support package to students in the program, with stipend levels the same on all three campuses. The Board of Regents tuition policy (Policy 940.31) allows campuses to "…set non-resident tuition for graduate research and teaching assistants at 100% of resident tuition." In accordance with BOR 940.31, Ph.D. students with financial support who are graduate research assistants (GRA) or teaching assistants (GTA) would be charged the in-state tuition rate, regardless of their official residency status. The tuition for these students may be covered by each campus with some combination of waivers, grant funds, and other funds (institutional fellowships, endowment income, industrial funding, etc). Fees are the responsibility of the student and follow the policies and rates of the home institution. In accordance with the current policies at all three campuses, financial support is reserved for students enrolled for 6 or more credits in an academic term. Financial support and the tuition reduction provided through BOR 940.31 would normally be limited to a maximum of 12 semesters of enrollment for each student.

6. Budget Detail

This section summarizes the detailed budget analysis and business plan for the start up of the program and when it is in full operation, serving a student population in the range of 50 to 70, similar to the top-ranked programs. Table 1 provides a budget summary for a projected start-up period of four years, during which the enrollment is projected to grow from zero to 25 students. This budget analysis is identical to the one included in the Level II submission, which has been reviewed thoroughly on all three campuses. The revenues and expenditures are in balance, even allowing for significant investment in the research infrastructure and capacity at Montana Tech.

Table 1. Summary Resource Analysis and Projection for MatSci Ph.D. Program Start Up

Academic Year	2014	2015	2016	2017
Enrollment	0	7	16	25
Faculty (FTE)	42 (3)	45 (7.5)	45 (12)	45 (17)
PROJECTED REVENUE	$516 K	$1,174 K	$1,676 K	$2,193 K
New Grant funding for Student Support (Tuition included)	0	$350 K ($42 K)	$800 K ($96 K)	$1,250 K ($150 K)
Internal Reallocations	$206 K	$494 K	$516 K	$543 K
New Revenue: MTech-Private fundraising & State	$310 K	$330 K	$360 K	$400 K
PROJECTED EXPENDITURES	$516 K	$1,174 K	$1,676 K	$2,193 K
Faculty costs: new and buyouts	$48 K	$348 K	$396 K	$444 K
Student Costs (stipends, tuition, research, summer symposium)	0	$406 K	$982 K	$1450 K
Course Development for Distance Delivery	$84 K	$84 K	$56 K	$28 K
Program Development & Administrative Support	$134 K	$136 K	$116 K	$111 K
MTech Research Infrastructure Investment	$250 K	$200 K	$180 K	$160 K

Projected Expenditures

a. Faculty. Because the 40+ faculty members planning to participate in the program are already committed to other programs, the three provosts have each committed to hire one new faculty member for the new program, and to provide funding to support adjunct faculty to fill teaching needs in existing programs that would normally be met by the existing faculty. The new faculty are projected to be recruited in Year 1 (2014) and to assume tenure-track positions in Year 2 (2015). At Montana Tech, where teaching loads are higher, additional funding has been budgeted within this line to reduce the teaching obligation for each faculty FTE involved in the materials Ph.D. program from four courses per term to two courses per term. This reduction would be accomplished most economically by finding qualified adjunct/part-time instructors to teach some courses in these faculty members' programs. Funding for adjunct faculty in Year 1 (the planning year) is estimated for one course buyout each semester at UM and MSU and four courses of buyout each semester at MTECH, to allow for planning and recruitment, program administration, and the MTECH faculty to accelerate their research and proposal writing. The same level of course buyouts are budgeted in Year 2 (2015) to allow the core courses to be taught and continue to allow the MTECH faculty involved to place additional attention on their research programs and grants. In Year 3, the funding for course buyouts doubles, so that specialized electives can be taught, along with the core courses, without harming the course offerings for other programs. By Year 4 (2017) the buyout budget is estimated to triple.

b. Distance Delivery of Courses. Because the new core courses and some electives need to be available for distance delivery, the provosts have committed to dedicate some existing curriculum design effort and funds for faculty stipends to accelerate the availability of these courses for on-line delivery. Each campus is responsible for and has in place the faculty expertise to develop two of the six core courses in Year 1 (2014) before the first students matriculate. The typical faculty stipend for distance conversion of a course is $3,000, and a full-time curriculum designer can typically support the development of at least six courses over the year. In addition, over the first few years, some existing and new graduate electives applicable to the theme areas of the program will be developed or adapted for distance delivery. The budget projection includes funding for curriculum design support and faculty stipend to prepare six electives in Year 2 (2015), four in Year 3, and two in Year 4 (totaling 6 core courses and 12 electives), after which the effort is planned to continue as part of the routine ongoing distance-conversion activity budgeted on each campus.

c. Cost of Education and Financial Support for Students. The resource requirements per graduate student are estimated to average $58 K per year. This amount is based on a GTA/GRA plus doctoral stipend totaling $24 K per year, funding to cover resident tuition ($6 K), and funding for the student's research supplies/costs/travel ($28 K). The $28 K per student average includes budget for the annual Summer Symposium, which will bring together in one place the faculty and students from all three campuses. Although summer symposia are not normal for doctoral programs, the faculty have included this face-to-face event as a mechanism to create and reinforce program identity and cohesion, and to allow the students and faculty to get to know each other, network, stay abreast of progress, and advance collaborations among the three campuses. The $28 K per student per year overestimates the cost for first- and second-year students who have not started their research; however these students will be taking more courses, with a significant fraction of these courses incurring distance-learning expenses for the sending and receiving campuses (about $4,800 per course in total).

It is assumed that the $58 K per year is covered by a combination of GTA, tuition waivers, and revenue from grants and contracts ($50 K/year). **Because the ability to fund these per-student expenses is so critical to the quality of the program, the budget projection is based on a requirement that for every admitted student, the faculty must have in hand approximately $50 K of grant/contract revenue per year allocable to these expenses.** Thus, the number of students and the cost of the program linked to enrollment would be automatically regulated by the success of the faculty in securing grants, with revenues and expenditures balanced. This requirement will incentivize faculty to obtain grants, keep the program fiscally solvent, and provide the external resources needed to create and maintain the forefront research infrastructure and activity necessary for the program to become competitive and sought-after by students. This approach to program admissions is typical of successful graduate programs in science and engineering across the country.

d. Administrative Support, Program Development, Recruiting, and Marketing. The administrative support and program-development/recruiting are projected to consist of one FTE of administrative support shared by the three campuses plus a modest budget for administrative operational expenses, typical of similar departments and programs, growing from $18 K in Year 1 (2014) to $35 K in Year 4. Operational costs include funding to support meetings of the External Advisory Board. About $80 K is budgeted in Year 1 (2014) and $75 K in Year 2 for operating expenses associated with program development, recruitment, and marketing, and new library acquisitions. These start-up funds are expected to decline to $40 K in Year 4 (2017). Subsequently these efforts would be expected to continue at a level comparable to ongoing recruitment/marketing of typical graduate programs. Within this total is $25 K per year for library database/e-journal acquisitions for materials science/engineering. The Library Deans identified $19.7 K to be needed for key information resources required for this program and not already available in the collections of one or more of the libraries, and the $25 K allows for a modest further addition of specific e-journals, print publications, and/or databases.

e. Infrastructure enhancements at Montana Tech. As noted by the AAAS Panel, infrastructure enhancements are needed at Montana Tech to reach the level required for doctoral education. Montana Tech plans to invest $160 K per year in these enhancements on a continuing basis, with an additional $150 K spread across the first three years (2013-2016). These infrastructure enhancements will include research instrumentation and equipment and technician support, optimized for the MatSci Ph.D. program but benefiting many programs and faculty—both graduate and undergraduate.

Projected Revenues

a. Grant Revenue Per Student. A major financial planning assumption for the MatSci Ph.D. program is that **for every admitted student, the faculty must have in hand $50 K of grant/contract direct revenue per year allocable to these expenses.** Thus, the program's enrollments and costs cannot increase faster than the grant revenues available. This funding will cover the student's research expenses, travel, professional development, and in-state tuition. For this analysis, in-state tuition is assumed to be $6,000. Since this amount is equal on the revenue and expenditure sides, the assumed amount does not affect the analysis overall. Not included in the analysis is any other funding in the grant (e.g. for faculty summer salaries, equipment, indirect costs, technicians, undergraduate researchers, or post-doctoral fellows).

b. Internally Reallocated Funds. Each campus has committed to reallocate a modest amount of funding or effort to the MatSci program. Such internally reallocated funds include the salary/benefits for the new tenure-track faculty member, funds for faculty stipends for distance delivery, the salary/benefits for the curriculum design specialist (assumed at one-third FTE per campus in Years 1 and 2), salary for administrative support for the program (assumed at one-third FTE per campus each year), and the routine operating costs for the program. In addition, Montana Tech would invest its graduate program development funds in this program during the start-up phase. Because the MatSci program is so multidisciplinary, and because faculty involved in the program are also affiliated with other programs and departments, these investments will also benefit other graduate programs, improve research competitiveness, and enhance instruction more broadly.

c. New Revenue Sources. The new revenues included in the analysis include private fundraising of an endowment for the program at Montana Tech, along with new funds appropriated by Montana's legislature for doctoral programs at Montana Tech. In November 2012, the Board of Montana Tech's Foundation endorsed a fundraising focus on Excellence in Graduate Education in the context of a larger campaign themed "Impact for Excellence." The goal is to raise at least $2,500,000 for this program over 4 years from private-sector entities and individuals, such as the stakeholders and supporters listed in the first two sections of Appendix II of the Level II Submission (included as Appendix I of this Business Plan). This endowment will provide $100,000 in annual revenue for the program in perpetuity, based on a 4% annual return. The Montana Legislature appropriated $300 K/year for the current biennium, and continuation of this funding is included in House Bill 2 in the current legislative session.

Budget Assumptions

Fundamental assumption: $50 K of grant funds per year per student is required to be in hand before student is admitted. This assumption guarantees that adequate resources will be available for the student's dissertation research and professional development. Thus, the per-student costs of education are balanced by new grant revenues, which pay for the student's stipend, in-state tuition, and research expenses. This amount was recommended and concurred in by the faculty. The $50K per year does not include grant funds for indirect costs, for faculty release time or summer salary, for equipment, for undergraduate researchers, or for other expenses not directly applicable to the per-student costs of education. An alternative reasonable assumption would provide institutional support of about $35 K for first-year students ($24 K (stipend/GTA), $6 K tuition waiver, $5 K travel/professional development and other costs), who are not doing research yet, but are taking courses. Institutional funding of first year students is the norm in several departments, and it would allow the program to grow faster but would require the campuses to identify funding for these students. Note that the annual grant expenditures for a portfolio of grants supporting an enrollment of ~30 Ph.D. students in five years, including IDCs, equipment, faculty effort, research expenses, travel, and undergraduate student researchers is expected to be in the range of $4 M to $6 M, including about $1 M to $1.5 M in IDCs. This new grant amount represents only a 2% to 3% increase on the collective annual base of R&D expenditures of the three campuses combined—a modest and achievable amount compared with the average annual growth rate of 3% to 4%.

Other assumptions:

- In state tuition is estimated at $6,000 per year, paid by research grants or tuition waivers. The current in-state tuition rates are as follows: MSU $6,150, MTech $5,800, and UM $5,850.
- All students will hold GTA/GRA appointments, thus all are eligible for resident tuition per BOR policy 940.31. [If some students do not hold GTA/GRA appointments and they or their employers pay their tuition, the revenues would be increased, but not the expenditures.]
- No assumptions have been made regarding the amount of start-up costs for new faculty. Each campus covers the expenses related to its faculty, courses, students, etc., including faculty start-up expenses. Each campus has its own processes, standards, and resources regarding faculty start-up costs, which are typically spread over three years and vary by discipline and level, ranging typically between $100 K and $600 K per tenure-track position. Because the MatSci program is very multidisciplinary, it cannot be predicted what the discipline of the hire will be or what mix of theorists (generally lower start-up) and experimentalists will be hired. Moreover, every time a faculty member is hired—whether a new position or a replacement—start-up commitments are made. The start-up costs have been committed by the provosts, but they are not included in this analysis.
- No assumptions have been made about grant support for undergraduate student researchers, faculty summer salary, equipment, or indirect costs associated with the new grants. These new grants will bring additional resources of these types and IDC revenues to the campuses. These revenues will be a significant financial benefit, not quantified or included in this analysis. Typically programs benefit from reinvestment of a portion of grant IDCs and grant funding for faculty release-time, and this possible revenue stream, which would be positive for the program's financial picture, has not been included in the analysis.
- No assumptions have been made about how other graduate elective offerings and their schedule might change as the new courses for the MatSci Ph.D. program come on line. Very likely, the core courses and electives in this program will be of interest and value to doctoral and master's students in other, closely related programs. No assumptions have been made about

whether or how many of the MatSci Ph.D. students will enroll in existing graduate courses, thereby increasing their enrollment and cost effectiveness.

7. Program Assessment

Benchmarks and assessment measures have been identified for the program to track and report the achievement of the program's goals and objectives and the value returned to Montana. The Benchmarks are based on factors identified in the National Research Council's 2010 assessment or research doctoral programs in the United States, and additional description is provided in the Level II submission. Table 2 summarizes the benchmarks and measures.

Table 2. Benchmarks[1] and Assessment Measures for the Proposed MatSci Ph.D. Program

Assessment Measures	NRC Assessment*		MUS Proposed Program	
	Top 20 programs	Bottom 20 Programs	Year 1: 2014/15	Steady State Goal (10 yrs)
Program Ranking (R Ranking, 5th Percentile)	Top Quartile	Bottom Quartile	N/A	Top 50% in ~10 years
Publications/FTE Faculty/Year	5.13	1.65	2	>3
Percent of peer-reviewed pubs with PhD student as first author	N/A	N/A	10%	>50%
Average citation per publication	2.25	1.21	N/A	>2
Percent of faculty with grants	91%	85%	60%	>90%
Percent of multi-PI grants with co-PIs from > one campus	N/A	N/A	10%	>35%
Allocable grant $ per FTE student	N/A	N/A	>$50K	>$50K
Percent of first year students with full financial support	91%	74%	>85%	>85%
Percentage completing in <6 years	59%	55%	N/A	>60%
Median Time to Degree	4.92	4.39	N/A	<4.8 years
Average No. Ph.D. Graduates/year	12.9	2.9	N/A	10
Minimum number of course credits taken at non-home institution	N/A	N/A	at least 9	Larger of 9 or 20%
Collects and analyzes post-graduation employment information	60% of Programs	30% of Programs	N/A	Yes
Percentage of first-year students w/ external fellowships	10%	9%	0%	10%
Number of enrolled students	98	19	7	60
Average first year enrollment	19	5	7	15
International students as percent of total students	52%	67%	<75%	<60%
No. of professional development student activities (out of 18)	17	16	16	18
No. of materials-based start-up companies and relocations to MT	N/A	N/A	N/A	TBD

[1] National Research Council (2010), J. Ostriker, et al, editors, "Data-Based Assessment of Research Doctoral Programs in the United States." The NRC does not endorse specific numerical rankings. However, the "top quartile" and "bottom quartile" approach discriminates between programs of consistently different quality and productivity.

8. Impact of Montana Tech's Participation in the Proposed MatSci Ph.D. Program

The proposal for the collaborative MUS MatSci Ph.D. program requires two decisions by the MUS Board of Regents: (1) whether to approve the program, and (2) whether Montana Tech, which is not yet authorized to award doctoral degrees, will be authorized to do so for students in this program, whose research and specialized coursework are conducted under the supervision of Montana Tech faculty. This section addresses the impacts, costs, and benefits of Montana Tech's participation in the program and possible authorization to award this degree.

Montana Tech is an essential institutional member of the proposed collaborative MatSci Ph.D. program. With its tradition and continuing role as the school of mines for Montana, Montana Tech has distinctive materials-related expertise vital to the continuing importance of natural resources to the future economic and environmental well being of the state of Montana and its people. Because of this distinctive expertise in metallurgy, materials processing, geomaterials, and associated fields, any materials Ph.D. program in Montana needs Montana Tech to be involved. Because of this distinctive expertise and Montana Tech's associated research infrastructure, already a few students in Ph.D. programs at MSU and UM perform their dissertation research at Montana Tech and benefit from significant doctoral-level supervision by Montana Tech faculty. Given the breadth of materials science and the program's specific theme areas that are most important to Montana, Montana Tech's participation is even more essential to the proposed MatSci Ph.D. program than it has been to the existing doctoral programs, where UM and MSU students with specific interests are sent to Butte for their dissertation research.

Given that the program needs Montana Tech's expertise, it could be structured either with Montana Tech being an equal degree-granting partner or as a non-degree granting partner. There are many advantages to Montana and other important constituencies of Montana Tech being a full, degree-awarding partner in the program.

1. Montana and MUS will benefit:

- The MatSci Ph.D. program will foster more intensive collaboration among the three campuses and with private entities across the state.
- Montana will become more attractive to high-tech, materials-based industry, creating jobs that allow more Montanans to work in the state after graduation, contributing to economic growth in Montana.
- Montana will become more attractive to prospective graduate students nationally and internationally who are seeking advanced degrees. Figure 3 compares Montana with other similar or nearby states in a few higher-education-related parameters. Montana is near the bottom in average income, undergraduate enrollment, graduate enrollment, and graduate degrees awarded, and in the middle of the pack for total R&D expenditures and educational attainment. These measures are normalized for state population.
- Montana and MUS will be able to capitalize more extensively on the significant distinctive materials-related expertise already at Montana Tech.
- Montana will join the ranks of competitor states (Arizona, Colorado, Idaho, Missouri, New Mexico, Oregon, South Dakota, Texas, and Utah) by having <u>at least</u> three different universities with doctoral programs.
- This program directly supports the MUS Board of Regent's Strategic Plan, especially its goals for Workforce/Economic Development (Increase R&D expenditures, Increase the number of graduate

students, Increase graduate degree production in STEM fields), and overall system Efficiency and Effectiveness.

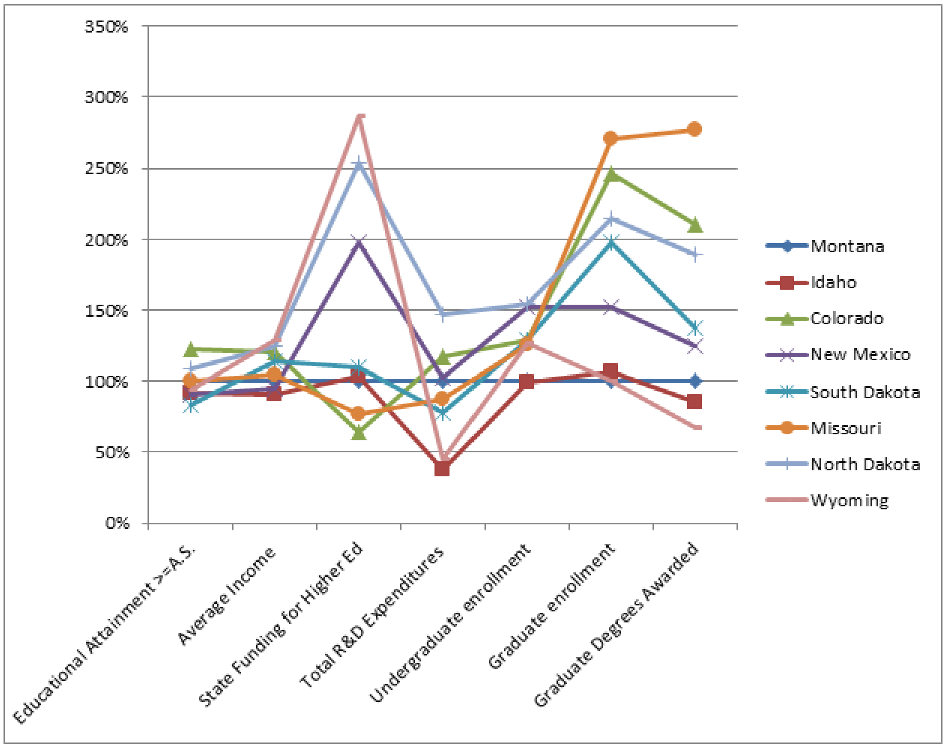

Figure 3. Comparison of Several States with Montana (100%) in Higher-Education Parameters

2. Montana Tech's undergraduate students will benefit.
- On-campus and collaborative research opportunities will increase for undergraduates.
- New research equipment for the Ph.D. program will also benefit existing programs and undergraduate research.
- New faculty will enrich the mentor pool and expertise base for undergraduates.
- The Material Science PhD will open up opportunities to a wide array of students across the campus. Chemistry, Biology, and Engineering faculty all have expressed an interest in participating in this program and it will invigorate the research activities and courses in these disciplines.
- Montana Tech's undergraduates will be in an environment providing greater exposure to research and networking/mentoring from near-peer graduate students who are working on their doctorates. This influence will help the undergraduates aim high, as they plan their educational and career goals and trajectories.

3. Montana Tech will benefit as an institution of higher education:
- Campuses that have PhD programs are held in higher esteem. This benefit is likely to improve Montana Tech's appeal to undergraduate students, as well as to the quality of the educational experience and awareness of career pathways provided to undergraduate students.
- A PhD program at Tech will allow the campus to recruit faculty from an expanded pool of applicants. Prospective faculty with strong commitment to teaching and research have chosen not to apply for or accept positions at Tech, because Tech lacks a PhD program.

- The Ph.D. program will help improve the campus infrastructure, in the form of a new distance classroom, new/improved laboratory space(s), forefront research instrumentation, and enriched seminar/colloquium activities. These investments will benefit all graduate programs, many graduate students in these programs, and undergraduate programs as well.
- The Ph.D. program will improve Montana Tech's grant competitiveness and bring additional extramural (mostly Federal and private) funding to campus, simultaneously increasing indirect cost revenues, research funding, and competitiveness for other grants.
- The PhD will make our degree inventory more in line with our peer institutions: Colorado School of Mines, New Mexico Tech (NMT), South Dakota School of Mines, and the Missouri University of Science and Technology—all of which offer Ph.D.s. In fact, currently Montana Tech is the only one of the 15 universities originally established as a school of mines which is not permitted to offer Ph.D. programs. The lowest number of doctoral degrees offered at these institutions is seven (SDSMT and NMT), and as a result Montana Tech's portfolio of federal research and development funds is only about 20% of SDSMT's (the second lowest funding).

4. Montana Tech's faculty will benefit:
- They will have increased research opportunities, increased funding opportunities, and gain credibility by being formally involved in doctoral-level education.
- Opportunities for collaboration with leading research groups and individuals across the nation will increase, because Ph.D. students will be available to participate in these projects.
- The research productivity, publications, and grant competitiveness of Tech faculty involved with the program will increase, due to the efforts of the doctoral students and the lower teaching workload of these faculty.
- The faculty involved will have improved opportunities for professional recognition and for gaining the professional credit that accompanies being a Ph.D. supervisor.

5. Butte and the Surrounding Community will benefit:
- New faculty and Ph.D. students will move to town and purchase or rent a home, send children to local schools, shop locally, etc.
- Ph.D. programs—especially in economically relevant fields, like materials science—tend to nucleate spin-off companies and attract high-technology business.

The following paragraphs consider the differential costs associated with whether Montana Tech awards the degree or does not.

If Montana Tech were to participate as a non-degree granting partner in this collaborative program, what costs in this proposal would be reduced? Montana Tech faculty and facilities bring distinctive expertise to the program, especially in materials processing, but also in other areas. Distinctive materials-related research infrastructure at Montana Tech would still need to be maintained and continuously updated at a standard that keeps it state-of-the-art. To replicate this infrastructure and the faculty expertise at one of the other campuses would be far more costly. Montana Tech faculty would still need to teach courses in the program, be the *de facto*, if not the official, dissertation supervisors and committee chairs. They would still need to serve on dissertation committees, attend summer meetings of the program, configure courses for distance delivery, and become more active in research and in grant-seeking than many currently are. They would not gain the professional advantage of serving as official Ph.D. advisors for students, and they would continue to have a disadvantage in grant-seeking, as reviewers conclude that the research being proposed would not be viable since Montana Tech would be perceived to lack the Ph.D. students to perform much of the research. The only reduction in costs might result from small administrative economies associated with the admissions process, which would involve coordination among two rather than three campuses. <u>These savings are likely to be less than $2,000 per year.</u>

Suppose Montana Tech participates as a degree-granting partner, what additional costs and benefits would be experienced? Montana Tech would need to notify its regional accreditor, the Northwest Commission on Colleges and Universities (NWCCU), about the substantive change associated with granting Ph.D. degrees. This cost would be the small one-time amount, of less than $1,000, to draft and submit the letter. Note that the accreditors are already planning a mid-accreditation campus visit within the next year or so, and the additional possible discussions associated with this substantive change would have a negligible impact on the duration and cost of this visit. Another expense would be associated with purchasing the parchment paper, printing the degrees, and providing the graduates with Ph.D. holders for these degrees. This continuing cost would not commence until the first student graduated (possibly as early as Year 4 for a student entering with a Master's degree, but more likely around Year 6). Although this would be an incremental cost for Montana Tech, it would not affect the overall cost to MUS of the program, as either UM or MSU would need to print the degrees for these graduates. Finally, the nominal workload of faculty members at Montana Tech would not change as a result of it being allowed to offer the Ph.D. Although Montana Tech must reduce the teaching assignments of the faculty directly involved in the program, this reduction will not apply to other programs and its cost is estimated in the resource analysis. They would need these course reductions to supervise the Ph.D. students doing their research on campus. Moreover, as time goes on, these faculty will be expected to be accountable for bringing additional research funds to campus—funds which will partially or fully support the lowered teaching loads in the long run. <u>The incremental cost is likely to be less than $1,000 in Year 1 to notify NWCCU and update Montana Tech's institutional accreditation. Once students start to graduate, Montana Tech would need to incur the costs of printing the diplomas, but these costs would not be incurred by UM or MSU, where the students would otherwise have graduated, so there would be no net costs to MUS. The financial benefits and revenue increases with Montana Tech being a full partner in the Ph.D. program are considerable as described above but not amenable to accurate projection.</u>

Concern has been expressed about Montana Tech becoming a doctorate-granting institution, and losing its status as a "primarily undergraduate institution" and as a "master's institution." Even with approval to award the MatSci doctoral degrees, Montana Tech would not become a doctorate-granting institution in the Carnegie Classification or according to the National Science Foundation (NSF).

NSF's threshold for an institution being considered Ph.D. granting is that it must award an average of at least 10 Ph.D. or D.Sc. degrees per year in all NSF-supportable disciplines combined. Carnegie classifies an institution as doctorate-granting if it awarded at least 20 research doctorates in 2008/09. Even with the ability to award Materials Science Ph.D. degrees as an equal partner in the MatSci Ph.D. program, Montana Tech will fall far short of awarding a sufficient number of Ph.D. degrees each year to reach this threshold. The South Dakota School of Mines and Technology, for example, has offered doctoral programs for several years, and it is currently authorized for seven different Ph.D. specialties. Nonetheless, as a result of low degree production, its Carnegie Classification is "Special Focus Institutions—Schools of Engineering." In the five years from FY2008 through FY2012, SDSMT awarded a total of 26 Ph.D.s—well below the Carnegie threshold for doctoral classification—with the highest annual degree production being eight degrees in FY2011.

NSF Definitions of Ph.D. Granting Institutions and Predominantly Undergraduate Institutions:

- "Non-Ph.D.-granting institutions of higher education are accredited colleges and universities (including two-year community colleges) that award Associate's degrees, Bachelor's degrees, and/or Master's degrees in NSF-supported fields, but have awarded 20 or fewer Ph.D./D.Sci. degrees in all NSF-supported fields during the combined previous two academic years."
- ""Predominantly undergraduate" institutions include U.S. two-year, four-year, masters-level, and small doctoral colleges and universities that (1) grant baccalaureate degrees in NSF-supported fields, or provide programs of instruction for students pursuing such degrees with institutional transfers (e.g. two-year schools), (2) have undergraduate enrollment exceeding graduate enrollment, and (3) award an average of no more than 10 Ph.D. or D.Sc. degrees per year in all NSF-supportable disciplines. Autonomous campuses in a system are considered independently, although they may be submitting their proposals through a central office."

Carnegie Classification Definitions of Doctoral-Granting Universities:

- "Doctorate-Granting Universities. Institutions were included in these categories if they awarded at least 20 research doctorates in 2008-09. First professional and Professional doctoral degrees (J.D., M.D., Pharm.D., Aud.D., DNP, etc.) were not counted for the purpose of this criterion. Institutions which granted fewer than 20 research doctorates can be identified by using Custom Listings to intersect categories of the Basic and Graduate Instructional Program classifications. As in previous editions, these categories were limited to institutions that were not identified as Tribal Colleges or Special Focus Institutions." (Source: http://classifications.carnegiefoundation.org/methodology/basic.php)
- Level of research activity. Doctorate-granting institutions were assigned to one of three categories based on a measure of research activity. It is important to note that the groups differ solely with respect to level of research activity, not quality or importance. The three categories are RU/VH: Research Universities (very high research activity), RU/H: Research Universities (high research activity), and DRU: Doctoral/Research Universities.

9. Conclusion

The proposed collaborative Ph.D. program in MatSci would fill an important need in Montana, is thoroughly planned, has addressed the concerns raised by the review panel convened by the American Association for the Advancement of Science in August 2012, is enthusiastically supported and approved by the three participating campuses, has a conservative and financially viable business plan, and would contribute positively to Montana and to the accomplishment of the strategic goals of the MUS and the participating campuses. The financial aspects of allowing Montana Tech to be a full partner in the program, authorized to award the degree, are positive. Costs associated with allowing Montana Tech to grant the degree are negligible, and the potential financial, system, institutional, and other benefits are significant but cannot be quantified accurately. Montana Tech, even with authorization to award this Ph.D. degree would not join the ranks of "doctoral institutions."

Appendix I

Appendix II from Level II Submission: Representative Stakeholders and Likely Sponsors

In-State Industry

John Krstulich, GT Solar, Missoula
Tom McIntyre, REC Silicon, Butte
Jim Liebetrau, AFFCO, Anaconda
Craig Wilkins, Zinc Air, Inc., Kalispell
Dan Brimhall, American ChemMet, Helena
Bert Robins, SeaCast, Butte
Arif Karabeyoglu, AeroTec, Butte
Gary Rivenes, Cloud Peak Energy
Jaye T. Picketts, Rare Element
Peter J. Simonich, PPL Montana, LLC
Jeff Ruffner, MSE-TA, Butte
Larry Twidwell, Montana Enviromet, Butte
Hugh Craig, Polymeric Interconnect, Butte
Lawrence Farrar, Resodyn Corporation, Butte
David Briggs, Purity Systems, Inc., Missoula
Don Kiely, Rivertop Renewables, Missoula
Don Profota, Lattice Materials, Bozeman
Hank Rawlins, Montana Process Engineering, Butte
Tom Russell, Emission Resource Group, LLC
Yuval Avniel, MicroPowder Solutions LLC, Missoula
Todd Johnson, Federal Technology Group, Bozeman
Dave Micheletti, Universal Technical Resource Services (UTRS), Butte
Randy Equall, Scientific Materials Corporation, Bozeman
Howard Bateman, Advanced Materials (Semi-Tool), Kalispell
Tom Hoffman, Summit Aeronautics Group (Boeing Fabrication), Helena

Out-of-State Industry (Based on Known Research Interests or Letters)

Exotic Metals, Kent, WA & Germany
Hercules
REC Silicon, Moses Lake, WA
Bloom Energy, Sunnyvale, CA
Taggart Global, Pittsburgh, PA
Imerys, Sandersville, GA
Boeing Materials, Seattle, WA
Newmont Mining Corporation, Denver, CO
General Electric, Fairfield, CT
Freeport McMoRan, El Paso, TX
Hecla Greens Creek Mining Company, AK
DuPont, Wilmington, DE

State Centers of Excellence

Optical Technology Center (OPTEC), MSU
Spectrum Labs, MSU
Energy Research Institute, MSU
Center for Computational Biology, UM
Center for Biofilm Engineering, MSU
Western Transportation Institute, MSU
Center for Advanced Mineral and Metallurgical Processing (CAMP), MTech

Federal Departments, Agencies and Laboratories Supporting or Performing Materials Science and Engineering Research (Partial Listing):

Department of Defense (DoD)
National Science Foundation (NSF)
U.S. Department of Energy (DoE)
National Institutes of Health (NIH)
National Aeronautics and Space Administration (NASA)
Idaho National Laboratory (INL), ID
Argonne National Laboratory (ANL), IL
Los Alamos National Laboratory LANL), NM
Lawrence Livermore National Lab (LLNL), CA
Oak Ridge National Laboratory (ORNL), TN
Brookhaven National Laboratory (BNL), NY
Sandia National Laboratory (SNL), NM, CA
Lawrence Berkeley National Laboratory (LBNL), CA
Pacific Northwest National Laboratory (PNNL), WA