University of Wyoming Engineering Initiative:

Toward Tier 1 for Wyoming

April 2013

Introduction

This report presents a vision and accompanying plan to fundamentally transform the University of Wyoming's College of Engineering and Applied Science into an outstanding engineering school, providing a lasting legacy of value to the citizens of the state. The university aspires to move the college forward with academic excellence in every respect: recruiting outstanding students, infusing curricular innovation, generating deep industry connections, and developing a research enterprise aimed at fueling the state's economy.

The motivation for engineering excellence stems from many individuals, but was focused by the passion of a collection of Wyoming elected officials, whose desires are clearly articulated in Governor Matt Mead's charge letter to the 2012 Wyoming Governor's Energy, Engineering, STEM Integration Task Force:

> *"It is only through a well-articulated, understandable strategy that we will be able to fulfill the challenge of becoming a Tier-1 academic and research institution in areas of excellence for Wyoming."*

The Task Force is comprised of a collection of outstanding government and corporate individuals who share a passion and affinity for the university and the state. During the past year, they have worked with UW's leaders to forge a vision for the future of the college. The present report represents the outcome of that endeavor.

In what follows, we lay out the strategy to advance UW's engineering school to national prominence, the result of which will have a profoundly positive impact on the future of Wyoming. Specific topics addressed with recommended actions include:

- Identifying performance metrics and providing a path to drive the college toward national prominence
- Elevating the quality of engineering undergraduates while forging authentic partnerships with industry
- Undergraduate curricular innovation stressing computational aspects of engineering
- Continuing UW's "rock solid" undergraduate engineering program, while graduating outstanding, well-rounded engineering students possessing professional experience and leadership skills obtained beyond the traditional classroom experience

- Developing niche areas of research excellence that have a major influence on Wyoming's future and, further, actively promoting deep connections between faculty researchers and industry and government agency partners

- Advancing economic development in the state through licensing intellectual property and promoting technology transfer

- Capital facilities designed to meet the technological innovation and teaching needs of engineering today

- Marketing the college and the university across the state and the nation

- Developing effective programs in Wyoming middle schools to introduce engineering as an exciting and rewarding career

A Premier College of Engineering—What is Tier 1?

The notion of a Tier 1 engineering school has caused widespread discussion as to its precise meaning. Recognition of engineering excellence comes from multiple sources including prospective students, engineering alumni, private industry, and the peer institutions that make up such an elite group. It is not difficult to identify a collection of outstanding engineering schools. Our personal experience, coupled with accepted national rankings and quantifiable performance metrics, readily paint the landscape of engineering excellence. Our goal is to be elite, but not elitist.

We have chosen to define Tier 1 engineering education in the US today through a collection of data from 10 institutions that, by any definition, represent engineering excellence. Five of the ten schools reside in the *US News and World Report* ranking of top 10 graduate engineering programs in the United States. We excluded 4 private schools as well as Cal Tech, a school with a mission substantially different from UW. The remaining five programs were identified from public institutions with outstanding engineering credentials and a mission similar to UW. The schools chosen for benchmarking engineering excellence, along with their *US News* 2014 national ranking for graduate schools in engineering are shown below. In the end, however, excellence in engineering is not a function of a rating in one set of rankings or another, but rather of the quality, impact, and visibility of the program in our nation and in the world.

Benchmark Tier 1 Institutions (US News Graduate Eng. Rank: 2014)

School	**Ranking**	**School**	**Ranking**
California—Berkeley	3	Texas—Austin	11
Illinois—Champaign-Urbana	5	Texas A & M	11
Georgia Tech	5	UCLA	16
Purdue	8	Wisconsin—Madison	18
Michigan	9	Washington	25

With 199 ranked schools, the top quartile of engineering schools is defined by those with a ranking higher than 50, making the above list truly elite. However, far more important than the numerical ranking is the immediate name recognition—the visibility—of engineering excellence associated with every one of these schools. We refer to this collection of schools in the report as the Tier 1 set. Clearly, other great schools exist and one can swap schools in and out. However, the metrics of interest change little or not at all.

How does UW Compare?

Using our Tier 1 set of schools, we have introduced a collection of some of the most important benchmarks associated with developing a national reputation in engineering while also providing a measure of the quality of students attending these schools—see Figure 1. The figure provides statistical averages of the key metrics of interest. In addition, the same performance indicators are presented for the University of Wyoming along with an easily readable ratio that benchmarks UW against the statistical average of the Tier 1 set. Finally the same information and ratios provided for UW are also provided for the University of Utah and the University of Arizona. Both of these schools are located in the mountain west and rank right at the top quartile of *US News* 2014 graduate engineering programs, with Arizona at 48 and Utah at 51. The University of Utah's information is of particular interest as the state of Utah has had roughly a 13 year history of its own "engineering initiative," providing us a window into what is achievable for UW.

We believe two metrics, more than any others, serve to define a national reputation for engineering excellence at the graduate level. They are the production of high quality Ph.D. graduates and research funding. High levels of performance in these metrics naturally lead to other positive performance indicators including refereed research publications, patents, and licensing of intellectual property. Doctoral education and research funding also promote excellence in undergraduate education by providing students with opportunities to learn at the cutting edge of technology.

In 2011, the Tier 1 set of schools generated funded research awards averaging $645K per tenure track faculty member ($$/TT). Research funding for UW was $162K/TT, representing a ratio of 0.19 of the Tier 1 average. In contrast, Utah's research funding was $551K/TT—a very impressive ratio of 0.85 of the Tier 1 set.

In 2011, the average annual Ph.D. production per tenure-track faculty member of our Tier 1 set was 0.71. Again, referencing Figure 1, UW's Ph.D./TT production ratio is 0.20 of the Tier 1 set. By comparison, Utah's ratio of Ph.D./TT production is 0.66 relative to the Tier 1 set—an indicator of a strong research college of engineering.

The Tier 1 Ph.D. production of 0.71 graduates per tenure-track faculty member is quite high as the time to graduation for a Ph.D. might require 5-6 years. Achieving this level of productivity requires the *average* faculty member to support 3-4 Ph.D. students at all times. Supporting a single

Engineering Metrics							
	Research Funding $/TT[1]	Ph.D. grads/TT[1]	MS grads/TT[1]	BS grads/TT[1]	US News (Graduate Engr)[2]	25th and 75th Percentile ACT Scores[2]	Acceptance Rate %[2]
School							
Cal-Berkeley	861,226	1.06	1.54	3.87	3	28-34	22
Illinois Urbana-Champ.	572,606	0.71	1.41	3.59	5	26-31	68
Georgia Tech	534,098	0.71	2.49	4.33	5	28-33	51
Michigan	520,826	0.59	2.33	3.55	7	28-32	46
Texas at Austin	634,067	0.70	1.78	3.88	8	25-31	47
Purdue University	653,849	0.71	1.52	4.43	10	23-29	68
Texas A&M	843,966	0.61	2.09	3.79	12	24-29	64
UCLA	652,464	0.87	2.86	4.99	16	26-33	25
Wisconsin-Madison	684,203	0.70	2.67	3.66	17	26-30	51
Washington	495,711	0.48	1.79	3.51	26	23-30	58
Statistics							
Average	645,301	0.71	2.05	3.96		26-31`	50
Max	861,226	1.06	2.86	4.99			
Min	495,711	0.48	1.41	3.51	199		
University of Wyoming	162,200	0.14	0.74	2.43	132		
Wyoming Ratio	0.19	0.20	0.36	0.61	34%	22-27	96
University of Utah	551,417	0.47	1.47	2.62	51		
Utah Ratio	0.85	0.66	0.72	0.66	74%	21-27	83
University of Arizona	349,955	0.53	1.23	2.85	48		
Arizona Ratio	0.54	0.74	0.60	0.72	76%	21-27	74
1. Source: ASEE 2011 Database							
2. Source: US News and World Report (2014)							

Figure 1. Engineering metrics of excellence showing (a) the averages from a set of premier engineering schools, (b) the metrics for the University of Wyoming and the ratio to the Tier 1 averages, (c) the metrics for the University of Utah and the ratio to the Tier 1 averages, and (d) the metrics for the University of Arizona and the ratio to the Tier 1 averages.

student may cost $40K annually, providing some insight into the funds needed to support the enterprise. It should come as no surprise then, that research funding and Ph.D. production are inextricably linked.

While Ph.D. production may be a key metric for the national reputation of an engineering school, production of masters graduates is a critical service to industry. If we examine masters graduates per tenure track faculty for UW and the Tier 1 set, we find that UW's ratio is 0.36. While well below the marquee programs, the number is nearly double UW's ratio for Ph.D. production which was 0.20. The University of Utah's ratio for this metric resides at a very respectable value of 0.72 of the Tier 1 set.

An examination of the University of Arizona's (UA) performance indicators shows their research funding ratio at 0.54 of the Tier 1 set. While significantly above UW's ratio of 0.2, UA falls well below Utah's funding ratio of 0.85. UA's Ph.D. production and MS production per tenure-track faculty member are much more in line with Utah's and, again, significantly higher than UW's.

What is Achievable?

As mentioned previously, the University of Utah is a valuable case study as it has been part of an engineering initiative for over a decade. In September of 2000, Governor Mike Leavitt announced ambitious plans to double the number of engineering and computer science graduates in the state in the next five years. Details of the Utah engineering initiative may be found at: http://leavitt.li.suu.edu/leavitt/?p=14.

Over a period of several years, approximately $10M/yr in recurring funding was injected into engineering programs in the state, shared by the University of Utah and Utah State. While the general consensus was that the funding was not sufficient to reach the stated goals, one can still see signs of a major positive impact from the program. For example, Figure 2 shows the normalized growth in funded research per tenure track faculty since 2007 for the University of Utah and our set of Tier 1 schools. The rate of growth for Utah is dramatically higher than for the Tier 1 universities, and as a result Utah now compares favorably with the Tier 1 universities in this performance metric as their research funding is now 85 % of the Tier 1 average. A similar positive trend is found when one examines Ph.D. production per tenure track faculty member. Utah's Ph.D./TT production has risen 25% in this period while the Ph.D./TT production of the Tier 1 set has essentially been flat, actually declining slightly. In short, the Utah experience shows that it is possible to achieve improvements in key metrics associated with Tier 1 excellence in engineering. While change has been rapid since 2007, the engineering initiative driving this change is now 13 years old.

Finally, it is important to also note that Utah's tenure track faculty have risen dramatically from 122 in 2005 to 149 in 2010. The growth of faculty is critical to providing stability in key areas. More on this later!

Goal #1

There is a direct correlation between research prominence and national reputation in engineering. *The University of Wyoming aspires to drive the College of Engineering and Applied Science into the top quartile of engineering rankings for graduate education.* Key indicators of performance to be monitored include the metrics of:

- research funding/TT,
- Ph.D. graduates/TT, and
- masters graduates/TT.

The data for the University of Utah and the University of Arizona serve to quantify metrics representative of schools at the top quartile. Driving UW's metrics toward values comparable to schools at or near the top quartile is an explicit and quantifiable goal. Over time, the national rankings from various organizations will naturally reflect improvements in the key metrics identified. We outline a plan to achieve this goal in the section on "graduate education."

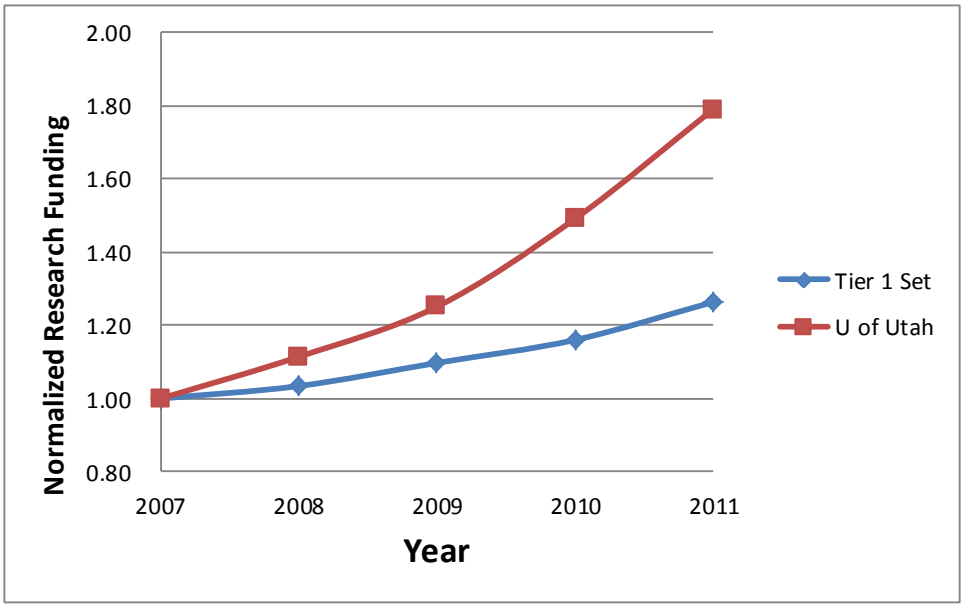

Figure 2. Normalized research growth (i.e., funding relative to 2007 levels) for the University of Utah compared to the average of the Tier 1 set.

Recruiting Undergraduate Students

A premier undergraduate school of engineering begins and ends with the recruitment of outstanding students. Outstanding students have immeasurable positive impacts on the program; they attract other outstanding students, they enhance the reputation of the school and are a powerful and quantifiable metric, they allow the faculty to elevate expectations in the program, and

finally, they go on to do wonderful things for society. Over time, they will also find ways to give back to UW in a multitude of ways!

There are various metrics that may be used to gage the quality of students but, without question, one reliable and moderately valid indicator of academic performance and a readily accessible data set is the entering ACT score for college freshmen. ACT scores are reported on a 36 point scale. The distribution of scores along this scale is highly nonlinear. For example, the information below shows the percentile difference between a 30 and a 36 is quite small compared to the difference between a 24 and a 30.

ACT Score	**Percentile Ranking**
36	99th %
30	95th %
24	74th %

Figure 3 shows a correlation between ACT scores and the first-year GPA for students at UW. The relation is monotonic and almost linear. It demonstrates the value, in terms of academic performance, of attracting students with outstanding ACT scores. There is a wealth of national data available to further support this view. In brief, the ACT score is a good indicator of the probability a student will succeed in engineering courses. At the same time, tests such as the ACT do not measure all of the characteristics needed for later career success, such as creativity, common sense, communication skills, ability to work as part of team, ethical behavior, and good work ethic.

One measure of the make-up of a freshman class of engineering students is to examine the ACT scores of the top quartile (75th %) and the bottom quartile (25th %) of incoming students. For the base set of Tier 1 schools in Figure 1, the 25th and 75th percentile scores are 26-31. In the case of UW these same scores are 22-27.

If one examines the top quartile, we find that an ACT of 31 corresponds to 25 percent of the incoming students residing at the 97th percentile of all students taking the ACT. UW's ACT top quartile score of 27 places 25 percent of our students at the 87th percentile nationally.

Repeating this same analysis for the bottom quartile we find that our Tier 1 students reside at the 83rd percentile while UW's reside at the 62nd percentile. It is the lower end of the student class where UW falls markedly behind the Tier 1 schools.

Finally, an interesting comparison with the University of Utah and the University of Arizona shows that their freshman class profile is nearly identical to UW's. In Utah's case, the similar class profile may suggest that Utah's emphasis with their engineering initiative has been research and graduate education. Our objective is to move UW to a top quartile ranking in both undergraduate and graduate education. The undergraduate effort begins with the recruiting of a great class of students, year after year.

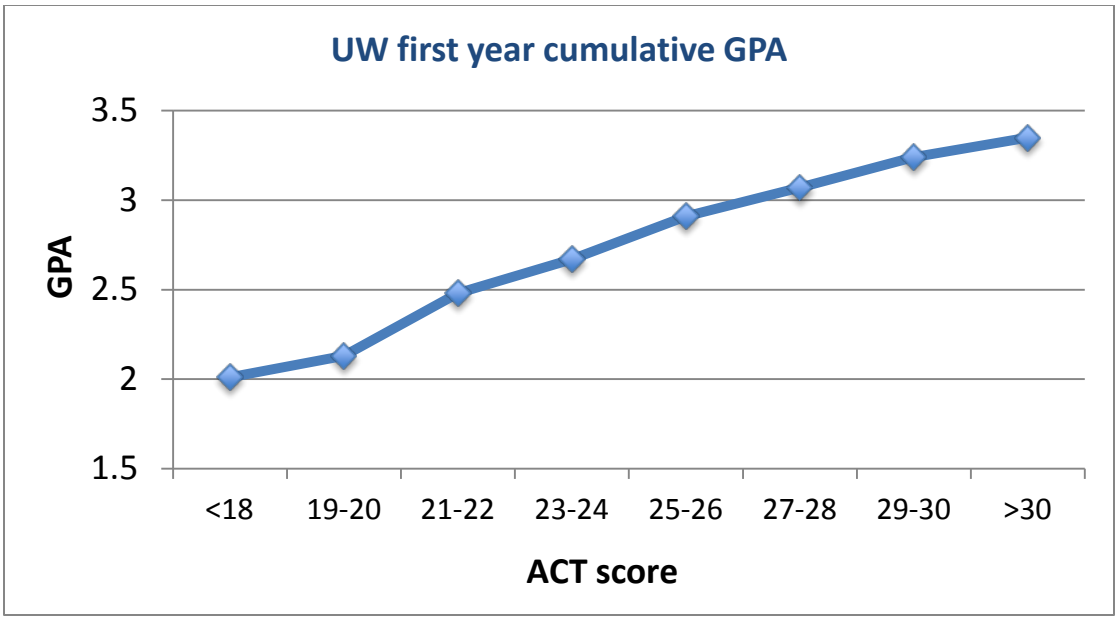

Figure 3. ACT score correlation to first-year academic performance at the University of Wyoming.

It is important to note that academic success is not tantamount to career success. Many very successful engineers who are leaders in their fields were not necessarily those who had the highest ACT scores, or, for that matter, college GPAs. UW must remain open to recruiting engineering students who possess other attributes that are likely to make them successful.

Goal # 2

UW will aggressively pursue outstanding students throughout Wyoming and the nation through a combination of marketing and scholarships. *We propose to provide "Tier 1 Scholarships" of $6,000/yr. annually to the top-quartile of entering first-year students with support lasting for four years for continuing students.*[1] We believe support at his level, combined with effective national marketing and pursuit of other goals outlined in this initiative, should be sufficient to drive our top quartile ACT scores to numbers comparable to our Tier 1 comparators—a score of 31 or greater to be precise. A natural consequence of improvements in our top quartile will be a rise in the bottom quartile as well.

A persistent national problem in engineering is the relatively low numbers of women in the profession. UW is no different and currently women make up 17 % of the undergraduate student population. UW has an opportunity to distinguish itself by recruiting from this poorly tapped talent pool, thereby dramatically altering the percentage of women in the college through a sustained long-term endeavor. *A start toward achieving positive change is a commitment to attempt to devote 1/3 of the top quartile Tier 1*

[1] A total of 500 Tier 1 Scholarships are being planned for based on an enrollment target of 2000-2400 undergraduate students. Moreover, this support would be in addition to other scholarship support for these students, e.g., Hathaway scholarships, private donors, etc.

scholarships to women—representing twice the current percentage of women undergraduate students in the college.

Goal # 3

The initiation of the Tier 1 Scholarship Program represents the perfect opportunity to begin a longitudinal study from program inception. *UW will track the performance of Tier 1 Scholarship students using metrics of GPA, freshmen to sophomore retention in engineering at UW, time to degree, job placement upon graduation and employer/employee satisfaction after graduation.* The relative small student population makes this endeavor a manageable task.

Finally, while UW must strive to improve the quality of undergraduate students, one must temper these goals with an understanding of the higher education landscape in Wyoming. By virtue of being the only university in the state, UW must provide unparalleled access to the students of the state. This access is clearly shown by UW's acceptance rate of 96%. In contrast, the Tier 1 engineering schools in our data set, all of which are located in states with other less selective public universities, have an acceptance rate of 50%. We believe in the open access model provided by UW in giving every qualified student the opportunity to pursue his or her dreams. Occasionally these dreamers produce memorable success stories. In short, recruiting more students at the high end is more important than excluding students at the low end.

Undergraduate Education

UW aspires to deliver an outstanding contemporary undergraduate engineering education to its students, with curricular innovation reflecting the technological pace of today. Our goal is to produce leaders in the field of engineering—engineers who will make a difference, regardless of the precise career they choose to follow. For example, many successful engineering students become engineers, but others become entrepreneurs or executives in businesses or nonprofits. One key to these students' success is a forward-looking curriculum.

Historically, theory and experimental observation formed the foundational pillars of engineering. However, over a period of several decades, computational science has emerged as a critical aspect of engineering solutions. Computational science, more a methodology than a discipline, facilitates simulation, data acquisition, asset management, and visualization and communication. It also facilitates solutions to a large class of problems whose solutions were previously out of reach. Finally, computational science is a gateway to successful high tech spinoffs in a host of important engineering and science sectors.

Computational science is so prevalent today that it is now considered as a third pillar of engineering and shares an equal footing with theory and experiment in importance. Indeed, the majority of advances in technology today are driven by computational solutions. However, while computational science is prevalent in graduate-level research, in the national arena it has yet to

penetrate the undergraduate curricula to the depth needed for undergraduate students to enter industry ready to contribute immediately to advances under development.

Few US engineering programs are as well positioned as UW to pursue computational science as an overarching theme in their undergraduate engineering education programs. UW's world class computational facilities, its setting in an emerging core for data centers, and the nimbleness associated with a small college are important drivers for success in such an endeavor. Moreover, engineering curricular innovation in computational science will provide a strong attraction for the exceptional students we seek to attract to our programs.

Goal #4

UW will undertake major undergraduate curricular innovation to make use of all 3 pillars of engineering education by infusing computational science into the core Engineering Science courses in the college of engineering. Engineering Science courses are taken by every engineering student and represent the foundation of upper division advanced course work. By elevating the presence of computation science in the core curriculum, genuine curricular change at the upper division can occur with the use of advanced computational science algorithms and software. The end result will be an undergraduate engineering program at the leading edge of engineering education in the US. We refer to this innovative curriculum advance as C-STEM.

While curricular innovation in computational science is foremost in our minds, the college of engineering will strive to produce well-rounded outstanding graduates prepared to meet the engineering challenges of the future. An important aspect of professional development of an engineer is a progression of academic and professional experience leading to licensure as a *Professional Engineer (PE).* An early step in the path to licensure is passing the Fundamentals of Engineering (FE) exam. All our students must take the exam as part of the college's graduation requirements; many engineering programs in the U.S. do not have this requirement, and only encourage their students to take the FE exam.

In October of 2012, the national pass rate for first-time test takers of the FE exam was approximately 70% compared to UW's pass rate of 83% for the same set of majors. Historically, UW students have consistently scored above the national average with pass rates typically in the range of 80-85%—despite UW's requirement that all students take the exam.

Goal #5

UW will continue to strive for engineering excellence of all students in the program. *The college aspires to have a consistent pass-rate for the FE exam of at least 90%.* Given UW's historical performance on the FE exam, a 90% pass rate is not unrealistic. Indeed, since 2002, a 90% pass rate has been obtained twice in 19 exams (the exam is administered twice a year). An assessment of program strengths and weaknesses and a drive for continuous improvement are critical in this endeavor.

A 90% pass rate on the FE exam will place UW significantly above national averages, providing a valuable marketing tool for student recruitment. Marketing the college is a consistent theme found throughout this report as part of our drive for Tier 1 excellence.

UW's performance on the national FE exam is a credit to the commitment to undergraduate education by the college's excellent faculty. *Competitive compensation for the faculty is essential if we are to retain faculty members as they represent the foundation to build toward a Tier 1 college of engineering for Wyoming.*

An essential part of an outstanding undergraduate engineering program is a deep and lasting partnership with industry. These connections provide direct employment benefits to our students and corporate partners while opening a communication pipeline to the very latest in technological advances from industry and research discoveries at UW.

A relationship between students and industry partners often begins through a valuable internship in the corporation. The internship is an important part of a student educational experience as they begin to launch their professional careers. Internships also provide a powerful form of recruitment by industry as both the student and the company can explore mutual interests in a long-term career.

Goal #6

UW's College of Engineering and Applied Science aspires to have 90% of its graduates complete at least one professional internship by the time of graduation. The college will actively partner with prospective employers to achieve this goal. Moreover, employment information collected by UW will be used as a means of determining the correlation between internships and future permanent employment.

An important aspect of a rewarding professional career in engineering and science is the opportunity to assume leadership positions within an industry or agency. Leadership development is often inadequately addressed in undergraduate engineering education, owing in part to some of the intangibles associated with defining and teaching leadership.

Goal #7

The college proposes to develop a unique relationship with its industry and agency partners by exploring opportunities to formally develop a required UW/industry/agency leadership program for all undergraduate engineering and computer science students. The integration of leadership development with industry and agencies could occur in multiple ways and continue throughout a student's education at UW.

Several interesting avenues exist for implementing a leadership theme. One possibility is to develop the college's internship (summer employment) program to include guided exposure to leadership practice in an industry or agency. A further interesting possibility is to develop a one-credit, three week short course that students would take once

in their academic career during the month of January (J-term). J-term courses are becoming increasingly popular at UW and the proposed course appears to be an excellent opportunity to take advantage of this time. A J-term course could be located on campus or embedded at an industry site. The opportunities for innovation here are exciting!

Other creative avenues for leadership development exist including partnerships with ROTC as well as the College of Business. Also worth exploring are focused seminar series of invited industry and agency speakers. These series can be built into existing courses, such as a capstone design course, or delivered as part of a seminar series for multiple degree programs.

One of the biggest marketing assets of an engineering school is the ability to advertise outstanding job placement data of its graduates. The college of engineering has failed to take advantage of this opportunity through any sustained form of data collection and the accompanying professional marketing of the data. UW currently has professional staff in place to actively promote job placement of its graduates as well as internships for its students. What is needed now is an accurate assessment of the success of these activities along with solid longitudinal data on professional employment and student satisfaction.

Goal #8

UW will develop a systematic approach to collect employment data of its engineering college graduates by initiating an aggressive survey in January of the preceding academic year's graduates. An effort will be made to reach every graduate and employment data will be collected and percentages computed for those responding to the survey. UW will monitor longitudinal data, seeking opportunities to improve the employment results while incorporating the latest results into marketing the program across the state and the nation.

UW does not need to reinvent the wheel when seeking to effectively promote employment opportunities for its graduates. Indeed, we can learn a great deal from engineering schools that specialize in marketing their students to industry. *The college will determine a set of best practices for effectively placing its students in engineering positions in industry. Based on the information collected, the college will aggressively pursue programs aimed at placing engineering graduates in professional jobs.*

Finally, in considering other avenues beyond the classroom to create a stellar undergraduate engineering experience, we agree with the Task Force assessment that UW alumni represent "an underutilized yet highly loyal resource." Opportunities exist for alumni mentoring programs, formalized recruiting using alumni (a common practice of private institutions), and alumni connections to job placement.

Goal # 9

The opportunities to engage engineering and science alumni are multifaceted and UW would be well served to survey the landscape of various forms of alumni involvement with

engineering schools. Armed with this information, the college will make a concerted effort to engage our alumni in activities designed to enhance the undergraduate experience.

In closing, we believe two objectives of our undergraduate programs should be foremost in our minds. First, when a student walks off campus for the last time, it is our hope that the student says, "I am glad I went to engineering school at the University of Wyoming." Second, we want all our engineering graduates to be highly sought after by industry, immediately upon graduation and for the long haul—to be viewed as the future leaders in the field and, hopefully, in the State of Wyoming. These objectives succinctly sum up our drive for undergraduate engineering excellence.

Graduate Education

UW's graduate education programs have mixed areas of excellence with some areas that are weak or have a very limited presence. The fundamental difficulty in advancing excellence is a lack of depth in faculty numbers in any particular area. For historical reasons, areas of excellence in the College of Engineering and Applied Science tend to be based on the expertise of a faculty hire and not an area of distinction defined by the university. As a result, these areas of excellence are vulnerable to a resignation or retirement of a key faculty member. This feature of the college stands in contrast with recent trends in other fields at UW, such as neuroscience and Earth sciences. Lack of stability in areas of excellence is undesirable and certainly runs counter to the notion of developing a Tier 1 engineering program.

An anecdotal example of the transient nature of areas of excellence in the college is found in the composite materials program developed by Professor Donald Adams beginning in the 1970's. Professor Adams turned the University of Wyoming into the premier institution of higher education for thermo-mechanical testing of composite materials. Companies and organizations from all over the world looked to UW to provide this information in an era where the use of composites was in its infancy. UW was a major player in the explosive entry of composites into the materials community. Professor Adams retirement after a stellar career signaled the decline of an area of excellence that could have been sustained. *Niche areas of excellence disappear as seemingly randomly as they appear*—not a sustainable model of excellence. The random arrival and decline of excellence is a consequence of a once-prevalent philosophy of "letting all flowers bloom." Going forward, the college must adopt a far more focused hiring strategy, aligned with areas of distinction identified in UW's strategic plan and aimed at the development of stable faculty strength in niche areas.

A converse example of building and retaining programmatic depth is the Department of Atmospheric Science (DAS). If we remove the word "department", atmospheric science is truly a niche area of excellence at UW. While DAS contributes to the teaching mission of the college, it has no true undergraduate program that must be supported, allowing the department to focus on graduate-level research. As a result of known stable resources, the program has developed an international reputation while standing the test of time. Many outstanding faculty members have come and gone, yet the department continues to flourish. The Atmospheric Science program is viewed as a model for developing sustained niches of excellence in graduate education.

A quick profile of DAS shows an annual state budget of $1.27M with 8 tenure-track faculty. Annual research expenditures per tenure track faculty are $523K which yields a ratio of 0.81 with respect to the Tier 1 set and on a par with the University of Utah college of engineering. The department also capitalizes on resources unique to UW and Wyoming; the King Air experimental aircraft is one of only two "fully-instrumented" (mission ready) research aircraft in the country and Laramie is also one of the best locations in the world for high altitude balloon launches. The depth of faculty resources, coupled with valuable assets unique to UW and the state, provide a formula for lasting excellence that we intend to emulate in other niche areas.

We have identified five niche areas of excellence that are of major importance to the state, that align with UW's strategic plan, and in which national prominence is attainable. A brief description of each niche area is provided below.

Unconventional Reservoirs

Unconventional hydrocarbon reservoirs represent the future of Wyoming's natural gas and oil production. Indeed, the economic vitality of the state in the coming decades remains inextricably linked to accessing unconventional resources.

Over the last eight years the state has heavily invested in developing energy programs at UW. This effort has created a platform for developing world-leading capability in key technology areas that will lead to breakthroughs in fundamental knowledge critical for optimal production of fossil energy resources, particularly unconventional reservoirs. Chief among them is the world's most advanced multi-scale flow and rock characterization research facility, established at UW over the last six years. In this facility, UW engineers and scientists are concerned with the development of a fundamental, improved understanding of flow and transport in unconventional reservoirs, e.g., shale oil and shale gas. Such understanding is pivotal to extracting maximum value from both unconventional and conventional reservoirs and is being obtained through collaborative multi-scale experiments, imaging, modeling, and simulation of flow and transport in porous media at multiple scales, i.e., meter to nanometer. This research will ultimately contribute to the design of strategies for improved oil and gas recovery from unconventional reservoirs.

UW benefits from an interdisciplinary array of faculty members with expertise in experimental science, mathematical and physical modeling, and high performance computing to advance the state-of-the-art knowledge in unconventional reservoir analysis. Further strengthening of this niche area provides UW an opportunity to achieve national and international prominence for the college—with lasting benefits to the state, the country, and the world.

Advanced Coal Technologies and Energy Conversion and Delivery

This niche area addresses the programs of education and research needed to create the value-adding technologies and expertise for converting Wyoming's energy resources and ensuring their reliable delivery to markets. A topic of primary importance is advanced coal technologies including coal to liquid fuels, hydrogen production, advanced combustion turbines, and advances in

coal gasification technology. Interestingly, the primary research advances needed to improve coal's viability as an energy resource focus on developing new materials capable of meeting increasingly severe service environments. Novel material processing and computational solid mechanics represent major contributors to this research endeavor. Advanced coal technologies provide an opportunity for coal to remain an important part of world energy supplies for the foreseeable future.

Other energy conversion and delivery topics include the sound development and use of Wyoming's renewable energy resources (wind, solar) and nuclear energy resources, possibly in conjunction with technologies for producing liquid fuels and chemicals. UW's chemical, mechanical, electrical, and energy-systems engineering programs will play significant roles in developing this niche, doing so in collaboration with expertise in chemistry, business, and pertinent other UW programs.

Computational Science and Engineering for Fluid Dynamics and Materials Science

As noted in the write-up on undergraduate education, computational science has become a third pillar of engineering, sharing an equal footing with theoretical research and experimental research. Computational science is inherently interdisciplinary, involving expertise in applied mathematics, computer science, and specific engineering application domains. The state of Wyoming is blessed with outstanding high performance computing resources including the NCAR-Wyoming supercomputer and UW's recently acquired on-campus Advanced Research Computing Center. In addition, UW has made a sustained effort over the last 10 years to hire faculty in an array of disciplines whose expertise lies in computational research.

The college of engineering has a core of expertise in computational fluid dynamics, computational materials science, and high performance computing, and collaborates strongly with the mathematics department in areas related to computational science. Computational science and engineering is not only perfectly suited to UW, it is one of the most likely sources of business spinouts from the college. For instance, Firehole Composites is a university spinout with approximately 15 engineers devoted to the computational analysis of failure of high performance composite materials. Numerous other opportunities in computational science and engineering, enabled by the university and state commitments to high performance computing, are poised to support an important aspect of economic development in Wyoming in diverse areas such as aerodynamics of wind turbines, reservoir simulation, solid and liquid combustion processes, water resources, and novel material design and characterization.

Water Resources

The importance of Wyoming's water resources cannot be overstated. Wyoming's location as a headwater state, its largely semi-arid climate, and the roles of water in Wyoming's economy make determining, developing, and managing its water resources critically important. Significant efforts are needed to understand the hydrologic and climate processes influencing the availability of water in Wyoming, and to develop means to ensure its optimum use and quality.

The Water Resource niche area focuses on the science and technology of computational and field hydrology and subsurface flow to address water-resource issues facing Wyoming and the west. Issues of immediate practical importance include the development of energy and mineral resources, agricultural and municipal water supply, and the sound management of watersheds. Two recent large research grants from the National Science Foundation are already advancing UW toward national prominence in field hydrology and subsurface flow. The grants have also provided strong collaborations across colleges, notably with the Department of Geology and Geophysics. Finally, this niche area connects closely with other niche areas of emphasis to UW including unconventional reservoirs, computational science applied to porous-media flow, and atmospheric science.

Biological and Biomedical Engineering

UW's academic planning has made the life sciences an area of distinction. As a result, the university has developed several outstanding programs including interdisciplinary Ph.D. programs in neuroscience, molecular and cellular and life sciences, and the biomedical sciences. Moreover, the past decade has seen biological and biomedical engineering become a significant contributor to growth in the field of chemical engineering nationally and at UW. The Chemical Engineering Department, which offers a Biological Engineering concentration area, now has active research programs in tissue engineering, regenerative medicine, and biomaterials for infectious disease diagnostics, and cancer prognostics, diagnostics, and targeted drug delivery. Electrical Engineering also offers a Bioengineering option. These programs are focused on problems of enormous importance to society in general and the state of Wyoming in particular. In addition to conducting research on health-related issues of critical interest to Wyoming residents, faculty are actively training students who progress to medical school and return to practice medicine in Wyoming. Through infrastructure and programmatic development, the college has an opportunity to bring national recognition to UW biological engineering programs and increase competitiveness for National Institute of Health (NIH) research awards, which are among the largest available for engineering faculty.

An added benefit of the biological engineering niche is the strong attraction of this field for women. Developing this area of excellence will contribute to the college's goal of women making up 1/3 of the undergraduate student population.

Goal #10

UW should boldly develop the niche areas outlined above over the next decade, with the goal of achieving international prominence in each. A commitment of 25-30 faculty positions, in addition to current resources in the areas, is viewed as sufficient to build the faculty depth needed to ensure lasting excellence while elevating UW to national recognition.

Generating momentum in the identified niche areas should lead to elevated funding levels through a national perception of leadership. The faculty numbers proposed here will position UW to compete for high profile national centers of excellence. These national centers typically come

with very substantial federal funding. Center funding is a major source of financial support for the Tier 1 schools noted in this report.

Increased research funding should also lead to opportunities to bring in "*research faculty*." *Research faculty* members are fully supported on grant funding, either individually or through centers of excellence. They add further levels of expertise while bringing in additional funding and advising graduate students. The *research faculty* member can be a powerful driver in advancing the metrics we identified as critical for a Tier 1 institution. At present, UW has very few *research faculty* members, primarily the result of insufficient levels of research activity to support them.

Finally, success in advancing the niche areas of research to national prominence will benefit from developing deep connections with industry and government agency collaborators. Industry research and development divisions provide cutting edge technologies aimed at solutions to their most pressing challenges. It is not uncommon for industry technology advances to lead to further innovation from university partners.

An excellent example of an industry-university partnership was the development of the *finite element method* used to analyze and design all modern structures. The Boeing Company did a great deal of pioneering work in the 1950's in an effort to analyze the extremely complex wing structures of commercial aircraft.. During the 1960's, significant finite element research was also advanced by professors at the University of California, Berkeley while working with structural engineers at Boeing. The synergy between these groups led to technologies that dominated structural analysis for 25 years and that now forms the basis of a multibillion dollar finite element industry with enormous benefits to society.

Another wonderful example of an industry-university partnership is the relationship between the University of Washington and Microsoft. During the early 1980's, University of Washington computer science students made their way across Lake Washington to work for a fledgling company known as Microsoft. In the 1990's, Microsoft exploded on to the international scene and became big contributors to the University of Washington program. Currently, US News and World Reports ranks the graduate computer science program at Washington as the 7th best in the nation. As a result, Microsoft has now been joined by companies like Amazon, Google, and Facebook—all seeking Washington talent to solve their problems. Indeed, a big problem for the university is the inability to produce enough graduates. University of Washington computer science faculty members promote one of their strengths as "the engagement between professors and the tech industry that will one day employ most of the graduates."[2]

The niche areas suggested in this report present superb opportunities to tightly integrate UW researchers with industry. For instance, advances in the field of unconventional reservoirs are

[2] http://www.nytimes.com/2012/07/08/technology/u-of-washington-a-northwest-pipeline-to-silicon-valley.html?pagewanted=all&_r=0

directly tied to industry leadership in horizontal drilling and hydraulic fracturing. Integrating this technology into the college will be a direct benefit to our students who can subsequently make an immediate positive contribution in industry. University researchers also have the opportunity to learn of the immediate challenges ahead with the opportunity to contribute to advances in a rapidly evolving field of huge importance to Wyoming.

An example of a strong partnership in computational science is the relationship between NCAR and UW surrounding the NCAR-Wyoming supercomputer. Student internships and joint faculty appointments are already underway. The NCAR-Wyoming relationship has ideally positioned UW to become a major research player in "big data," a new frontier in computational science.

Goal #11

Industry input is a critical aspect of a successful roll-out of the various niche areas. Industry provides the college a valuable connection to the leading technologies being pursued while identifying challenges and research opportunities with a longer time horizon. *The college will strive to create an atmosphere that promotes industry collaboration on research and academic programs that are responsive to the most current technologies utilized today. We embrace the idea promoted by the Task Force of periodically conducting workshops with corporate CEO's and research vice presidents to keep the college connected to the most pressing challenges of the day.*

A further important aspect of collaboration between the college and industry is the opportunity to hire "professors of the practice," engineers and executives from industry on loan to UW for one year (or more) who would bring their wealth of practical experience to bear on the education of our students. Such professors of the practice have a unique contribution to make in preparing students for the world of work.

The heart and soul of UW's research enterprise lies in the talented graduate students who work with the tenure-track faculty. Graduate assistants are often found in the laboratory, devoting substantial time to extensive experimental studies. They also often play a major role in field work—taking extended stays in the field when faculty are simply unable to do so.

In order to fully develop the niche areas to true national distinction, an infusion of top flight graduate student talent is essential. As in the case of adding faculty to the niche areas, we propose to provide secure long-term support in the form of graduate fellowships for each of the niche areas. These fellowships will be targeted at the most outstanding graduate students and are intended to be used solely to support the research mission. Hence, in contrast with UW's standard graduate assistantships, students would not be asked to contribute to the teaching mission.

Goal #12

We propose to ensure stability of graduate assistant researchers by adding 100 fellowships to the college. Assuming 5 niche areas, 100 fellowships would allow the college

to commit to supporting an average of 5 incoming students per niche area and extending their support for up to 4 years. Furthermore, we propose to fund these students at $33K a year with a 10 month appointment. After adding tuition, fees, and health insurance, the total level of support is estimated at $40K/year.

The gold standard for graduate research fellowships in the U.S. is the National Science Foundation Graduate Research Fellowship Program (NSF-GRFP). Through this intensely competitive program, NSF annually awards approximately 2000 doctoral level fellowships in STEM fields. Fellowship awards total $40,500/yr including a $30,000 stipend and an educational allowance of $10,500 to cover tuition and fees. UW's proposed graduate fellowship program is very comparable to the NSG-GRFP and will position the college to compete for the best academic talent in the nation. The infusion of graduate student talent, combined with depth of faculty numbers and the state's unique resources, will ensure major contributions to the research enterprise and national recognition will naturally follow.

While the proposed niche areas are directly relevant to Wyoming's future, we recognize that the future of Wyoming and the nation is far from static. Periodically, a careful evaluation of niche areas of emphasis should be undertaken to accommodate changing environments and technologies along with new opportunities.

Economic Development and University Spinouts

Google, Sun Microsystems, Silicon Graphics, Cisco Systems, Netscape—these companies are just a few of the high profile business spinouts from Stanford University that fire the imagination of entrepreneurial success. While Stanford enjoys a reputation as one of the finest research and entrepreneurial universities in the country, there are other notable schools. Universities highlighted in a recent article by Capital Formation Institute[3] (CFI) include Purdue, Wisconsin – Madison, and Iowa State (ISU). CFI notes: "ISU, for example, has over 450 active licenses and ranks in the top 5 for active licenses and licenses executed …".

UW's engineering college has some notable successes related to university spinouts. In the past year, two companies born out of research in Mechanical Engineering have gone public. IDES Inc., the world's leader in delivery of a plastics database for engineering applications was publicly acquired in 2012. Firehole Composites, a company developing advanced failure analysis software for composite structures, was publicly acquired in the spring of 2013. Firehole customers include Boeing, Red Bull Formula 1 Racing, General Electric, and Owens Corning. In both the spinouts noted, the parent companies have chosen to leave Wyoming companies in Wyoming—a marvelous outcome for the state and an indicator of the long-term value of spinouts.

[3] http://www.cfi-institute.org/VP%20-%20University%20Spinouts%20Best%20Practices%20and%20Issues%20-%20Palmintera.html

Despite the success of the past year, economic development and university spinouts are currently an underappreciated aspect of the college. The views on business spinouts are not a reflection of on any group of individuals but rather an artifact of the history of higher education. We believe this culture must change if UW wants to fulfill the vision of a Tier 1 engineering school. Some concrete statements on best practices produced by CFI include:

- "Strong and focused university research feeds the pipeline for commercialization. Model universities have built strong, focused research bases by first assessing core competencies and then developing strategic plans around them. Following these plans they have (a) hired 'stars' in targeted fields, (b) targeted federal R&D funds, (c) increased corporate-sponsored research, and(d) promoted state initiatives that leverage federal and corporate funds." We believe much of the advice outlined here is contained in the action items and goals of this report.

- "Entrepreneurial culture is key. Creating an entrepreneurial culture is both "bottom up" and 'top down' , requiring a combination of leadership from the top and entrepreneurial drive from the bottom."

Goal # 13

The college of engineering can make significant advances toward Tier 1 status by *recognizing entrepreneurial activity as a third leg of its mission combined with excellence in teaching and research.* By adopting this attitude, and providing tangible incentives and rewards for entrepreneurial activities, UW can leap ahead of the vast majority of colleges and universities and join a select group of schools. Business spinouts resulting from technology transfer can have an enormous impact on the state economy**.**

Marketing the College

While the preceding goals and objectives outline a solid approach to advance the college of engineering, they will not bring UW the national recognition sought without effective marketing of the initiative and the college. This marketing must be "permanently" sustained and at the highest professional quality. The finest colleges in America relentlessly market their institutions through multiple media outlets, never missing an opportunity to tout their virtues. Indeed, we believe that "perception is reality" is a suitable cliché for defining the importance of marketing.

The marketing effort must touch a broad spectrum of audiences. First and foremost, a statewide effort must be undertaken to elevate our citizens' pride in the college and bring awareness to the college and the initiative underway. The same approach should be extended to the entire Front Range as this audience represents an excellent source of high quality students. Although many Colorado students find their way to UW, we believe we can do much more to attract them—promoting *excellence* in addition to value. Finally, a targeted national marketing program must be undertaken that reaches prospective students as well as peer colleges and universities. Raising our profile with our peers is a particularly important aspect of gaining national recognition.

We refer to our discussion of the Tier 1 set of schools where we noted: "far more important than the numerical ranking is the immediate name recognition of engineering excellence associated with every one of these schools." Recognition is a surely the result of excellence, yet it also leads to further excellence.

UW has some built-in advantages when it comes to marketing the college and the Engineering Initiative. To begin, in a few years, the university will boast a collection of stunning facilities that provide integral support for the college including the Energy Innovation Center of the School of Energy Resources, the Enzi STEM Building, the Energy Engineering Research Facility, and the new engineering building currently in the planning stages. Taken collectively, these facilities will be among the finest the nation has to offer. UW must showcase these facilities as part of a marketing plan—including the visionary planning currently underway.

UW also has an opportunity to partner with a collection of wonderfully supportive industry partners. These partners can help to provide strong and consistent messaging about numerous terrific engineering opportunities. By promoting these opportunities, our corporate partners stand to gain substantial long-term benefits as the quality and number of graduates rise.

Finally, marketing is in large part about image and one cannot change an external image without first creating an outstanding internal image. In this vein, it is imperative to bring the faculty and staff of the college fully on board with the notion of developing an outstanding engineering school. In doing so, UW has an opportunity to promote itself through every message leaving the college. Engagement across the state and the nation represents an opportunity for shameless self-promotion.

This program, as it develops, will provide a model for other programs at UW. Thus, other colleges not included in this particular initiative should not view the initiative as competitive with them, but rather as providing a model for how they can be further developed. The program is an example of how a rising tide can raise all ships. As we achieve greater success in engineering, so in the future can we achieve greater success in other areas of endeavor that are important to our State as well.

Goal #14

UW will develop a professional marketing plan to promote the engineering initiative to prospective students, citizens in the state, and our peer institutions across the nation. The marketing plan should commence with the official launch of this initiative, signaled by Task Force endorsement, legislative financial support, and Trustee approval. Painting the vision through marketing is an important aspect of a long-term drive for excellence.

Finally, we believe one additional audience deserves special attention in the marketing of UW's engineering initiative; the middle school children across our state. In brief, a concerted and sustained effort should be made to develop an engineering presence in middle school.

Goal # 15

There is no question that engineering remains a mysteriously underrepresented field of choice in K12 career discussions. This unfortunate circumstance is arguably driven by lack of exposure to the profession. *UW proposes to work with legislators and K12 to develop a one-semester engineering course for middle school kids involving:*

- College preparation
- Benefits of an engineering degree and higher education in general
- Examples of "cool" engineering—the possibilities are unlimited!
- The science and math behind engineering

We believe this program has an opportunity to fundamentally positively alter the lives of many young students who might never consider engineering as a career.

The involvement of K12 and the university necessitates a careful collaboration with all parties involved. Funding considerations, personnel commitments, and finding some champions in K12 are all necessary for success. We suggest a reasonable approach is to find a couple of early adopter school districts who are willing to invest the effort—over time the payoffs may be remarkable. Finally, legislative approval is a must and any such program should not proceed prior to developing momentum for the project with key elected officials. *Furthermore, funding for the proposed initiative has not been included in the Engineering Initiative request as we believe it should be included as part of the K12 funding profile.*

Budget

An annual budget increase of $14.77 M is required to fully fund the University of Wyoming Engineering Initiative. The budget is directly tied to each of the key areas identified in this report. We echo comments from the governor's Task Force for the Engineering Initiative in that this leap forward requires a broad commitment to excellence.

Resource Commitments	Number	Annual Budget
Faculty Positions	25-30	$ 5,600,000
Graduate Fellowships	100	$ 4,000,000
Undergraduate Scholarships	500	$ 3,000,000
Academic Professionals & Technical staff	6	$ 1,200,000
Support Staff	8	$ 320,000
Professional Marketing & Support		$ 400,000
Major equipment maintenance		$ 250,000
Annual Total		$ 14,770,000

Notes
1. Current college budget with employee benefits is $16.6M
2. Budget estimate above includes employee benefits
3. Request represents approximately 4 % of UW's Section 1 budget

Some budget notes and highlights:

- Faculty positions are devoted to building critical depth to ensure sustained excellence in the niche areas identified.

- Graduate fellowships are nationally competitive and will provide the research engine for the niche areas of excellence.

- Academic professionals such as research scientists and engineers are essential for success in the laboratory driven environment of engineering. Technical staff are also a critical part of the research enterprise and the college is currently understaffed with technical support.

- Undergraduate Tier 1 Scholarships will provide $6,000/yr of support for the college's top quartile of undergraduate students for a four year period. Combined with other scholarship support, UW has an opportunity to recruit an outstanding engineering class every year—the foundation of a Tier 1 program.

- Marketing of the programs nationally and to the state will benefit UW and the state far beyond the college of engineering. We envision outsourcing much of the marketing to a professional organization.

- Failure to plan for maintenance costs of the expensive equipment found in engineering can cripple the operation of the college. A good estimate of maintenance costs is 5-10% annually of the original purchase. The proposed budget is expected to cover maintenance for the 25-30 new faculty hires expected in the college.

The magnitude of the proposed advances for the college of engineering will require a staged funding approach. Academic hiring takes careful planning and there is a definite annual hiring season for faculty that is difficult to circumvent. Moreover, we believe there is merit in developing the niche areas in series as opposed to simultaneously developing them.

To accommodate the staging of the niche areas and the thoughtful development of the initiative in general, we believe the funding should be ramped up over time. A five-year horizon is believed to be sufficient to fully develop the program with proposed annual funding shown.

Year 1	**$5 M**
Year 2	**$7.5 M**
Year 3	**$10 M**
Year 4	**$12.5 M**
Year 5	**$14.77 M**

Finally, private giving is an essential aspect of ensuring long-term success of the Engineering Initiative. In particular, we believe an endowment of $30-40 M is needed to provide the college with critical funding to advance excellence on all fronts. Some examples of the use of these funds include:

- Providing funds for industry visiting faculty to teach critical technologies
- Salary retention for key faculty of outstanding quality
- Named professorships providing discretionary funding for "star" faculty
- Start-up funds for attracting new faculty ($300K-$500K per faculty member is not uncommon)
- Endowed faculty positions
- Developing innovative alumni programs

Goal #16
UW will work with the UW Foundation to formalize plans for a fund raising effort devoted to an excellence endowment of $30-40M for engineering. This program may be a component of UW's next Capital Campaign.

Capital Facilities

Advancing UW to a Tier 1 college of engineering for Wyoming requires numerous programmatic developments outlined in this report. However, many of these changes cannot occur

without substantial growth and upgrades of the college's capital facilities. In brief, the college is space constrained to the point where modernization of teaching laboratories and curricular innovation are being stifled.

Figure 4 shows the footprint of the engineering complex consisting of a collection of buildings built at different times. The heart of the college is the venerable engineering Main Front Building built in 1927. An even older building, referred to as the Sawtooth, was built in 1925 and occupies the central core footprint of the complex. While these buildings represent a substantial amount of the total square footage available, neither is suitable for the placement of modern labs with their demanding power, ventilation, and IT requirements. The inability to properly upgrade these facilities with state of the art laboratories is problematic as 55 % of the total space in the engineering complex is devoted to laboratories.

The Engineering West Wing, also shown in Figure 4, is 52 years old. The size of this building is misleading in that 2 of the 3 floors are used for general university classrooms, leaving only the basement floor for engineering. The location of classrooms in the building, combined with the age of the building, also inhibits laboratory developments.

The newest part of the complex is the engineering north and east wings shown in blue that were built in 1980. From a practical perspective, any upgrades to engineering facilities must occur in this part of the complex. However, the "new" (1980) building is completely full and, indeed, there is an acute shortage of laboratory space. This space shortage has had numerous adverse effects on the research and teaching enterprise; student labs are severely undersized, some experimentally oriented faculty members have no lab space, and hiring decisions are impacted as experimentally oriented faculty may be passed over because of their laboratory needs.

To bring the college facilities up to meet the anticipated demands in classroom and laboratory space, a new building is in the design phase. The building is envisioned to provide 170,000 square feet of space of which roughly 2/3 is devoted to laboratories. However, the proposed new engineering building is not just about additional space, far from it. The need for the building is also a consequence of society's information and technological explosion. New discoveries astound us on a yearly basis and their developments rely on cutting-edge engineering facilities across the country. To venture into the Tier 1 arena, outstanding state-of-the art facilities are essential.

In the design of new engineering facilities, UW has an excellent opportunity to promote innovation through architecture. Construction of a new engineering building affords us the opportunity to weave programmatic integration into the fabric of the office and laboratory arrangements. This concept is nontraditional but not really new. It was the core architectural principle behind Bell Laboratories' Murray Hill headquarters, completed in New Jersey in 1941 and arguably the twentieth century's greatest center of innovation. The facility's design, especially its hallways and office configurations, enabled engineers and scientists from many disciplines to interact with one another, regardless of their department affiliations or project assignments. It

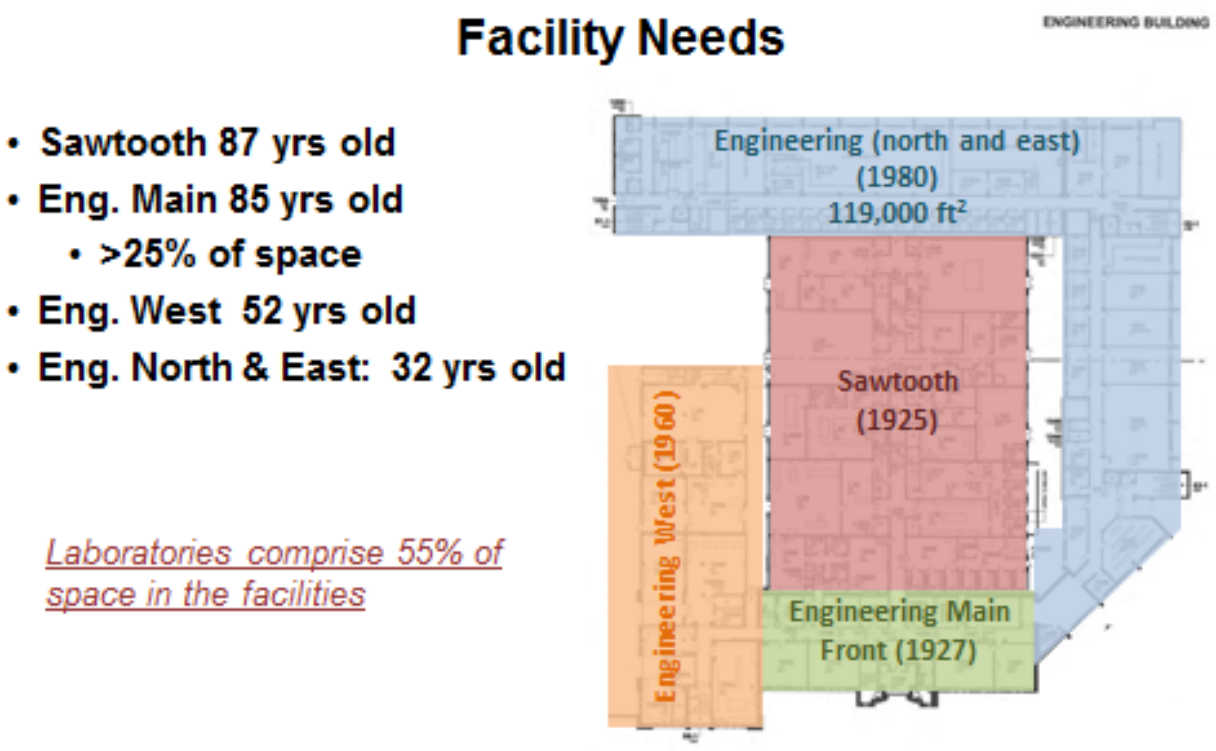

Figure 4. Footprint of current college of engineering facilities.

helped introduce newly minted Ph.Ds. to "the guy who wrote the book." It mixed theorists with experimentalists. From this interdisciplinary ferment emerged the transistor, the laser, satellite telecommunications, the solar cell, light-emitting diodes, the principles enabling digital communications, digital cameras, cellular telephone networks, and the largest number of Nobel prizes of any corporate laboratory in history.

Advancing UW's niche areas of excellence will require strong interdisciplinary connections across departments and colleges. Adopting the building concepts from Bell-Laboratories will emphasize collaborative spaces for faculty and students, while diminishing the architectural barriers that separate different departments and subdisciplines.

In addition to thoughtful placement of our faculty colleagues, the design of the building will focus on encouraging conversation. We envision a building with inviting spaces and corridors designed to create "people eddies," where interaction among faculty and students will naturally occur. Student lounge access for undergraduates and graduates should also be prominently located—all designed to facilitate interactions while generating a powerful attraction for prospective students. In brief, we want the building to naturally market *excellence.*

Goal # 17

The university planning process affords us the opportunity to create the engineering building of our dreams—and the dreams of the future outstanding students we expect to draw to the college. The building's Level 1 Plan provides a sound assessment of the space needed for laboratories, classrooms, and offices. This plan has been completed with an eye toward the laboratories of the future along with thoughtful plans for expansion of the college.

The integration and layout of the building including architectural planning begins with Level 2 planning that has yet to commence. *UW will work carefully with architects to develop a Level 2 plan for a spectacular facility focused on collaborative integration of faculty by niche areas described in this report.* Historically driven disparate departmental interests will be avoided in favor of creating environments that promote collaborative relationships focused on advancing the research goals of the college. An important part of this effort will be the creation of interdisciplinary collaborations between colleges as well as within the college, because much of the best work in science and engineering emerges when interdisciplinary teams work collaboratively on common problems.

The facility will also be inviting for prospective students, while providing a sense of community for current students. We view the *Energy Innovation Center* built for the School of Energy Resources as an excellent example of a facility that has the "WOW" factor the Task Force is advocating to see in engineering building.

While integrating engineering faculty in the new building to support the niche areas of research is foremost in our minds, we have also carefully considered opportunities beyond the college. The Department of Mathematics is arguably the closest department outside the college in terms of faculty collaboration in a host of important research programs. We believe there is merit in exploring the possibility of locating the Math Department in the proposed new engineering building. The synergy of having our math colleagues next door as opposed to across the campus is a valuable asset for inspiration and technological development, particularly in the innovative computational aspects of education and research highlighted in this report.

Goal # 18

Faculty members in the Department of Mathematics are enthusiastic about the opportunity to join their engineering colleagues in a visionary engineering facility. *UW will determine space and cost estimates for moving the Math Department to the new engineering facility. If cost projections are feasible, Level 2 planning will address this exciting opportunity to develop a truly interdisciplinary strategy for advancing engineering excellence.*

Current capital facility funding costs for the engineering building are estimated at $110M. A key component of the funding portfolio is a $15M match from corporate or private donors.

Goal #19

The UW Foundation will make engineering building matching support their highest priority for FY2014. Moreover, if matching funds in excess of $15 M are obtained, UW will seek state support to match these excess funds.

Capital Facility Integration

UW has been extremely fortunate to have the opportunity to develop several outstanding facilities in support of science and energy education. It is important to frame these new facilities in the context of the current needs for the college of engineering. A brief summary of the major STEM-related facilities is provided below.

Michal B. Enzi STEM Facility: The Enzi Laboratory is devoted to support undergraduate science instruction for students in every college in the university except law. The building will house major science laboratories for chemistry, biology, and physics. Computational labs supporting undergraduates in mathematics and computer science are also envisioned for the facility. Every engineering student will spend time in the Enzi facility in their first and second years as they develop their core knowledge in the basic sciences. However, the Enzi facility will not support upper division or graduate engineering course and the building provides no research laboratories. Ground breaking for this facility occurred in March 2013.

Energy Innovation Center: The Energy Innovation Center primarily supports research activities and teaching related to energy. Initial projects include research in enhanced oil recovery, and multiphase flow through porous media (expected to move to the high-bay facility when it is completed), as well as research devoted to conversion of fossil energy resources higher value products. A portion of the space is devoted to house the School of Energy Resources and the Enhanced Oil Recovery Institute staff. In addition, the facility will offer a distance collaboration center, and 3-D visualization research lab, and a state of the art classroom as shared assets for the campus. Finally, the facility offers significant hotel office space for visiting scientists, engineers and other professionals. The facility is expected to have some interaction with petroleum engineering but the majority of engineering disciplines will not directly work in the facility. This facility was completed in spring 2013.

Energy Engineering (High Bay) Research Facility (EERF): The high bay research facility is a yet to be developed building designed to house large scale experiments that are beyond the size of a traditional engineering laboratory. A substantial portion of funding for this facility has come from corporate donations and the desire of donors are reflected in the original outlay of the building. Specific labs to be included are a geomechanics lab, a core-flood facility, a structural engineering lab, a possible wind tunnel and supporting facilities, among others. The high bay facility is currently in the Level 2 planning stages where architectural drawing and design specifications are being laid out.

New Engineering Building: The proposed engineering facility is an integral aspect of the vision and plan for advancing a set of Tier 1 engineering programs for Wyoming. The design and plan of the facility will be thoughtfully integrated to support the objectives of the college and STEM education in general.

Current plans envision locating the new engineering building across Lewis Street and adjacent to the current engineering complex. The proposed location is consistent with the goal of tightly integrating engineering faculty and laboratories with undergraduate science education in the Enzi STEM building, the geosciences housed in the Geology and Geophysics building, and the School of Energy Resources whose new home is the Energy Innovation Center.

In contrast to the envisioned location of the new engineering building, current plans call for the EERF (high bay) facility to be located on the east campus, not far from the central energy plant. The high-bay facility is designed to have an interior clearance of 20 feet and horizontal crane access to move materials from large over the road vehicles (18 wheelers). High bay and horizontal cranes mean clear spans that are not conducive to building floor levels above. Because the EERF requires an estimated 80,000 gross square feet footprint with adjacent service yards, it is not a good fit for the residential neighborhood of the NW science/engineering cluster. The footprint alone would occupy the majority of a city block in this area. The east campus is also much better suited for high frequency heavy traffic loads that may involve hazardous waste. Noise generation and extreme power demands are additional considerations for locating the building on the more industrial east side of campus.

The Road to Tier 1

The Engineering Initiative at the University of Wyoming represents one of the most exciting developments in the history of the college. The initiative poses substantial challenges that can only be met with a deep and lasting partnership between the university, the state, and private industry. A summary of the vision, complete with objective metrics used to measure UW's progress toward attaining that vision, is provided below.

- Identify the qualities of the best engineering schools in the nation and outline a path of excellence to lift UW into the top quartile of national rankings for undergraduate and graduate engineering education. Key metrics we are tracking include research funding/TT, Ph.D. graduates/TT, and MS graduates/TT. Our goal is to develop through engineering education leaders who will raise the economic competitiveness of the State of Wyoming and, ultimately, who will not only fill existing jobs, but contribute to the creation of new ones within the state.

- Through effective marketing and financial support, aggressively pursue the most talented prospective undergraduate students in Wyoming and the nation. The goal is to raise ACT scores of the top quartile to 31, representing students at the 97th percentile of ACT test

takers. A score of 31 would place UW's top quartile of students on a par with the very best programs in the nation.

- Use UW's outstanding computational resources to advance undergraduate curricular innovation by infusing computational aspects of engineering into every aspect of the program from the first year to graduation. The college's small size is a significant advantage as we develop this recognized third pillar of engineering to a level of comparable importance to theory and experiment. Curricular innovation of the magnitude envisioned here will place UW's programs in the vanguard of undergraduate engineering in the United States.

- Graduate outstanding, well-rounded engineering students possessing professional experience and leadership skills obtained through industry internships and programs aimed at leadership development. The college will match the emphasis and passion for undergraduate education with a mission devoted to connecting graduates with professional employment opportunities.

- Boldly develop niche areas of research that have a major influence on Wyoming's future and that align with UW's strategic plan. The niche areas will capitalize on unique assets possessed by the university and the state, making them a natural fit for the college. Lasting excellence in the niche areas will be achieved by hiring 25-30 faculty members to build sufficient programmatic depth to provide immunity from inevitable faculty resignations and retirements. Niche areas of research excellence will be further strengthened with an infusion of 100 graduate fellowships aimed at attracting the brightest academic talent from across the world.

  Research in niche areas will be further strengthened by a concerted effort to integrate faculty into the leading technologies utilized in industry today. This synergistic relationship will have an immediate positive impact on research programs while ensuring our students are receiving the most advanced engineering education possible. UW's industry partners will also benefit by an infusion of academic talent aimed at the pressing challenges they currently face,

- Embrace a culture of economic innovation and entrepreneurial spirit by actively encouraging the development and licensing of intellectual property as well as technology transfer from research discoveries.

- Develop outstanding facilities needed to allow the college to grow while providing critical new space for laboratory research.

- Effectively market every aspect of the college and the university within the state and across the nation. The importance of a professional marketing program to the success of the entire endeavor cannot be overstated.

- Develop effective programs to introduce engineering as an exciting and outstanding career in middle school and/or junior high school throughout Wyoming. This objective is a priceless service to the youth of our state who will, in turn, give back to Wyoming in profound ways.

With a commitment and a vision UW will arrive at a Tier 1 engineering college that will benefit the state in immeasurable ways with a lasting legacy.