Planning for Future Research in Public Universities in Uncertain Times

Merrill Series on
The Research Mission of Public Universities

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TABLE OF CONTENTS

MASC Report No. 118

Introduction

Mabel Rice

The Fred and Virginia Merrill Distinguished Professor of Advanced Studies and Director, Merrill Advanced Studies Center, The University of Kansas

The following papers each address an aspect of the subject of the eighteenth annual research policy retreat hosted by the Merrill Center: *Planning for Future Research in Public Universities in Uncertain Times.*

We are pleased to continue this program that brings together University administrators and researcher-scientists for informal discussions that lead to the identification of pressing issues, understanding of different perspectives, and the creation of plans of action to enhance research productivity within our institutions. This year, the focus was on the adaptation and innovation regional Universities are developing as sources of federal research funding contract.

Our keynote speaker for the event, Dr Sally Frost Mason, discussed the current funding environment and a few new approaches which could be used to improve future prospects.

Benefactors Virginia and Fred Merrill make possible this series of retreats: The Research Mission of Public Universities. On behalf of the many participants over more than a decade, I express deep gratitude to the Merrills for their enlightened support. On behalf of the Merrill Advanced Studies Center, I extend my appreciation for the contribution of effort and time of the participants and in particular to the authors of this collection of papers who found time in their busy schedules for the preparation of the materials that follow.

Thirty-one senior administrators and faculty from five institutions in Kansas, Missouri, Iowa and Nebraska attended the 2014 retreat. Though not all discussants' remarks are individually documented, their participation was an essential ingredient in the general discussions that ensued and the preparation of the final papers. The list of all conference attendees is at the end of the publication.

The inaugural event in this series of conferences, in 1997, focused on pressures that hinder the research mission of higher education. In 1998, we turned our attention to competing for new resources and to ways to enhance individual and collective productivity. In 1999, we examined in more depth cross-university alliances. The focus of the 2000 retreat was on making research a part of the public agenda and championing the cause of research as a valuable state resource. In 2001, the topic was evaluating research productivity, with a focus on the very important National Research Council (NRC) study from 1995. In the wake of 9/11, the topic for 2002 was "Science at a Time of National Emergency"; participants discussed scientists coming to the aid of the country, such as in joint research on preventing and mitigating bioterrorism, while also recognizing the difficulties our universities face because of increased security measures. In 2003 we focused on graduate education and two keynote speakers addressed key issues about retention of students in the doctoral track, efficiency in time to degree, and making the rules of the game transparent. In 2004 we looked at the leadership challenge of a comprehensive public university to accommodate the fluid nature of scientific initiatives to the world of long-term planning for the teaching and service missions of the universities. In 2005 we discussed the interface of science and public policy with an eye toward how to move forward in a way that honors both public trust and scientific integrity. Our retreat in 2006 considered the privatization of public universities and the corresponding shift in research funding and infrastructure. The 2007 retreat focused on the changing climate of research funding, the development of University research resources, and how to calibrate those resources with likely sources of funding, while the 2008 retreat dealt with the many benefits and specific issues of international research collaboration. The 2009 retreat highlighted regional research collaborations, with discussion of the many advantages and concerns associated with regional alliances. The 2010 retreat focused on the challenges regional Universities face in the effort to sustain and enhance their research missions, while the 2011 retreat outlined the role of Behavioral and Social sciences in national research initiatives. Our 2012 retreat discussed the present and future information infrastructure required for research success in universities, and the economic implications of that infrastructure, and the 2013 retreat discussed the increasing use of data analysis in University planning processes, and the impact it has on higher education and research.

Once again, the texts of this year's Merrill white paper reveal various perspectives on only one of the many complex issues faced by research administrators and scientists every day. It is with pleasure that I encourage you to read the papers from the 2014 Merrill policy retreat on *Planning for Future Research in Public Universities in Uncertain Times.*

Executive summary

Planning for Future Research in Public Universities in Uncertain Times

Sally Frost Mason, President, University of Iowa

- The current climate for university research presents us with some significant challenges. Total federal R&D spending and federal non-defense R&D dollars have declined in the past ten years, and the prognosis for the future is pretty stagnant. Projecting to 2021, federal funding is forecasted to have only very modest growth.
- While the United States' public investment in research over recent years has declined, many of our international colleagues/competitors are enjoying major upswings in federal research dollars. State legislatures and university governing boards are re-examining the role of research in a state-supported institution, and usually these controversies center on a university's emphasis on teaching and a university's role in state economic development.
- Economic issues play into many such controversies across the country. Metaphorically, the public university research enterprise is in the midst of its own "climate change" in three major areas: state priorities, federal funding, and international competition. As with any kind of change, adaptability remains key. I propose three broad areas in which we must think about playing a new game: 1) Research portfolio diversification, 2) new partnerships, and 3) interdisciplinary approaches.
- We must remain vigilant and redouble our institutional advocacy for the nation's research enterprise. We must create physical spaces that are flexible enough to encourage interdisciplinary research, and classrooms that support inquiry-based learning. We must revisit our standards for promotion and tenure - publication should remain important to the promotion and tenure process, but we must also develop real standards for assessing the impact of interdisciplinary work, innovation and excellence in teaching, and public engagement.

Engaging with the Private Sector: Nebraska Innovation Campus

Harvey Perlman, Chancellor, University of Nebraska

- There are at least three trends that must be accounted for as we plan our research future. First, while innovation is a major driver for economic growth, most public companies are withdrawing from investments in basic research. Yet, companies also understand they must position themselves to access research that has commercial value and that research takes place largely within universities. Thus there are market forces that make university-private sector partnerships essential.
- Second, federal research support is uncertain, particularly in this period of political dysfunction in Washington. If Universities are to sustain their core research enterprise, it seems sensible to diversify our sources of funding. Other potential sources are the private sector, international engagements, philanthropy, and internally generated resources.
- Third, the political pressure on government expenditures causes even public funding agencies to demand more evidence of returns from the investments in research. We would be foolish to ignore this. Increasingly, federal research funding programs are insisting on proof of commercialization prospects for research proposals or insisting that private sector companies be a partner in funded research.

- All three of these trends dictate that universities develop stronger ties with the private sector as an alternative source of research funding. I think we are far beyond the question of whether we should engage with the private sector in research partnerships. I believe that is a given and a necessity. However, there remains much to be considered in how these relationships are structured, implemented, and assessed. Getting these items right will have a lot of influence on the future of our research enterprise.

Adaptive Planning in a Chaotic Research Environment: Aligning Academic and Business Issues

Brian Foster, Provost and Professor Emeritus, University of Missouri

- Uncertainty is everywhere and can pose both challenges and opportunities. Adaptive planning must address both in an on-going, responsive way. The most important guiding principle is to build the plan on institutional strengths, to position the institution favorably in relation to other universities.

- It is critical to work with non-traditional constituents whose interests, political positioning, and other properties can help build on the institution's strengths—constituents such as large corporations, government agencies, beltway bandits, national labs, and economic development agencies.

- The key to engagement is to have real discussions, to bring together people who are positioned very differently and who have different perspectives. Real discussions will get the disagreements, value differences, and special interests on the table so they can be dealt with.

- The environment differs for every institution; the responses differ for every institution. The most that can be made of the specific information is that it provides the first steps for mapping the particular institution's environment, linking it to the broad direction it wishes to take, and creating a viable plan for implementing the goals to get to where the institution wants to go.

- Research is deeply embedded in the broader Higher Education dynamics. Like other elements of Higher Education, it cannot be seen as separated from fiscal, political, regulatory, instructional, facilities and other elements of the university—and of Higher Education broadly.

Enhancing University Research through Corporate Engagement and Collaboration

Jeffrey Vitter, Provost and Executive Vice Chancellor, The University of Kansas

Julie Nagel, Executive Director of Corporate Partnerships, The University of Kansas

- As part of our strategic plan, we seek to promote active entrepreneurship and vibrant external partners. A key component of this strategy was the creation of the Office of Corporate Partnerships, developed to diversify KU's research portfolio.

- We have created a one-stop shop at KU for external groups looking to collaborate with us. Having these groups working under a single set of metrics provides for cross-collaboration. A portal for both faculty and industry sponsors to work through to create research-based partnerships removes barriers companies often cited as reasons for not working with universities.

- KU has many different products (or domains) that companies may want to access. Interactions between KU and a company can lead to other forms of partnership with the company, which can move the company along a conceptual path of increasing engagement. We facilitate all aspects of industry-sponsored research at our core, and we lead the university-wide strategy on how to coordinate these different areas with a central message.
- It is crucial for us to share information about company visits and interactions and to put forward a coordinated face to companies - so we know exactly how the company has worked with the university in the past, which helps us expand the collaboration in the future. By sharing, each of the different groups that works with companies can leverage the others and create a greater benefit for the university.
- We opted to use the Salesforce.com Customer Relationship Management tool (CRM) and configured it to track all our company engagements. Today, we have data feeds coming in from numerous units across multiple campuses. These data feeds include details on tech transfer, development, research, and numerous other ways in which companies engage with KU.
- Between Fiscal Year 2011 and 2013, our licensing revenue increased by a multiple of 15, or by a multiple of four if you exclude an outlier that generated significant revenue to KU. Licensing agreements increased by 15 percent, patent issues increased by 131 percent, and industry-sponsored research is up 40 percent.

Revolutionizing science through simulation: A junior researcher's perspective on research challenges in uncertain times

Baskar Ganapathysubramanian, Assistant Professor, Mechanical Engineering, Iowa State University

- Universities must encourage faculty to aspire towards a diversified portfolio of problems as well as funding agencies to target. There has to be a conscious move away from funding from a single federal source (like NSF in engineering, or NIH in medical sciences). This includes a healthy distribution of funding between industry and federal sources.
- Promotion and tenure documents may look different in this context of multi-disciplinary work, with half-dozen or more co-authors on papers, jointly mentored students, and multiple co-PIs on grants becoming the norm. The administration should have clear guidelines for faculty to articulate their contributions for P&T as well as awards/recognition. Departments should not discourage junior faculty from participating in large grants.
- The university and college can initiate research in strategic areas that are of relevance at the university/state/national level, by means of awards which enable the formation of large teams and provide pursuit funding.
- A key factor is trained support staff who are well versed in the budgetary and regulatory intricacies of various funding sources (NSF vs NIH vs DoD). Providing travel grants to visit funding managers across the country is clearly a low-risk, high-reward investment for the university. Additionally, universities can make industrial partners feel welcome by making IP issues straightforward.

- Universities (especially in the Midwest) can leverage existing facilities to create win-win conditions by collaborating to establish large scale centers. This avoids duplication of infrastructure in a narrow geographic area and can promote significant cost-matching. Buy-in from the faculty can be cemented by making other university faculty part of centers, and by awarding courtesy appointments. It appears that this is strategically promising for the group of universities attending the Merrill conference in the areas of engineering sciences, agriculture, and medicine.

Interdisciplinary collaborations at work in brain-machine interfacing

Jonathan Brumberg, Assistant Professor, Speech-Language-Hearing, University of Kansas

- It is now possible to translate the experimental conclusions of cognitive and computational neuroscience into practice for diagnosing and rehabilitating disorders with a neurological deficit.
- Cochlear implants and deep brain stimulators are great examples of the translational research potential at the intersection of engineering and neuroscience. Computers are interfacing directly with neural tissue in a one-way, input fashion. The reverse design pattern in which neural activity controls a computer is also relevant for rehabilitation purposes, and are more traditionally considered brain-machine interfaces.
- Recent trends in national and local policy have led to some uncertainty for the future of the research missions of public universities. These trends may potentially increase diversity of scientific study and add to our ongoing research activities. Suggestions for how to enhance university involvement in interdisciplinary research:
  - Including recruits with non-traditional backgrounds
  - Focus on the potential for interdisciplinary application of applicant research
  - Continued training for managing broad scope of interdisciplinary research
  - Establishing expectations for promotion and tenure
  - Identifying alternative funding sources
  - Draw from funding typically associated with each collaborating discipline
  - Look to commercial and foundation partners
  - Establish appropriate relationships with collaborating disciplines
  - Enable cross-disciplinary student mentoring, course instruction and research opportunities

Collaborative research between engineering and life sciences: Influence of surface attachment on the biological properties of proteins

Shannon Bartelt-Hunt, Associate Professor, Civil Engineering, University of Nebraska

- Collaborative research between the basic sciences and engineering is critically important to the ability of academia to answer future societal challenges. Despite the importance of fostering collaboration between scientists and engineers, there can sometimes be institutional or interpersonal roadblocks that limit successful collaborations.

- I joined the faculty in the Department of Civil Engineering in January 2006 and almost immediately began to collaborate with Dr. Jason Bartz on experiments to investigate the environmental behavior of the prion protein. In the beginning, we kept the research question very simple. By keeping our question simple, we were able to learn the terminology and techniques of each other's discipline, and we also successfully answered our question. A more complex or complicated question might be important to answer, but with initial collaboration, I would encourage keeping it simple.

- Another trait of successful collaborations is that they raise questions that may not have been ever thought of by an individual working in a single discipline. Also, the answers to these questions many times require the knowledge of people from disparate disciplines. Our collaborative work allowed us to develop a conceptual model of prion disease transmission that encompasses both environmental behavior and passage into and within the host animal. This linked environmental and biologic model would not have been possible without our collaborative research relationship.

- What contributes to a positive collaborative relationship? Working collaboratively requires that you take the time to understand each other's language and respect each other's expertise. Meeting in person on a regular basis is very important to establish a collaborative relationship. At the same time, you must read the literature outside your discipline to learn more about the terminology and work being done in your collaborator's discipline.

- A collaborative research relationship requires trust between individuals. Collaboration means that you will share ideas, resources, equipment, and student advising activities, often without knowing ultimately what benefit or products may arise from this work. This requires a leap of faith and a commitment to the long-term collaborative relationship.

- Institutions can provide incentive and support for collaborative research, acknowledging the time investment in developing a collaborative relationship, which may have a longer return period for funding and publications compared with single discipline research. Collaborative research is often published in journals outside your discipline area, and this is significant for faculty going through the promotion and tenure process - there must be an understanding and appreciation of this work and its contribution both to your own discipline as well as other disciplines.

Research, Productivity, and Pressures on Faculty in an Era of Disruptive Change

Danny Anderson, Dean, College of Liberal Arts & Sciences, University of Kansas

- The factors driving change converge in the everyday life of the tenured or tenure-track faculty at public research universities. From the faculty point of view, these tensions create confusing and frustrating situations. The faculty career is one of increasing anxiety and tension as they are asked to juggle additional balls to enable the enterprise to adapt to rapidly changing conditions.

- University presidents and chancellors, provosts, vice chancellors for research, and deans can enable their faculty and strengthen their research universities by adopting and adapting three key strategies to fit our unique institutional cultures:

    1. Communicate laser-sharp focus regarding vision and goals. Clarity of focus includes a clear understanding of individual faculty roles and contributions to the goals. Because

department chairs directly relay central administrative goals to faculty, it is essential to aid them in this communication challenge with clear priorities and consistent talking points; support for effectively using departmental talent is essential.

2. Construct conditions that motivate. As the academic career becomes more complex, the external motivations of carrots-and-sticks are not sufficient for inspiring engagement. Recognizing and supporting faculty autonomy, mastery and purpose is more effective for leveraging employee engagement.

3. Cultivate faculty engagement over the entire arc of a changing career. By focusing on the full arc of the faculty career and intentionally designing strategies to sustain faculty members for the long game, we can strengthen our institutions and strengthen faculty engagement.

- These three strategies exemplify practices in a research university that create the opportunity to lead. With clarity of vision, conditions that motivate, and cultivation of faculty careers over the life span, these strategies call upon presidents, chancellors, provosts, and deans to lead as genuine collaborators with faculty in the reinvention of the university during an era of disruption.

Stabilizing Research Departments in a 10% World

John F. Leslie, Head, Department of Plant Pathology, Kansas State University

- Most land grant universities have 150+ years of history of conducting research in Science, Technology, Engineering and Mathematics (STEM). Support for the research mission has varied through the years in terms of both amount and source.

- Since a high water mark for external funding in the 1960s, funds for STEM research have been slowly whittled down with most federal programs supporting STEM research now having a success rate near or below 10%. The scarcity of funds has led to questions regarding criteria for faculty to obtain tenure and promotion, and the measures used to evaluate department and institutional excellence.

- The survival of institutions and their constituent departments remain a primary, if uninspiring, goal. Faced with declining budgets and loss of faculty and other staff, successful departments have become more collaborative in their research efforts, more cautious in their hiring patterns, and more deeply involved in interdepartmental and inter-institutional research efforts.

- Institutions with a clearly enunciated vision for their future and the ability to form multi-dimensional collaborations – administration and faculty, across discipline boundaries, and between basic and applied researchers – are the best positioned to not only survive, but to prosper in a 10% world.

Strategic Investments in Research in Microbiology and Immunology – Importance of Technology Infrastructure

Mark McIntosh, Professor and Chair, Molecular Microbiology and Immunology, Director of Research Core Facilities, University of Missouri

- Managing a microbiology and immunology basic science research department has long focused on developing a balanced faculty that provides breadth in expertise and that works within the institution to fulfill the three fundamental missions of education, scholarly research and discovery, and community service, whether local, regional, national or international.

- Infused into those missions in all basic and applied sciences over time has been an increasing emphasis on economic development as the fourth mission. The historical management perspective however has changed over the past several years with the growing emphasis on building comprehensive research teams that tackle complex research problems with a "translational" goal.
- This emphasis requires more targeted recruitment strategies, replacing the "cast a broad net and pick the best scientist no matter what the subject matter" approach. In parallel, high throughput, high resolution and highly analytical technical instrumentation and data analyses have become essential for the development of any comprehensive research strategy.
- This report will summarize the significant institutional challenges to investigator-driven research in the current federal funding climate and propose strategies for integration of highly focused basic science investigators into an interdisciplinary research network that depends on technology infrastructure to ensure and enhance research productivity.
- It is written from the perspective of a basic science chair at a public research institution who has experienced the transition from a siloed departmental set of academic objectives to an environment of networked and interdisciplinary research. It also touches on the growing concerns within such institutions in generating sufficient institutional resources to build an appropriate infrastructure capable of sustaining cutting edge research.

Interdisciplinarity in Uncertain Times: Research Centers

Karen Burg, Vice President for Research, Kansas State University

- The barriers to interdisciplinarity in a university setting are many. The typical university units naturally promote territorialism. The perceived incentives for faculty members to participate in interdisciplinary research is low. Interdisciplinary units are inherently more difficult to manage, and a high university investment is required. Importantly, the return on investment is ill-defined and, although potentially extremely high, very difficult to quantitate.
- Interdisciplinary is a great buzzword, but is an exceedingly difficult activity to manage. The National Academies (2014) has released many position papers promoting the concept and has provided compelling rationale for striving to achieve interdisciplinarity. Interdisciplinarity is the convergence of multiple disciplines that results in longer term effects. That is, each participating discipline is richer for the experience and gains in some tangible manner.
- **A**n interdisciplinary center generally spans university units and provides a collaboratory and infrastructure for team-based work. The ideal center relies on a core of permanent research faculty, rather than building on the talents of tenured or tenure track faculty, who have multiple responsibilities beyond the bounds of the center. Research faculty provide an environment which is industry friendly – particularly with respect to goals, deliverables, and metrics - they also provide a student friendly environment – i.e. training of students in a real world, collaborative environment.

- The center is, in effect, a flexible clearinghouse. The institute or center must be independent from but complementary to departments and should serve as a hiring draw for departments (due to the ready-made collaborators and infrastructure). Longer-term stability is provided by the appointment of permanent research faculty members as the core. In contrast, tenured and tenure-track faculty are involved as dictated by the scientific needs of projects and investigator availability.
- There are several important reward concerns. In particular, effort toward and participation in a center must be recognized by tenure/promotion committees. Rewards are based on output; common output includes congressional testimonies, public policy initiatives, popular media, or product development. Center research tends to lend to multiple author publications, which incorporate different perspectives from different disciplines. Letters of support from collaborators, defining the critical role of a center researcher, can be vital to the tenure and promotion process.
- The described interdisciplinary center model is industry friendly, major government initiative friendly, and student friendly. Center research faculty complement departmental unit foci and provide stability. When based on existing collaboratives, a center provides a rich training environment. Most importantly, the center provides a microenvironment where the disciplines gain independently and collectively.

The New Role of Land Grant Universities in the 21st Century: An Essay

Henry Foley, Senior Vice Chancellor for Research and Graduate Studies, University of Missouri

- Historically, land grant universities provided broad access to needed higher education for people of all backgrounds, especially from the industrial classes. The land grant universities played a significant role in advancing the state of agriculture and industry in the United States. By the end of the 20th century, the mission of the land grant institutions rested firmly on the three strong pillars of teaching, research and outreach.
- Today, many land grant universities have added economic development as a fourth pillar under their missions. The federal government made clear that research universities, including the land grant universities, were to take on the challenge of driving economic growth. They were to do fundamental research and convert its outcomes into new products, processes, and innovation and in a transparent, demonstrable way. Land grant universities began to pay much more attention to technology transfer as it relates to economic development. The land grants are well suited for this because of their historical role as socially responsible institutions that seek to improve the well-being of citizens in their states and the nation.
- At the University of Missouri, our research strategy is to become an even larger and more powerful engine of innovation and economic impact in the Midwest. With total research expenditures well over $270 million per year, our research engine's displacement is significant, but we expect and need this displacement to grow. Our goal is to become the very best among Midwestern land grant institutions at the conversion of the products of research and scholarship into innovations that will make life better. By growing new businesses, by supporting and improving existing businesses and by growing jobs, we can play a significant role in raising prosperity.

- At this point in our history and that of our nation, we are asked to do even more than before; we are expected to drive innovation to help the country achieve renewed prosperity through sustainable economic growth. To do this, is to be an "engine of innovation." To succeed at this, we need to bring our institutions closer to the real economy and to the business community. We need to do so locally, regionally, nationally and internationally. We need to test new approaches that will set the course for the land grant university for the rest of the 21st century, a course that will integrate the strengths of our past with entrepreneurship to bring forth more innovation from our research and scholarship than ever before.

Top Secrets to Growing University Research in Uncertain Times

Prem Paul, Vice Chancellor for Research and Economic Development, University of Nebraska

Monica Norby, Assistant Vice Chancellor for Research, University of Nebraska

Nathan Meier, Director of Research Strategy, University of Nebraska

- Flat federal funding for academic science and engineering research, increased competition and lower success rates for grants, heightened rivalry for top faculty talent and a larger burden of costs for research compliance make these uncertain times for university research.
- Like the federal agencies, we have to balance our investments in single investigator and inter-disciplinary centers and large teams. Our Programs of Excellence funding and other funds enabled us to hire new faculty, both senior and junior, in targeted areas. Multi-disciplinary cluster hires enabled us to build strong teams in a short time. Areas in which we have invested central resources include materials and nanoscience, atomic and molecular physics, virology, early childhood education, water and food security, computational sciences and digital humanities.
- We support junior faculty leadership development through our Research Development Fellows Program, a focused year-long experience of formal and informal learning sessions designed to help early stage investigators conceptualize project plans, interact effectively with program officers, identify funding opportunities, plan and draft effective grant proposals and develop an understanding of the proposal review process.
- We created an office that provides grant support to faculty from idea generation to facilitating team building and external review of proposals prior to submission to funding agencies. Our faculty have benefited from these services, which have increased their funding success. This focus on enhanced grantsmanship also includes developmental assistance with graphics and generation of grant proposal budgets.
- An effort to build connections among faculty through interdisciplinary faculty retreats in targeted thematic areas has been fruitful. The most recent retreat involved more than 275 faculty, featured nationally recognized speakers and talks and "quick pitches" by UNL faculty, panel discussions, networking activities and breakout sessions focused on thematic areas. At the conclusion of the retreat, a new seed grant program was announced. These retreats have proven essential to build faculty connections and stimulate the level of cross-disciplinary collaboration and innovative thinking needed for long-term funding success.

- Data-driven decision making, emphasis on individual investigator and team-based projects (including multi-institutional and interdisciplinary efforts), targeted hiring and infrastructure investments, and focused research and faculty development resources represent some of the strategies necessary to maintain market share and facilitate academic R&D in the face of stagnant or diminishing extramural funding.

A Newcomer's View of Research Administration in Uncertain Times

Sarah Nusser, Vice President for Research, Iowas State University

- State investment and federal funding are at best volatile and more likely to be shrinking; we are experiencing increased scrutiny of our administrative, educational and research practices; and the role of research is also being reframed as part of the broader creative and translational process of innovation.
- We are working with a few basic tenets to help us move forward. First and foremost is the importance of a diversified portfolio in managing volatility in funding opportunities. The second focus area is preparing our faculty to respond to opportunity as it arises. A third and trickier consideration is managing risk in the research and development process as funding sources, regulatory guidelines, and commercial opportunities expand. Finally, serious strategic planning and effective resource management are required to meet our goals.
- We tend to invest heavily in the star researchers and research-intensive colleges, departments, and programs where the return on investment is most significant. However, there are pockets throughout the rest of the university that have the capacity to engage in sponsored research. These researchers may lack the knowledge required to identify funding sources and develop successful proposals, as is often the case with new assistant professors in research active domains. This problem is readily addressed by existing faculty development programs.
- ISU has a distributed and heterogeneous network of pre- and post-award support. To assist academic units with limited grant support, we are creating a shared pre- and post-award service that will be available to individuals, research groups, and academic units. Anticipated benefits of this initiative include more efficient administrative processes in submitting grants and higher quality proposals. We also hope this reduces the barriers for capable faculty to submit proposals for sponsored funding.
- We are discussing how we evolve our culture and support activities that foster commercialization of research outcomes. In partnership with ISU's Economic Development and Industry Relations unit, our main activities have focused on two areas: (1) initiating pilot programs to better understand what training is needed in order for our faculty to be successful in translating their research to commercial applications, and (2) determining what to prepare for as an institution in order to manage risk in the translation process.
- In recent years, the burden, complexity, and risk associated with research conduct and compliance have steadily increased. The dynamic, conflicting, and arcane regulatory environment makes it difficult for researchers to understand and engage with this responsibility, particularly given their intense workload. As we migrate to new software systems for compliance committees, we have an opportunity to evaluate our processes and see if we can reasonably address these forces.

Anticipating New Directions in Human Subjects Research

Michele Kennett, Assistant Vice Chancellor for Research, University of Missouri

- Human subjects research, highly regulated and overseen through the Institutional Review Board, is still viewed by many as a barrier to research. The question is, how we can as institutions, move from being the barrier to research to aiding in creating a culture of compliance?
- The changing funding environment is at the top of most lists of challenges. With decreased federal funding there is increased competition for research dollars and increased look to industry to remain competitive. In addition, institutions face challenges in dealing with the increasing number and complexity of regulations. Increased complexity of contracts creates challenges, extending timelines for study implementation in an already competitive environment. Difficulty recruiting subjects poses another challenge. Inadequate research training, poor mentoring of new researchers, research coordinators without appropriate skills to carry out a research protocols and lack of professional compliance staff, all cause inefficiency in the research enterprise and leads to dissatisfaction and frustration.
- Times have changed, we need to rethink and reanalyze our interpretations. Many in human subjects protections are currently rethinking the reliance on a single IRB in multicenter trials. Another area being explored is the option for equivalent protections in human subjects protections. Federal regulation dictates the regulations applied to federally funded research but flexibility is possible in non-federally funded research, provided it provides equivalent protections. This may lead to a lessening of the burden for some types of research i.e. research in schools.
- Metrics can show the value of what we do in human research protections. Today's systems allow us to track and quantify the many activities that go into human subject protections. Metrics allow us to calculate time from submission to approval and identify where delays occur.
- Investigators often do not have the toolbox that would allow access to pertinent information directly related to their research needs. A toolbox would allow investigators to access information needed for IRB submission, forms and templates, FDA regulations, and guidelines on how to navigate the human subjects research experience. With the technology available to us, the ability to create a more centralized place for investigators and compliance staff to interact is possible.

Building Research Capacity and Infrastructure

Chitra Rajan, Associate Vice President for Research, Iowa State University

- The last seven to ten years have been very challenging for universities: we have seen a growing scarcity of resources for research due to decreases in federal funding and reductions in state support. At the same time, research administrative costs have been increasing, as greater resources (including staff time) are required to handle the growth in compliance, accountability and reporting requirements.
- Despite severe cuts in state funding over a 3 year period, ISU was able to make critical investments, develop new programs, and improve processes and overall efficiencies. Some of these efforts included institutional strategic investments, new faculty hires (cluster hires), and a strong commitment to provide the research support services and facilities needed to enable research excellence and knowledge transfer.

- Most notably, the VPR Office has stepped up the resources available to help faculty submit grant proposals and manage awards by offering a comprehensive menu of research development and support services chain (identify funding opportunities; proposal preparation and submission; project management and compliance; reporting and closeout), making it easy for faculty to develop, prepare, and submit grant proposals by reducing administrative/clerical work. The VPR Office and the Office for Sponsored Programs Administration also provided several training and workshops for support staff in departments and centers to upgrade their skills in grant preparation and post-award and project management.
- There is a strong commitment that all support service units under the VPR Office will be well managed, service-oriented, and responsive to faculty needs. Staffing for many of the critical research support offices such as sponsored programs administration and responsible research has increased, making it easier for these units to keep up with the growth in the volume and complexity of sponsored funding contracts. There are resources now for staff professional development and a cultural shift that emphasizes consultative decision making, and continuous self-assessment and improvement.
- By building on existing strengths, and working across and between disciplines, ISU was able to see growth in external funding from a range of sources across the breadth of the university's research activity. It is critical that research universities develop a plan to diversify their funding portfolio to hedge against the vagaries of external funding and make selective, strategic investments even in difficult times. It is crucial for research universities to develop long-term sustainable plans for programs and units; and, although it may be politically unpopular to do so, discontinue support for unproductive and under-used programs and units. It is important that research universities are willing to take some calculated risks.

Clinical Research: New Frontiers

Richard Barohn, MD - Vice Chancellor for Research, University of Kansas Medical Center; Director, Frontiers: Heartland Institute for Clinical and Translational Research, University of Kansas Medical Center

Laura Herbelin, BSc - Research Instructor, Department of Neurology, University of Kansas Medical Center

Lauren S. Aaronson, PhD, RN, -Professor, School of Nursing and Dept. of Health Policy & Management, School of Medicine; Deputy Director, Frontiers: Heartland Institute for Clinical and Translational Research, University of Kansas Medical Center

- Both NIH and PCORI recently have created and funded large programs aimed at doing clinical research better and more efficiently so that discoveries are brought to patient care and improve the health of the public more rapidly.
- The CTSA program is managed by the new National Center for Advancing Translational Science (NCATS). Today, five academic institutions and 10 health care institutions comprise the Frontiers program, and investigators from all of these sites are eligible to apply for and use Frontiers resources.

- Among the successful programs under the Frontiers umbrella is a pilot study funding program. Pilot study funding for a project has varied from $20-30K for each project. The Trailblazer program provides a smaller amount of funding on a more flexible basis. These applications may be submitted at any time and undergo an administrative review.
- NeuroNEXT is a consortium supported by the National Institute of Neurological Disorders and Stroke (NINDS) (http://www.neuronext.org). It was created to expand the capability to conduct clinical studies in neuroscience. Through the NeuroNEXT program, KUMC is currently involved with four studies, focusing on four diseases.
- The Patient-Centered Outcomes Research Institute (PCORI) was established as part of the federal Affordable Care Act. The overall goal of PCORnet is "to improve the nation's capacity to conduct clinical research by creating a large, highly representative national patient-centered network that supports more efficient clinical trials and observational studies"
- Central to this new frontier is collaboration. The shared hope is that through collaboration we can more rapidly and more rigorously find answers to the questions that matter most for achieving a healthier public.

Can Research Inform us about the Efficacy of University STEM Education?

Joseph Heppert, Associate Vice Chancellor for Research, University of Kansas

- The increased climate of accountability around the use of taxpayer funding has come to rest on the U.S. public higher education system. Key accountability metrics include both student retention in college and time to degree. These metrics present challenges for traditional models of university STEM instruction, which are perceived to contribute to higher than institutional average attrition from the ranks of STEM majors. Degree obtention rates of 60 percent represent a national average for U.S. Engineering programs, for instance. These challenges could, if left unaddressed, become a threat to the structure and mission of public research universities.
- There are many instructional models that accommodate a broader range of learning student learning styles, improve success in learning and increase student engagement with subject matter. We need to consider whether public research universities should systematically turn the tools of rigorous quantitative and qualitative research inward to study the instructional changes being driven, in part, by a culture of increasing accountability.
- The key questions we must ask: Can rigorous quantitative educational research answer fundamental questions about the efficacy of university curriculum reform, what are anticipated institutional commitments and costs for these studies, and what are reasonable boundaries for the implementation of such programs?
- It is to our advantage to demonstrate that resources aimed at STEM curriculum enhancement are providing the anticipated benefits for our students. We have the tools of research at our disposal, faculty who could benefit professionally from partnering in such studies, and the need to move away from an anecdotal narrative for evaluating the efficacy of educational change.
- This process can contribute to protecting the diverse, interrelated missions of public research universities and provide a narrative for engaging a sometimes-skeptical public in the discussion that the research and educational missions of the university are indivisibly linked.

Department of Defense Research Funding: Opportunities, Idiosyncrasies, and Risk Analysis

Kurt Preston, Associate Vice Chancellor for Research, University of Nebraska

- Notwithstanding the relative modest proportion that DoD basic research funding takes in the federal budget, there are some disciplines, such as engineering, where the DoD basic research funding effort comprises a significant portion of its resourcing. Mechanical engineering, electrical engineering, and aeronautical engineering respectively receive 80%, 61%, and 35% of their federal basic research funding through the DoD.
- The take away message from examining the DoD RDT&E budget is that there are two highly differentiated funding modalities. The first modality is the basic research mode in which one finds grants awarded, largely to research universities, through the vehicle of a broad agency announcement (BAA.) The second modality funds applied research and advanced technology development. In general terms, there is an inverse relationship between involvement by universities and maturity of the technology. The further one departs from basic research, the smaller the proportion of funding is likely to be found going to a college or university.
- There are two modes of DoD science and technology (S&T) funding. The first, basic research, is designed to engage the university research faculty member. The second mode, the rest of the (S&T) funding, rarely benefits university research faculty members unless they lead or find themselves in a team focused on applied DoD problems. It is critical to understand that applications, demonstrations, and systems are all outside the realm of basic research in the DoD context.
- DoD research funding has a place in planning for future research in public universities in uncertain times. However, the DoD is not the principal source of research dollars to colleges and universities. It is a distant fourth behind NIH, NSF, and DOE. It is unlikely that DoD research funding would form the basis for funding the University research enterprise. Nonetheless, the DoD basic research program provides a vehicle for university principal investigators to be involved in the defense of the nation through their research activities.

Building upon Existing Research Strengths in Uncertain Times: Analytical Chemistry and ISU

Emily Smith, Associate Professor, Department of Chemistry,
Iowa State University

- Competitive start-up funds and space requirements for a research group are the most significant challenges to maintaining research strengths in the chemical sciences. The average start-up package for an assistant professor of chemistry for 19 selected universities across the Midwest is roughly $810,000 for an assistant professor, excluding associated costs for renovating space. The average start-up package for a senior faculty member is approximately $1.7 million excluding renovation costs.
- Industrial connections are increasingly seen as an important source of funding and partnership in times when obtaining federal funding for basic research is a growing challenge. These connections make particular sense for applied research projects that may offer a shorter-term payoff in the form of developed products or new measurement techniques. There is existing evidence for the successful partnership between industry and academic

departments with analytical chemistry divisions. Named endowments, donated equipment for departmental use, and the use of equipment at remote sites may be beneficial approaches for fields in which analytical measurements are taken.

- The careful planning of shared university (center) equipment purchases may alleviate need for a portion of start-up funds for new faculty members, and the entire university community might benefit from the addition of on-site equipment experts.
- It is necessary to invest time and money in advertising the unique strengths within and outside one's own organization. Seminars and local conferences have been the traditional route for achieving this. Existing research strengths at public universities in uncertain times may not remain strengths unless the university invests both time and money to maintain them. This may be accomplished with traditional as well as innovative strategies. Leadership from all levels will be key to successful implementation of these strategies.

Enhancing the Success of Early-Career Faculty in STEM Fields During Uncertain Times

Joy Ward, Associate Professor, Ecology and Evolutionary Biology, University of Kansas

- Early-career faculty face numerous challenges when working to establish an upward professional trajectory, particularly those in STEM fields. Federal resources for basic and applied science have diminished since ARRA funding ended. This presents challenges within universities, since investment in tenure-track faculty is often substantial (particularly in STEM fields), and the loss of faculty members through tenure denials is far from ideal.
- Teaching release: There are times when early-career faculty members would greatly benefit from teaching release for short periods of time (1-2 semesters) in order to enhance their research programs, and this may be essential to their success. Teaching release for early-career faculty to attain the momentum needed to sustain a long-term research career may be best applied in mid- to late stages of the pre-tenure period.
- Networking: Early-career faculty are eager to develop close networks with other colleagues that may be in different, yet complimentary fields. This may facilitate the formation of large multi-disciplinary teams that will eventually be highly competitive for large grants. Development of these networks can be particularly strong within new cohorts, since all are adjusting to new positions at a new university.
- Service: Within departments, there tends to be a movement towards minimizing hours spent conducting service for early-career faculty, mainly because this allows for greater time for teaching and development of research programs. I strongly agree with this practice, as the demands on early-career faculty can be overwhelming, and teaching and research productivity will be more heavily scrutinized when tenure decisions are being made.
- Mentoring and feedback: Early-career faculty require excellent senior faculty mentors, and these mentors need to be clear and outspoken if deficiencies exist that may block the candidate from gaining tenure. The mentor should then work with the early-career faculty member to overcome these deficiencies as soon as possible. On the other hand, when early-career faculty are thriving, and are clearly on a trajectory to gain tenure, it is imperative that faculty mentors convey this information to the candidate as well.

37 Years an Academic Scientist

Christopher Sorensen, Courtelyou-Rust University Distinguished Professor, Kansas State University

- Despite a universal decline in science funding, we all owe our prosperity and our health prospects to advances in the sciences. NIH Director Francis Collins stated in recent testimony to Congress, "Our nation has never witnessed a time of greater promise for advances in medicine." Yet NIH's budget for fiscal year 2014 (FY14) is 11.7% below the FY04 peak. How can our universities help us win the grants to keep our researches going?
- Solid infrastructure is the foundation – access to diagnostic equipment that is too expensive and require too much expertise to run and money to maintain by a single investigator. Things like electron microscopes, XPS and X-ray diffraction. It is the university's role to provide these devices, man them with expert operators and provide for their continued maintenance.
- Other ways the universities can help researchers: develop outreach connections across a wide range of venues such as K-12 schools, community colleges, minority institutions, civic groups, museums, etc. In addition, it would be very useful to have readers to read drafts of our grants and give advice - readers who know the current trends and buzzwords, the ins and outs of the funding agencies.
- In a recent editorial in *Science*, John Edward Porter argued that "we must convince the public and our representatives that cutting research is not a pathway to deficit reduction; it is a pathway to increased health threats, lost lives, and economic insecurity". And yet, Porter points out "there has been little outreach by scientists to the public to help them understand how science contributes to better health, job creation, and global competitiveness." Furthermore he writes "Scientists remain largely invisible to the public"
- You would think professional teachers would be terrific at communicating these important messages to the public. Let's try to communicate by writing op-eds and letters to the editor of local newspapers about the latest scientific breakthroughs and their implications for society, by volunteering to speak at local organizations, chambers of commerce, junior high and high schools about our work or the latest discoveries. We could offer to be a scientific advisor for candidates or create and serve on science advisory committees.
- In addition, I believe that we have the opportunity to profoundly influence the future every class day by teaching the value of science to our students - by letting our students know that we not only teach but do research as well. By being good and reasonable people to win their respect and thus ensure our arguments gain efficacy. What we do in the classroom might not have an effect overnight, but it will certainly change the future.

Planning for Future Research in Public Universities in Uncertain Times

Sally Frost Mason, President, the University of Iowa

Research will and must remain one of the core missions of our public universities. At the same time, public expectations—whether it's from our public citizenry or leadership—are changing regarding both what we do and how we do it. These changing expectations obviously can lead to uncertainty and challenges. But that has been the case forever, if we think about it. Today's uncertainties and challenges are not necessarily the same ones we faced ten, twenty, or a hundred years ago. But our public universities—one of the great achievements of American society—have always risen to the challenge of leading our communities, our states, our nation, and the world into new discovery. And we will continue to do so as we move further into the twenty-first century.

Let me start with a brief review of how the current climate for university research presents us with some significant challenges.

The first challenge is the muted projections for federal research funding. A quick graph in **Figure 1** below shows that even in the recent past—since

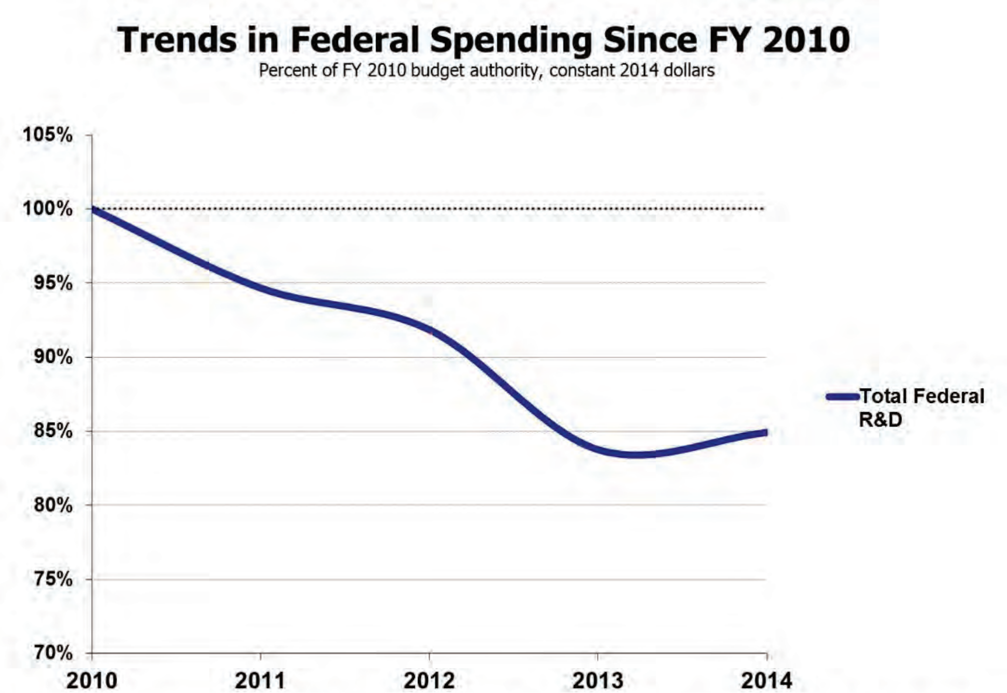


Figure 1 Source: AAAS presentation titled "Federal R&D in FY 2015: Context, Overview, Outlook" for the Council on Government Relations, 6/12/2014.

2010—total federal spending R&D spending has declined in constant 2014 dollars.

And as **Figure 2** from the American Association for the Advancement of Science clearly indicates, federal non-defense R&D dollars have in fact declined in the past ten years, and the prognosis for the future is pretty stagnant. Projecting relatively far into the future—to 2021—all likely scenarios—including the president's request, the Budget Control Act and American Taxpayer Relief caps, post-sequestration scenarios, and the Ryan/Murray Congressional proposal changes—are forecasted to have only very modest growth.

If we dig into some of the details of the FY15 base R&D budget, we see in **Figure 3** that many of our stalwart basic science federal funding programs—such as the National Institutes of Health and the National Science Foundation—are declining this year in constant dollars. This year, though, those doing research in en-

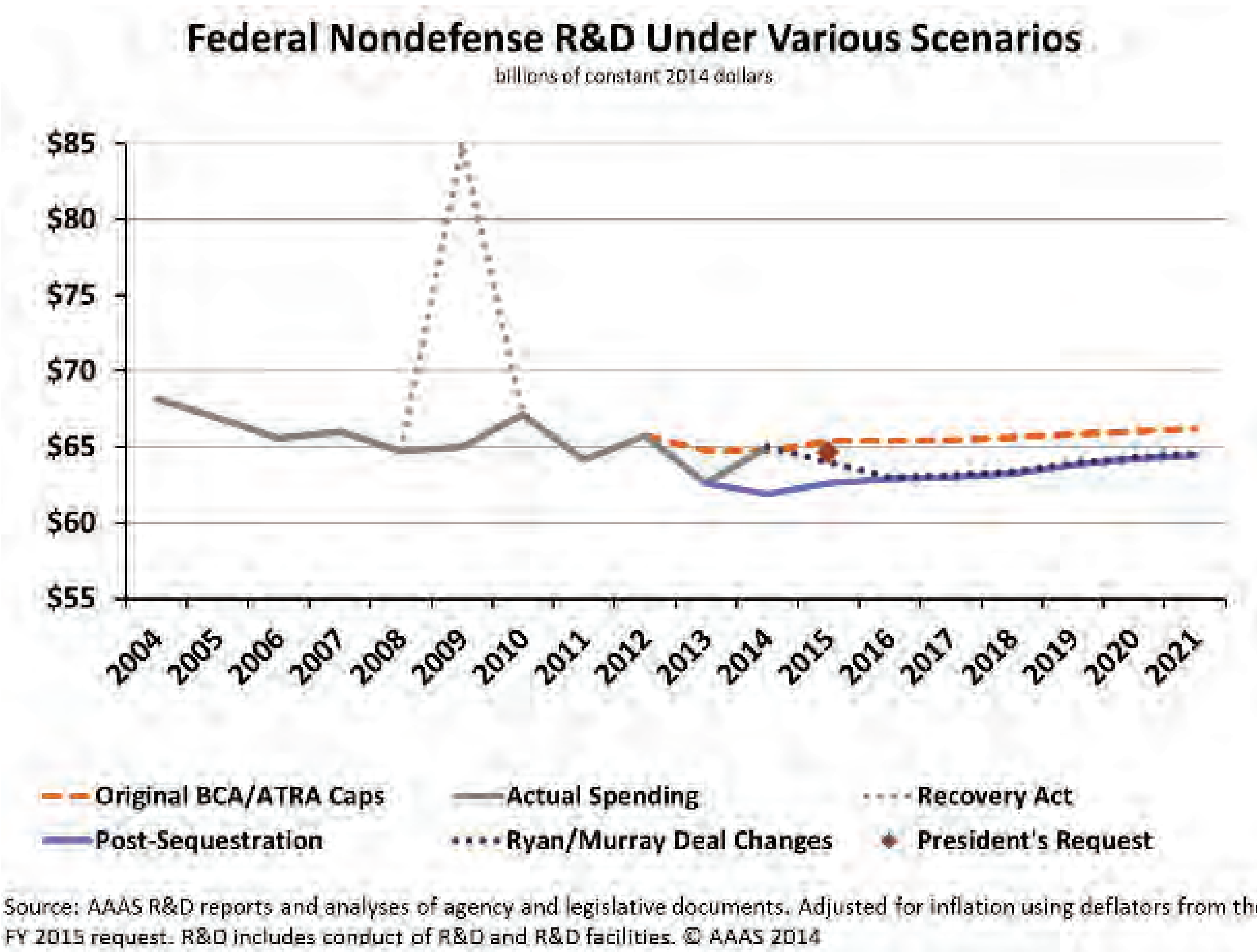
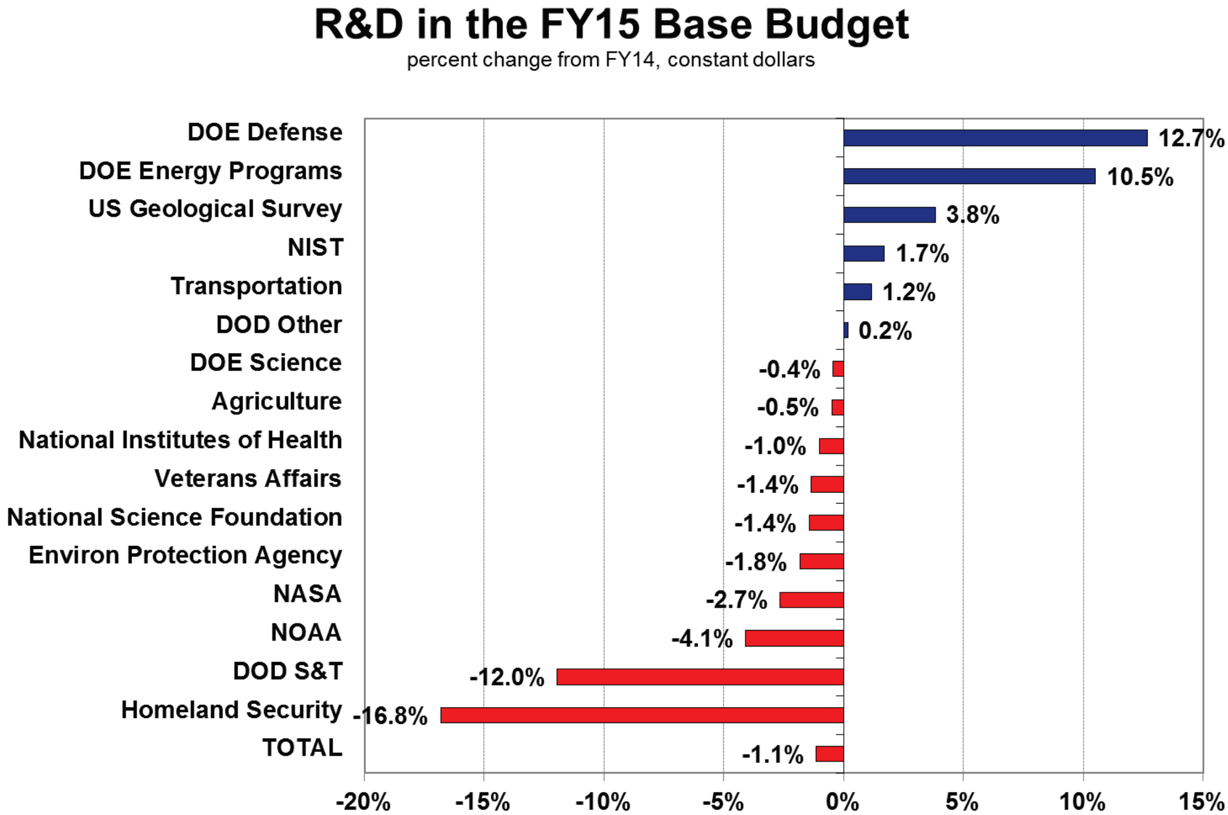


Figure 2 Source: AAAS presentation titled "Federal R&D in FY 2015: Context, Overview, Outlook" for the Council on Government Relations, 6/12/2014.

ergy, transportation, or advanced manufacturing will do better. All in all, the U.S. federal investment of nearly $140 billion in R&D, including the Department of Defense, remains a significant amount.

But this leads us to the second major challenge in the current research climate: international competition. While the United States' public investment in research over recent years has declined, remained stagnant, or increased only modestly—and will most likely continue on these trends for the foreseeable future—many of our international colleagues (and competitors) are enjoying major upswings in federal research dollars.



Source: AAAS analysis of the FY 2015 President's Budget. Does not include additional funding proposed via Opportunity, Growth, and Security Initiative. NOTE: Inflation is 1.7%. © 2014 AAAS

Figure 3 Source: AAAS presentation titled "Federal R&D in FY 2015: Context, Overview, Outlook" for the Council on Government Relations, 6/12/2014.

China garners the most attention in discussions about upward R&D trends, and the numbers bear that out. **Figure 4** from AAAS showing Organization for Economic Co-operation and Development (OECD) data confirms that China has substantially increased its R&D spending. The graph depicts gross domestic expenditures in the government, business, and higher education sectors, all held constant in 2007 dollars. Clearly, in the past ten years, the United States once again has remained relatively stagnant while China has been aggressive and robust. The business sector has led this increase in China, whereas the US, although recovered from the recession, has increased R&D expenditures much more modestly. In fact, US R&D expenditures in higher education are still down -1.3% from 2008. As with China, US increases have been mainly driven by business at 5.8%, and government remained modest at 1.0%.

South Korea (the darker blue line) has shot well past everyone.

I've focused on the national and international scenes here, but issues at the state level also are having significant impacts on the research at our public universities, our third challenge. Across the country, a number of state legislatures and university governing boards are re-examining the role of research in a state-supported institution, sometimes amidst great controversy. While often these controversies do not involve funding dollars to the extent that federal policy does, the climate for and definition of research can be significantly impacted. Usually these questions and/or controversies center on a university's emphasis on teaching and a university's role in state economic development.

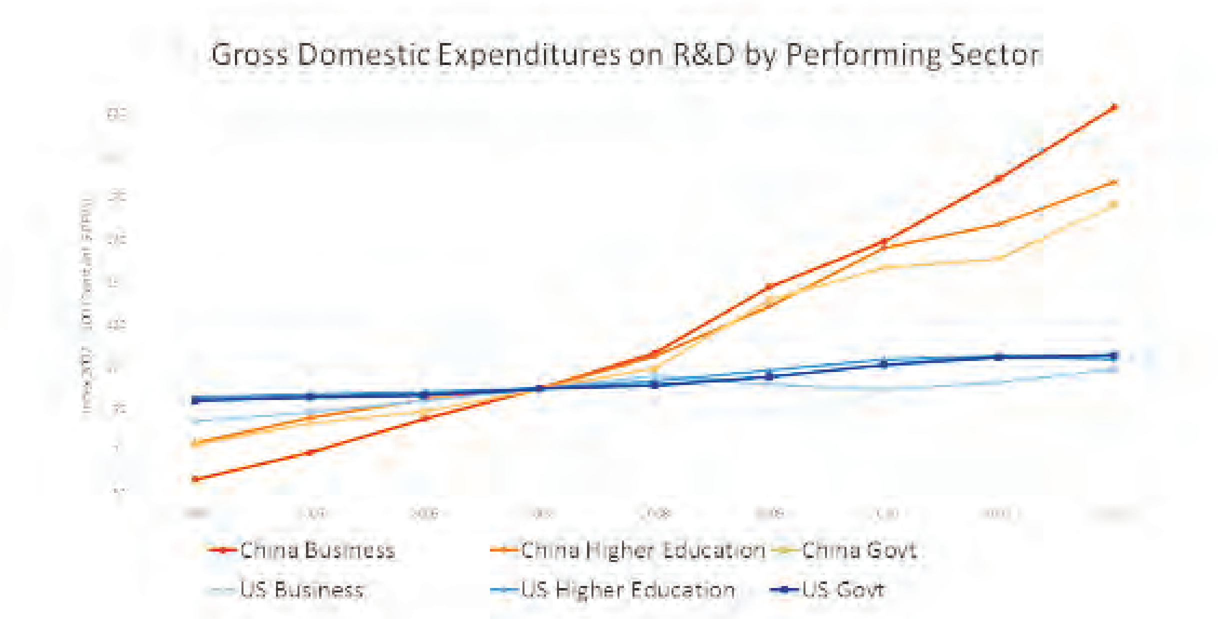


Figure 4 Source: OECD Main Science and Technology Indicators (MSTI) database.

If we expand our view to other OECD countries and other economies, we see a number of similar trends. **Figure 5** depicts research intensity—that is, R&D as a percentage of GDP—over a twenty-year period, from 1992 to 2012. For the first time, China's R&D intensity (1.98%—the light blue line at the bottom) caught up with the European Union (1.97%—the green line) in 2012, having previously surpassed the United Kingdom and Canada in 2011. We can also see that, although itself declining some in recent years, Japan (the yellow line) remains well ahead of the United States (the red line) in research intensity, and

Perhaps nowhere has the controversy been more heated than in the state of Texas. Texas is in the news again with

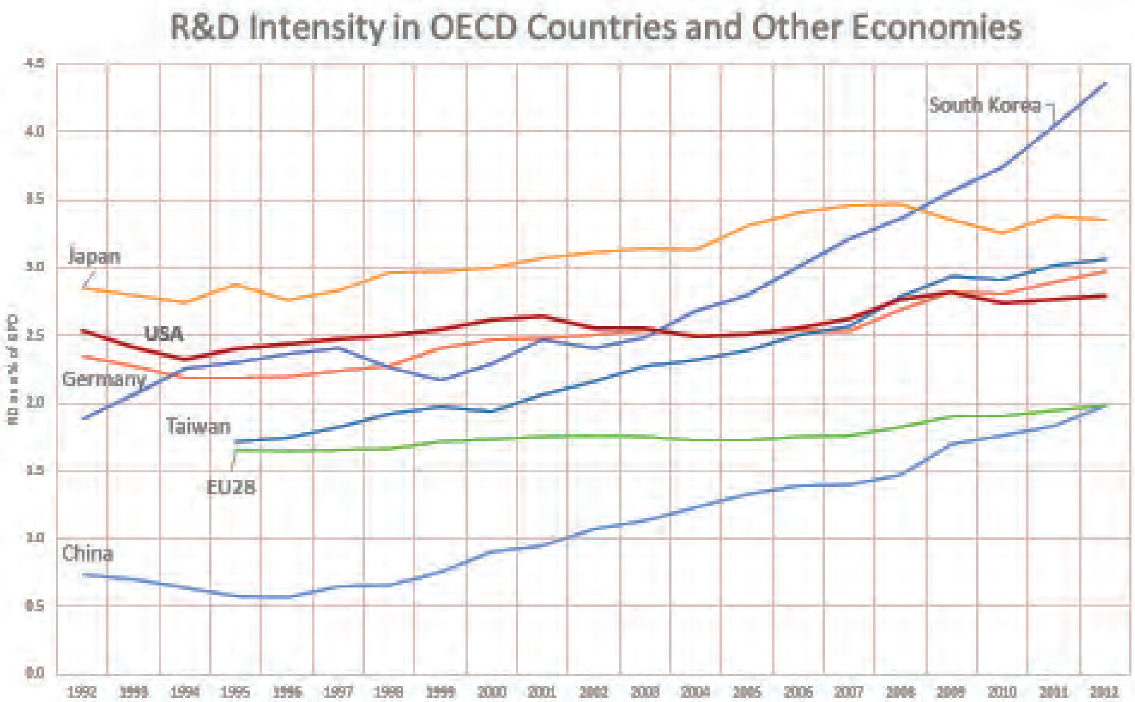


Figure 5 Source: OECD Main Science and Technology Indicators (MSTI) database.

the impending resignation of UT-Austin President Bill Powers (though he has gotten a year's reprieve). Many issues are in play in Texas, but the controversies at hand in the Lone Star state revolve around disputes among Governor Rick Perry, the system governing boards, and the university campuses themselves.

Since 2010, controversy has swirled among the Texas A&M and UT systems thanks to higher education reforms recommended by the Texas Public Policy Foundation, a conservative research group that advocates departing from the traditional research-driven model for academia. The TPPF and its ideas were embraced by Governor Rick Perry and some of the Regents he appointed. The "Seven Breakthrough Solutions" generated by the Foundation include creating a new accreditation system that would grade institutions on how effectively they deliver on promises to students, as well as splitting university budgets for teaching and research. Rick O'Donnell, a senior research fellow at the Texas Public Policy Foundation who had a short but fiery tenure as a special adviser to the UT board, went so far as to once write that academic research "has few tangible benefits." In 2011, a collaborative plan did emerge called "A Framework for Advancing Excellence Throughout the University of Texas System," and while it did not move as aggressively in the directions the Texas Public Policy Foundation, the governor, and Rick O'Donnell were advocating, it did include stronger emphasis on faculty teaching.

Economic issues play into many such controversies across the country, whether it's the pressure for university activity to promote state economic development, or the pressure to link institutional and academic program funding to student job placement. A state experiencing the latter is Maine, where significant budget deficits at the public colleges and universities are leading to program eliminations. Many factions claim that that these cuts are often based on student career utility as opposed to academic merit.

Let me emphasize that I do not believe that research, economic development, teaching, and student success are mutually exclusive. I don't believe that, even in tough economic times, we need to sacrifice one for the other. In fact, at Iowa, we're finding ways to make sure these various parts of our mission are mutually supporting, and I'll discuss those later. But I do want to mention here that in Iowa, we too are experiencing pressure from our governor, legislature, and governing board in some of these arenas. Currently, we are in the midst of two Board of Regents initiatives—a system-wide transformation and efficiency review, and the implementation of a new performance-based funding model that places a heavy, though not exclusive, emphasis on enrollment of Iowa resident students. My approach is to work to use these board priorities to strengthen the university across the board rather than to fracture it. I am asking our university community, how can we best fulfill the full spectrum of our traditional academic mission, including research, and at the same time meet the expectations of our state's leaders?

Metaphorically, the public university research enterprise is in the midst of its own kind of "climate change," especially in three major areas: state priorities, federal funding, and international competition. As with any kind of change, adaptability remains key. And as with climate change itself, complete reversal of the higher education research landscape is unlikely if not impossible at this point. Some level of adaptation is necessary. Of course, we hope that federal funding will increase again, that the United States will maintain leadership in a competitive international field, and that our institutions will continue to enjoy the support of our states' leaders and citizens. But even as our public universities remain committed to our core missions, we have always changed and adapted along with society at large—and led that change if we're doing our jobs right. Granted, this is a time of particular change and uncertainty. But we can navigate these times and come out stronger rather than weaker. But it will take vision, planning, and proactivity to be successful in the future that lies before us.

So how are we to rethink our approaches to the research enterprise in these uncertain times? I propose three broad areas in which we must think about playing a new game: 1) Research portfolio diversification, 2) new partnerships, and 3) interdisciplinary approaches. And as I discuss each of these, I will share with you some of the initiatives that we are undertaking at the University of Iowa as way of example.

First is diversifying our research portfolio. All of our institutions have their particular strengths and emphases. At the University of Iowa, while we have many areas of excellence and renown, many know us especially for our medical and health care research, and for our world-class University of Iowa Hospitals and Clinics. Five of our eleven colleges are in health fields: the Carver College of Medicine, the College of Pharmacy, the College of Nursing, the College of Dentistry, and our newest college, the College of Public Health.

It should come as no surprise, then, that for many years, the National Institutes of Health has been our biggest research funder. But as **Figure 6** demonstrates, and as I noted before when discussing federal funding, those NIH dollars are decreasing. Since FY2010, NIH funding—represented on the chart by the grey bars and the black line—has decreased from 47% of Iowa's total research funding to 38%, and it's gone from $219 million to $163 million. Even so, the NIH remains Iowa's single largest federal agency sponsoring our research. As you can also see from this chart, we have responded by shifting our portfolio more toward industry partners. Since FY2010, industry funding has increased from 7% of Iowa's total research dollars to 17%, from $31 million to $71 million.

One prominent example on our campus is our research on driver safety. The University of the Iowa is the home of the National Advanced Driving Simulator, the most sophisticated research-driving simulator in the world. Developed by the National Highway Traffic Safety Administration, NADS offers the world's highest fidelity real-time driving simulation experience. The driving simulator has allowed us to leverage a growing partnership with Toyota. The University of Iowa Public Policy Center has recently received three grants totaling $17.2 million as part of the Safety Research and Education Program established by the recent Toyota Economic Loss class action settlement in California.

Principal investigator Daniel McGehee, director of the Public Policy Center's Human Factors and Vehicle Safety Research Program, has worked with Toyota

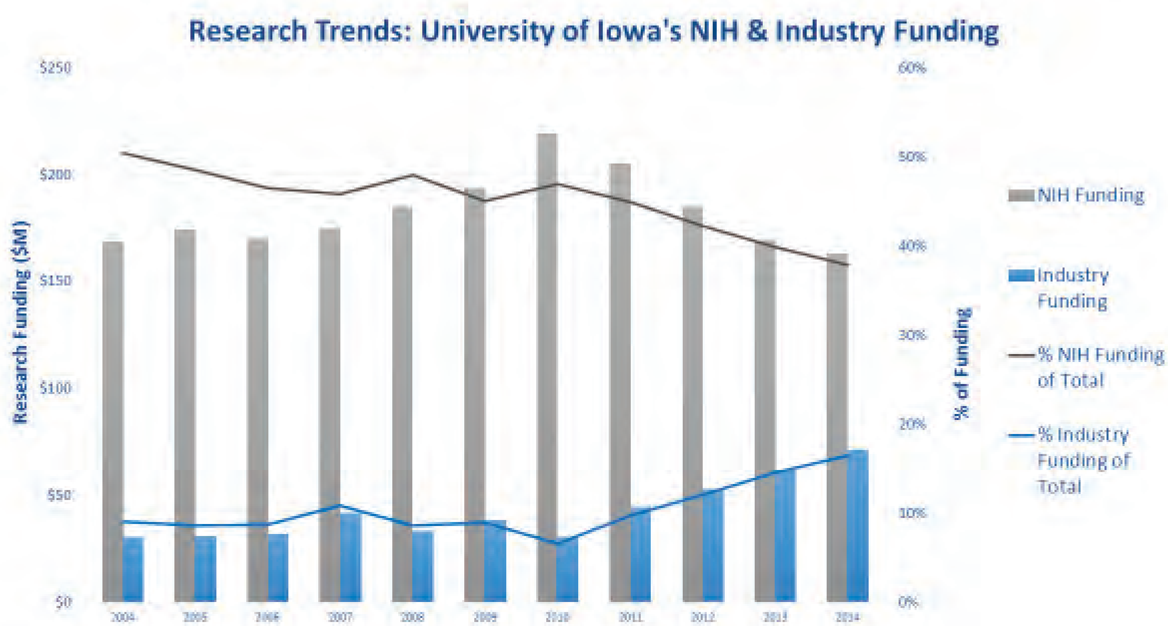


Figure 6

before, having this year finished a three-year, driving-safety-related contract from Toyota that examined foot behavior at the early stages of the driving sequence, such as vehicle entry, engine start-up, and gear selection. The projects resulting from the new Toyota grant will include an impressive array of multi- and interdisciplinary efforts, as well as new partnerships: a national survey on public perceptions of vehicle safety technologies as well as drivers' understanding and use of defensive driving techniques; a national education campaign growing out of the national survey, designed to reach 90 percent of U.S. adults multiple times (this education campaign is in partnership with the National Safety Council and Iowa City-based Digital Artefacts, a private multimedia firm); a study at the National Advanced Driving Simulator that examines replicating emergency events in a controlled and safe environment; a study in the Department of Neurology to measure and improve younger and older driver behavior when accelerating and decelerating; and an engineering analysis being conducted by NADS and the Department of Geography to determine if multiple car sensor systems can be used together to prevent certain types of crashes.

In addition to increased research funding from private industry, we at the UI have also broadened our relationship with the federal government—with the Department of Defense in particular. Our most prominent current projects under the auspices of the DOD involve Professor of Biomedical Engineering Karim Abdel-Malek's research on human modeling and simulation. Dr. Abdel-Malek is also the director of the College of Engineering's Center for Computer Aided Design, which has played a prominent role in the Virtual Soldier Research program. With DOD as well as private industry funding, Dr. Abdel-Malek and the VSR have created Santos, a human modeling and simulation environment used by military and commercial clients to assess human factors in the design of equipment, armament, vehicles, and other large equipment.

Other Iowa researchers have also secured funding from the Department of Defense, such as Professor of Sociology Steven Hitlin, who has a special interest in values and morality. With nearly $600,000 in funding from the DOD Office of Naval Research, Professor Hitlin is conducting a study called "Moral Schemas, Cultural Conflict, and Socio-Political Action."

The UI recognizes the tremendous potential of the Department of Defense as a research funding source, and we are taking a proactive approach to encourage more faculty and staff to explore the possibilities. For example, our Office of the Vice President for Research and Economic Development has presented informational sessions by Lewis-Burke Associates for researchers on DOD funding for health research. These sessions explain the complex DOD landscape for health research, review the trends and priorities across programs, and address such questions as how working with DOD differs from other research agencies, the best points of contact for faculty in approaching DOD, and what messages best resonate with DOD health officials.

The second area of playing a new game in our research mission is new partnerships. My previous comments on diversifying our research portfolios focused on new partners, but those that remain in our traditional areas of funding: government and industry. At Iowa, we're also expanding our thinking about what kinds of partnerships can move our research enterprise forward, including the nonprofit sector, the private sector outside of traditional industries, regional economic development entities, and entrepreneurship. Let me share a couple of examples of the first two—the nonprofit sector and the private sector—on our health sciences and health care campus at the University of Iowa.

The Fraternal Order of Eagles Diabetes Research Center is a historic partnership that was formally established in September 2008. This was the first time the University of Iowa had partnered with a nearly million-person international donor organization. And for the Fraternal Order of Eagles, it is the largest organization-wide project ever undertaken in the group's long history of giving to health-related causes.

The FOE and UI partnership began at the 2006 Eagles convention in Grinnell, Iowa. The then-Grand Worthy President-elect Bill Loffer proclaimed to Dr. John Stokes, a physician-scientist studying and treating kidney disease with UI Health Care and member of the Iowa City Eagles Aerie, that the Eagles should fund a diabetes research center to find a cure for this disease that affects one in three of Eagles members. (By the way, Dr. Stokes sadly has since passed away.) The timing for this proposal was fortuitous. The university was in the midst of planning the UI Institute for Biomedical Discovery—now the Pappajohn Institute—which would house high-quality, high-reward interdisciplinary research for complex illnesses like diabetes.

Over the next two years, meetings between the Eagles and the UI led to a partnership that included a commitment by the Eagles to raise $25 million and an agreement that the research center would be housed in the new Pappajohn Biomedical Discovery Institute building, which opened in 2014. The FOE gift funds endowed chairs and fellowships for diabetes researchers, provides seed grants for innovative research ideas, and helps recruit leading scientists in diabetes research and translational medicine.

In the years before the opening of the physical facility, the research center already accomplished much, including the first round of FOE Diabetes Research Center research grants to fund four innovative pilot projects by young investigators; the selection of the first FOE Diabetes Research Center Faculty Scholar, Dr. Christopher Adams, an endocrinologist and associate professor of internal medicine; and the hiring of our new Center Director, Dr. E. Dale Abel, a renowned diabetes expert.

It is the mutual goal of the Fraternal Order of Eagles and the University of Iowa to understand and ultimately cure diabetes by moving research findings into the clinical setting as quickly as possible. This unique partnership demonstrates how a shared vision between a service organization and a university research enterprise can create an entity that is both innovative and essential.

The University of Iowa established another unique partnership and received another incredible $25 million gift in 2013. This gift from Stephen A. Wynn, chairman and CEO of Wynn Resorts, Limited, of Las Vegas, was made to support the UI's Institute for Vision Research and to accelerate progress toward cures for rare, inherited retinal diseases. In Mr. Wynn's honor, the institute is now named the Stephen A. Wynn Institute for Vision Research.

The UI's ophthalmology program is one of the best in the country, and Mr. Wynn—who had no previous ties to the University of Iowa and himself suffers from the degenerative eye disease retinitis pigmentosa—recognized Iowa's excellence in this area of research. Mr. Wynn himself has said, "The army of clinicians and scientists at Iowa's Institute for Vision Research have uncovered many of the secrets of the genome and are now on the cusp of applying them in the clinic. I never dreamed that I would witness such breakthroughs in my lifetime, but the breakthroughs are now at hand."

One of the most unique results of this partnership, and one that put forward the University of Iowa name in an unprecedented way, happened in 2014. Lazier Partners Racing chose to bring awareness to the Wynn Institute at the Indianapolis 500. Buddy Lazier, the 1996 Indianapolis 500 winner and 2000 Verizon IndyCar Series champion, drove the No. 91 University of Iowa Stephen A. Wynn Institute for Vision Research car in the 2014 race.

I mentioned earlier that state economic development has become an increasingly important state priority for our public universities, and that is certainly true in Iowa. And as I mentioned earlier, we at Iowa are embracing that emphasis and moving full steam ahead by both re-energizing older and creating new programs.

In 2012, I hired a new vice president for research and soon added "economic development" to his title. Dan Reed's strong entrepreneurial perspective stems from a dual academic and industry background, with teaching, research, and leadership experience at the University of North Carolina, the University of Illinois, and Microsoft.

Along with our Associate Vice President for Economic Development David Hensley; our state economic development director David Conrad; and our government relations team, Vice President Reed has affirmed the university's commitment to, as he himself has said, "a new, more robust partnership with the citizens of Iowa, state and local organizations, and our sister universities, bringing all of our assets to bear on the challenges ahead in this rapidly changing, globalized world."

Dan has envisioned what he calls a new compact with our state to work in partnership in order to accelerate business and cultivate Iowa's workforce. The prongs of this compact include turning research ideas into innovative technologies for companies, creating startups and jobs, solving business problems, and providing business and IT training not only on campus but in communities across the state. I won't go into all the details or pieces of this ambitious economic development plan, but let me highlight a few initiatives.

Our region itself is thinking in new ways, and that includes a branding initiative called the Iowa Creative Corridor. This is a regional alliance in the Iowa City and Cedar Rapids area that, in the initiative's own language, is working to "connect, celebrate and support all those who dream big, push boundaries, and create here. The 'Big Idea' is one region creating, living, building together and being a globally known magnet for creative people, families and commerce," with the goal of "an ever-thriving region, with residents building innovative organizations, participating in vibrant communities, and exuding so much pride that we're known around the world."

The Creative Corridor has been doing much to promote and encourage innovation and entrepreneurship through traditional and new social media, summits and other programs, and a "We Create Here" pride campaign. Along with the long-standing Iowa City Area Development Group, a more traditional but still highly innovative organization, our university research enterprise is building many more connections through community and corporate partnerships.

Our UI Partners initiative focuses on the direct business assistance piece mentioned earlier. We created UI Partners specifically to help small Iowa companies innovate and grow. We want to work directly with businesses to solve their information technology (IT) challenges, using practical insights and ideas drawn from university faculty, staff, and students. We also will provide free IT needs assessments for businesses, whether it be about creating websites, managing databases, e-commerce or general tech support, as well as general business planning. And we bring leading-edge informatics expertise and business training to organizations, startups, and established businesses, too. I mentioned again that aligning our research and economic development activities with student learning is beneficial from all directions, and UI Partners also gives students opportunities to work on projects that allow them to build their résumés while connect with innovative Iowa businesses.

The University of Iowa is also eager to help create new startups and jobs in addition to providing support to existing businesses. This is the purpose of the UI Ventures initiative. This project works somewhat in the opposite direction of UI Partners in that we are working to bring funding, venture capital, mentors, executives, and entrepreneurs to the university in order to assist our faculty members, postdocs, and students in accelerating their own startups and entrepreneurial projects.

One other new initiative that brings UI expertise directly to Iowa communities is our planned engagement centers, co-located with Iowa's community colleges. We are creating the first one at home in Iowa City and are working on opening one in the near future in Council Bluffs in western Iowa. These integrated centers will leverage University of Iowa expertise and assets onsite to meet the needs of Iowa businesses and communities in such areas as information technology, leadership, entrepreneurship, and workforce development, training, and retention, all directed toward the specific needs of the local area. Our larger vision is to secure state funding in the future for a network of these engagement centers across the state.

Let us move to our third area of playing a new game: interdisciplinary approaches. I think we all understand that the problems confronting our world today are not one-dimensional. They are not always neatly mapped to traditional disciplines. The pressing issues, or grand challenges, of our time—such as human health, climate change, and international conflict—require interdisciplinary approaches. We must break down the siloes we have often built within our institutions. Businesses and other types of organizations are doing it all the time these days, and we must continue to do so as research universities.

At Iowa, like a number of other institutions, we have proactively constructed interdisciplinary teams over the past few years in our faculty hiring through clusters. The primary objectives of the Cluster Hire Initiative are to (a) address important scientific and/or societal challenges; (b) promote multidisciplinary research, scholarship, and creative work; (c) advance undergraduate and graduate teaching and learning; (d) enhance community engagement and service; and (e) benefit the people of Iowa and beyond.

Our cluster hire initiative has developed on campus through a competitive process, building on our current strengths while also forging paths in new directions within those areas of strengths. Since we began the initiative, we have developed innovative clusters in a diverse array of subjects and have added a number of talented new faculty to our institution who effectively cross departments, programs, and colleges. These new cluster areas are water sustainability, public digital arts, public humanities in a digital world, the aging mind and brain, genetics, obesity, and informatics.

While not part of our cluster hire initiative, and while not a full-fledged dedicated faculty program, I would like to mention one other area where Iowa has done some innovative things in order to capitalize on our strengths. As I mentioned earlier, we have a world-class academic medical center on our campus. That has led to some obvious strong cross-disciplinary work, such as in biomedical engineering, where, for example, we have become leaders in simulation, as I noted earlier.

But Iowa also has very strong humanities programs. For example, as "the Writing University," we host the world-renowned Iowa Writer's Workshop, the top nonfiction writing program in the country, and many other prominent writing programs. In recent years, then, medical humanities has become an innovative and successful area of development at the University of Iowa. I don't have space to discuss these programs in detail, but just the list suggests the impressiveness of activity in this burgeoning area of inquiry: the Program in Bioethics and Humanities, a research and education consortium within our Carver College of Medicine; the Writing and Humanities Program in the Carver College of Medicine, which offers individual consultation on medical students' writing, writing and medicine electives, extracurricular activities, writing contests, and more; the Humanities Distinction Track, an official credential available to our Carver College of Medicine students; the Medical Student Humanities Interest Group, which coordinates student-initiated activities; conferences and symposia, such as the annual conference (now in its ninth year) entitled "The Examined Life: Writing, Humanities, and Arts in Medicine," and this year's "Health Humanities: Building the Future of Research and Teaching" symposium, a working symposium through the UI's Obermann Center for Advanced

Studies; and a professional creative writing journal, *The Examined Life.*

Of course, as we shift to more interdisciplinary work, we need to provide facilities that foster and facilitate it. One example on the UI campus is a new facility I mentioned before, the Pappajohn Biomedical Discovery Building, which, as I said, will house the Fraternal Order of Eagles Diabetes Research Center and other centers and groups. Writ large, the building houses the newly formed Pappajohn Biomedical Institute. Within the concept of "biomedical discovery" is the goal of breaking new scientific ground by pushing and crossing traditional disciplinary boundaries. This project houses generic wet laboratories with appropriate support space and core facilities to foster a new investigative model that allows interdisciplinary research teams to focus on specific research problems. The institute and building emphasize greater collaboration, exploring high-risk and high-yield questions, and making the bench-to-bedside nature of research even quicker and more effective than ever before. By enhancing clinical translation, we realize better treatments and outcomes for patients, and better lives for all.

As I suggested earlier, university research is not—if it ever was in the first place—a self-contained part of the academic enterprise. But especially in these changing times, we need to integrate research with the other two legs of our mission stool: teaching and service. And as we do so, we need to demonstrate to our publics the value of research to these other core missions. Many institutions are now using the language of the Kellogg Commission on the Future of State and Land-Grant Universities that recasts our core missions in terms of learning, discovery, and engagement. None of our activities can any longer be conducted in isolation.

The links between graduate education and research are obvious, but we must also continue integrating the research enterprise into undergraduate education. I often tout the benefits of attending college at a research university with high school (and even younger!) audiences. Recent examples include a Rotary Youth Leadership camp in Grinnell, Iowa, and a group of students on campus in a program called the Secondary Student Training Program. The latter is a program run through our Belin-Blank International Center for Gifted Education and Talent Development, and it's for tenth and eleventh graders interested in STEM areas. These talented young people are on campus for five weeks during the summer, conducting scientific research in university laboratories under the guidance of a faculty mentor. They also produce a research project/paper as a part of the program. Let me just share with you what I said to them:

> The research university is a very special place. It is in the laboratory, the library, the faculty studios and offices of a research university where the most cutting-edge knowledge is created and discovered. A research university is doing its job best when that cutting-edge knowledge makes its way to the general public and into undergraduate classrooms. And I think a research university is achieving its pinnacle of success when undergraduates are actively engaged in

the research itself. So a research university is a great place for a college education!

Of course, the most direct and common way that our faculty research is shared with our undergraduates is when they present and discuss it in their classrooms. But young students need to be actively engaged in the research process, too, and we have to be sure to provide the infrastructure and encouragement to make it so. At Iowa and s number of other institutions, many undergraduate students have opportunities to work in labs and on research projects as interns, student employees, or undergraduate assistants, as well as through special projects, as our UI Honors students do.

At Iowa, though, we take extra steps to make sure these opportunities happen, that students are connected with them, and that students are supported and encouraged in their research activities and interests. The Iowa Center for Research by Undergraduates (ICRU) hosts numerous workshops and information sessions for students covering a range of research-related topics, and it serves as a clearinghouse for information on research opportunities across campus. ICRU staff also provide direct support to students interested in seeking research opportunities, and faculty and staff in search of student researchers. ICRU hosts bi-annual undergraduate research festivals, which provide an opportunity for undergraduate researchers to present their work. We also participate in the "Research at the Capitol" event, along with Iowa State University and the University of Northern Iowa, when students display their research in the State Capitol Rotunda in Des Moines. ICRU also recognizes outstanding undergraduate researchers and faculty mentors with special awards. The program also provides research support and funding for students working with faculty, including the ICRU Research Fellows Program. Each year, 150 students are selected by mentors to work on research projects and receive $2,000 to $2,500 scholarships for doing so.

We also need to bring the big questions of our faculty and institutional research into the classroom in new, inquiry-based ways. At Iowa, we're doing that through our new TILE classrooms. TILE stands for Transform, Interact, Learn, Engage. Faculty need to be trained as TILE instructors, and the goals of the initiative are to transform teaching practices through lively interaction, enhanced learning, and increased faculty/student engagement. TILE instructors pursue student-centered, active learning for a classroom built around the issues of pedagogy, practice, and technology. Our TILE classrooms—of which we have several now on campus—are equipped with circular tables, laptops, flat screen monitors, multiple projectors, and whiteboards to encourage and support collaborative and engaged active learning. The faculty workstation is not at the front of the room, as with a traditional lecture-based classroom, but instead in the middle, creating a free-flowing learning environment where the lines between instructor and student are shared and blurred.

A new initiative that utilizes TILE classrooms to engage students with our faculty's research is what we're calling TILE-Constellation Courses. The first of these was offered this past academic year, called "Origins of Life in the Universe."

This year-long course involved six of our top faculty in physics and astronomy, biology, geosciences, and anthropology. The class emphasized inquiry-based activities to build success in critical thinking, teamwork, and effective written and oral communication. Topics presented included the origin of the universe, the biochemistry of life, the origin of life on Earth, the evolution of life on Earth, the origins of humans, and the prospect for finding life elsewhere in the universe.

Experiential learning is another important area of emphasis for today's students, and at Iowa, entrepreneurship is catching fire and connecting undergraduates to our faculty in real-world applications of their business acumen. Economic development and student engagement meet in our entrepreneurship certificates (including technology and the performing arts), the John Pappajohn Entrepreneurial Center, and the Bedell Entrepreneurship Learning Laboratory.

The John Pappajohn Entrepreneurial Center is housed in the Tippie College of Business, but it is a collaborative effort in partnership with the Colleges of Engineering, Liberal Arts and Sciences, and Medicine. JPEC offers a wealth of programs for our students, including business plan and elevator pitch competitions, seminars and workshops, and actual start-up business support in the Bedell Entrepreneurship Learning Laboratory. JPEC also offers similar programs and consultation to businesses and entrepreneurs throughout Iowa.

The Bedell Entrepreneurship Learning Laboratory is a business incubator for entrepreneurial students pursuing the creation of a startup while attending the University of Iowa. Individual students and teams in the program receive a dedicated office space in our remodeled 10,000-square-foot facility, allowing them to concentrate on developing their business concepts. Bedell students also benefit from one-on-one mentoring and coaching from our faculty and professional staff, funding opportunities, workshops and training, and networking and community exposure. Dozens of successful businesses have spun out of the Bedell Lab, including those that offer design services for communities and charities; a mobile app to encourage recycling; genetics and genomics research software; a free information-sharing site called ClusterFlunk.com that provides a virtual meeting space for students taking the same college courses; and much more.

Although I'm emphasizing student entrepreneurship here, we also have a growing number of programs and facilities that focus on business and research spinoff incubation for our faculty, staff, community and corporate partners. These include our long-standing UI Technology Innovation Center, as well as our relatively new UI BioVentures Center, which includes wet labs for life science companies. The Iowa City CoLab is a partnership between the university, the Iowa City Area Development Group, and several corporate partners, providing space and economic development and workforce development services for interstate commerce companies in our service territory. And the UI THINC Collaboration Space is a new additional innovation and collaboration student space. THINC is collaborative-friendly, featuring comfortable furnishings, whiteboard walls, and a gaming room to help augment creativity. THINC is ideal for entrepreneurial students who are in the early stage of business development and need a space to meet with business partners or mentors. Students can also use THINC to meet with business consulting clients or work on team projects. And it's a great study space, too!

In addition to the teaching and learning arena, we must demonstrate our research value in terms of public engagement. I have already talked at length about economic development and entrepreneurship in other contexts, so let me highlight here a couple of other ways we are pursuing public engagement at Iowa.

Perhaps the most obvious way our faculty and staff can take our research to public awareness is direct contact. Of course, many of us have done this in myriad ways for many years. At the UI, we're redoubling our efforts to bring the best of our faculty work to Iowa citizens through the new Hawkeye Lunch and Learn series, which we launched in 2014. Sponsored by the Office of the Provost, these monthly presentations aim to build connections among Iowa communities, university faculty, and industry and government leaders. We want to highlight ways the university is working with partners across the state, strengthening existing relationships, and creating new ones. The monthly talks are presented first in Des Moines at the UI John and Mary Pappajohn Education Center. They are also streamed online and then re-presented at home in Iowa City. Our presentations so far have been wide-ranging. Provost and Engineering Professor Barry Butler spoke on "Wind Energy: Past, Present, and Future." J. A. Van Allen/R.J. Carver Professor of Physics Don Gurnett discussed his role in the Voyager 1 and 2 missions launched in 1977. UI Chair in Public Affairs, former Congressman, and former Chairman of the National Endowment for the Humanities Jim Leach spoke on Nazi seizures of art, which was the basis for the recent film *Monuments Men*. Neuroscientist Steven Anderson discussed "The Aging Brain in the Workplace: How's That Going to Work?" Art and Gender, Women's, and Sexuality Studies Professor Rachel Williams shared her work with women's studies students at the Iowa Correctional Institution for Women facilitating classes about healthy relationships. Curators from the new UI Mobile Museum talked about this collaboration between the Office of the State Archaeologist, the Old Capitol Museum, and the UI Museum of Natural History. The Mobile Museum is a 38-foot, custom-built RV featuring exhibits on Iowa history, archaeology, and paleontology, as well as an interactive digital wall that allows visitors to explore UI research and creativity (and yes, the Mobile Museum itself was also there). And Sean O'Harrow, Director of the University of Iowa Art Museum talked about "Two Years in the Life of Iowa's Most Famous Painting." Sean discussed our most famous piece in the collection, Jackson Pollock's painting *Mural*, which has recently undergone technical study and conservation treatment by research scientists at the Getty Conservation Institute and conservators at the J. Paul Getty Museum in Los Angeles. In July 2014, we celebrated *Mural*'s return to Iowa, exhibited until April 2015 at the Sioux City Art Center.

One other innovative initiative that is bringing multidisciplinary UI expertise to our state's communities, with a special emphasis on opportunities for graduate research and learning, is the Iowa Initiative for Sustainable Communities. Founded in 2009 by Charles Connerly, director of the UI's School of Urban and Regional Planning, the IISC has grown into a campus-wide initiative that helps Iowa's communities build more sustainable futures by addressing the economic, environmental, and socio-cultural issues of today. The IISC previously matched Urban and Regional Planning graduate students with projects in a number of Iowa communities (transportation, local foods, energy, community gardens, waste systems, etc.). Now, the expanded IISC is funded through the University of Iowa Office of the Provost; supported by the Office of Outreach and Engagement; and administered through the School of Urban and Regional Planning. IISC now has a dedicated coordinator, graduate assistant, faculty/staff advisory board, and campus-wide affiliated faculty and staff.

The most extensive project so far has been with the community of Dubuque. From 2011 to 2013, IISC partnered with Dubuque's Sustainable Dubuque Initiative on such areas as sustainability indicators, renewable energy, poverty, local foods, and the Green and Healthy Homes program. Not only did our work in Dubuque earn rave reviews in town and back on campus, but the nation noticed as well. I am very proud that Dubuque was recognized in *The Guide to Greening Cities*, published in 2013, as a national leader in developing sustainability partnerships, with our IISC Dubuque partnership highlighted. And we were even more proud that our graduate students involved in the Dubuque project received the 2013 Student Project Award from the American Planning Association's American Institute of Certified Planners, the organizations' highest honor for a planning student project.

Let me just briefly summarize my suggestions on how we might think about "playing a new game" in the current public university landscape. First is research portfolio diversification, seeking new partners for our individual institutions in governmental and industry funding. Second is seeking new partnerships outside of the traditional government and industry sectors—in, for example, the nonprofit sector, nontraditional private partners, regional economic development, and entrepreneurship. Third is increasing our commitment to interdisciplinary approaches, capitalizing on our institutions' current strengths and forging new paths through cluster hires, innovative new programs, and new facilities that encourage interdisciplinary work. Amidst all this, we must nurture programs that bring our research expertise into our core missions of undergraduate education and public engagement.

As with anything in life, these ideas are easy to say but not always easy to do. I hope I've demonstrated to you that we are hard at work implementing these ideas at the University of Iowa, and we've done so through a commitment to innovative thinking. But even once we actually have "boots on the ground," so to speak, implementing new programs and approaches, there are still fundamental policy and practical implications for us as institutions. These policy implications can be challenging and certainly need to be addressed at the same time we are shifting our approaches to the research enterprise. Let me just suggest three important areas that must be confronted to play this new game.

The first is probably obvious: continued advocacy for federal research funding. We know that the federal budget is constrained and that there are forces in Washington advocating for continued cuts, including cuts in areas where we have traditionally enjoyed rock-solid support and ongoing growth. We must remain vigilant and redouble our institutional advocacy for the nation's research enterprise.

Second—and of course this is also related to funding, but more at the state and private level—we must create the physical space for new approaches to happen. These include spaces that are flexible enough to encourage interdisciplinary research, as well as classrooms that support inquiry-based learning.

And third, we must continue to revisit our standards for promotion and tenure. Traditional publication, of course, can and should remain important to the promotion and tenure process. But we must also develop real standards and commitment to these areas that have often been more difficult to measure and/or have sometimes received little more than lip service in the promotion and tenure process: interdisciplinary work, innovation and excellence in teaching, and public engagement. Just one example: at Iowa, I have appointed an Associate Provost for Outreach and Engagement, and one of her projects is to work on a method of capturing faculty engagement activity—and of course defining it in the process—so that we may also have some consistency across campus when we talk about faculty achievement for promotion and tenure.

Change is daunting, no doubt about it. But the university has always been about change—the very essence of discovery is the new. Public universities can be difficult ships to steer, but if we're doing our jobs right, we as teachers, researchers, and administrators are always moving them into new, unexplored waters. That needs to include how we go about doing our business as well as what subjects we wish to explore.

The University of Iowa began over 165 years ago with a handful of faculty, one building, and a few dozen students to teach. Today, we are a world-class, multifaceted enterprise with over 30,000 students. We conduct groundbreaking research in myriad areas for the betterment of all society, we pursue creative endeavors that the whole world recognizes and is inspired by, and we are engaged with our community and state, making life better for all Iowans, in ways our university founders probably never dreamed of. We wouldn't have gotten where we are today if we had not planned and innovated in uncertain times. After all, what times are ***not*** uncertain? Haven't we been successfully navigating new waters since the beginning? Hasn't that always been our stock in trade?

Engaging with the Private Sector: Nebraska Innovation Campus

Harvey Perlman, Chancellor, University of Nebraska

On April 18, 2008, Nebraska Governor Dave Heineman signed Legislative Bill LB1116 into law, requiring that by 2010, the Nebraska State Fair move from its historic location on 250 acres adjacent to the University of Nebraska-Lincoln to the center of the State in Grand Island. In turn, the bill transferred the property to the University for the purposes of creating Nebraska Innovation Campus. The bill was enacted in the Nebraska Unicameral with only 3 dissenting and 2 abstaining votes, but that did not reflect the intense controversy that led up to its passage.

The University along with several influential business leaders in Lincoln initiated the proposal. The State Fair Board strongly objected. As a statutorily designated member of the State Fair Board, I quietly stopped attending the Board's meetings. The original proposal would have moved the State Fair to another site in Lincoln but, in the end, an agreement was negotiated in which the $50 million cost of moving the Fair was borne in various amounts by the City of Grand Island, the State, the University, and the Fair.

As a Fair Board member I knew the condition of the fair grounds. No significant investment had been made there for decades as attendance at the Fair had consistently declined. The buildings were in a sad state of decay, some were no longer open to the public. The utility infrastructure, including water, sewer, and electricity, needed significant upgrades.

It was clear to me and others that the Fair Board had neither the resources nor the revenue to invest in the property and the future of the Fair itself was in jeopardy. But tradition in Nebraska dies hard. Notwithstanding that since the move the State Fair has prospered in Grand Island far beyond anyone's imagination, there are those who mourn the loss of the September event in Lincoln as well as the economic benefits it was assumed to bring to the city.

So why would the University embroil itself in such a controversy and, more significantly, why would business leaders in Lincoln as well as the City itself support the legislation? And why would the Legislature come eventually to overwhelmingly support adoption of the bill? The reason was the prospects of what a new Innovation Campus could do for the University and the economic future of both the City of Lincoln and the State of Nebraska.

Our proposal, certainly not in itself unique, was to create a research and technology park designed to attract private sector companies to locate adjacent to the University to engage in joint research or other relationships with the University. We predicted that the University would occupy one-third of the campus and private sector companies or amenities would occupy two-thirds. Because of the flood plain issues, of the 250 acres, approximately 120 acres are available for development, allowing for approximately 2 million square feet of leasable building space.

We predicted that the campus could generate 5000 jobs and would take from 15 to 20 years to develop. While companies from any sector would be welcome as long as they had a relationship with the University, the priority themes of the campus would be "food, fuel, and water" reflecting the obvious strengths of the University and the primary economic drivers of Nebraska.

During the legislative process I often argued that the infrastructure on the property was obsolete and the Fair had no resources to replace it. With the transfer of the property to the University I discovered, unfortunately, that I had been right about the infrastructure and I was in no better financial position. However, we were able to select a private developer who was willing to make some initial investments, as well as utilize TIF financing to move the project forward.

To date, we have opened two buildings with office space and a conference center. Two more food science laboratory buildings and a set of green houses are under construction. With the exception of the Conference Center, all buildings are owned by and leased from the developer. We have signed our first major private sector tenant, ConAgra Foods, who will expand its joint research with our Food Science Department, a department we intend to move in its entirety to Innovation Campus.

From the outset we understood that we could not attract private sector companies to locate on a property that was managed by the State and subject to the associated regulatory processes. We created the Nebraska Innovation Campus Development Corporation, an independent 501(c)(3) company managed by a Board of Directors, a majority of whom were from the private sector. NICDC has a ground lease from the University's Board of Regents for the entire property and is the contracting party with the developer or with any future tenants. Thus, the commercial relationships between NICDC and the private companies are shielded from public records laws and other public regulations.

In addition to traditional partnerships with the private sector, two additional facilities are planned for Innovation Campus. The first, an accelerator for start-up companies, will be designed to give a short-term boost to enhance the prospects for success of early stage companies.

The second is what we are calling a "Maker Space." Conceptually, it will be a space with a variety of tools, equipment, and supplies that will allow students, faculty, or community members to join a "Maker's Club" and then to use the facility to "make stuff." We announced a student "Maker's Club" and within three months it is the largest student organization on campus with over 400 members. We hope this, and other activities, will create a real innovation culture that will spread to the rest of the university.

So, what does all of this have to do with the future of university research? At the risk of stating the obvious, it seems to me there are at least three trends that must be accounted for as we plan our research future.

First, there is the macroeconomic phenomenon that, while innovation is a major driver for economic growth, most public companies are withdrawing from investments in basic research. Driven by the market demands of quarterly income statements as a determinate of stock price, long-term investments without short term returns are problematic. And there is nothing more long-term or uncertain as basic research. Yet, companies also understand they must position themselves to access research that has commercial value and that research takes place largely within universities. Thus there are market forces that make university-private sector partnerships essential.

Second, the continued level of federal research support is uncertain, particularly in this period of political dysfunction in Washington. If Universities are to sustain their core research enterprise, it seems sensible to diversify our sources of funding. Other potential sources are the private sector, international engagements, philanthropy, and internally generated resources.

Third, the political pressure on government expenditures, like the pressure on private sector companies from quarterly income reporting, causes even public funding agencies to demand more evidence of returns from the investments in research. We all know this is shortsighted but we would be foolish to ignore it. Increasingly, federal research funding programs are insisting on proof of commercialization prospects for research proposals or insisting that private sector companies be a partner in funded research.

As seems obvious, all three of these trends dictate that universities develop stronger ties with the private sector as an alternative source of research funding.

Of course, as we have discovered, this is easier to say than to accomplish. Merging the different cultures into a partnership presents some unique challenges. And attempting to account for success or failure also has its complexity. What follows is largely a random set of issues we've seen and steps we've tried to take to address them. They are presented descriptively, not normatively, since it is too soon to know what will be successful and what will not.

The "myth" of adjusting to the "speed of business." We have often heard from business leaders how bureaucratic Universities are and how slow we are in making decisions. If only we could act at the "speed of business".

Of course some of this is true. Public accountability and regulation inevitably build delays into any public organization's decision-making. But private sector companies can also have elaborate bureaucratic processes, particularly when making significant, long-term investment decisions. Market forces can be unrelenting. A change in stock price can instantly alter a company's priorities or at least slow decision-making. Negotiating with several potential partners in recent months convinces me that engagement with the private sector can require patience and flexibility. It is also true, however, that one must be ready to respond quickly when a company is ready to engage.

The agreement. Particularly in relationships with companies that are expected to be on-going rather than one-off transactions, reaching a long-term agreement can be a challenging proposition. Private sector lawyers, and university lawyers, are paid to protect their clients from the unexpected. Of course this is a non-sequitur because one cannot plan for the unexpected. Similarly, in longer term relationships, neither party wants to be constantly renegotiating a contract or be in a position where each new initiative requires a new agreement.

We have worked hard to develop master agreements that handle all of the major issues that are likely to arise. Our goal is a situation where, under our master agreements, the only elements needing negotiation for a new initiative are the scope of work and the price. Issues of accountability, reporting, intellectual property, and dispute resolution should all be within the master agreement.

Indeed, probably the most important term of a master agreement is the dispute resolution provisions. You can be assured disputes will arise, and they can do so at the researcher level, at middle-management, or elsewhere in the two organizations. We have tried to include a term in our agreements that specifies how a dispute rises through both organizations for resolution. So, for example, in one of our agreements a dispute at a lower level rises to my office and the company's research vice-president. At that level we hope to negotiate a resolution. This allows the dispute to be put in context of the entire array of joint activities and interests.

In a long term relationship, one cannot look at a single dispute in isolation but rather it must be examined in the context of the larger relationship. (My father was an auto parts wholesaler and he always told me that it doesn't hurt to give into a long term customer on a dispute, even if that customer is wrong. You can always get even in the next transaction.) If we cannot resolve it, the dispute goes to a professional mediator and if not resolved there, to mandatory and binding arbitration. Similarly, if a dispute arises over the relative intellectual contribution to an innovation, a third party expert is brought in to resolve the dispute.

Having a good dispute resolution process relieves the pressure to attempt dealing with the unknowable. In the end, the goal should be a relationship of trust where if one has to ever pull out the master agreement after it is signed, something has gone wrong.

Intellectual property provisions. There is a vast literature on attempting to resolve the IP considerations when engaging with private sector companies in research and I don't want to repeat it here. These are difficult and complex issues.

The respective interests change depending on whether the research is jointly funded or individually funded by the company and the extent to which either of the parties brings background technical information to the research. There are several models. In the ideal world, the parties can agree on a mechanism that is based on objective criteria and is essentially automatic with no room for disputes around valuation or likely commercial success. One has to remember that a private sector research partner may be more sensitive to the competitive advantage of a technology than they are to the market value of that technology.

In the end, the terms will likely be driven by whether the university regards its involvement in these relationships as short-term or long-term. In one-off licensing deals, I have always thought the University should be fairly compensated for its innovation. In longer term relationships, there are often returns beyond royalties that may suggest a less aggressive posture. And establishing a methodology avoids the costs of constant negotiation over IP rights for each innovation that is produced by the joint enterprise.

Faculty, of course, have significant concerns going into a research relationship with a private company. Since under our rules the faculty member is entitled to a share of the licensing or other revenue from an innovation, the IP terms are of personal interest. But they also want to be assured their inherent skill and experience is not exclusively acquired by a single company—that they are free to engage with other companies on similar but unrelated projects. One has to assure faculty that the University is not selling them into indentured servitude and one has to fight hard on their behalf to make sure this doesn't happen.

Organizational Structure. As I have alluded to, the returns on the investment in private sector relationships can come in many forms, sometimes in unusual and unexpected ways. This is particularly true in longer term relationships but sometimes in one-off transactions as well. In organizing our effort to engage with the private sector we have created what is perhaps a structure that is idiosyncratic and based more on the personnel in place rather than on any organizational theory.

We have two separate 501(c)(3) companies managed by separate boards with a majority of private sector members. We have spun off the commercialization of faculty innovations into NUtech Ventures, a private company with a mixed board of directors from the university and the private sector. As I have mentioned, we also have a separate company with a separate board and CEO managing Innovation Campus. We also have an "industrial relations" unit of our Office of Research and Economic Development designed to foster private sector research engagements.

In one of our negotiations with a major international company to license University technology, we ended up accepting a license royalty, a significant philanthropic gift, and a research agreement, all within the same transaction. And we still have some hope they may locate on Innovation Campus. It was not rocket science to realize that one ought to think holistically about relationships with the private sector. The key is the relationship and benefits can flow in both directions in a variety of different forms. Initially we worried that the natural instinct of the CEO of NUtech Ventures, for example, would be to channel a company's interests toward licensing technology and the head of Innovation Campus would push toward a physical presence on the property. This circumstance is not likely to maximize the University's interest.

We have created a team approach where all three directors get credit for an engagement with a private sector company regardless of the nature of that engagement. We have a bonus plan where individual bonuses are calculated on the overall success of our engagement with a private company. It's not clear to me this would work were it not for the personalities of the people involved. The point though is that when engaging the private sector one ought to have multiple definitions of success and eliminate barriers that may reduce the overall returns to the University.

In conclusion, I think we are far beyond the question of whether we should engage with the private sector in research partnerships. I believe that is a given and a necessity. However, there remains much to be considered in how these relationships are structured, implemented, and assessed. Getting these items right will have a lot of influence on the future of our research enterprise.

Adaptive Planning in a Chaotic Research Environment: Aligning Academic and Business Issues

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It has become a commonplace that higher education today exists in an environment of fundamental change that is often unpredictable (Christensen and Eyring 2011; Duderstadt 2012). It is not just that there is serious change underway; change in the research environment and other areas is strongly interactive, such that change in one area ripples through other areas. Formal planning will be especially important, given the volatility of the higher education environment, but planning as usual won't be effective, given that strategic planning is often seen in a rather linear manner—as something that keeps institutions on a fixed path (Academic Impressions 2013). Changes in the environment are often seen as emergencies which are seen as abnormal conditions from which we need to recover or get back on track.

Change—especially in the intermediate or long term—is not abnormal. Moreover, as noted above, it is multidimensional, with different kinds of change interacting in complex ways. Good plans must be dynamic and adaptive to accommodate the rapidly morphing environment. But equally important, they must provide direction such that infrastructure, human resources, IT capacity, and other critical elements—things that often require a long time and large investments to be achieved—are present to support high-impact research and other academic functions.

In this paper, I take a broad anthropological approach to examining how we can at the same time be adaptive and have effective, long-term direction, with particular attention to academic research. The relevance of Anthropology is that anthropologists routinely deal with extraordinary complexity: human evolution, changing environments, fundamental cultural differences, differences in economic, social, aesthetic, linguistic, and political norms and much more.

Dimensions of Change and Volatility

Given that the change that is currently challenging Higher Education is multidimensional, it poses particularly difficult challenges to planning. It is perhaps useful to approach the issue in three overlapping steps: (a) external (environmental) and internal changes, (b) Higher Education's responses to these challenges, both on the <u>business</u> side and the <u>academic</u> side of the universities, and (c) adaptive planning in a chaotic environment. Because of the close connections among the many factors, and given that a simple, linear representation of the changes is not possible, the presentation will be somewhat redundant and circular.

<u>External, or Environmental, Changes</u>

Most (but not all) of the environmental changes have their direct impact on the business side, and they take several fundamentally different forms: very broadly, resources (core revenue, research funding, expenses), international environment, regulation and compliance issues such as export control, classified work, fiscal management, general accountability, IT changes, and relations with private business sector and other constituencies. There are many other significant areas of change, but to discuss each one would not be possible in this context. Those listed here, though, need special attention in relation to planning.

Resources, of course, receive a great deal of attention in the press, in policy discussions, and in planning on campuses. There is a great deal of concern about core institutional funding. This is about state appropriations for public institutions—a resource that has decreased steadily for more than ten years (Schulenberger 2012: 82-86), and there is little optimism that this trend will be reversed significantly in the foreseeable future. Philanthropic fundraising and endowment income are less important for most publics and, although they are significant for most institutions, they are not a major part of core operating funds even for most privates.

A major source of core revenue for virtually all institutions is tuition, which has become a policy focus in several ways. Tuition revenue is profoundly affected by current demographics (especially decreases in number of high school graduates in many areas), competition within the education sector, and the changing distribution of potential students across socioeconomic, racial/ethnic, gender, international, and other categories. Moreover, tuition revenue is determined by a combination of the number of students and the level of tuition that they pay—the latter a matter of high visibility and political interest as affordability and access to higher education becomes an ever more important focus in political and policy arenas (Gardner 2014). In any case, there has been a strong trend for increasing tuition levels. Finally, student loan debt has become a very hot topic that could become a crisis should there develop a crash in the student loan business similar to that in 2008 in the financial industry—an issue that is of great concern to many in government and in higher education.

In the research area, resource issues are not just about decreases in funding (though there are serious concerns about this matter). In addition, there are many developments that restrict the use of funds. Priorities for research funding are changing, as reflected in distribution of funds across different agencies, in broader impact issues, and in recent congressional discussions about limiting the kinds of humanities, arts, and social science research that can be funded. Moreover, a very substantial amount of funding now comes from agencies such as Homeland Security, often in the form of contracts with specific deliverables. Contract work with the corporate sector has become an ever increasing source of research funding—again, with clear deliverables.

An ironic issue in the research area is that externally funded research and contract work—whether funded by government or from the private sector—often (one might say usually) does not fully fund indirect costs. Thus grants and contracts have to be subsidized by tuition, state appropriation, or other funding sources—in effect a substantial reallocation of core funds from their initial purpose (Lowry 2014). An interesting twist on the fact that F&A rates generally do not cover all indirect costs is that the problem of limited institutional core resources is exacerbated if the amount of funded research grows or is even held steady.

The international environment for American higher education is unpredictable but potentially of very high impact. One critical element is that the U.S. for cultural reasons does not generate a viable pipeline for people in the STEM disciplines, and a large proportion of students and faculty in science and engineering are of international origin. In addition, many Asian American students who come from recent immigrant families choose STEM fields and are very successful academically. But perhaps most daunting is the stunning investment that other nations (e.g., China, India) are making in higher education—on the one hand becoming ever more competitive with American institutions for students, and on the other hand, beginning to challenge America's prominence in research.

A significant international issue revolves around American security and intellectual property (IP) issues that touch on research. Although a substantial portion of the STEM research workforce consists of graduate students, many students cannot work on projects which are subject to export control restrictions. Similarly, export control places strong limits on international collaboration/communication of U.S. researchers. Security and IP regulatory issues are of real concern with respect to ensuring our national security; but our interventions produce side effects that are controversial (e.g., embargoing dissertations and faculty publications). These side effects can have significant impact on other critical academic issues such as scholarly communication, peer review, and promotion and tenure.

Compliance and regulatory issues go far beyond export control to areas as diverse as conflict of interest, IRB, SEVIS, and HIPPA, and have required substantial staff support for the compliance functions themselves, significant time on the part of faculty and staff, and the constant risk of significant penalties should there be lapses. State regulations on universities offering on-line courses to students whose home is in other states provide an excellent example of the costs of being entrepreneurial (though a fix on this one is in the works).

Technology change is a key environmental issue for higher education—especially changes in information technologies. IT has fundamentally changed instructional delivery (e.g., Chowdhury 2014), management systems, research methods, and much more. For example, recruiting students, admissions, registration, and academic records are now supported by ERPs, as is the case with accounting, HR management (e.g., hiring, evaluations, payroll), space allocation, and institutional research. Although such technology is often seen as a way of reducing costs, in general the IT systems are extremely expensive to install, maintain, update, and often to replace. Data storage issues have become daunting in several respects: for expense, for adapting as the technologies change, and for risk management (e.g., failure of a major data warehouse could be devastating).

Needs and demands of constituent - groups has become one of the most daunting issues facing universities, given the diversity of these groups—alumni, legislators, athletic fans, students and parents, professional organizations, donors, business collaborators, to name just a few. It is critical that the many groups have different, often conflicting, demands—e.g., research vs. instruction, access vs. rankings, or diversity vs. privilege. One constituency is particularly relevant to this paper. Increased interaction with the business sector on its turf is a significant environmental challenge. Higher Education business practices are similar to those of the corporate business sector, but there is a major difference in how a business and the business side of a university are positioned: the academic side of higher education is largely about creativity—i.e., research, arts, problem solving (see Foster 2006). This creative environment builds on a mindset that is all about finding new ways of understanding, of managing, of solving problems—of getting out of the box. Research, high-quality education, service functions—all of the academic functions are about doing something that has never been done before…something that by definition can't be structured. The point is that the sole reason for existence of the business side of the university is to support the academic side. This gives a critical perspective on academic business operations and on academic planning—on how one plans to do something that has never been done before… or how to plan to provide the resources/infrastructure necessary to do something that's not been done before. It is this interface between the business-side's responsibilities and the unconstrained creative environment of academic units/activities that sets the business side of the university apart from the business sector.

It is important to note that the business sector has a creative side, but this is not the core of the business practice in the same sense that it is in the academy. Clearly both the Universities and corporate businesses must adapt to the changing environment in order to survive, and such adaptation may even be a matter of creating new business models, products, and management processes. An especially interesting aspect of corporate creativity is product development. It is common for radically innovative product development in corporations to be separated from the management side of the business in a "skunk works" in which current design standards, cost issues, infrastructure, and other matters are kept from impeding creativity—from creating, say, a "new car" that is really just another Oldsmobile or Plymouth.

It is also important to note that the academic side of the university has its own regulatory/accountability processes to deal with—e.g., accreditation, peer review, rankings, IRB, and FERPA, though in the academic domain it is somewhat (if not perfectly) sensitive to the kind of free thinking that is the heart of creativity. This is a key element in the difference between the academic and business side of higher education: the interface between operations, regulation, and so on is sensitive and must somehow align the two elements. But increasingly, there is political interest in regulating the academic operations in ways not done in the past—e.g., specifying educational outcomes, constraining research funding in ways that determine what kinds of research can be done, thus creating an environment that significantly hampers creative activity in all fields.

The issues discussed above are primarily grounded on the business side of higher education, at least with regard to the direct impact. It is important to note that a key difference between the business side of higher education and the private corporate sector is that most of higher education has not been driven by a profit motive. This has changed significantly in recent years as universities are more engaged in economic development, in IP commercialization, in (hopefully) profitable on-line education, and in contract work. Economic development, contract work, IP development, and other matters bring higher education into direct interaction with the business sector on the latters' turf.

An interesting twist on this issue is the special place of basic research, which doesn't have an immediate, predictable ROI. This being the case, the private sector has all but abandoned basic research (e.g., the end of Bell Labs), which has been de facto outsourced to higher education and a few independent research organizations. Higher education now provides the subsidies that the private sector is unwilling to do. In addition, although many of the REALLY big IP opportunities come from important results in basic research, higher education is not

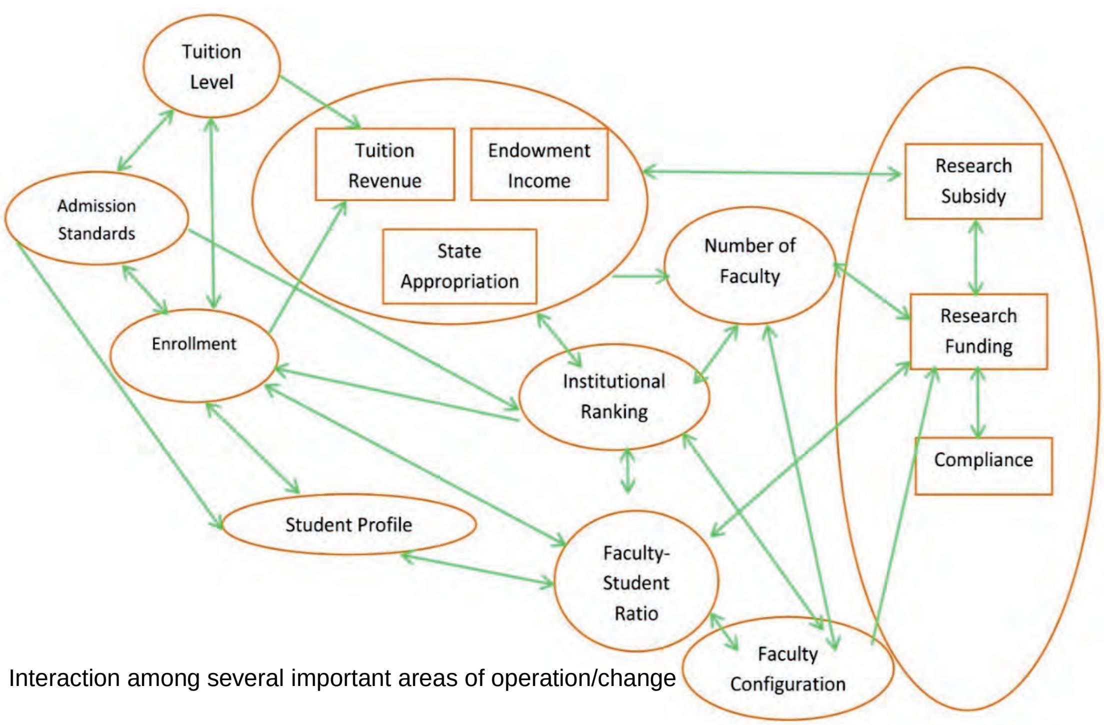


Figure 1: Interaction among several important areas of operation/change

well positioned to commercialize it—e.g., the costs of product development and the risks in protecting patents (e.g., from patent trollers). The convergence of public relations, politics, accountability, and related matters has come to affect finances (see above), enrollments, state appropriations, research funding, and much more. The point is that such issues can often hit a tipping point which could have game-changing impact on the fundamental business model of higher education, with profound effects on research **(Figure 1).**

Internal Change

Some of the most important change develops internally, though the complicated relations between institutions and their environments often make the internal/external distinction problematic. And the issue is made even more complicated by the differences among sectors. For example, much (perhaps most) of the major external impact is based on science and technologies that at the most fundamental levels were created by research universities. Thus, although the IT technologies themselves were not generally developed in universities, much of the underlying mathematics and science was.

That said, technologies have enabled extremely creative innovation in instructional delivery modes and other areas. Many of these educational applications were developed within universities, though it is important that corporate entities (e.g., Wiley, Pearson) are now playing a large part in their dissemination. And it is probably safe to say that the highest-level, most broadly used software for, say, simulation-driven hands-on learning classes will come from the private sector, as will the most sophisticated technologies used in on-line learning (Chowdhury 2014). Similarly, we are seeing profound technology-driven change in scholarly communication—especially scholarly publications. The issue is too complex to address here except to say that the changes involve both higher education and the publishing industry, with significant impact on publishing (especially university presses), libraries, the peer review process, and much more. The importance of these changes is that the dissemination and archiving of research results is at the heart of what we do in the research arena (Foster 2012).

More firmly within higher education, a groundbreaking research result could fundamentally change a University's research plan–e.g., by opening up new opportunities for translational research, for commercializing IP that arises from the results, and/or opening up whole new tracks of basic research. These outcomes are among the best of all possible research results, but they can also be major challenges. To take advantage of new research paths, major investments may be required or, worse, major past investments may become irrelevant. In addition, the potential for extremely large financial returns from developing some resulting IP can be (is likely to be?) claimed by corporate players who will challenge the patent necessary for the IP development. The costs of defending potentially VERY valuable IP in a patent challenge can be millions of dollars.

A more long-term structural kind of evolution is that, although higher education is very discipline-grounded, the disciplines have been morphing for a long time and they continue to do so. In some cases these changes may involve the emergence of new disciplines such as geospatial analysis, which involves the convergence of many disciplines and involves applications in areas as diverse as medicine, public health, journalism, law enforcement, and marketing. Moreover, some disciplines have merged and re-organized—especially in the biological sciences, which over the past several decades have seen merging and morphing of agricultural sciences, bio-engineering, medicine, microbiology, botany, biochemistry, and much more. Such changes involve significant adjustments to institutional structure (e.g., departments, colleges), to research infrastructure (strong links to the business side), to curriculum, to faculty socialization, to scholarly communication, to credentialing, to rankings, and to accreditation.

An important point to stress here is that planning for the unforeseen can involve potentially positive outcomes as well as negatives; not all surprises are bad news. But the magnitude of the positive challenges can be extremely large and complex, and IF a university is to pursue such opportunities, a plan must be in place.

Higher Education's Responses to the Current Volatility

Perhaps the most important observation about Higher Education's response to the current changes is that little or no fundamental change has taken place (see Christensen and Eyring 2011). There are a few exceptions, perhaps the most visible being Arizona State University's dramatic initiatives in course delivery, marketing, the Starbuck's project, enrollment management, curriculum structure, strategies for getting research funding, economic development strategies, and structure of academic units. But for the most part, higher education's responses have been short-term efforts to mitigate the challenges, with the goal of protecting the status quo rather than a long-term strategy and action plan for adapting to the deeper changes. The measures taken on the business and academic side differ greatly, of course, but the interactions are profoundly important.

In any case, all of the above environmental issues have profound implications for the internal academic functions, and the academic functions pose a daunting environment for operations of the business side. A key element of all the above is universities' research and increasingly important relations with the business sector.

Responding on the business side

Responding to change on the business side, the big focus is on revenue and expense, though the latter is somewhat problematic, since most institutions have a very limited understanding of their costs. In fact, many conversations with provosts and other administrators indicate that serious cost accounting is rare in higher education. One reason is that it is costly to do real cost accounting, both at the accounting level and, even more, at the level of creating the necessary data base. But perhaps more important, it just is not in the culture of higher education. The one area where significant cost analysis is done is research, as part of the input for indirect cost negotiations.

Increasing revenue dominates most of the discussion about funding challenges on the business side, and the most common item for discussion is tuition and/or, for publics, state funding (both issues with very complex and conflicting engagement of constituents). Increasing tuition revenue can take two forms: raising the level of tuition or changing enrollment patterns (e.g., increasing numbers, changing the balance of in-state and out-of-state, changing the balance of graduate and undergraduate, recruiting full-pay international students, or changing the distribution across different disciplines). But any changes raise issues with how financial aid is configured (ultimately the discount rate), and many issues concerning costs arise. Perhaps the most critical issues related to tuition and enrollment patterns are (a) whether the growth is in high-cost or low-cost programs, and (b) whether the programs have capacity to take in more students. These issues overlap in complicated ways; for instance, it may cost more to add twenty students to a low-cost program that is at capacity (leading to a step function in cost) than in a high-cost program with excess capacity, for which cost may be essentially zero. This raises a very difficult area of cost accounting: marginal costs.

Inevitably, such discussions will include philanthropic fundraising. This is, long term, an important topic, but it is not a short-term solution for big revenue changes, and in any case, for most institutions, even very successful fundraising will provide only relatively small changes in the institution's budget. It is also important to note that fundraising is not without significant cost, especially for an institution that does not have a robust structure in place.

Creating new revenue sources is the other topic that comes up frequently. The idea that on-line delivery of education could be a profit center is commonly raised, though some providers claim that on-line delivery is more expensive than traditional face-to-face instruction. Contract work often is mentioned—e.g., with corporate clients—but costs are generally not well understood, and pricing is problematic. Another commonly discussed approach is commercialization of intellectual property created by the university's staff, faculty, and students. Again cost issues—and risk of such things as patent trolling—are significant, and production of significant revenue is rare. Another important area for revenue creation is auxiliary operations such as book stores and residential life. Perhaps the main point here is that we need to be talking about not just revenue, but new net revenue (see pp. 26-27 on research funding).

The issue of savings almost always arises in these discussions. Perhaps the most promising are changes in administrative structures—e.g., shared services. Often major efficiencies can be achieved by fundamentally reengineering administrative systems (e.g., HR processing or academic support systems such as admissions). But many of the discussions are more vaguely focused on cutting certain support functions or eliminating degree programs. The latter rarely happens, and when it does, it tends to produce minimal savings, especially in the short term, since existing students must be served. In fact, many proposals for program elimination focus on humanities and social sciences, which tend to be instructional profit centers (significant enrollments, many service courses, and relatively low costs of delivery—one doesn't save money by cutting a profit center). Merging departments and/or colleges or schools also arises in discussions about cutting expenses, and again, real savings tend to be minimal without fundamental changes in curriculum, instructional delivery, research, and other functions.

In any case, higher education institutions most commonly address the financial challenges by short-term measures such as keeping salary increases at a low or modest level (a source of significant short-term impact, since salary is a very big part of college and university budgets). Another common measure is to defer maintenance and needed renovation—an action that is not highly visible in the short term, but which can add up to catastrophic consequences if pursued for a long time. A very common strategy, sometimes linked closely with enrollment strategies, is to hire more adjunct faculty, who tend to be paid less and teach much more than regular faculty—a strategy that has received a good deal of national discussion recently, both positive and negative.

Changing technologies have been adopted in many areas on the business side. Not everyone is a fan of ERP systems, but they have been very broadly adopted and among other benefits, they increase universities' ability to integrate data from HR, facilities, student matters as diverse as admission, financial aid, and academic performance. Electronic Medical Records have brought important changes to health care delivery. And social media has changed branding and marketing in virtually every corner of the university. Costs, risk management issues, rapid and often fundamental change, and strong opposition to certain technologies by some key constituencies pose daunting challenges, but overall the effects have been positive.

Compliance and regulatory requirements are not issues that can be avoided for the most part. The risks of failure are great, including public relations, potential civil suits, and severe penalties from regulatory agencies—e.g., financial penalties, loss of certification, or loss of research or other funding. That being the case, institutions' investment in compliance tends to increase constantly. This is an outcome that leads to more general conflict between the academic and business sides of universities, since it increases administrative costs in ways that often are not transparent and come at the cost of cuts (or lack of new investment, salary increases, and more) on the academic side.

Responding on the academic side

Responding on the academic side of higher education is dramatically different from the business side in part because it is embedded in centuries of tradition (highly sacred rituals that drive many behaviors and practices), accreditation, and a long list of other conditions. But as noted above, the most important issue is the underlying fact that the academic side of the university—certainly research and arts, but also instruction and many service functions—is primarily about creativity, and a closely related sacred idea is about academic freedom and faculty control of curriculum and research agendas—all very important ideas, even if sometimes used in ways that are not useful (especially from the business perspective).

Finding new revenue is probably the most important idea that arises from faculty—although it's also important to note that few faculty have a deep understanding of how revenues are generated. And most faculty, in line with most academic administrators, have little sense of the complexity of cost issues. Nevertheless, it is often the revenue side that dominates the discussion on the academic side. Many of the issues discussed above (i.e., regarding responses on the business side) are equally applicable for the academic side, though complicated by the highly principled ideals and practices of the centuries-long academic traditions.

Finding ways to cut administrative costs is another issue that arises frequently. This idea is entirely in keeping with the point that the university's or college's reason for existing is academic, and administration's function is to support the academic side. This concern has been fueled recently by media coverage of some research showing that in recent years, administrative positions have increased faster than faculty—a significant issue from all perspectives. Certainly the goal of cutting administrative costs by system redesign, shared services, and other initiatives (see above) are shared with administrators, though the precise content may not align so well. It is very common for faculty to have only limited understanding of various administrative functions or of the administrators responsible for them (as, it should be said, is true for many people on the business side who have limited understanding of functions, underlying mind-set, and focus on creativity on the academic side).

Focused investment in a limited number of strategic areas is another idea that arises in the academic side, generally with administrative buy-in. Such discussions usually focus on areas of strength and, correspondingly, at least some disinvestment to provide funds for the focused areas. Such ideas of focused areas most often are based in research, but have strong links to philanthropic fundraising, faculty hiring, state funding, corporate partnerships, and institutional stature. Although the very general idea of focus and supporting strengths is appealing to most academics, the actual implementation usually runs into resistance very quickly. One of the main impediments is the faculty focus on disciplines and the fact that many focus areas will be interdisciplinary. Some of this resistance is grounded in highly principled commitment to the disciplines in which faculty were trained, socialized, and in which they advanced their careers; but much is also based on protecting turf of departments and colleges.

Gaining efficiencies in delivery of curriculum seldom arises in faculty discussions—e.g., increasing the number of cross-listed courses, eliminating redundant courses or program elements that overlap multiple programs (e.g., research methods). Such matters run immediately into concerns about academic freedom and faculty control of curriculum—and, of course, usually unmentioned, issues of turf protection, which often are incentivized by budget processes, space allocation, and other business practices. Occasionally faculty will lean favorably to reducing or eliminating programs that just don't conform to their mind set—e.g., the unfavorable opinion those in a basic research area often have for applied programs in the same general area, and vice versa. Again, such issues are related to highly principled commitment to and belief in the underlying ideas of a discipline—and of turf protection or even expansion.

The international dynamics have become influential in day-to-day operations, in determining the vision for our future, and in creating a daunting competitive environment. Many of our academic moves internationally have to do with recruiting international students for reasons outlined above—e.g., to create a viable STEM pipeline and to generate tuition revenue. The dramatic growth of investment in higher education around the world will make the international competition for these students a major issue in the future. Ironically, there is a strong focus on integrating the international students into American universities and getting them functional in English, while American study abroad programs are far less likely to stress language competency and social/academic integration in the foreign university. This is an imbalance that will have a strong negative impact on the U.S. global positioning in the future.

Global collaboration—and competition—in the research domain is one of the most important elements of the future success of the U.S. Many related issues have been mentioned above—e.g., the negatives include export control and strong investment in research by China and India and elsewhere. Many universities have strongly supported international research collaborations (e.g., conferences, research time abroad for faculty and students) but they are in the early stages of development, and their political, policy, and public relations future remains uncertain. The only thing that is certain is that research in many fields in our universities MUST develop effective international collaborations/competitive positioning if it is to be effective over the next few decades.

Compliance and regulatory issues are extremely relevant to the needed progress in international effectiveness, on both the research and educational side—e.g., for economic development and medical care, as noted above.

In addition, the regulatory, compliance, and accountability issues on the academic side raise critical challenges. As noted above, compliance on the business side is often seen by faculty as a negative, but accreditation and other academic issues are often seen as opportunities for leveraging more resources. For example, losing accreditation in a professional program because of not meeting certain regulations is just not an option.

Just as accreditation can provide opportunities, political and other constituent groups can be a valuable resource, but they can also pose regulatory, funding, and other restraints that are damaging to higher education. Such restraints may stem from principled, but controversial, policy issues. Or they may stem from fiscal or other interests of a specific group.

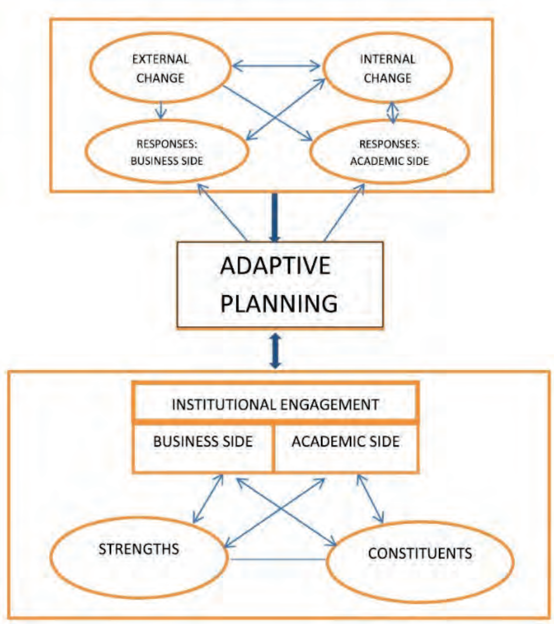
Or they may stem from raw politics. Regulatory and related constituent issues are among the most critical challenges we face in navigating our chaotic environment—issues for which most universities have strong if not always successful assets.

Changing technology has impacted academics in many more ways than can be addressed here—in instruction, research, and in the many support functions like campus IT services.

The increased emphasis on hands-on, active learning is an important link to technology. Clearly there is increased pressure to prepare students for jobs or careers, and practical application of what they learn in classrooms is highly valued, as is providing students with high-level analytical and problem-solving skills. And the shift toward the flipped classroom, in which interactive learning is a key element, further strengthens the move to greater degree of hands-on learning. It is difficult to make a negative argument about hands-on learning…except that it is very expensive to deliver in most cases, among other things requiring a great deal of faculty time—a problem that can be mitigated by technology.

Figure 2

Adaptive Planning Graphic



Summary: Aligning the Business and Academic Sides of Higher Education. The academic and business sides of higher education are like two different planets in the sense that they are intimately connected, but with underlying dynamics that are not just different, but often contradictory. The business side is very complex given the many-dimensional connections with the broader business, political, policy, demographic, and other elements of the environment, but it is highly structured as is any business operation. The academic side, though, cannot be structured in the same way, given that its main purpose is creativity—doing things that have never been done before—which is done, ironically, in an environment buried in centuries of tradition. But that said, as indicated above, creative activity can't take place without adequate infrastructure, which must be created and built without knowing just where the academic activity will go.

Thoughts on Adaptive Planning in a Chaotic Research Environment

All of the above provides context for addressing adaptive planning in a chaotic environment. Clearly planning cannot be a simple, linear, fixed set of priorities that are associated with resource development and allocation. Nor can we do comprehensive, highly accurate models of the future to inform the investment in people, allocation of time, development of curriculum, management of research and/or instructional capacity. Uncertainty is everywhere and can pose both negative and positive surprises—challenges and opportunities. Adaptive planning must address both in an on-going, responsive way.

What follows is a set of thoughts on adaptive planning but, as a matter of principle, no straightforward, clear process can be laid out. Three guiding principles at the highest level begin to define domains in which the planning will occur. The plan itself must be layered: at the highest level will be what is often called mission and vision, which determine where the institution is going. Then, to achieve the vision/mission will be broad goals, which will have operational outcomes; then there will be objectives that will have to be met to reach the goals, tactics for reaching the objectives, and a detailed action plan for implementing the tactics. The number of levels and the terminology are not so much of importance as that the plan be layered such that the higher level elements (vision, goals) are fairly long-term (e.g., years, even decades), while the lower-level elements are shorter term, getting down to the action plan, which changes day by day.

Ultimately, the different-level elements of the plan must be aligned/adjusted to the environmental dynamics that were described earlier in the paper; accordingly, environmental issues will have to be broken down in various levels. For example, for revenue elements of the plan, it will be necessary to have a prediction of where certain kinds of revenue are likely to go over the next decade or more in order to address vision and broader goals; but shorter term trends also have to be considered (say, three to five years at the objective level) and year by year, or even quarter by quarter for tactical and action-plan level planning. Similarly, other dimensions of environmental change will have to be aligned with different levels of the plan—e.g., political dynamics at the long-term national and state levels, the immediate election results, and session by session legislative trends. Other dimensions would include major policy issues; the student market (including demographics); the competitive environment for student recruitment, research grants, etc.; the dynamics of the regulatory environment; and the dynamics of scholarly communication.

<u>Guiding Principle 1: Institutional Strengths.</u> The most important guiding principle is to build the plan—the priorities—on institutional strengths. If the point of the plan is to take the institution to where it wants to go, then building on institutional strengths is the most likely way to get there, the end goal being to position the institution favorably in relation to other universities and other kinds of competitors. Similarly, it is critical to position the institution such that it is viewed favorably by its many constituencies (see Principle 2). Strengths can mean many things, even for institutions that are very similar: even for constituent groups for very similar institutions, the idea of strengths has extraordinary variety, to the point that strengths in one institution would be weaknesses in another. It is critical to be clear that strengths are not defined as highly ranked programs, though such programs may be an element in de-

fining strengths. That said, the institutions that are represented in this retreat are all major public research universities, and there will be significant overlap in the idea of what is a strength. A few examples:

- A record of high-impact outcomes in a particular area, which will occur most likely in research. High impact outcomes are what we want, but as discussed above, they may pose opportunities or challenges (see p. 29).
- A forward-looking strength might be in emerging areas which are not of high prestige today but for which the institution is well positioned—e.g.,
- Emerging high-demand areas for academic credentials—e.g., in a profession such as Medicine, or in interdisciplinary technical areas such as informatics;
- Emerging science areas that are the result of the complex dynamics that are operationally morphing the disciplines (see p. 30).

<u>Guiding Principle 2: Constituent Expectations, Demands, and Needs.</u> A second guiding principle is to systematically align the plan with the expectations of the many external constituencies. Alignment of the plan with constituents' desires must be done holistically, not taking each constituent alone, but considering how the many demands and expectations come together: complementary, overlapping, inconsistent with, or irrelevant to, each other. The constituencies of a research university are extremely diverse, ranging from legislators, donors, parents, employers of graduates, professional organizations, corporate partners, alumni, and much more. The key is to identify their needs and expectations and map them on one another to see patterns that can be in some way used strategically. An important footnote to this matter: it will be critical to work with non-traditional constituents whose interests, political positioning, and other properties can help build on the institution's strengths—constituents such as large corporations, government agencies, beltway bandits, national labs, and economic development agencies.

As with the strength areas, the constituents' needs and expectations will vary according to the level of the plan that they engage with: e.g., a long-term emphasis on biomedical research, short-term hiring of graduates in certain fields, building a new stadium to enhance the stature of athletics over the long term, or giving a small one-time amount to go to the president's discretionary fund. Another kind of example would be a dean's advisory board that strongly advocates for a doctoral program in a particular area. Another example might be an influential legislator who is an alum and who has a broad agenda (say, in health care, economic development, or the arts) who needs a major institutional investment to move his/her agenda forward. A key point here is that a very high-capacity donor, a powerful legislator, a highly committed alum with little financial capacity all fit into the picture at different levels of the plan. There is no clear way to build such dynamics into the plan, but the plan will not be a plan unless these dynamics, in all of their complexity, are systematically considered.

<u>Guiding Principle 3: Engaging the Institution Broadly.</u> A third guiding principle

is to foster an extremely broad institutional perspective and engagement. In some ways, this is similar to finding a direction that meets the needs of different external constituents. Thus, just among faculty it is critical to cross the boundaries of the academic disciplines and the closely associated organizational units like departments, centers, colleges, and schools. But in addition to the disciplines themselves, there are the broader, highly influential groups of faculty such as those in basic and applied research and academic vs. professional. But this is only the academic side of the organization; there is also the business side, including budget and fiscal management, facilities, enrollment management, government relations, research administration, fundraising, economic development, human relations, hospital administration, and much more. And then there is athletics. It is not reasonable to expect that all of these groups will come together in total, passionate agreement about the institution's direction/plan, but strong push-back from key elements of the institution is likely to severely impair the chances of reaching the goals of the plan.

My own prejudice on this matter is that the key to engagement is to have real discussions, not just show and tell, to bring together people who are positioned very differently and who have different perspectives. Real discussions will get the disagreements, value differences, and special interests on the table so they can be dealt with. There will be significant ideas that will meet opposition strong enough to prevent them from being implemented. And reality is that it will seldom happen that everyone agrees on anything, and some actions will have to be taken about which there will be disagreement and/or opposition. A critical element of such discussions is to systematically consider the incentive structures put in place by, say, facilities assignments, budget, P&T, curriculum, teaching load, and other operational elements (some of which may come from outside the University, such as accrediting bodies, professional associations, and corporate partners).

Aligning the Principles, the Plan, and the Environment. All of the external and internal change facing the institution MUST be figured in such that it is feasible to move forward, building on the first three principles. There is no point in building on strengths that require massive investment that the institution cannot afford. By the same token, no strength could go forward if there was no faculty interest and influential donors and legislative constituents were strongly opposed. In fact, all of the external change (i.e., the changes discussed above as well as the institution's responses to date) must be systematically built into framing the first three principles and taking the next step to vision and goals. And this must be done in a systemic way that takes into account not just each factor on its own, but the complicated interactions among the many factors. Thus, for a simple example: the size and nature of the student body, curriculum, faculty profile, public service, professional engagement each impacts faculty workload and productivity rippling over into grant funding, publications, IP development, and facilities (e.g., see Figure 1). And it is all affected by state funding, regulatory burdens, salary competitiveness, and effective support from staff, post docs, and graduate students. Again, the point is that the external influences must be mapped systemically onto the priorities/goals that are crafted with reference to the three guiding principles. Research cannot be separated from the broader institutional (or broader Higher Education) dynamics.

An obvious, but sometimes overlooked, requirement is that there needs to be an implementation plan that is closely aligned with the higher levels of the strategic plan. This may consist of bringing together the plan—say, the objective, tactic, and action plan levels—which must be structured to reach the goals and objectives. Clearly, there must be evaluations and accountability at all levels—and clearly, the levels cannot be separated in this accountability process. There are countless reasons the plan could fail. One, of course, is that it just didn't make sense. Another is a fundamental change in, say, state appropriations. Another would be regulatory changes that preclude some of the necessary actions to reach the objectives and goals. Some could be long-term disruptions, and some could be short-term. The important point is that all of this MUST be a core element in the planning process.

A critical point about my representation of the environmental changes, about higher education's responses, and examples about the planning process: these MUST NOT be seen as anything other than consciousness raising. The environment differs for every institution; the responses differ for every institution. The most that can be made of the specific information is that it provides the first steps for mapping the particular institution's environment, linking it to the broad direction it wishes to take, and creating a viable plan for implementing the goals to get to where the institution wants to go.

Finally, I need to come back to the point that this paper is about research. The main point is that research is deeply embedded in the broader Higher Education dynamics. Like other elements of Higher Education, it cannot be seen as separated from fiscal, political, regulatory, instructional, facilities and other elements of the university—and of Higher Education broadly.

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Enhancing University Research through Corporate Engagement and Collaboration

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The University of Kansas is undergoing a transformation. It is driven by our strategic plan — aptly named *Bold Aspirations* — which guides and inspires us to raise the expectations we have for ourselves, the aspirations we have for our state, and the hopes we have for our world. We are in the third year of *Bold Aspirations*, and the level of change on campus so far is unprecedented.

Bold Aspirations outlines six important goals for the university. This paper relates specifically to Goal 4, which is focuses on engaged scholarship: "to engage local, state, national, and global communities as partners in scholarly activities that have direct public impact." As part of that goal, we seek to promote active entrepreneurship and vibrant external partners. A key component of this strategy was the creation of the Office of Corporate Partnerships, developed to diversify KU's research portfolio. The Office of Corporate Partnerships was introduced into KU's existing commercialization enterprise, and in the two years since the office's creation, we have already seen an increase in the amount of corporate and foundation research funding as a percentage of our overall research portfolio.

Creating the Office of Corporate Partnerships

As background to understand the broader context surrounding the creation of the Office of Corporate Partnerships, KU's historical approach to developing partnerships with businesses was local and *ad hoc*. The university did not have impressive levels of corporate-funded research. KU's research assets were not organized as efficiently as they should have been to encourage engagement with outside groups.

The KU Center for Technology Commercialization (KUCTC) was established in 2008 as the separate 501(c)3 charged with the management and commercialization of the university's intellectual property — but this activity was its *only* function. As a glaring example of why such a structure was far from ideal, research agreements with industry sponsors were done by 16 different groups, across KU's two campuses.

In 2011 we broadened the scope of our commercialization enterprise and began consolidating corporate assets under single umbrella. We created a new position of Associate Vice Chancellor of Innovation and Entrepreneurship to head KUCTC, which strongly signaled our new emphasis on this topic. Later that year, we created the Office of Corporate Partnerships and made it a direct report to the Associate Vice Chancellor of Innovation and Entrepreneurship. We also brought into the fold our technology transfer and faculty startup resources. The idea behind this consolidation was straightforward: By bringing together these previously disparate functions — technology transfer, faculty startup formation, and corporate partnerships — we could position ourselves to be more efficient and more flexible in pursuing agreements with industry partners. In fact, we were so committed to the synergies and nimbleness represented by the new organization; we recently changed the name of KUCTC to KU Innovation & Collaboration (KUIC).

The benefits of this new structure are already apparent. For example, we have created what amounts to a one-stop shop at KU for external groups looking to collaborate with us. Having these groups working under a single set of metrics provides for cross-collaboration. An example is efficiently working out an intellectual property section in an industry-sponsored research agreement that will allow for easy downstream licensing activity. A portal for both faculty and industry sponsors to work through to create research-based partnerships removes barriers companies often cited as reasons for not working with universities. The net result is that we can more effectively translate KU research to make a real positive difference in people's lives.

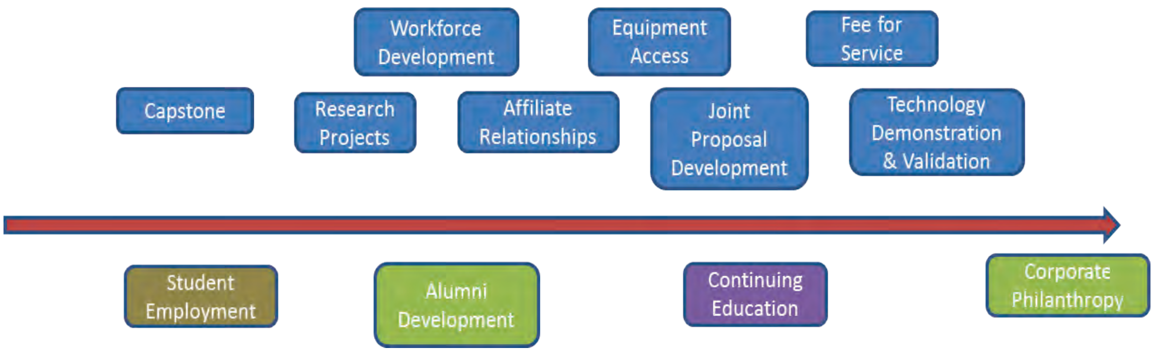
Five-year plan for commercialization

When we reorganized our commercialization and entrepreneurship assets in 2011, we assembled a five-year strategic plan with three key goals: 1) to create a national model; 2) to improve our financial performance; and 3) to improve our customer experience, which includes both internal customers (faculty) and external customers (companies.)

To reach these goals, it was clear we needed to create a strategic systems plan. At the time, we did not have systems of record and infrastructure that would allow us to meet those goals. But we did not just want to "catch up" to what other universities were doing. Rather, we aspired to outpace other universities and install new systems in new ways that would leverage each other and enable us to work with companies more easily, while allowing us to make more informed, data-driven decisions on a smaller budget.

How companies partner with KU

Today, companies can partner with KU in many ways. To put it another way, KU has many different products (or domains) that companies may want to access. These products include faculty expertise, lab capabilities, student talent, workforce development opportunities, technology licensing, and of course philanthropy, which entails sponsoring scholarships, professorships, and other university needs. Some companies just need one of these KU products. Other companies may want to interact with KU in a number of domains. More significantly, interactions between KU and a company can lead to other forms of partnership with the company, which can move the company along a conceptual path of increasing engagement, as indicated in the figure below:



There are several groups across campus that are involved in these various products that make up KU's portfolio. But today, they all come together under the umbrella of the Office of Corporate Partnerships to ensure they work together in an efficient and integrated manner. It does not concern us how a company wants to partner with the university; what matters is that the company does want to partner with us in some way. Because of the Office of Corporate Partnerships, when a company approaches us with a need or idea, we can now expose the company to the entire menu of KU resources — resources the company might not have even known about prior to contacting KU. For example, under our current system, it would not be unusual for a company to approach KU to explore the capability of a specific laboratory, yet end up investing in KU via a sponsored research engagement as well.

The Office of Corporate Partnerships is based upon that comprehensive philosophy. We facilitate all aspects of industry-sponsored research at our core, and we lead the university-wide strategy on how to coordinate these different areas with a central message. Yes, we like to have many boots on the ground and many ongoing conversations with companies. But at the same time, we want all that communication done in a coordinated and traceable way so that KU staff in different units know what their colleagues are doing and saying. Thus, it is crucial for us to share information about company visits and interactions and to put forward a highly coordinated face to companies. By so doing, we know exactly how the company has worked with the university in the past, which helps us expand the collaboration in the future. By sharing, each of the different groups that works with companies can leverage the others and create a greater benefit for the university.

Building our team

We continue to build out the Office of Corporate Partnerships utilizing a distributive model for company engagement. As part of this model, we have jointly funded staff positions in a number of our key schools — business and engineering, for example — enabling us to have deep knowledge of the research and priorities within those schools.

While school-specific or subject-specific expertise is important, companies often have broader interdisciplinary needs. An understanding of those broader needs is why it is so important for our school-specific staff to work together and communicate with the representatives from the other schools and units. Additionally, these individuals act as liaisons with the industry agreements group. They still serve as the single KU face for the company, but in addition, they conceptually have the industry agreements group and the tech transfer group behind them supporting that transaction. This model has proven successful at building more partnerships within the academic units.

Industry portal

When the Office of Corporate Partnerships was established, it was obvious that our external customers — our company collaborators — needed an easy way to work with KU. We did not want KU to be a "black box" in which partners had to come to the table and then struggle to figure out our university. We wanted to make it easy for companies to access the products we offer. Thus, we created an "industry portal": a single entry point for potential company partners to access the specific things they wanted at the university. We have a website that supports this function as well. The different products that companies want to access are organized in this central location.

Earlier in this article, we discussed the industry agreements group. It too is a key part of the industry portal. A research focused collaboration typically requires negotiation of one or more legal agreements to enable the collaborative work. An effective approach has been for the industry agreements group to handle the negotiation of those contracts as a single entry point for all of KU. The number of agreements we have done through the industry portal continues to increase, while our negotiation time continues to decrease. We track these two metrics on a monthly basis.

One of the great strengths of the new structure is that our industry agreements group liaises with the licensing associates in the technology transfer group. The industry agreements team negotiating the contract understands the priorities and goals of the Office of Corporate Partnerships. As a result, we can ensure that IP language favors downstream licensing so that there are no surprises on the backend. This approach has allowed us to be more efficient and strategic in the execution of research agreements with company sponsors.

Technology and a common tracking system

As previously mentioned, one immediate success was the tracking system that we put into place for the Office of Corporate Partnerships as part of the overall strategic systems mission.

Prior to the installation of the tracking system, we relied solely on monthly meetings to share information on corporate engagement. As one might imagine, monthly meetings were not an especially efficient or comprehensive way of sharing the hundreds — or thousands — of different corporate touches made by faculty and staff across the university.

Consequently, we envisioned a customer relationship management (CRM) system, which is a best practice employed in the corporate world to track all sorts of data, especially in sales. We opted to use Salesforce.com and configured it to track all our company engagements. Today, we have data feeds coming in from numerous units across multiple campuses. These data feeds include details on tech transfer, development, research, and numerous other ways in which companies engage with KU.

The CRM tool functions as a system of record for the Office of Corporate Partnerships. The system allows us to track all industry engagement data that previously had been scattered across different systems. Additionally, we went back and loaded data from the previous five years. This tool now allows the Office of Corporate Partnerships to track all company meetings and to build institutional knowledge about company partners. The system is also available to the internal stakeholders who contribute to the system, using the following general principle: "if you give data to the system, you get a seat at the table." These internal stakeholders can log into the system, do reporting, and see activity just as Office of Corporate Partnerships staff can.

Additionally, the CRM has become a strong prospecting tool for different divisions across KU that work with companies. For example, the CRM allows the Office of Corporate Partnerships to identify company partners that have teamed with KU in some capacity but perhaps not on research. For technology transfer, the CRM enables more efficiently marketing of KU technologies available for license by identifying new company prospects. Our Career Services staff members use it to prospect new companies to engage in career fairs. In addition, our Endowment team uses it to get background on new philanthropic target companies.

Using data from the CRM

Having that much data in one place really empowers us to dig in, do some robust reporting and analysis, and find new ways to do business.

For example, we have configured a 360-degree report showing all the interactions any given company has with KU in a single one-page report output. The report includes market information about the company and areas in which KU excels that might be useful to the company. These reports are used by deans, faculty, senior administration, and other KU officials as intelligence prior to meeting with a new potential company partner.

Another application we have added is data.com, a tool that provides us contacts from any company in our database.

We also have developed partnership reports, which enable us to understand KU's portfolio of partner companies. We define a partner as a company engaged in at least three broad categories across KU, such as tech transfer, career services, development, or research. By this definition, KU currently has more than 80 companies as partners. With our new tools, we are now digging deeper to discover how we can weigh individual partnerships differently. For example, a monetized partnership will be weighted more heavily than a non-monetized interaction, allowing us to further narrow the portfolio.

Another interesting thing we saw coming out of the CRM was how other groups within KU's commercialization unit have been able to leverage the data. For example, one of the primary functions of our tech transfer group is to market KU intellectual property for licensing. But prior to 2011, the group really did not have specific targets or vehicles to get the right information to those targets. Sure, they had some database tools with market information, but the processes were not targeted and efficient. However, things changed when the CRM came online. Suddenly our tech transfer group could easily run reports within the system on all companies that already had engagements with KU. The tech transfer group can narrow companies that are in the same industry sector as the technology they are marketing using Standard Industry Classification (SIC) codes or North American Industry Classification System (NAICS) codes. They now have an instant list of leads to market the technology, and they then use data.com to pull the contacts. The total package allows them to market technologies at a must faster rate, which we expect will lead to more licenses executed annually.

It's working … and we are developing more infrastructure

Our efforts are already bearing fruit, as evidenced by our core metrics. Between Fiscal Year 2011 and 2013, our licensing revenue increased by a multiple of 15, or by a multiple of four if you exclude an outlier that generated significant revenue to KU. Licensing agreements increased by 15 percent, patent issues increased by 131 percent, and industry-sponsored research is up 40 percent.

And we are not stopping there. We have more infrastructure improvements in mind that we think will further leverage what we have already put into place. We have gathered requirements for a faculty expertise search functionality that would leverage KU's implementation of Professional Record Online (PRO) system where all faculty CV data are held electronically. Our vision for this tool is to be able to research scholarly and research activity of all faculty — not limited just to STEM faculty, as many search expertise functionalities are limited at other universities. We think companies would find such a system very helpful in locating research experts at KU in particular areas where they have a need. Additionally, we anticipate a benefit for our faculty by promoting multidisciplinary team formation, and it will help our students find faculty mentors and labs that meet their interests. Other external organizations and media outlets could also use this tool. The tool could also be benefit our local economic development partners, who could use it to help recruit prospective companies to the area.

An interesting possibility is to combine the intelligence from our faculty expertise search tool with the company leads provided by the CRM. For example, we can make use of a search expertise functionality that can easily search faculty from a research or creative activity standpoint. We also have cataloged all the companies that work with KU, and they are all classified and searchable by SIC and NAICS codes. How can we best tie these two capabilities together? One of the roles of our KUIC staff is to align industry needs with KU capabilities. Can we perform that matchmaking more effectively with semi-automated tools? That challenge is next on our agenda: to join the database that holds our faculty expertise with our CRM by industry sector in order to visualize the end result. We continue to envision how we can use these systems more creatively in order to get better results and with fewer staff resources.

Onward and upward

The University of Kansas has come a long way in the past two years. Moving forward, under the umbrella of the Office of Corporate Partnerships, we will continue to find new opportunities to engage with industry partners in ways that mutually benefit the university, our state, and society overall.

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Revolutionizing science through simulation: A junior researcher's perspective on research challenges in uncertain times

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Simulation science can serve as a powerful strategy to explore and understand complex phenomena. It is especially suited to gaining insights into events occurring at extreme scales (very small and fast or large and slow), rare events (hurricanes, earthquakes), or events that involve interplay of a large number of phenomena (biological processes, multi-scale phenomena). Progress in cyber infrastructure (hardware) and concurrent development in computational tools (software) place practitioners of simulation science in a unique position. They can serve as a bridge between experiments and theory, supplement experimental observation with computational insight, and enable high throughput exploration and design. I show specific examples of how simulation science can effectively bridge disparate disciplines to solve complex problems. Such multidisciplinary activities seem to increase the possibility of research funding. Based on these experiences, I share my opinions on how administrators can enable faculty to successful multidisciplinary teams.

My research group has domain expertise in developing high performance computational methods and associated tools for modeling and controlling transport phenomena, particularly in the context of advanced energy generation and storage. This is an emerging topic of research owing to the ever-increasing need for high-performance materials, devices, and processes in sustainable energy applications. We work on integrating three key scientific issues related with this effort, namely: *(1) accounting for the multi-scale, multi-physics nature of these processes, (2) the necessity of accounting for the inherent uncertainty in these processes, and (3) the importance of experimental validation and verification of any modeling framework.* This scientific viewpoint has encouraged us to work very closely with experimental scientists and practitioners to ensure that our computational advances directly enable the science problem at hand. This has resulted in very productive partnerships with a variety of research groups (architects, control scientists, computer scientists, civil engineers, agronomists, chemists, physicists and mathematicians). I illustrate a few concrete examples of this collaborative viewpoint.

Simulation science for sustainable buildings:

The construction, operation, and maintenance of buildings require an enormous amount of energy. Buildings consume approximately 36%-41% of the U.S. total annual energy usage and about

40% of the global energy consumption [1-3]. Even Heating Ventilation and Air Conditioning (HVAC) systems alone for the U.S. use approximately 16% of the U.S. annual energy usage [3]. In recent years, there has been a conscientious push towards developing sustainable methods of designing buildings. Designs that leverage natural flows (wind and buoyant ventilation), and passive heating/cooling (thermal mass effects) hold promise for energy efficiency. To efficiently leverage these naturally available energy flows (passive solar heating, natural ventilation and cooling strategies), various elements need to operate together -- windows need to be opened or closed, shading devices opened or closed. Additionally, active systems need to be activated to start operation once the natural forces are no longer available at proper strength.

This vision calls for a holistic approach towards the design of space, envelope, and environmental control and operation systems in order to reduce their impact on energy resources and the environment. Motivated by this, we formed an interdisciplinary team consisting of an architect, a computational scientist, a control theorist, and a material scientist. We are working on coupling *engineering expertise in computational fluid dynamics (CFD), advanced control system design with architectural design and human factors to build simulation expertise and associated tools for designing free ventilation, heating and cooling strategies in green buildings*.

The overarching challenge with integrating sustainable strategies for conditioning the indoor space is the ability of sustainable buildings to consistently maintain indoor occupant comfort. That is, under a variety of external conditions, the building design should ensure a reasonable modicum of comfort for the occupants. While this task is inherently difficult, there is historical precedent of sustainable buildings that achieve reasonable indoor comfort under extreme outdoor weather conditions. A particularly relevant set of architectures include domed houses in Turkey and Syria, and wind-catchers in Iran. With this motivation, we have been studying the adobe houses in Harran, Turkey. This is part of our long-term goal of comprehensively understanding, and incorporating promising features of the Harran house (channeled natural ventilation co-opted with thermal mass effects) into sustainable designs in the US and Turkey. These vernacular buildings constructed with mud and bricks provide agreeable thermal comfort levels even under very high ambient temperatures, high solar radiation, and low precipitation levels. Thermal comfort is maintained via an interesting interplay between thermal mass effects and natural ventilation.

We use simulations as a powerful tool to help predict flow physics and identify problematic regions of existing buildings, and aid in the design and optimization of energy efficient newly constructed buildings. Computational Fluid Dynamics (CFD) simulations break up the building into a set of pieces, also known as mesh elements, and resolve the governing equations of fluid flow and the energy equation on each piece/element. This discretization process of the building zone allows CFD simulations to easily analyze thermal comfort in many different places in the occupied zone and identify ventilation patterns. This provides a detailed picture of how energy and air flow in the building. We have made progress in developing mathematical formulations for modeling natural ventilation in complex geometries. Note that it is difficult to model natural ventilation as it constantly fluctuates in real time in response to changes in wind direction and intensity [4]. Standard computational fluid dynamics approaches (CFD) based on Reynolds-Averaged-Navier-Stokes (RANS) models have been shown not to work for this class of problems. Recent results suggest that a more high-fidelity approach using Large-Eddy-Simulation approach would enable accounting for the effects of natural ventilation [5]. This calls for a concerted high-performance computing based approach to design, explore and benchmark the ability of LES to account for natural ventilation. We have very promising preliminary work on a massively-parallel finite element method variational multiscale based LES framework for natural ventilation.

This collaborative effort has enabled us to integrate architecture with high performance computing towards understanding how thermal mass effects and natural ventilation affect comfort in the Harran house. We are able to unravel the competing effects of buoyancy and wind driven natural ventilation, thermal mass, short-wave and long-wave radiation, conduction, convection, wind thermal energy, and surface roughness. We have shown that this model performs very well in comparison with experimental measurements made at the Harran house. This sets the stage for future developments in adaptive controls and architectural design to extend these concepts to sustainable buildings in the US.

Simulation science for sustainable solar energy:

Organic solar cells (OSC) represent a very promising low-cost, rapidly deployable strategy for harnessing solar energy. Organic solar cells manufactured from organic blends are amenable to roll-to-roll processing on flexible substrates, have high optical absorption coefficients, allow low-temperature processing, and

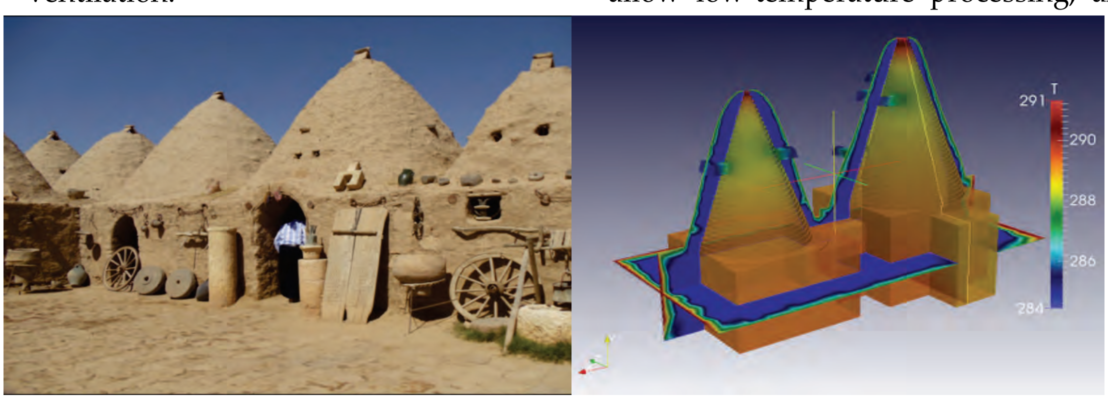


Figure 1: Left: Picture of the Harran house. Notice the set of domed, corbelled roofs. Right: A high resolution computational fluid dynamics analysis of the house. This reveals that the thermal mass of the thick walls and the natural convection play equally key roles in maintaining reasonable temperatures indoors.

are easily tunable by chemical doping. The past decade has witnessed considerable advances in organic photovoltaic technology, both in terms of understanding of physical aspects of the underlying processes and in improvements in power conversion (PCE) efficiencies (from PCE below 3% to currently the highest reported efficiency 9% obtained in laboratory conditions). This improvement was made possible through a three-pronged approach: (i) new materials development, (ii) new device designs, and (iii) morphology control via processing.

Despite these significant advances, wide-spread use and profitable commercial production of OSCs are currently limited. These goals await an increase in PCE to the 15-20% range and an improved life span. Two key advances are necessary to improve PCE. The first is a ***predictive framework*** enabling practitioners (chemists, material scientists, and manufacturing) to obtain targeted morphologies by tailoring competing phenomena during manufacturing. Secondly, we must be able to ***quantify the relationship*** between morphology and photovoltaic performance. Taken together, the need for these advances presents a fundamental materials barrier to understanding the process-structure-property relationship governing OSC behavior. These challenges -- and moving beyond experimentally dominated, trial and error strategies -- serve as compelling reasons to develop computational frameworks that can be used as ***virtual manufacturing tools and virtual characterization tools*** for detailed, rapid and cost-effective analysis and design of organic solar cells. My group is developing computational tools in conjunction with experimental groups at KAUST (Saudi Arabia), NIST, UC Davis, UC Santa Barbara, Academica Sinica (Taiwan), and Imperial College (England). Some integrative activities include:

A new paradigm for computational science and predictive modeling in organic photovoltaic technology: This collaborative group has formulated, implemented and verified a computational framework of morphology evolution during solvent-based fabrication that approaches device scale. This work is of significance, taking into account that this field is an experimentally dominated field and faces significant challenges related to morphology visualization, and linking processing conditions with morphology. This research offers unique possibilities to explicitly visualize the temporal morphology evolution of 3D structure, including internal structure, from early stages to the final structure. Our work allows predicting the three-dimensional nano-morphology evolution over large time and space scales during solvent-based fabrication of thin film organic electronics, which has enabled a deeper understanding of the physics involved in this process and thus, allows the design of better electronics.

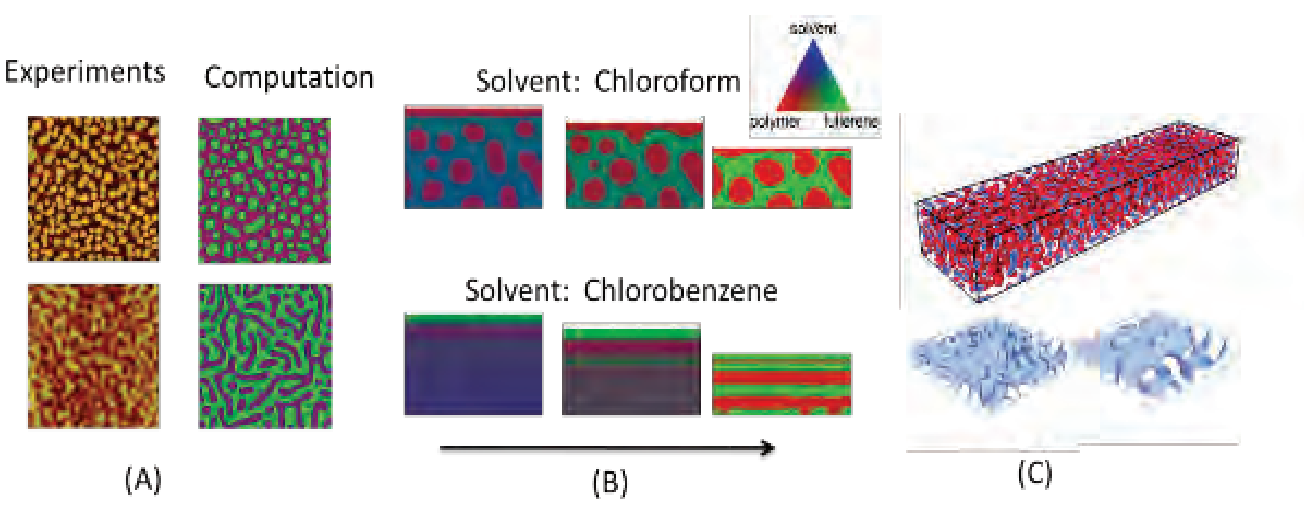
A major hindrance to the efficient and commercial production of organic solar cells is the optimal choice of fabricating conditions out of innumerable possibilities. These include choosing from a wide variety of solvents and mixtures of solvents, the substrates used for fabrication, the applied fluid stresses, and the temperature at which fabrication and post-treatment annealing is performed. Experimentally exploring these infinite possibilities is infeasible. Our recent work has resulted in virtual frameworks that model the fabrication of organic photovoltaic cells. This is analogous to the development of virtual wind tunnels that accelerated the design and development of the next generation of aerodynamic cars and airplanes.

In conjunction with experimental colleagues, we have developed methods of characterizing morphology using a graph-based approach. While earlier analysis of imaged structures was purely visual and thus only qualitative, the graph-based approach brings a greater degree of quantitative rigor to this aspect of the field. The analysis facilitates the prediction and interpretation of time-varying three-dimensional snapshots of intermediate morphologies and enables high-throughput sorting of morphologies. The high throughput sorting has provided valuable insights towards more targeted synthesis and materials design. It has also enabled the selection of optimum blend compositions; and, thus, significantly reduced the design time-line for next-generation organic photovoltaic devices. This tight integration of experimental and computational efforts has resulted in substantial breakthroughs in this field.

Simulation science for engineered plants:

Crop production has to double over the next decade to support population growth and altered eating habits (e.g., increased animal production in Asia). This has to be accomplished on the same or even a reduced area of available land. At the same time, climate change may lead to increasingly adverse environmental conditions for crop production. Recent events such as the extreme drought of 2012 showcase the urgency and need for producing more resilient crops. Current methods to engineer crop performance are based on expensive, agronomic experiments in multiple field environments

Figure 2: (A) Comparison between our numerical results and experimental results, (B) Difference in morphology evolution due to two different solvents. The arrow points along increasing time and decreasing height of the film layer [62]. (C) Representative 3-D APFO3:PCBM nano-morphology. The two slices below show the effect of two different evaporation rates on the average feature size of the morphology.



that link genotypes and phenotypes with crop performance. There is, thus, a need for establishing reliable associations between DNA markers, phenotypes and crop performance, before DNA markers can be directly used for engineering crop performance. My group is part of a working group (consisting of agronomists, engineers, statisticians and computational scientists) that built on the hypothesis that an integrated approach combining genetic experiments (genomics and high-throughput phenotyping), advanced phenomics (high resolution x-ray visualization, lab-on-a-chip measurements), physics-based numerical modeling (nutrient and water transport and uptake, root growth dynamics) will deliver reliable, predictive and cost-effective associations between genotypes, phenotypes, and crop performance. A specific focus has been to use computational fluid mechanics and mathematics to describe how the phenotype of plants controls tolerance to drought. These models will enable us to discover plant phenotypes (i.e. traits) with optimum resistance to drought.

<u>How can institutions help</u>:

These three examples provide concrete evidence that a multi-disciplinary approach involving experimental and computational expertise can be leveraged to solve complex societal problems (which could ensure a steady source of research funding). These examples also suggest that institutions can enable and proactively encourage such research teams. These activities can be divided into three classes: Initiate, Encourage, and Enable. I briefly outline how institutions can do (and are doing) so:

<u>Encourage</u>: Universities must encourage faculty to aspire towards a diversified portfolio of problems as well as funding agencies to target. There has to be a conscious move away from a 'gold-standard' of funding from a single federal source (like NSF in engineering, or NIH in medical sciences). This includes a healthy distribution of funding between industry and federal sources. One way to accomplish this is to actively encourage faculty to have a healthy distribution of short term and long term research projects, as well as to inculcate interest in collaborative efforts: multi-, inter- disciplinary. Fundamental research integrated with applied research (associated with targeted applications) is easier to articulate and argue for, especially with mission specific agencies (DoD, DARPA, DOE, etc.). Iowa State University encourages faculty to do this by providing a clear message that team oriented large projects are valued.

In addition, there has to be clear feedback and reward/advancement for faculty following this strategy. Promotion and tenure documents may look different in this context of multi-disciplinary work, with half-dozen or more co-authors on papers, jointly mentored students, and multiple co-PI's on grants becoming the norm. The administration should have clear guidelines for faculty to articulate their contributions for P&T as well as awards/recognition. While a focus on foundational research is important, departments should not discourage junior faculty from participating in large grants.

<u>Initiate</u>: The university and college can initiate research in strategic areas that are of relevance at the university/state/national level. For instance, ISU recently launched the Presidential Initiative for Interdisciplinary Research "to support research efforts that could lead to major advances, discoveries and technologies". These are awards in areas that are (a) of strategic importance to ISU, (b) core strengths to ISU, or (c) topical with a high return on investment. These awards enable the formation of large teams and provide pursuit funding. In addition, colleges have similar (albeit smaller scale) programs that initiate activities of strategic interest at that scale. This has multiple ramifications - as an internal funding mechanism in a funding climate where insistence on preliminary data is widening, as an incubator of entrepreneurial ideas, and for providing successful role models for junior faculty to aspire towards.

Enable: Universities should play a key role as an enabler by providing trained support staff who are well versed in the budgetary and regulatory intricacies of various funding sources (NSF vs NIH vs DoD). Universities should also enable faculty to nurture relationships. An example of this is providing travel grants to visit funding managers across the country. This is clearly a low-risk, high-reward investment for the university. Additionally, universities can try to make industrial partners feel welcome by making IP issues straightforward. Universities can also streamline activities and enable formation of teams by making strategic investments, and laying down guidelines for internal competitions for limited submission proposals. A case in point is the NSF MRI call, which results in a feeding frenzy of a diverse set of internal proposals every year. ISU has identified and disseminated a multi-year list of strategic ideas for this competition (Year 1: HPC, Year 2: materials, Year 3: Bio etc.). This has significantly bolstered team building and has encouraged various groups to work together to form teams with a concrete multi-year plan. The multi-year list also serves as a template for making strategic hires.

Universities (especially in the Midwest) can leverage existing facilities to create win-win conditions by actively collaborating to enable large scale centers. This avoids duplication of infrastructure in a narrow geographic area and can enable significant cost-matching. Buy in from the faculty can be cemented by making other university faculty part of centers, and by awarding courtesy appointments. It appears that this is strategically promising for the group of universities attending the Merrill conference in the areas of engineering sciences, agriculture, and medicine.

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Interdisciplinary collaborations at work in brain-machine interfacing

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Public universities are facing growing uncertainty, specifically in our ability to recruit students and secure appropriate funding to support our research programs. In this paper, interdisciplinary and translational research are discussed as avenues of growth that have the potential to increase research productivity, and diversify institutional research portfolios capable of weathering these unstable times. Cognitive neuroscience, neurocomputational modeling and brain-machine interface research will be discussed as frameworks for pursuing interdisciplinary and translational research.

Brain machine interfacing (BMI) is a relatively recent addition to the field of neuroscience, and derives from a longstanding history of cognitive neuroscience. It is truly an area of *applied* neuroscience in the sense that the intended goals of BMIs are to use neurological activity for interacting with computer-based devices without direct manipulation by a human controller (cf. keyboard typing, mouse clicking, etc.). Such an achievement depends greatly on our ability to quantitatively model the brain (i.e., neurocomputational modeling), and associate those measurements with sensory perception and motor behavior. One major application of BMI devices is for rehabilitation and assistive technology, including the remote control of movement devices (robotic exoskeletons, wheelchairs) and communication systems (e.g., augmentative and alternative communication devices). The development, deployment and use of BMI technology relies on a coordinated effort to effectively integrate expertise from a number of disciplines according to the needs underlying the specific BMI application.

For success in an academic research environment, much of this expertise can be drawn, or developed, from student involvement, particularly at the graduate level. Management of such an interdisciplinary project, however, requires team leadership with sufficient experience in many, if not all, areas of expertise. The present paper begins with an overview of cognitive and computational neuroscience research in speech and language, follows with examples of BMI research for communication and concludes with a discussion of strategies for facilitating interdisciplinary research, recruiting future generations of researchers, and engaging our regional and national communities. Speech, language and hearing neuroscience is specifically explored as a prime example of interdisciplinary research with many potential translational applications. Three neurotechnological applications are discussed, each of which have important societal value: cochlear implants to restore hearing for those with profound hearing loss, deep brain stimulators for ameliorating motor symptoms of Parkinson's disease, and brain-machine interfaces to enable communication for individuals with locked-in syndrome. Advancement in areas such as these have the potential to drive even greater discoveries and benefit to society. Specific suggestions are provided for fostering interdisciplinary research at public universities.

Introduction

Cognitive and computational neuroscience has for many years been at the forefront of discovering the link between brain and behavior as we experience the world. Using advanced neuroimaging and electrophysiological tools such as functional magnetic resonance imaging (fMRI), positron emission tomography (PET) and electroencephalography (EEG), we have been able to infer relationships between changes in the metabolic and electrical activities in the brain to distinct sensory, motor and cognitive functions. Areas of particular interest are in the neuroscience of reading, speech and language production, speech perception and language comprehension. It is now possible to translate the experimental conclusions of cognitive and computational neuroscience into practice for diagnosing and rehabilitating disorders with a neurological deficit. The remainder of this paper will discuss the interdisciplinary basis of speech and language neurological research, translational applications of neuroscience research and end with suggestions on supporting the growth of interdisciplinary research, in an otherwise uncertain time, using applied speech neuroscience as a framework.

Cognitive & computational neuroscience in speech-language research

Speech and language are uniquely human capabilities that in many ways define our species, yet are also some of our most underrated, or overlooked abilities. Often, it is not until a deficit is encountered that we truly realize the importance of speech and language in our daily lives. Deficits in speech, language and hearing often have a neurological origin, which requires comprehensive study of the related brain structures and activations in individuals with, and without disorder. Some of the earliest cognitive neuroscience investigations took place in the nineteenth and early twentieth centuries as researchers were uncovering the critical role of specific areas of the brain for producing speech (e.g., Broca's area) and understanding speech (e.g., Wernicke's area). One of the most frequent methods used at the time relied on associating post-mortem anatomical examinations of human brains with the presence or absence of specific production or comprehension deficits. At the same time, investigators were also discovering that electrical stimulation of brain tissue could elicit behavioral responses and that specific deficits or overexcitation led to the occurrence of seizures, which could be alleviated by resection of the dysfunctional tissue. Importantly, both approaches provided the first steps toward understanding how the brain mediates speech and language, and whether they realized it or not, these early cognitive neuroscientists were engaging in interdisciplinary research involving medical treatment of patients, neuroscientific study and an understanding of speech-language processing. This last point is very important for the topic of the present paper; cognitive neuroscience has been an interdisciplinary field from its inception.

In the twentieth century, the advent of non-invasive functional neuroimaging methods (PET, fMRI) helped to expand speech and language neuroscience beyond the study of disorder using innovative techniques. With these new methods, it was finally possible to systematically investigate, in large populations of individuals without impairment, prior conclusions regarding the speech and language processes of the brain obtained from anatomical and electrical stimulation studies [see Price (2012); and Indefrey & Levelt (2004); for reviews]. In the years since, multiple regions have been shown to contribute to speech preparation and production, as opposed to a single region described by Broca. Similarly, speech perception and language comprehension are subserved by a number of anatomical regions working in concert. In more recent years, the dramatic explosion of computational power has led to the development of neurocomputational models of speech and language processes (Saltzman & Munhall 1989; Guenther et al. 2006; Houde & Nagarajan 2011). These models extended previous theoretical models by using computer programs to simulate the information processing by the brain according to empirical evidence from functional neuroimaging studies. As a result of the advances in modern cognitive and computational neuroscience, the study of the brain mechanisms of speech, language and hearing has grown even more interdisciplinary to include computer scientists, electrical & biomedical engineers, linguists and psychologists (among many others). An engineering branch of computational neuroscience seeks to move from using a computer to model the brain toward the brain modeling, or controlling, a computer. This inversion of computational neuroscience is at the heart of brain-machine interfacing.

Applied neuroscience

The term applied neuroscience is used here to refer to any aspect of neuroscientific research that results in our ability to alter or influence neurological processes for rehabilitation. Some visible examples of this type of translational research include the neuropharmaceutical treatments (e.g., antidepressants) and neurologically targeted rehabilitation of stroke and traumatic brain injury. Some neurotechnological translational research examples include intervention in cases of sensorineural hearing loss via cochlear implants, and motor deficits associated with Parkinson's disease via deep brain stimulation. In both of these cases, neurological models were first constructed based on empirical evidence, then "inverted" to allow communication between computational devices and neurological tissue.

For developing cochlear implants, the physiology of the cochlea was first mapped and discovered to encode acoustic frequency according to location along the basilar membrane. This frequency information is then electrically transmitted through the auditory nerve to the nervous system via movement of the inner hair cells of the cochlea. For individuals with profound sensorineural hearing loss, encoded sounds are not transmitted to the central nervous system, though the location-frequency representations of the cochlea and auditory nerve are preserved. In accordance with this model of cochlear function, the cochlear implant uses a miniature computer to acquire and analyze incoming sound for its frequency content and electrically stimulate the cochlea at the appropriate location via implanted electrodes. In this way, the peripheral nervous system and a computational device are in direct communication to provide the central nervous system with restored hearing information for processing.

Similarly, in the case of deep brain stimulating implants, neuroscientfic investigations first uncovered the function and structure of the brain regions implicated in the motor deficits associated with Parkinson's disease. These structures, known as the basal ganglia, are important for selecting and initiating voluntary movements such as reaching with the arm or speaking. Two specific areas, the globus pallidus (GP) and subthalamic nucleus (STN), appear to be particularly affected in Parkinson's disease; their dysfunction causes the basal ganglia network, through its connection with neurological motor pathways, to excessively inhibit movement. Here, the network of structures are still intact, but are improperly activated resulting in the motor symptoms of Parkinson's disease. The deep brain stimulator addresses this neurological deficit through direct electrical stimulation of the GP and STN resulting in the disinhibition of voluntary motor behavior, and the alleviation of Parkinsonian motor symptoms. Through a theoretical and quantitative description of this complicated neural circuit, it was possible to identify a specific portion of basal ganglia that under electrical stimulation had the potential to ameliorate the motor dysfunction of Parkinson's disease.

Both of the above applications, cochlear implants and deep brain stimulators, are great examples of the translational research potential at the intersection of engineering and neuroscience. In these examples, computers are interfacing directly with neural tissue in a one-way, input fashion (e.g., they direct the nervous system to act in a prescribed manner). The reverse design pattern in which neural activity controls a computer is also relevant for rehabilitation purposes, and are more traditionally considered brain-machine interfaces.

Brain-machine interfacing

In its most general sense, a brain-machine interface is any device designed to enable control of computational devices (e.g., robots, assistive or augmenting technology, communication aids) using brain activity alone, without any overt motor intervention. One area of particular interest is in the development of a BMI as an assistive communication device for individuals with quadriplegia and mutism, which is often the result of amyotrophic lateral sclerosis (ALS) or brainstem stroke. Both of these conditions can lead to locked-in syndrome (LIS; Plum & Posner 1972), or the state in which an individual is completely unable to perform voluntary motor behaviors despite intact cognition and sensation. As a result of such profound speech and motor deficits, individuals with LIS are typically unable to use even the most advanced computer-based augmentative and alternative communication (AAC) devices. High-tech AAC devices are currently capable of detecting the smallest amount of voluntary movement behavior (e.g., muscular activity and eye-gaze location) to facilitate artificially aided communication, but even these capabilities are ineffective for individuals with LIS. In contrast, brain-machine interfaces are an ideal alternative for individuals with LIS; a BMI requires only a consistent and reliable source of neurological activity for mapping user intentions onto a communication device.

Principles of BMI development. A number of varieties of BMI devices for communication have been developed in recent years, each focusing on some aspect of neurological activity that can be willfully modulated by a participating user. Some examples include the P300 Speller (Donchin et al. 2000), sensorimotor rhythm keyboard spellers (Miner et al. 1998), event-related desynchronization keyboards (Neuper et al. 2003; Obermaier et al. 2003) and steady state visually evoked potential spellers (Friman et al. 2007). See (Brumberg & Guenther 2010) for a review of each of these techniques. Each BMI example follows a core set of design principles in which a number of factors are optimized. These factors include:

1. Choosing the desired outcome
2. Determining the outcome delivery method
3. Selection of information bearing neural signals from participant
4. Statistical signal processing: mapping brain signals to outcomes
5. Training / treatment

All of the previously mentioned BMI examples selected *communication* as the desired outcome, and *typing* for the delivery method. Each example differed in the type of neurological activity used for the BMI, ranging from neural signals related to intended motor actions (e.g., imagined or attempted limb movements or visual evoked potentials), but all used non-invasive techniques involving the recording of electroencephalography. The statistical mapping procedures often depend on the neurological signal acquired for controlling the device, but usually rely on some form of machine learning algorithm. An alternative BMI device to those mentioned enables continuous control of an artificial speech synthesizer, with the long-term goal of providing a means for fluent speech production (Brumberg et al. 2010). This method also selects *communication* as the desired outcome, but uses *continuous synthesizer control* with instantaneous auditory output as the delivery method. For this BMI, motor-related neurological signals have been targeted both from intracortical microelectrodes (Brumberg et al. 2010) and electroencephalography. The last principle, training / treatment, is an area of recent attention and can most benefit from collaboration with speech-language pathologists specializing in AAC in order to help BMI users learn the skills needed to control their devices.

Institutional support for interdisciplinary research

Computational neuroscience, brain machine interface, and many initiatives for translational research result in outcomes that are both important to scientific advancement and have benefit to society. Research universities that support such initiatives can leverage these positive outcomes to further grow their local, regional and national standing. The question of how to best grow and support these lines of scientific inquiry is doubly important as public universities change their plans for future research in response to uncertainty in public higher education. Much of the discussion of uncertainty is related to the stability of federal funding of scientific research, and state funding of public education institutions. In many ways, as research faculty of public universities, we are being asked to do more with potentially much less. That said, public universities are in a unique position to thrive even in this difficult environment given our reputations as the face of our respective states' generators of educated citizens and engines of innovations. We also have a special ability to reach a broad cross-section of the population, ranging from our own students and faculty, to the local communities who represent either future students, or future voters who will be responsible for our long-term success. A focus on interdisciplinary and translational research is one avenue for of growth that is already fully compatible with the research missions of public universities. Further, these research efforts have the potential to truly do more with less (though we should always strive to do more with more), and the linking of multiple disciplines can spur new ideas to attract currently non-traditional contributors to public university research.

Engaging in community partnerships, and encouraging student participation in research.

The best way to increase the likelihood of continued success as a public institution is to give current and future voters a reason to support our endeavors. Many universities already participate in research experience programs where undergraduate students work alongside faculty and graduate student researchers in a laboratory setting. These experiences are critical for shaping future careers and perspectives, and should not be limited to undergraduates; opportunities for high school and middle school students can have a similar impact, and help direct younger students to our programs.

In the applied neurosciences, community and student engagement are especially important. Neuroscience education occurs primarily at the graduate level, and public perceptions of neuroscience often conjure images of medical doctors wearing white lab coats in hospitals. However, modern applied neuroscience in the form of brain machine interfacing is much more accessible -- commercial devices exist for acquiring neurological data (e.g., Emotiv Epoc), recent national initiatives in computer programming education has increased the number of young students with the skills to develop advanced software, mobile and educational computer hardware is more affordable than ever (e.g., RaspberryPi, Arduino), and a generation of "makers" are creating sophisticated robotics, electronics and even communication aids in their parents' basements. In addition, there is a growing awareness of speech-language-hearing disorders, their neural bases and technological remedies, and an increasing number of students interested in pursuing health and rehabilitation (e.g., speech-language pathology, physical and occupational therapy) who need and want experience with tomorrow's technology for aiding future clients. Public universities are in a prime position to guide and inspire this growing population of young people with sophisticated skills and knowledge to pursue public collegiate education and make innovative and lasting contributions to our regions and country.

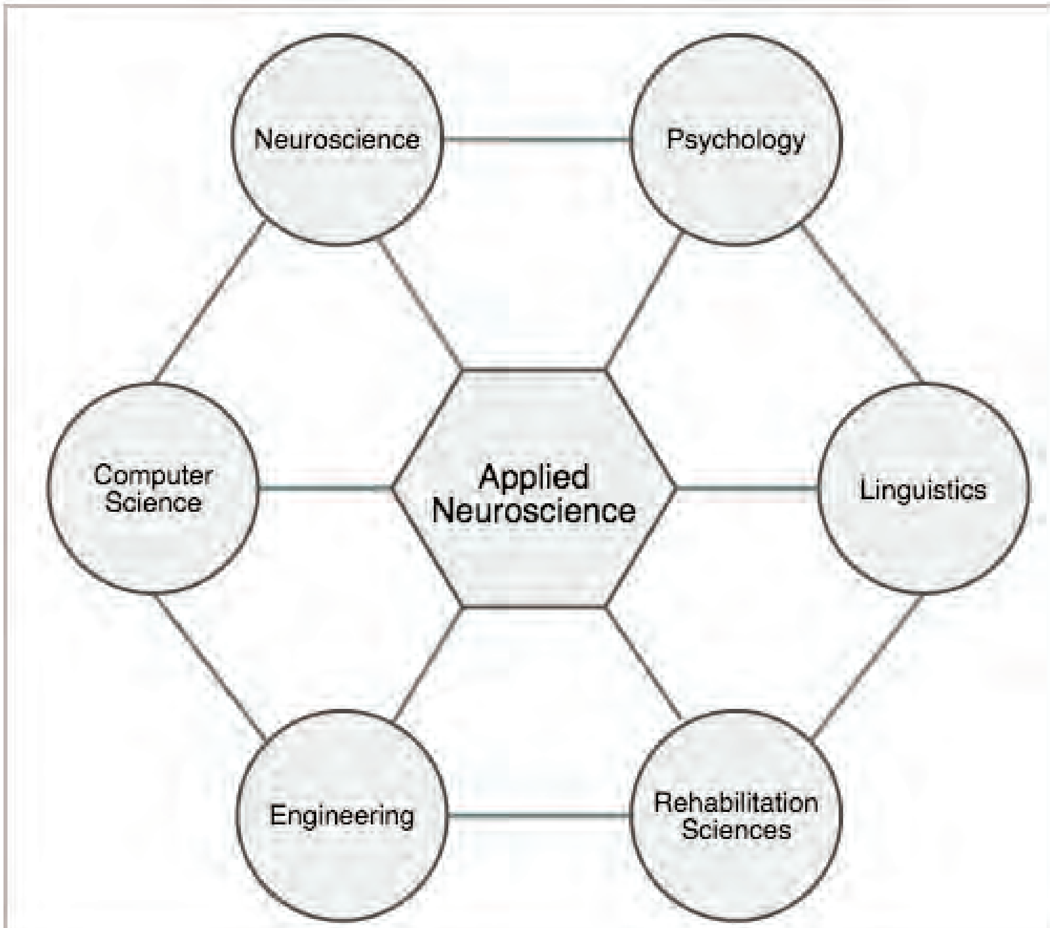

Figure 1. In this example, each field ordinarily searches for faculty, applies for funding, recruits students and publishes in discipline-specific fashions. With the incorporation of an interdisciplinary field, such as applied neuroscience, the individual disciplines can more easily collaborate, transfer knowledge and ideas, and identify new areas of research that can benefit our students, universities and communities.

Adapting education for faculty to maximize funding.

In these times of uncertain federal funding, junior and senior research faculty must begin to look elsewhere for research support. Especially in the sciences, the gold standard (particularly for promotion and tenure) has been significant external funding from the federal government (e.g., National Institutes of Health, National Science Foundation). The effect of either declining or unstable federal funding will hopefully result in an increase in funding from other sources including private foundations, research institutes and commercial partners. Institutional support should be increased to help investigators navigate the changing landscape of research funding, and identify new and creative models for maintaining our research programs. This is especially true for junior faculty who may have less experience in obtaining external funding.

One area of particular growth for brain-machine interfacing is collaboration with commercial partners. As an area of applied science, BMI for communication are intended to be used by individuals as an AAC device. Fortunately, a strong industry already exists for developing AAC devices with frameworks in place for interfacing with federal medical agencies including Medicare, Medicaid and the FDA. Increasing outreach to (new) faculty from the offices of technology transfer and business will be especially helpful for pursuing collaborative and sponsored projects from commercial partners for translational research applications. Finally, as a result of these changes in funding, departmental and college committees for promotion and tenure may need to reevaluate, or at least consider, the differences between candidates in federal-rich vs federal-sparse funding intervals. These discussions should result in feedback to candidate faculty to help establish a standard against which future plans may be made.

Recognizing interdisciplinary connections in your field; building interdisciplinary faculty.

Interdisciplinary and translational research programs have the potential to increase the relevance and impact of public universities on their communities. Additionally, many national funding agencies are now requiring some practical or translational outcome for research proposals. Therefore, pursuing interdisciplinary connections and collaborations will have a significant impact on the success and future of public universities in terms of local, regional and national support.

To build and maintain such programs, universities, colleges and departments may need to reconsider the method by which they recruit new faculty. Researchers with experience in multiple areas of study are prime candidates to lead interdisciplinary efforts and forge new connections between departments, programs and schools; however, these faculty candidates often do not fit in existing departmental models for faculty search and recruitment. In the past, departments may have limited the scope for faculty recruitment to either replace or augment an area of strength or bridge a gap in a domain specific area of work. To support interdisciplinary growth, departments may find it advantageous to look outside-the-box for potential faculty candidates with multiple interests and who are capable of increasing the diversity of perspectives, skills and research. Similarly, once hired, interdisciplinary faculty may need additional support to make the appropriate connections for obtaining courtesy and / or joint appointments with relevant collaborating departments and programs. Discussions with senior faculty mentors will be important to determine the impact of supplementary appointments, scholarly publishing in a variety of journals and sources of funding on the promotion and tenure process.

Additionally, agreements between programs may be necessary for enabling primary mentoring of graduate and undergraduate students, standing on dissertation committees, and other university service opportunities. Finally, interdisciplinary collaborations within the university and beyond are sometimes best discovered and grown by student efforts. We can support these efforts through cross-department, cross-school workshops where faculty and students can meet and showcase their work. Such workshops can be expanded to regional meetings to establish strong ties with our neighbors to take advantage of our pooled resources.

Facilitating interdisciplinary research

Recruitment strategy	• Including recruits with non-traditional backgrounds • Focus on the potential for interdisciplinary application of applicant research
Professional development & mentoring	• Continued training for managing broad scope of interdisciplinary research • Establishing expectations for promotion and tenure
Diversify funding opportunities	• Identifying alternative funding sources • Draw from funding typically associated with each collaborating discipline • Look to commercial and foundation partners
University connections & networking	• Establish appropriate relationships with collaborating disciplines • Enable cross-disciplinary student mentoring, course instruction and research opportunities

Table 1: A summary of suggested considerations for growing university involvement in interdisciplinary research.

Summary

Recent trends in national and local policy have led to some uncertainty for the future of the research missions of public universities. Rather than presenting an obstacle to future research, these trends may potentially increase diversity of scientific study and add to our ongoing research activities. Success during these uncertain times depends on our ability to reach out to new audiences to highlight the importance and impact of public universities on their communities as well as adapting to the new realities of local and national funding. Investing in interdisciplinary and translational research can address many of these challenges and serve to reiterate the need for public research in our culture and economy.

Many academic institutions are already engaging in interdisciplinary and translational research, and the suggestions discussed in this paper are designed to focus on these efforts as part of the discussion on the future of research at public universities. The main areas of emphasis include: (1) engaging our communities, especially new generations of students from primary school through college to stimulate an early interest in research, (2) adapting continuing and professional development for faculty to broaden their scope of research to help better demonstrate the need for public university research while searching for additional opportunities for alternative funding (e.g., private foundations and industry collaborations), and (3) discussing and planning for targeted interdisciplinary hires, and post-hiring support (e.g., considerations for promotion and tenure, cross-university affiliations, and infrastructure needs for interdisciplinary faculty).

Table 1 provides a succinct summary of suggested considerations for how to enhance university involvement in interdisciplinary research. Interdisciplinary research is not a solution in itself, and universities pursuing such initiatives should do so carefully to ensure sufficient planning, resources, and support are available to future interdisciplinary and translational researchers. If so, their addition will contribute toward a diverse institutional research portfolio capable of adapting to the changing landscapes of today and tomorrow.

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Collaboration between engineering and the life sciences: Influence of surface attachment on the biologic properties of proteins

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Collaborative research between the basic sciences and engineering is critically important to the ability of academia to answer future societal challenges. Despite the importance of fostering collaboration between scientists and engineers, there can sometimes be institutional or interpersonal roadblocks that limit successful collaborations. I have been fortunate to work as part of a successful collaborative team since 2006, and in this white paper, I will offer my personal narrative of collaboration as an example of what I think makes a strong collaboration between engineers and scientists.

I joined the faculty in the Department of Civil Engineering in January 2006 and almost immediately, I contacted Dr. Jason Bartz in the Department of Medical Microbiology and Immunology at the Creighton University School of Medicine. I had read some articles describing work investigating the environmental behavior of the prion protein, which is the infectious agent for a group of diseased called prion diseases. Prion diseases, or transmissible spongiform encephalopathies, are fatal, neurodegenerative diseases that include bovine spongiform encephalopathy also called Mad Cow Disease; scrapie, a prion disease of sheep and goats, and chronic wasting disease, which affects deer, elk and moose.

In particular, scrapie and chronic wasting disease have been shown to be transmitted in the environment, although at the time we began our collaboration, very little was known about the fate of the prion protein in the environment. Jason was very responsive, and almost immediately, we began to collaborate on experiments to investigate the environmental behavior of the prion protein. In looking back at the start of this collaboration, I believe that something that lead to our success was that in the beginning, we kept the research question very simple.

To illustrate this point, one of our first questions was ‘What is the most environmentally-relevant form of the prion protein?” To answer this question, we incubated prion-infected brain homogenate at one of two different temperatures that simulated either a carcass decomposition environment (37°C) or ambient temperatures (22°C) and then collected samples at pre-determined time points ranging from 0 hr to 1 month.

To answer our question regarding prion conformation as a function of time, we exposed the brain homogenate to antibodies that response to a particular epitope on the protein. If that portion of the protein was degraded, the antibody would not bind, and we would not 'see' that portion of the protein. By keeping our question simple, we were able to learn the terminology and techniques of the other discipline, and we also successfully answered our question. A more complex or complicated question might be important to answer, but with initial collaboration, I would encourage keeping it simple.

As any collaboration progresses, you learn more about the discipline and language of your collaborator, and begin to work together to pose questions. I feel this is another trait of successful collaborations – they raise questions that may not have been ever thought of by an individual working in a single discipline. Also, the answers to these questions many times requires the knowledge of people from disparate disciplines. To illustrate this point, as our collaboration progressed, we began to formulate research questions together.

Once such question was "Does attachment to soil influence the biologic properties of the prion protein? Biologic properties such as infectivity and replication are a function of protein conformation and protein conformation can be influenced by attachment to surfaces. To investigate this question, we attached prions to various types of soils or soil minerals and then evaluated their ability to replicate using *in vitro* and *in vivo* techniques. Our collaborative work allowed us to develop a conceptual model of prion disease transmission that encompasses both environmental behavior and passage into and within the host animal (Saunders et al. 2012). This linked environmental and biologic model would not have been possible without our collaborative research relationship.

Over the past eight years of our collaborative research, I have learned what contributes to a positive collaborative relationship. First – working collaboratively requires that you take the time to understand each other's language and respect each other's expertise. I would suggest that meeting in person on a regular basis is very important to establish a positive collaborative relationship.

Also, you must begin to read the literature outside your discipline to learn more about the terminology and work being done in the discipline of your collaborator. This takes a significant investment of time, but I find that this is a critical component to working together. Second, a collaborative research relationship requires trust between individuals. Collaboration means that you will share ideas, resources, equipment, and student advising activities, often without knowing ultimately what benefit or products may arise from this work. This requires a leap of faith and a commitment to the long-term collaborative relationship.

Institutions can do things to incentivize and support collaborative research. Administrators must recognize that initiating a collaborative relationship is time-intensive and may have a longer return period for funding and publications when compared with single discipline research.

Similarly, collaborative research will often be published in journals outside your discipline area. There must be an understanding and appreciation of this work and its contribution both to your own discipline as well as other disciplines. This is important for faculty going through the promotion and tenure process. Institutions can also have policies and programs in place to allow faculty from outside your institution to serve as student committee members or co-chairs. Institutions could also give credit to faculty for advising students in another department or outside your institution.

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Research, Productivity, and Pressures on Faculty in an Era of Disruptive Change

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Around 2009 and 2010, we began to use a new term as we looked at the future of higher education: the "new normal." During the Great Recession of 2008, state support for public higher education declined. Institutions cut programs, reorganized schools, and reprioritized initiatives to protect their core mission. At national meetings in 2009 and 2010, chancellors, presidents, provosts, and deans exchanged stories of local tragedies and coping strategies. At the same time, they began to imagine new ways to steward higher education resources. Leaders from every public institution can probably tell their own versions of this tale.

By these same years of 2009 and 2010, we also had developed a new relationship with technology. MySpace and Facebook gave a new meaning to social networks. GoogleBooks and GoogleMaps redefined information networks. Twitter convened new online publics. And the 2007 launch of the iPhone followed by other smart phones created a new experience of mobile networks (Jones 18-38).

Harvard business professor Clayton Christensen and others have characterized this convergence of economic pressures and technological change as an unprecedented era of disruption. In summer 2014, *The Economist* featured the topic of higher education change on its cover with the lead, "Creative Destruction: Reinventing the University" (June 28-July 4, 2014). About the same time, in *The New Yorker*, Harvard history professor Jill Lepore questioned Christensen's model, especially when applied to higher education. At the 2014 Merrill Research Retreat, Sally Mason, president of the University of Iowa, framed the issue differently. She pointed out that public higher education has frequently operated under disruptive conditions of changing social and political expectations, and we should not be surprised that today we face another wave of changing expectations. I add to this conversation my concern for capturing at least portions of the faculty point of view: How faculty members experience and respond to the calls for change and the opportunity to reimagine their roles in the university.

The factors driving change converge in the everyday life of the tenured or tenure-track faculty at public research universities. Their careers are a juggling act combining research, teaching, and outreach under conditions of increasing constraint and unique opportunity. Nicholas Lemann, dean emeritus of Columbia University's Graduate School of Journalism, suggests that throughout the late 19th and 20th centuries the ideal of mass higher education and the American research university were able to "flourish in tandem." Today, however, the political and social expectations have shifted. External stakeholders seek accountability, transparency, metrics, and rankings focused on universities as "skills-conferring, teaching-centric institutions." In contrast, writes Lemann, "…most of the senior leaders of universities believe that the institutions' core mission is research."

From the faculty point of view, these tensions create confusing and frustrating situations. Faculty members juggle many different balls striving to respond to multiple, competing priorities. On the one hand, faculty are asked to place a greater emphasis on students by increasing success as measured by retention, progression, and graduation measures, as well as implement a variety of "high touch" practices to achieve these goals. Faculty are also aware of the institutional bottom line: in tuition-dependent institutions, financial stability corresponds to student enrollment. On the other hand, for research universities, rankings depend on research productivity as measured by a variety of metrics: publications, citations, external funding, and highly prestigious national and international awards. Outstanding faculty make strides to excel as teachers and mentors, to stand out as researchers, and, in an age when the role of the research university is poorly understood by the general public, to participate in community engagement and outreach activities. These are all excellent goals. And it is important to note that the role of the tenured or tenure-track faculty appointment is vulnerable, especially in the way that public higher education relies on the use of contingent or adjunct faculty not on the tenure track and that all faculty roles are subject to increasing scrutiny. The faculty career is one of increasing anxiety and tension as they are asked to juggle additional balls to enable the enterprise to adapt to rapidly changing conditions.

There are many different surveys and assessments in higher education, yet not a common reference point for broadly benchmarking and tracking faculty work satisfaction on the tenure-track. *The Chronicle of Higher Education* annual survey, "Great Colleges to Work for in 2014," includes an article by Audrey Williams June, "The Uncertain Future of Academic Work." June notes the pace of change in academic work conditions, measurements of faculty productivity, cost containment practices, and expanding reliance on part-time or temporary faculty. There is a mismatch between institutional goals of quality instruction and institutional commitment among the professoriate. Jeffrey Williams, also in *The Chronicle of Higher Education*, describes the situation as "the great stratification" created by increasing specialization of "the faculty member" into "a multiple being, of many types, tasks, and positions." In summer 2014, the American Council on Education's Presidential Innovation Lab released a white paper, "Unbundling Versus Designing Faculty Roles." Whereas faculty members may think of themselves or their careers in terms of the "single provider," the faculty role is today subject to "the differentiation of tasks and services" that may be distributed "among multiple providers and individuals" (1). The faculty role can be and is being unbundled. Although "[u]nbundling does not have to have a negative impact," the white paper notes that "historically it has been implemented without being carefully designed" (2). These touch points of rapid change, rising productivity pressures, stratification, and unbundling create a context for considering broadly the data from surveys like the Collaborative on Academic Careers in Higher Education (COACHE) at Harvard University's Graduate School of Education. For example, noting that mid-career associate professors report the lowest satisfaction rate among faculty, that such dissatisfaction grows the longer the faculty member remains in rank, and that such dissatisfaction affects women and minority faculty members in greater numbers, COACHE director Kiernan R. Matthews provides data-informed advice for supporting mid-career faculty. Or to state Matthews' proposal differently, we must become intentional in listening to faculty voices and we must become intentional in designing faculty careers for the future.

Within the context of employee satisfaction, the 2010 Gallup Survey, "State of the American Workplace," provides an interesting framework for thinking about how we might categorize the challenges for supporting faculty to ensure our success in higher education. Administered about the time of the Great Recession of 2008, the survey notes that there are about one hundred million fulltime employees in the United States, and rather than satisfaction vs. dissatisfaction, the survey uses response data to group employees by their level of engagement with the workplace. About 28% of the respondents are "engaged employees." They care about change, want to see good things happen, and want to help the organization move forward. In the next group, about 53% are individuals who are "not engaged" with their work. They are not actively disruptive but they don't know or care about the mission. Finally, there were 19% of the individuals responding who were considered to be "actively disengaged." They don't like the change that is occurring and they want to see it stopped. They resist. This distribution curve of almost 30% engaged, 50% not engaged or on the fence, and 20% disengaged and resisting may not seem too distant from faculty reactions on our campuses during the same period as the Gallup survey. Jim Clifton, CEO of Gallup, in *The Coming Jobs War*, notes that "the most powerful behavioral lever" for increasing performance and productivity in the workplace is "increasing the number of employees who are engaged" (112).

With mounting challenges, shifting social expectations, redefinitions of the role of the professoriate, increasing calls for productivity metrics, scarce resources, and an increased pressure for boards, presidents, and provosts to exercise greater top-down decision-making to drive agile change, we need to focus on the role of our faculty and opportunities to increase their engagement. We need to develop effective leadership strategies if they, and by extension the universities where they work, are going to succeed. I have dwelled on the many contextual factors that affect our present moment, because understanding them is essential for developing our best plans as university leaders. All university presidents and chancellors, provosts, vice chancellors for research, and deans can enable their faculty and strengthen their research universities by adopting and adapting three key strategies to fit our unique institutional cultures.

Strategy #1: Communicate laser-sharp focus regarding vision and goals. Faculty members seek to understand where the institution is heading and why that is the best direction. Faculty engagement and commitment are inspired by the larger vision of where the organization is headed and why this destination is essential to the university's identity, success, and distinctive core competency. After such a vision is identified and communicated, there is the equally important communication challenge of ensuring that individual faculty members understand their roles and contributions.

At the level of the larger "why" and "where," confusing goals, unconvincing or uninspiring rationales, or multiple top priorities will create the sense of faculty members being asked to juggle too many balls. Shifting priorities and unexpected new goals, in the name of agility and responsiveness, will likely be experienced like a curve ball thrown into the juggling act.

Clarity of focus includes a clear understanding of individual faculty roles and contributions to the goals. If the faculty engagement distribution mirrors the Gallup survey of U.S. employee engagement, the top 30% support change. But this top 30% will become frustrated as they strive to fulfill their 40% teaching, 40% research, and 20% service performance expectation hearing one semester that research productivity is the top priority, another that student retention and graduation is the top priority, and yet another semester that metrics for rankings are the top priority. And when the top 30% of engaged faculty become frustrated, the next 50% of those not yet engaged or on the fence become much harder to reach and convince to commit to institutional excellence. This then is likely to create an amplifier that magnifies the voice of the 20% who actively resist change.

Communication strategies must recognize the multiplicity of the faculty: both the different strengths of individual faculty members to contribute uniquely to different aspects of the collective goals, and the changing arc of faculty careers that may allow individuals to develop different strengths over the course of a career. While there may be collective goals related to retention, graduation rates, student learning, pedagogical innovation, course redesign, curriculum change, technology in the classroom, assessment, increased publication and citation counts, more grant dollars, and greater recognition with highly prestigious awards (to name just some of the many balls we are juggling), individual faculty members will contribute to these goals in different ways, taking a greater lead in one area rather than another, but seldom taking the lead in all. Our faculty evaluation processes, performance expectations, and especially our communication about change all need to acknowledge that an individual faculty member cannot and is not expected to do it all. He or she may need to set one or two of the balls on the ground, while juggling others with greater concentration and skill. Because department chairs directly relay central administrative goals to faculty, it is essential to aid them in this communication challenge with clear priorities and consistent talking points; support for effectively using departmental talent is essential.

Strategy #2: Construct conditions that motivate. As the academic career becomes more complex, the external motivations of carrots-and-sticks are not sufficient for inspiring engagement. Journalist Daniel Pink draws upon social science research in his book *Drive: The Surprising Truth About What Motivates Us* to note that in the workplace carrots-and-sticks tend "to encourage short-term thinking at the expense of the long view" (48). Derived from 19th-century management technology based in compliance and control (86), a carrot-and-stick approach is more effective for routine tasks that "aren't very interesting and don't demand much creative thinking" (60). Motivation, however, leverages employee engagement by recognizing autonomy, mastery, and purpose.

- Autonomy, not to be confused with independence, means self-direction toward accomplishing a goal; it can often involve a team.
- Mastery emphasizes deep engagement with the process of accomplishing the goal: "the desire to get better and better at something that matters" (109), which is often characterized as the state of "flow" defined by psychologist Mihaly Csikszentmihalyi.
- Purpose links autonomy and mastery: "The most deeply motivated people—not to mention those who are most productive and satisfied—hitch their desires to a cause larger than themselves" (131).

Pink provides numerous examples of business organizations that are drawing upon these research-based strategies to improve employee morale and increase productivity. And he emphasizes that these practices do not undermine accountability. This motivation-driven philosophy "presumes that people *want* to be accountable—and that making sure they have control over their task, their time, their technique, and their team is the most effective pathway to that destination" (105).

Although academic freedom, research opportunities, and teaching choices would seem to make the university highly receptive to motivation-focused leadership practices, contextual forces are pulling in the other direction. Transparency, accountability, and performance metrics are key characteristics of public higher education in the 2010s. State legislatures and institutional governing boards increasingly seek to use these yardsticks for performance-based institutional funding; usually these efforts seek to accomplish a specific social agenda. Similarly, presidents, provosts, deans, and chairs may create internal performance metrics as the starting point for change. During a period of fiscal peril, like the post-2008 recession period, it is not surprising that legislatures, boards, presidents, and provosts increasingly rely upon top-down decision making to ensure the health of their universities. Risky times demand rapid responses. At the same time, returning to my emphasis on the faculty point of view, the incentives for getting on board with new plans and initiatives and the extrinsic motivators employed to generated faculty buy-in are usually more characteristic of 19th-century management for compliance, control, and counting. The unexplored path is leadership by intrinsic motivation to increase professional engagement and productivity.

More broadly, there remains a tension between intrinsic faculty motivations and the extrinsic carrots available to drive faculty behavior. Metrics and efficiencies can be powerful plot points in the story we tell to represent the impact that universities have to benefit society, but they are not sufficient to intrinsically motivate faculty to achieve the excellence we seek in teaching, research, and service to our world. We need accountability and metrics, and we need them to be meaningful and supportive of the intrinsic motivations that increase engagement and productivity. Accountability and metrics frame the story of faculty success; accountability and metrics that do not resonate with the faculty will not force success or create cultural change. Restraint on extrinsic motivation and careful listening to faculty needs to attend to ways we can support intrinsic motivation and build new paths to lasting institutional transformation.

Strategy #3: Cultivate faculty engagement over the entire arc of a changing career. We repeatedly say in higher education, "A great faculty makes a great university." Because of this principle, we devote resources and energy to searches and hiring. We strive to broaden perspectives and strengthen our dialogues through diversity. We invest in developing and retaining faculty talent. Yet higher education drops two very important balls in this part of the juggling routine. First, as COACHE surveys indicate, there is predictable variation in faculty engagement over a career as punctuated by promotions in rank and intensified by years in rank. Many resources support faculty in their early career to reach tenure and promotion to associate professor. The path from associate to full professor, however, has less structure and more room for wandering. Kiernan R. Matthews describes the associate professor "let-down":

> Along with tenure comes an increased teaching load, greater expectations for service and advising, a more competitive market for grants, and the disappearance of mentoring programs that supported them as early-career faculty. In light of recent attention on "student success," these faculty are now being asked to add to their expectations for research excellence the new requirements to track student progression course by course, even week by week.
>
> The toll of these obligations is heavier on women and faculty of color who, given their fewer numbers at this rank (in many disciplines), are asked to serve more, advise more, show up more—and not just for their department and the university, but for their discipline too. (1)

Because of this mid-career slump, I speculatively wonder about the Gallup engagement distribution curve, wondering how an individual faculty member may move from engaged to not engaged and even to disengaged and resisting at different points in a career.

Looking at the characteristics of faculty relationships with the university may lend some insight into this dynamic. As Nicholas Lemann notes in "The Soul of the Research University," faculty employment is unique: "Most people work for their employers. Faculty members at research universities work for their disciplines." We reinforce this unstated tension between loyalty to the university and loyalty to the discipline through many mechanisms that privilege and reward loyalty to the discipline, not least of which is the basic process of promotion and tenure review.

Both Matthews and Lemann make specific proposals that would address these challenges and create new opportunities for engagement over the arc of a faculty career. Matthews identifies an excellent range of practices that make visible the stages of a career and create programs for building conditions of loyalty to the institution. Lemann in turn notes that when research careers are "more oriented toward the institution" where they take place "and less toward the discipline," there are many benefits such as new opportunities for institutional alliances, internal research and teaching collaborations, and a rethinking of promotion and tenure incentives. One of the most striking features of faculty presentations at the Merrill Retreat, in contrast to a national conference based on disciplinary specializations, is the sense of belonging and pride in one's home institution. Repeatedly faculty members take pride in telling the story not of "research in the abstract" but of the way that their specific university enabled them to accomplish certain goals as a research faculty member. By focusing on the full arc of the faculty career and intentionally designing strategies to sustain faculty members for the long game, we can strengthen our institutions and strengthen faculty engagement.

In conclusion, these three strategies exemplify practices in a research university that create the opportunity to lead like researchers. With clarity of vision, conditions that motivate, and cultivation of faculty careers over the life span, these strategies call upon presidents, chancellors, provosts, and deans to lead as genuine collaborators with faculty in the reinvention of the university during an era of disruption. These strategies create opportunities for leadership experiments, to identify best practices and bright spots that can inspire the 50% not engaged to join the 30% of engaged employees who care about change and want the university to thrive. As Sally Mason noted, it is urgent and important for university leaders to convey optimism about our collective ability to make the best of all opportunities and to see our challenges as opportunities. The "new normal" and our new technologies have created many opportunities, and we must have optimism about our creativity, insight, and drive to take full advantage of the circumstances. Engagement and optimism can energize each other. The intentionality realized in these strategies will strengthen the university community and honor the principle that "A great faculty makes a great university."

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Stabilizing Research Departments in a 10% World

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Land Grant universities have a long history of a trifold mission of teaching, research and outreach (extension) in the agricultural and mechanical arts. The form of this mission has evolved over the 150+ year history of these institutions as the number of people involved directly in production agriculture has dwindled since the early 1900s and rural populations have decreased accordingly. Different departments and specialty areas within the university have changed as have the expectations of faculty.

For faculty, the most significant change in expectation has been that those in STEM-related disciplines are expected to obtain and maintain extramural funding for research programs. This funding may come from a variety of public sources - usually federal or state government - or private, usually grower groups, commercial companies or foundations. This expectation has become larger with time, starting as a minor component in the early 1900s when John Wesley Powell first made the case for government support of research as we know it through the US Geological Survey. After World War II, this change became even more profound as the amount of money directed to publicly funded research, primarily through the Federal government, increased rapidly.

More senior attendees of this meeting probably can recall times when individual investigator grants above the 50th percentile in a federal grant panel stood a good chance of being funded. Such expansion encouraged many students to pursue careers in STEM disciplines, and often as academics. At that time, many scientists at the state Agricultural Experiment Stations (AESs), who also usually were faculty at the state's land grant institution, were not usually heavily involved in the quest for external funding because there were sufficient funds to support their research efforts through the AES. Research funds from USDA for additional projects usually came with a lower reimbursement for indirect cost expenses than did funds from other federal agencies such as NSF, NIH, USDA, DOE and USAID, but there were sufficient institutional resources to cover the costs associated with proposal preparation and grant administration.

Since a high water mark in the 1960s, however, the overall funding trend line has been downward. For agricultural scientists, this change has meant that research funds from their AES are primarily tied up in salaries, often only faculty salaries, and that conducting a viable research program required external funding. As states have reduced funding for higher education, AES funding usually has declined as well, but unlike universities who can increase tuition to increase funds available, AESs have been faced with massive funding reductions that have necessitated changes in mission and their approach and view of external funds. State-associated budget reductions often are presented as across-the-board budget reductions, departments often lose a faculty position that is vacant due to retirement or resignation. Such losses are effectively strategic cuts that leave a department unable to do all that it could previously since the specialization of most faculty members is not usually duplicated within a department. Maintaining core capabilities and addressing new areas in a field are particularly difficult under such circumstances.

The Value of Research

Research lives a bit of a schizoid life. In some ways research is the absolute king on campus. Research outputs – both quality and quantity – are used as measures for institutional quality and measures of scholarly activity more often than just about anything else. Grant funds (preferably from a federal source that pays full overhead), *h*-factors and various citation impact statistics, amongst others, dominate discussions of institutional quality. Becoming a member of the US National Academy of Sciences can be a bit like striking gold for a faculty member in terms of the offers they may receive from institutions looking for a means to increase their standing in ranking systems. Indirect costs associated with externally funded research, although rarely recovered *in toto*, are critical components of many institutional budgets and often enable scholarly or other activities in areas that are not closely related to the research project that generated them. Thus, reductions in funding for STEM-related research can crimp budgets in many areas across campus.

From another perspective, research is more a stepchild or royal bastard than the king/queen of the castle. State budget cuts are often distributed across the board, but in a manner that protects the instructional component of a university's activities. Internal services take many of these hits, with research support, especially in technical staff, infrastructure and equipment maintenance, usually hit hard as well. As budgets become more heavily driven by tuition these problems increase as questions often are raised about the propriety of using tuition funds for anything other than the direct support of the teaching mission. Then there is the public misperception of faculty as working only when they are standing in front of class, with research considered to be a hobby or a "spare" time activity. In the face of this combination of factors it is little surprise that academic administrators often choose research activities for cuts when there are no good budget choices available to them and something has to go.

The recent decrease in the availability of federal funds for research has pushed both of these perspectives to even greater extremes. Those who can win consistently in a world where the funding success rate is 10%, or less, become more valuable as faculty and more vulnerable to poaching by competitors. As the research enterprise becomes more costly to fund in terms of both money and public relations, its presence on many campuses decreases and these institutions become (or revert to) primarily tertiary teaching institutions rather than research universities. In so doing student and public exposure to the research enterprise is reduced and the way of thinking that underlies the research process is limited to professional practitioners rather than permeating society for the benefit of all.

Faculty Success

No one at a university can succeed if the faculty are not successful. Defining success is a bit like defining "better", it depends on where you are and where you are trying to go. In some instances success is the best teaching evaluation scores possible, while in others success requires maximizing the appropriate research indicator(s). Most commonly some combination of the two extremes is the desired goal with additions for service and outreach required as well. At many research universities in STEM disciplines, tenure expectations include the receipt of a nationally competitive (usually federal) grant, and the graduation of a Ph.D. student in addition to high profile scholarly publications and perhaps the placement of a postdoctoral colleague in a significant permanent position. Newly hired faculty may also be required to do extensive committee and other service work and to teach large introductory classes on a regular basis.

The 10% world is having a significant impact on these expectations. The reduction in federal funding often costs universities faculty positions as research and indirect cost revenue streams shrink. Hiring a new faculty member to replace someone who has left or retired is not automatic and newly hired faculty are often treasured. In my department we often minimize service work until after a tenure decision has been made and try to keep teaching loads as light as possible, to enable more research to be done.

Issues of students, grant funding, and publications are often entangled. External funds are needed to continue projects beyond the initial start-up period. In a 10% world, obtaining these funds is increasingly difficult. Is the expectation that all STEM Assistant Professors are capable of landing a major federal grant realistic, when success rates are at or below 10%?

More established faculty also are having great difficulties. Yet if there is no money, how can a new faculty member demonstrate that they have enough ideas and capabilities for a sustainable 25+ year career? Acquiring additional teaching duties is the traditional price for not acquiring reliable external funding in a STEM discipline, but the current contraction is too severe for simply increasing teaching duties for a few unsuccessful mid-career faculty to suffice as a solution. What obligations do institutions have to faculty who are hired with a significant research output expectation?

In a 10% world our standard assumptions and expectations are failing to serve us either individually or institutionally. Many responses, *e.g.*, hiring researchers on non-tenure-track lines or hiring faculty whose sole job is to teach, are philosophically and intellectually unsettling or unacceptable given the values of free speech within the Academy and the expectation for faculty to be continuously searching for new knowledge through cutting edge research. If we need to reduce the number of faculty to meet the 10% world's harsh economic demands, how should we do it? Will we end up with a series of elite institutions where most research is done? Or will we instead end up with some elite institutions and a number of very good and excellent research units at other locations where they are effectively orphans. Can we afford the balkanization that results from such egalitarian dispersion? Or should we instead be thinking about ways in which excellence is concentrated at a relatively few locations and be altering the missions of departments, colleges and institutions to these new realities?

Departments

The center of academic life for a faculty member is the department to which they belong. Departments provide an environment within which faculty members work, but are not usually an entity that one works "for". Departments are the entities most commonly evaluated in comparisons of different universities, and their performance often is tracked as individual entities. They are the heart of academic communities and the comparisons of them with family units is not at all out of place. Look at the lengths to which most departments will go to avoid not tenuring an Assistant Professor when the time comes. A former Dean told me that seeing even a single "no" vote, beyond the curmudgeons who could never vote "yes", was a cause for worry because it was so much more difficult to vote "no" than it was to vote "yes".

Keeping departments healthy and happy, not just functional, requires a sense of common purpose and a togetherness that is both practical and personal. Faculty in a well-functioning department can survive many of the vagaries of a 10% world because they have a vision for where they want to go and have identified potential means to get there, both individually and collectively. They are capable of independent work and capable of being team members. Departments have cultures that are a product of the people who populate them.

Non-faculty staff often are important bits of "glue" that keep things together as others come and go. In effective departments they "own" a bit of the department just as much as a faculty member would. In a 10% world this diverse ownership and ability to work in teams (or as a team) provides the resilience needed to survive and continue to thrive. Leaders for departments are numerous, with senior faculty often the largest cohort. Formal leadership also comes from a peer (Chair or Head), who commonly has little, if any, formal leadership or management training. Such a "professional amateur" needs significant patience and buy-in to be successful and a willingness to go along and get along to keep a top-ranked department functioning at its maximum abilities.

Continuing Department Head Fears and Whines

Department Heads are the middle management of an academic institution, but unlike their industrial counterparts more desire to go back down to the faculty level than to progress up the administrative ladder. Few are trained for the job and even fewer had being Department Head as a career goal. Most serve out of a sense of duty to their colleagues, their department or their institution.

These reluctant leaders are now thrown into a 10% world in which static or declining budgets at the department level are the norm. The valuation an institution puts on a department is often difficult to discern - until the bottom falls out because a stellar faculty member leaves for greener pastures or departmental stalwarts retire and someone must pick up the essential duties that they had flawlessly an selflessly performed for years.

The safety nets currently available to Department Heads might suffice to hold small objects dropped from a few feet above them if the object hits the net instead of a hole. Ripping the net or hitting the hole can degrade a department's capacity almost overnight. For example, major equipment can cost hundreds of thousands if not millions of dollars to replace or repair, with departments often on the hook for all or much of the expense. Loss of a major grant can leave a stellar research group in tatters. Technicians and postdocs scramble for alternatives that allow them and their families to continue to live indoors and eat regularly while graduate students struggle to find ways to finish nearly completed research programs and avoid the pain and loss of time that comes with identifying a new advisor and research project.

Hiring and evaluating faculty also brings unanticipated tensions. The criteria for success of a new Assistant Professor often has changed little, even though the external resources required for such success are more difficult to obtain. Making the top 10% cut in any field as an Assistant Professor is an admirable feat that is all but expected in most STEM disciplines given current funding levels. Anticipating not only whether a job candidate is likely to be funded but also whether they will be a long term fit with other faculty in the department requires careful vetting, hard questions and broadly strategic thinking on the part of all who are involved in the hiring process.

Finally, with the limited resources available, rewarding those who have done excellent work and are deserving of recognition financially and otherwise is difficult. Telling a faculty member that their performance is "average" may be true, but most faculty have been in the upper portion of every evaluation they have experienced since they were in primary school. If there are 12 people in a department with four Nobel prize winners and four more National Academy of Science members there are probably several very good faculty members who are receiving at best average and more likely below average performance reviews. In a 10% world these highly qualified individuals would be primary targets for other institutions to lure away, potentially leaving a stellar department with a dismal future in terms of younger faculty to serve as replacements for their more senior colleagues. Open market negotiations for top faculty are common at all institutions. In a 10% world these negotiations become even more critical as only the very best faculty are likely to be funded continuously and provide the core support needed for the institution's research enterprise to succeed.

Interdisciplinary Efforts

Departments serve as the fundamental blocks on which the institution rests, but aspersions about academics being in silos, insulated from the rest of the world abound. The suggested cure for these issues is interdisciplinary centers wherein individuals from various backgrounds and diverse fields of expertise are hired to focus on a common problem. In some cases new buildings are built and faculty are moved from their current departments to a different physical location, while in others, the center is a "virtual" one whose members are physically dispersed on campus but have occasion to get together on a regular, usually at least weekly, schedule.

These efforts can be productive when they work as envisioned, and can provide a means to build teams that are competitive for large multi-PI grants that can be a critical part of the survival strategy in a 10% world. Yet for productive research departments there are often down sides. These departments are often already interdisciplinary in nature with various faculty approaching a broad common problem from multiple directions. Collaborations that range across the basic-applied spectrum occur more naturally in such departments, since those involved are often at different stages of a common research pipeline, rather than trying to tie multiple pipelines together to give a novel output. Successful departments also have identifiable areas of strength in which multiple faculty combine their skills to attack common problems as a team, in much the way envisioned for interdisciplinary centers.

Interdisciplinary centers, if not carefully implemented, can disrupt highly functional departments. For example, siphoning off faculty with expertise in a particular part of a field, *e.g.* genetics, to work with others from different departments who have similar expertise but in a different department, can lead to the effective creation of a new department under the guise of creating a center. In so doing the best faculty from several different departments may be brought together and in the process devastate the departments they were in with their effective departures leaving programmatic holes that cannot readily be patched.

If faculty that belong to an interdisciplinary center have a tenure home in a department, then the problem of having two masters arises. Both the department and the center claim the faculty member, with the center providing a research home (and perhaps even research support) and the department providing a tenure and disciplinary home. Both have expectations as the faculty member should be contributing to both. Should the faculty member leave, then the question of whose faculty position it really is – center or department – can lead to major disputes. Successfully developing and implementing a center without diminishing its contributing departments is far from a trivial task.

Then there are questions such as does the center have the academic standing of a department, and can it offer courses and degrees under its own name or only under the name of the departments in which its faculty are tenured? For faculty, the simple manner of determining who conducts annual performance evaluations and the standards against which performance is evaluated can be crucial to job satisfaction and productivity. In the long run, the critical question is whether the new resources available and the unique intellectual atmosphere that lives within the center justifies the trouble and care that it takes to manage it. Interdisciplinary centers may help some faculty survive in the 10% world, but they are neither a panacea nor a cure all for currently limited external funding.

An Obvious Vision and Associated Advice

In a 10% world the obvious vision is that we are all in this together and must collectively find a way to survive. This message needs to reverberate within departments and centers, but it needs repetition from the administration all the way up to the level of the governing board. Communication must be clear, frequent and never in just a single direction. Writing is common as are speeches and presentations, but one-on-one communication and communication across administrative levels are essential as well. In many cases this type of communication carries with it implied congratulations for a job well done. Why would a President, Provost or Dean spend their time with faculty, staff or students who are not delivering something of great value to their institution? Senior leadership also should model efforts to explore alternatives for getting things done so that everyone else knows that such efforts are both expected and supported.

Collaboration becomes the key to implement the vision. Collaboration in any and every possible form is essential to maximize local areas of strength and to enable extensive participation in the core areas of institutional competency. Maintaining recognizable core and specialized competencies for which the institution has an outstanding reputation provides firm positions to which other programs can be tethered until circumstances change and enable growth and expansion.

Stakeholders from alumni to students to faculty and staff and university friends need to be able to own successes and to work together using their varied strengths and skills to advance the institution and its critical programs. Developing the institution as a “destination” requires a change in attitude, and a kind, but firm, resolve to build areas of strength to their highest possible level while ensuring that all programs are competitive and of at least “average” quality. Faculty are notorious for acting independently and for functioning as “Lone Rangers” when it comes to promoting their programs. Such independence may have been necessary to obtain a Ph.D. in the first place, but it can hamper the efforts to form suitable teams that can address the big picture problems for which funding often is available.

Stabilizing and institutionalizing departmental cultures so people cooperate because they want to rather than because they have to, makes collaboration easier for everyone. Working with your friends is almost always more fun than working with your colleagues, unless the two groups are more or less the same. A 10% world presents stresses, but the stressors are more readily weathered if they are confronted by a group that can work and play well together.

Changes for a 10% Era

The first fact to recognize in the 10% era is that survival until times get better is critical. Yet mere survival of everything and everyone is not a very inspiring goal. The 10% era is one in which relatively strict winnowing occurs as the academic enterprise is forced through a bottleneck of restricted funding. Getting through the bottleneck with style and grace refines skills and reinforces alliances that are necessary for success once the winnowing is complete. Astute academic management during the winnowing process can lead to a major shuffling and rearranging of priorities and academic strengths within and between institutions. Style and grace change the perceptions of what is occurring and provides another reason for stakeholders to buy into the change process.

Partnerships in a 10% world need to become symbiotic relationships in which both partners can anticipate the other's needs and desires. Both administration and faculty share the goal of their institution being widely recognized and respected, and of providing important services and information for stakeholders, often on a global basis. Fiscal decisions, especially those where budgets are cut, need to be made with unremitting focus on their implications. Losses of positions, whether through strategic or across-the-board cuts, almost always lead to a strategic loss, whether intended or not. Having a sense of where we want to go provides a different lens to use when viewing a series of less-than desirable options.

Conclusions on a 10% Era

The current fiscal crisis that is engulfing university research is leading to major rethinking of the value of research. With funds for research more difficult to attain, the value of research is being questioned. In spite of the efforts and thought being put towards obtaining research funds from foundations, companies and other private sources, there is no effective alternative to government funding for the research enterprise that has developed since the end of World War II.

The possibility that the country's research enterprise may be reduced during this 10% era is quite real and faculty and administrators must work together to ensure that the embers that ignite research activity survive the current fiscal quenching. Without a vision for an institution's role in research, such efforts are hampered and detrimental strategic decisions may be made unknowingly. Collaborative efforts have become all but essential to obtain the external funds upon which most research programs rely. These collaborative efforts may result from departmental or interdisciplinary interactions depending on the nature of the question being asked. Enabling these efforts is probably the single most important thing that can be done to ensure the survival of research activities through this 10% era.

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Strategic Investments in Research in Microbiology and Immunology – Importance of Technology Infrastructure

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Current challenges to investigator driven research

The national climate for biomedical research has changed dramatically over the past 10-12 years since the last stages of the doubling of the NIH budget were completed in 2003. These changes have resulted in significant new challenges to the concept of investigator-driven basic research at medical schools and undergraduate research campuses across the nation. The biomedical research enterprise, fueled by the resources provided to the NIH and other federal research agencies during the growth period, was incentivized to recruit an expanding work force to meet the research objectives of individual investigator research grants.

The growth of individual laboratories and trainee populations was unsustainable over the long term as the federal research funds began to diminish. Federal funding in real dollars is currently 25% below the levels reached in 2003, resulting in a hyper-competitiveness for limited resources and an abundance of young investigators struggling to find research-based academic positions or the necessary funding to launch and sustain a productive research career[1]. As grant application rates have risen considerably over the past 10 years, success rates have tumbled from 20-30% at the beginning of this century to the current state of 10-13%. Paylines were reduced to the 6th-8th percentile for many NIH institutions, with a 3-4 percentile bump for early stage investigators (see individual NIH institutional data on the web). These historically low levels have had a depressing impact on the continued recruitment and retention of bright young scientists that are the future of our scholarly environments at research institutions. As a result, new strategies have to emerge for building research strengths and infrastructure that are interdisciplinary in nature and responsive to the changing requirements for successfully competing in the current environment.

Historically, in a medical school setting, basic science departments focused on recruiting academic expertise that centered on human clinical interests in infectious diseases, immunity and human diseases that were associated with either of these "subdisciplines". In most cases, individual faculty research interests were somewhat isolated, giving the department as a whole a breadth of perspectives that encompassed the scope of medical microbiology and immunology expertise. The teaching mission was concentrated on the one hand to providing a basic understanding of all aspects of infection and immunity, and related human physiological consequences, to an informationstressed medical student class through didactic lecture and case examples, and on the other to training the next generation of basic scientists to join the academy and continue the more or less siloed disciplinary environment. On an undergraduate campus, the scope of academic expertise to meet student intellectual interests expanded outside the biomedical realm to include microbial interactions with animals and plants, as well as environmental and industrial microbiology.

When a tenure track faculty position was vacated or a new position created, the recruitment strategy was to replace that expertise in a general sense – e.g. bacterial or viral pathogenesis, host immunity, etc. A search ensued by casting a broad net in the designated subdiscipline, hoping to catch the best available young scientists in that area. Most searches were targeted to the Assistant Professor level and most candidates were coming out of postdoctoral fellowships, with little or no experience with major grant applications, and thus little or no funding to initiate the transition to independence. By the time the top candidate or two was selected, interviewed and a transition package negotiated, the replacement process could be expected to take 6-12 months. That process worked well in the sense of infusing the faculty with youth, intellectual creativity and technical rejuvenation. It created many opportunities for the pipeline of young scientists being trained around the country, most supported by individual or training grants from the NIH.

Prior to 2003, the recruitment packages for faculty candidates at the Assistant Professor level were designed to give the investigator enough resources to get an independent research program off the ground and to the point of being competitive for federal grant awards. The standard calculation was three years of full salary support and $300-500K to fund equipment, personnel and supplies for the transition period. This assumed no additional specialized high end instrumentation was needed or what was needed was already in place within the institution. Those estimates were defined by statistical data that suggested approximately three years from faculty appointment to the first awarded federal grant, up from one year in 1980 (2). With the first award and subsequent renewal, the institution's investment was quickly recovered. I should point out that there were also occasional targeted searches for investigators at a more senior level, with higher levels of investment required and correspondingly higher levels of expectations, including that these recruits were expected to bring significant grant resources with them along with an established and recognized research program. In other words, though there was a greater upfront investment, there was less risk in evaluating the long term potential of the recruit to maintain a productive research program.

In the period since the NIH doubling, the landscape around biomedical research has changed dramatically, especially with respect to recruitment of faculty investigators in the early stages of their careers. Young scientists are having to spend more time in prefaculty training positions because of the decline in open faculty positions. According to an NIH study, the average age at which PhD recipients are recruited into their first tenure track position is now 37 years and, when you couple this fact with the ever diminishing grant funding success rates, it now takes an average of 4-5 years in that position to win an initial federal grant, if at all[2]. As a result, the initial investment by the institution in salary and startup must consider additional resources for the fourth and fifth years of faculty development, resources that are substantially at risk. This pushes the packages to $700K-$1M for an untested Assistant Professor, and higher for established investigators. Furthermore, the extended transition period for junior faculty runs head-on into the tenure clocks of many institutions, which are still geared to 5-6 years. If the first award occurs near the decision year, there are no definitive data to assess long term stability for many research programs.

What about retention of not only those junior faculty with a high likelihood of success, but also of the top research faculty once their research programs have become firmly established and adequately funded? Given the fact, as will be discussed in the sections that follow, that many institutions, including MU, have begun to emphasize targeted recruitment of faculty into strategic areas of research strength and who have a strong federal funding record, what investments must be made to enhance the probability for successful strategic recruitment and reciprocally for keeping the best early stage investigators from being poached? In our collective discussions here at MU, the solutions revolve around the establishment of critical environments – a creative (innovative) and supportive environment, which includes technology enhancement, to attract the best and brightest, and an effective mentoring environment to support and retain our strongest young investigators.

1. A creative environment really depends on minimizing barriers to effective interdisciplinary research interactions, including the development of research and technology centers that promote such interactions. The era of individual investigators working with one or two students in an isolated laboratory is approaching extinction as faculty (and funding agencies) realize the effectiveness and impact of scientific collaboration to bring diverse intellectual and technical skill sets together to address significant scientific questions.
2. A supportive environment emphasizes recognition, as well as rewards (including competitive salary structures and incentives), for achieving important benchmarks in scientific discovery that bring visibility to the institution, not only in scientific citation, but in research funding as well. A supportive environment also recognizes the critical importance of investments in research infrastructure, especially with respect to cutting edge instrumentation and the technological support needed to transfer these technologies to individual/collaborative research programs.
3. An effective mentoring environment is essential in the early and sustained success of the next generation of academic scientists. A strong mentorship program will connect faculty early in their careers with established investigators who are experienced, not only

in the relevant scientific disciplines and technologies and can provide peer review for grant applications and manuscripts, but as well in navigating the ever more difficult regulatory environment and government reporting on such issues as animal welfare, radiation safety and human subjects research. Institutionally, resources must be directed toward career development and effective teaching modalities. Faculty mentoring should also include an ongoing evaluation of how their respective research interests connect to advertised research priorities at federal agencies like the NIH.

Departmental strategies for targeted recruitment and integration into an interdisciplinary framework

We are now in a period where federal funding of basic biomedical research is not allocated in a way that affords the predictability and stability for growing research programs as it once did. To be more effective in the environment of increasing competitiveness for these critical but limited resources and to be more responsive to developing research initiatives from institutions like the NIH, public research institutions must be more creative and realistic in their approaches to investing in research scientists who fit well with interdisciplinary programmatic strengths. They must use these strengths as well to explore new funding opportunities in both the public and private sectors. This implies strategically targeted recruitments that fill important needs in currently strong research areas at the expense of the previously favored broad spectrum approach, despite the latter's evidence of success in clearly identifiable examples. Recruitments and retentions for that matter must be evaluated with integration in mind, integration with existing research strengths and integration with changing funding agency strategic plans (e.g. see NIAID Strategic Plan 2013; http://www.niaid.nih.gov/about/whoWeAre/planningPriorities/Documents/NIAIDStrategicPlan2013.pdf). There are clear examples from recent NIH initiatives in the Human Genome Project, the BRAIN Initiative and the Human Microbiome Project, all of which allocated impressive research resources toward establishing basic research foundations that will underpin much of the "translational" research efforts for the next decade or so.

These research initiatives, and the subsequent applicable biology, are increasingly dependent on an interdisciplinary team approach. It is imperative to build collaborative research strengths in genomics and metagenomics, bioinformatics, comparative animal models, cellular and structural biology, and drug design and development to be able to effectively compete for resources under these strategic initiatives. In parallel, there are changes in the expectations from the funding agencies for team-based research approaches, and thus there must be changes in how public research institutions respond.

1. Multi-investigator R01-type grants are gaining traction and increasing support because they bring together diverse research talents to address a research problem from a variety of technical perspectives. These grants are less expensive than the previously popular Program Project grant be-

cause they direct all the funding resources to the science and eliminate administrative structures that are not necessary to accomplish the ultimate objectives. There are no institutional requirements that the multi-investigator team reside on the same campus; however, recruitment can be influenced by the increased likelihood of such proposals being developed when recruitment is targeted to research interactions.

2. Teamwork and complementary skill sets may be needed to overcome risk-averse scientific review panels which dominate current review processes. Many individual investigator grants can be (and are) criticized because of the limited expertise/experience of the investigator. Strategic team building eliminates this as a legitimate scientific criticism in many cases.
3. The general strategy of building interdisciplinary research teams that seek funding and publish findings together also requires that universities reevaluate current promotion and tenure policies. At present, there are significant pressures on junior faculty for "independent research" for positive tenure and promotion decisions. Within the productive interdisciplinary team, however, individual contributions are relevant to the success of the whole and can be evaluated for their respective merit.
4. As faculty become more entrepreneurial and seek new avenues for research funding from the private sector, these relationships should also be evaluated and recognized for their contributions to the academic pursuit of scientific discovery and should also be identified in faculty promotion and tenure documentation.
5. Whether in the academic setting of a university or medical school (e.g. basic/clinical integration) or in a university/industry partnership, there is an increasing emphasis on "translational applications".

For an academic research department to be effective in the research environment that is likely to dominate the national science agenda for the foreseeable future, there must be a continuous assessment of departmental research strengths relative to campus and regional intellectual and technical resources and NIH research priorities. How well do investigator research strengths integrate with campus and regional research opportunities and match with changing NIH strategic plans? From such assessments, a strategic recruitment plan should emerge that makes these integrations more effective, resulting in enhancement of opportunities to be competitive for multi-investigator research programs and a greater turnaround time for institutional return on investment.

Using the Department of Molecular Microbiology and Immunology at the MU School of Medicine as an example, the analysis of our research strengths with those of the campus as a whole and the available technical resources enable a more effective strategic plan for targeted recruitment of new faculty talent to develop. One advantage is that MU is a comprehensive campus, with multiple colleges engaging in life sciences research. As we look around campus (concentrating on areas likely to synergize with

MMI), easily identifiable strengths include:

- Comparative medicine – with the Colleges of Medicine and Veterinary Medicine, the Division of Animal Sciences in Agriculture and three NIH-funded Animal Resource Centers (mutant mouse, rat and swine), MU has a strong cadre of research expertise in the genetic manipulation of animal models for both agricultural and medical research.
- Plant and animal genomics – MU has long been a national leader in plant genetics and genomics and continues to invest in partnerships that enhance this strength (including the recent agreement with the Danforth Plant Science Center in St. Louis to strategically recruit four new investigators to build greater integration between the two campuses). MU has made seminal contributions to both the bovine and swine genomic projects and is a national leader in genetic manipulation of swine as animal models for human disease.
- Biological engineering and nanotechnology – Bioengineering faculty research strengths focus on nanostructured biocomposites for tissue integration, development of novel sensing mechanisms and platforms, single molecule technologies for disease biomarker detection and improved DNA sequencing, epigenetics and proteome detections, and nanoparticle development for targeted tissue delivery of molecular reagents and vaccines.
- Structural biology – Significant intellectual technical resources for crystallography and x-ray diffraction, NMR spectroscopy and mass spectrometry provide critical opportunities for determining protein structures, protein-protein and protein-lipid interactions, and macromolecular identification.

The MMI departmental research strengths are centered on:

- Viral pathogenesis, including capsid and polymerase structure and function, antiviral therapies (small molecules and RNA aptamers), viral-cellular interactions in viral entry, replication and assembly and the use of viral vectors in gene therapy for human genetic disorders like Duchenne muscular dystrophy and spinal muscular atrophy;
- Immune response to viral and bacterial pathogens and autoimmune diseases including diabetes, multiple sclerosis, asthma, inflammatory bowel diseases;
- Bacterial genetics and pathogenesis, including membrane biology, adhesion of host cell receptors, invasion structures and functions, bacterial genetics and genetic manipulation, metagenomics of the microbiome, bacterial toxins and their molecular interactions with mammalian cellular targets and genetic diversity generating elements.

With these two comparative lists in mind, we would focus the development of a recruitment strategic plan to take advantage of the likely connections between departmental strengths, those of our comprehensive research campus and developing NIH research initiatives (along with entrepreneurial opportunities in the private sector). One objective of such integrated recruitment would be to create interdisciplinary centers of excellence that amplify the potential of any individual or small group of investigators to compete effectively for public or private sector resources. Integrated within this plan would also be an increasing emphasis on "translational partnerships" in the clinical sciences (human and veterinary medicine), the agricultural sciences, bio- and chemical engineering, and of course economic development. For example:

- In the area of virology and viral pathogenesis, our nationally recognized strength is in HIV/AIDS, hepatitis C and emerging viruses like Ebola and SARS/MERS. Strategic recruitment of investigators with interests in viral structures as targets for drug development, viral vaccine development and delivery and viral diagnostics will open up significant new opportunities not only for federal research programs, but for global infectious disease initiatives and pharmaceutical industry partnerships.
- In the area of microbial pathogenesis and the microbiome, we have developed a technology pipeline to interrogate the microbial metagenome within any population niche (clinical or environmental). Collaborations are rapidly developing with animal scientists interested in the ruminant microbiome and its relationship to animal health and food production, plant scientists interested in the plant rhizosphere and it role in plant nutrition and disease, human nutritionists interested in dietary caloric extraction and health/obesity, and clinical scientists interested in the relationships between the human microbiome (especially gut and vaginal) and human health/diseases. Given that NIH has already invested heavily in the foundation for studies in the human microbiome and has recently announced major new initiatives in these areas (included in Priority 3 of the recent NIAID Strategic Plan referenced above), strategic recruitment of metagenomics and informatics expertise that can collaborate with ongoing campus program development represents an exciting new opportunity.
- In the area of immunology, NIAID continues to emphasize basic innate and acquired immune mechanisms and the complex interactions between microbial pathogens and the immune system to develop and test therapeutic and vaccine strategies. In addition, new emphasis is being placed on development of the innate and acquired immune systems in relationship with the gut microbiome. Departmental research strengths in T and B cell development, immune memory and innate defenses and autoimmune diseases provide a foundation for targeted recruitment (in cooperation with Veterinary and Animal Sciences and Bioengineering) in the function of a healthy immune system, vaccine development and robust protection against bacterial and viral pathogens, and the underlying causes of diseases like diabetes, allergies and inflammation.

Technology infrastructure and development investments

Maintaining a cutting-edge technology infrastructure is essential to creating an institutional environment where our investigators can effectively and productively meet their ongoing and developing research objectives and within which we can recruit strategic new talent. On many of our campuses, there are unique resources (like the MU Research Reactor) that bring national visibility to the institution and are a strong marketing tool for recruiting the top scientific talent. However, there is significant (and continually expanding) expense associated with high-end instrumentation and the technical expertise needed for continued development of the technologies and communication of their potential to the research communities on our campuses. As a result, public institutions, in this period of diminishing state and federal revenue sources to support the necessary technological infrastructure, will benefit from innovative ideas to centralize (and not duplicate) the needed technologies and to communicate their availabilities to the local and regional scientific communities. This concept has been critically important on the MU campus and has great potential within the Missouri-Kansas region in general. I will briefly discuss how the MU campus is currently implementing a core facility infrastructure and the development of recent initiatives to communicate these technology capabilities to other regional institutions.

The real thrust to identify and consolidate our institutional technology resources began in the late 1980's with the development and implementation of a "Core Facilities" concept. For example, MU had 3-4 electron microscopes scattered among its various colleges and not enough local resources to maintain and operate them effectively as separate instruments. Consolidating them into an Electron Microscopy Core streamlined their operational requirements and made it possible to recruit top technical talent to provide the technical expertise that campus investigators needed to justify specific experimental strategies in their grant applications. Similar consolidations and investments have been made since that time to centralize instrumentation and expertise in NMR spectroscopy, mass spectrometry (for both macromolecules and small molecules), confocal microscopy, flow cytometry, DNA and RNA genomics and transcriptomics, bioinformatics, structural biology and x-ray diffraction, and transgenic animal production. The result is a robust core facility system that is administered through the campus Office of Research (www.research.missouri.edu/division/cores). It is also important to emphasize that other technology facilities on our regional campuses are less centralized but nonetheless available for collaboration. On the MU campus, these include the VA Biomolecular Imaging Core (small animal whole body imaging), the Brain Imaging Core (with a 3T MRI), the Plant Transformation Core, the International Institute for Nano and Molecular Medicine, the Nanofabrication and Material Sciences Core and of course the MU Research Reactor.

The advantages of centralizing such technologies of course are easy to enumerate. They provide the cutting-edge technologies and state-of-the-art high end (and very expensive) instrumentation needed to produce competitive research proposals. They provide technical expertise on site – as investigators integrate the newest and most sensitive or quantitative technologies into their research program, they rely on the technical support and consultations with the core facility technical staff. And as importantly, they offer the services at competitive rates because they can spread the costs over many projects and investigators. Implementation of many of these technologies on a departmental or even college level would be cost prohibitive.

There are considerable challenges as well, even with a robust core facility system. (i) High end technologies are expensive from both the equipment and technical personnel perspectives. Spreading the fixed costs out to keep fee structures low and affordable requires an adequate user base. At any one institution, there may be a limited number of specific technology users (though it is absolutely essential to their research progress). According to national core facility benchmarking studies provided each year by iLab Solutions, the current rate of institutional subsidization of such technologies is 30%. (ii) State-of-the-art instrumentation is evolving at a rate faster that its depreciation, making it continuously more difficult to keep pace. This is clearly apparent with genomics technologies where implementation of the latest instrument (at $500-700K per instrument) is soon outdated by the introduction of a new technology. (iii) And finally, the critical technical expertise on site is increasingly difficult and more expensive to recruit and retain. Without this expertise, the technologies are available to only a select few highly trained scientists.

With the increasing costs to individual institutions of providing core technological resources, especially when the user base for any one expensive technology may be limited at a given institution, there is merit in marketing these technologies regionally. Such a strategy would benefit the institution supporting the technology by spreading costs over a stronger user base and would open new opportunities for collaboration, and it would also benefit the regional institutions by preventing the unnecessary duplication of expensive technologies. There is a strong interest from the Missouri-Kansas region to develop strategic partnerships that encourage and support technology sharing in this way. A consortium of institutions, including MU, KU, KU Medical Center, Kansas State, and the Kansas City Area Life Sciences Institute, with its academic, health and corporate membership, have recently undertaken a project to bring the regional technical and intellectual resources together using a web-based communications and marketing tool to illustrate the regional capabilities and academic expertise and provide its representative scientific communities a source of information for identifying needed resources. This tool, to be known as the BioInnovation Research Exchange (BRIX) is being developed in partnership with a California-based company called Assay Depot, founded by MU graduate Kevin Lustig. The tool should be ready for implementation within calendar year 2015.

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Interdisciplinarity in Uncertain Times: Research Centers

Karen Burg, Vice President for Research, Kansas State University

The Interdisciplinarity Advantage

Evolving research problems are complex, we therefore need experts and tools from multiple fields. Surprisingly, we take for granted that carpenters, plumbers, electricians, and others work together to build houses (would you make an offer on a house that was built solely by a team of plumbers?), but our existing research structure remains highly compartmentalized and we seem insecure and somewhat inept in promoting interdisciplinarity. The simple fact remains – interdisciplinary approaches allow disruptive leaps forward, rather than incremental steps. They allow more complete solutions to the world's complex problems. Interdisciplinary centers, if built thoughtfully, provide a means to realizing complete solutions.

The Challenges of Interdisciplinarity

The barriers to interdisciplinarity in a university setting are many. The typical university is configured in units and units naturally promote territorialism. Each unit has unit specific goals, and the unit leaders and members are generally quite familiar with the goals and the rewards system. Therefore, those activities not captured within goals or rewards are generally given significantly lower to no attention. Additionally, infrastructure is built to support the unit goals. Each unit, for example, has service infrastructure (e.g. human resources, sponsored programs, etc.), so creating initiatives that span units leads to logistical issues of knowing which service units to access and how those units will handle additional workload. The perceived incentives for faculty members to participate in interdisciplinary research is low. Tenure and promotion is discipline specific, while economic development and intellectual property is not uniformly valued across a university. Interdisciplinary units are inherently more difficult to manage, for a variety of reasons, and a high university investment is required. Importantly, the return on investment is ill-defined and, although potentially extremely high, very difficult to quantitate.

Interdisciplinary is a great buzzword, but is an exceedingly difficult activity to manage. The National Academies (2014) has released many position papers promoting and outlining the concept and has provided compelling rationale for striving to achieve interdisciplinarity. Indeed, according to Popper (1963) "we are not students of some subject matter, but students of problems. And problems may cut right across the borders of any subject matter or discipline". A series of discipline related buzzwords has emerged over the years. Multi-disciplinary, for example, is a convergence of people and ideas for a defined amount of time, with generally no long-term impact. That is, upon removal of the impetus for the multi-disciplinarity, the participants return to their disciplines. Interdisciplinarity, however, is the convergence of multiple disciplines that results in longer term effects. That is, each participating discipline is richer for the experience and gains in some tangible manner. In this instance, there are marked effects on the participating disciplines. Transdisciplinary is a melded discipline; the participating disciplines contribute to the creation of a new, standalone discipline.

Considerations in Purposefully Building Interdisciplinarity

The needs of an interdisciplinary center that is not located in a college or department are unique. Points to consider include the physical and budgetary location, the budget and deliverables, the academic review process in place, the staffing necessary from the unit or from the university, the focus on student participation (as students are centric to the university mission), and the realities of faculty involvement. A center generally spans university units and provides a collaboratory and infrastructure for team-based work. The ideal center relies on a core of permanent research faculty, rather than building on the talents of tenured or tenure track faculty, who generally have multiple responsibilities beyond the bounds of the center. Research faculty are 100% dedicated to research, yet they can connect with tenure/tenure-track faculty who are dedicated to teaching, research, service. Research faculty provide an environment which is industry friendly – particularly with respect to goals, deliverables, and metrics - they also provide a student friendly environment – i.e. training of students in a real world, collaborative environment.

There are several classic structural problems, specific to centers. First, simple use of the term interdisciplinary does not guarantee interdisciplinarity. Seeding money for cross-disciplinary interactions in the foreground does not ensure interdisciplinarity in the long-term; typically, once the money disappears so do the participants. Often, research groups are not cohesive and do not tackle well-defined problems. Research administrators often define a list of people and disciplines, with little regard to the research problem or to the potential for integration of these individual efforts. The accounting for indirect returns, proposals submitted, etc. cannot stimulate competition with departments or the center will not survive. Often there is lack of administrative support units such as human resources or sponsored programs. There is a myth of self-sufficiency; nationally, very few institutes or centers realize complete self-sufficiency. This is typically due to an unrealistic view of return on investment and lack of a business plan. Often the center lacks a unified and unifying problem definitions and project directions.

The center is, in effect, a flexible clearinghouse. The institute or center must be independent from but complementary to departments and should serve as a hiring draw for departments (due to the ready-made collaborators and infrastructure). A permanent director is responsible for marketing and direction.

Longer-term stability is provided by the appointment of permanent research faculty members as the core. In contrast, tenured and tenure-track faculty are involved as dictated by the scientific needs of projects and investigator availability. It has been shown that a flexible and dynamic participation model of this type provides benefits. According to Rhoten, "Researchers who felt free to enter and exit collaborative relationships reported more progress with their interdisciplinary projects and greater satisfaction in their professional lives overall".

Budget and Deliverables

Many centers and institutes are developed on the enthusiasm of the technical experts and without in-depth attention to the financials. Hence, a business plan must be developed with contributions from finance and technical personnel. A focused mission statement should provide the "filter" for investment in future projects. A realistic return on investment should be identified, along with a self-sufficiency plan and related metrics. Annual and multi-year reviews should be defined, along with assessment plans and goal setting exercises. The unit will need mavens, connectors, and salespersons (M. Gladwell, 2000). That is, needed are individuals with great expertise in the discipline but high critical thinking skills, individuals with ability to connect, and individuals with ability to communicate the value of the center. Generally center connectors include industry and education liaisons, while mavens include human resources and sponsored programs personnel. Highly functional centers incorporate research personnel with respect to technical diversity.

Rewards System Overhaul

There are several important reward concerns. In particular, effort toward and participation in a center must be recognized by tenure/promotion committees. Rewards are based on output; common output includes congressional testimonies, public policy initiatives, popular media, or product development. Center research tends to lend to multiple author publications, which incorporate different perspectives from different disciplines. Letters of support from collaborators, defining the critical role of a center researcher, can be vital to the tenure and promotion process.

Center Impact

Center education and training impact may be monitored by a count of new "languages", number of disciplines, performance in courses and retention, as well as student participation in research programs. Research metrics may be monitored by a count of publications, presentations, and intellectual property development. The metrics should be meaningful – for example, the number of disclosures filed may suggest positive impact; however, licensing is probably a more meaningful measure of translation and impact. It may be possible to identify short-term, high return intellectual property opportunities to support the broader center mission.

Thus, the described interdisciplinary center model is industry friendly, major government initiative friendly, and student friendly. Center research faculty complement departmental unit foci and provide stability. When based on existing collaboratives a center provides a rich training environment. Most importantly, the center provides a microenvironment where the *disciplines gain independently and collectively*.

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The New Role of Land Grant Research Universities in the 21st Century: An Essay

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Part 1. *A Time of Change and a Call to Action*

Recently, higher education celebrated the 150th Anniversary of the Morrill Act. It is nothing short of astonishing that land grant universities were conceived and birthed during some of the darkest days of this nation's history. It was this visionary act in the 19th century that set the country on the path to the American Century. It was the land grant universities that provided broad access to needed higher education for people of all backgrounds, especially from the "industrial classes." With new curricula in agriculture and mechanical arts, experiment stations and agriculture extensions, the land grant universities played a significant role in advancing the state of agriculture and industry in the United States. By the end of the 20th century, the mission of the land grant institutions rested firmly on the three strong pillars of teaching, research and outreach.

Today, just 14 years into the 21st century, many land grant universities, including the University of Missouri, have added economic development as a fourth pillar under their missions. Multiple factors brought on this change at the confluence of several potent socio-economic factors that have had a significant impact on the nation in less than two decades. In 2000, the stimulation of the stock market by the seemingly unlimited potential of new web-based technology companies came to an abrupt end when the dot-com bubble burst. After a slow recovery, the economy suffered mightily again and merely eight years later in 2008, when the housing and mortgage bubble burst. After these two shocks, jobs lost in the downturns were not added back as the economy slowly improved. Over several decades, prior to these economic downturns, our nation's economy had been steadily shifting away from manufacturing.[i] The economic crises of 2000 and 2008, and the retrenchments that ensued in their wake precipitated an irreversible loss of jobs. These job losses in turn diminished the middle class and widened the gap between the upper and lower economic classes in the US.

Other factors are also in play that have spurred the land grant universities to embrace economic development as a social responsibility. Whereas in the post-world War II decades from the 1940s to the 1980s large corporations prospered, and in turn they richly supported research laboratories that conducted fundamental research. Bell Laboratories epitomized such laboratories. Staff scientists at

Bell Labs were doing basic research of such a high caliber that it led to many Nobel Prizes. Breakthroughs included the solid-state transistor, the detection of the "background" radiation in the universe, and the development of the laser. Many of the programming languages used today to write computer code stem from basic research done at Bell Labs and RCA-Sarnoff Labs.[ii] In the 1970s, 80s and 90s, the post-war economies of Japan and Asia rose from the ashes of their earlier destruction and became excellent manufacturers and effective competitors. This new global competition caused many of the largest American companies to cut back on their budgets for fundamental research. They either shuttered such laboratories outright or transitioned them into tech-service organizations doing little or no fundamental research. When scrutinized from a financial perspective, investments in fundamental research could not be justified. Fundamental research had not continued to lead to significant returns in an acceptable time frame, and the returns were episodic. With the loss of these corporate laboratories, the nation lost a source of seed corn for a continuous new crop of technologies. It was the new technologies based on science done in these labs that had led to so much economic growth and prosperity. Without the steady flow of new science to lead to new technology, what would be the effect on the economy? To whom would the responsibility for doing fundamental research be transferred?

Another factor affecting land grant universities and their thought leaders were analyses from think tanks and other academic observers. Many began to note that the pace of innovation in the United States was slowing measurably during the last 20 or so years. A new global competitor, China, was on the scene. By many measures, from the numbers of patents issued to the possession of the world's fastest super computer, China appeared to be ascending while the US was descending. The argument that these prognosticators made ran along these lines. Because China was funding fundamental research more innovation is expected from China. China will have continued economic growth while, in this country, we will not. Instead of investing in new research, we seem to be rending the last remnants of innovation from research done in the past. We cannot do this for much longer and maintain growth; we need investments in basic research to foster innovation and prosperity again. The argument continues that growth is sputtering because the current investments in basic research do not rival those that were made by prior generations. Hence, the pace of innovation will slow even more in the US and with it the rate of economic growth will diminish further. Some economists contend that we are reaching a point in the US where there are real limits to further future growth that will lead to economic stasis or secular stagnation.

Finally, in 2008 a new administration took office in the midst of a financial crisis that was nearly as bad as that which ensued after the stock market crash of 1929. Their goals and objectives also affected land grant universities. The Obama administration set out on a course of neo-Keynesian stimulation of the economy with extra governmental (deficit) spending. This spending went to corporate enterprises critically in need of support (General Motors), into new technology firms that were also aligned with the administration's agenda to move toward sustainable energy (Solyndra) and into academic research aimed at spurring innovation. Through the America Response and Recovery Act (ARRA), the Federal Government[iii] invested over $830 billion in the economy beginning in 2009. Spending included "shovel ready" infrastructure projects, education programs, tax incentives, and new energy initiatives. Funding of about $ 7.6 billion was allocated for scientific research with the greatest portion of that spending (~$6 billion) going to NSF, DOE and NASA.

With this federal largesse for academic research came some harsh criticism that such spending would not stimulate the economy, or at least that it would not do so in the near term. The administration responded by creating metrics that would indicate that it had indeed been economically stimulating in an appropriate time frame. Thus, ARRA funding for universities brought with it new reporting requirements about metrics such as job growth per dollar of funding expended. Soon after this the NIH along with the NSF and OSTP created STAR METRICS - Science and Technology for America's Reinvestment: Measuring the Effect of Research on Innovation, Competitiveness and Science. STAR METRICS is a federal agency and research institution collaboration aimed at creating a repository of data and tools that would be useful to assess the impact of federal R&D investments.[iv]

John Holdren is the Assistant to the President for Science and Technology and Director of the White House Office of Science and Technology Policy. In June 2010 he said, "It is essential to document with solid evidence the returns our Nation is obtaining from its investment in research and development. STAR METRICS is an important element of doing just that." At the same time Francis Collins, Director of the NIH said this: "STAR METRICS will yield a rigorous, transparent review of how our science investments are performing. In the short term, we'll know the impact on jobs. In the long term, we'll be able to measure patents, publications, citations, and business start-ups." The President, Dr. Holdren, Dr. Collins and others in the federal government, made clear that research universities, including the land grant universities, were to take on the challenge of driving economic growth. They were to do fundamental research and convert its outcomes into new products, processes, and innovation and in a transparent, demonstrable way.

Clearly, for all these reasons astute land grant universities began to pay even more attention to technology transfer as it relates to economic development. The land grants are well suited for this because of their historical role as socially responsible institutions that seek to improve the well-being of citizens in their states and the nation. Thought leaders and top administrators in Washington, D.C. challenged research schools to be more relevant and active in economic development. They tied demonstrated success in technology transfer and economic development to potential for continued success in bringing federal support for research to these campuses. Whereas, in previous times, the linkage between federal investments in basic scientific research and their economic impact was left mostly unstated and implicit, almost taken on faith, now it was to be explicitly demonstrated. The new metrics would go considerably beyond the usual academic measures that universities had tracked for decades. Hence, adaptation to this new paradigm was essential. As a result, many land grant universities assimilated this new thinking, and many of these institutions added economic development as the fourth pillar upon which their missions rested. To its credit, the University of Missouri had added the fourth pillar of economic development to its mission in 2004.

Part 2. A Plan of Action at the University of Missouri

At the University of Missouri, the research strategy is to become an even larger and more powerful engine of innovation and economic impact in the Midwest than before. With total research expenditures well over $270 million per year, our research engine's displacement is significant, but we expect and need this displacement to grow. Our goal is to become the very best among midwestern land grant institutions at the conversion of the products of research and scholarship into innovations that will make life better. By growing new businesses, by supporting and improving existing businesses and by growing jobs, we can play a significant role in raising prosperity. The leadership of the federal agencies that provide our funding expect nothing less of us. The achievement of this goal will benefit our state and region as we meet these new federal expectations. There is harmony between achieving success at the federal level with sustained research funding and success at the state and regional level in terms of economic growth.

If we accept the idea that land grant universities, such as the University of Missouri, are to be engines of innovation and economic lift, then we have to consider how best to do this. In the past, especially in the early to mid-20th century, outcomes of research in agricultural science and engineering were "translated" to the agricultural community through the agricultural extension. At the same time, the agricultural community "translated" their needs and experiences back to the university also through the conduit of the extension. The key to the success of land grants universities in agriculture was this involvement of the community in informing our research. Knowledge gained from agricultural research and field-testing was brought to the classroom as the most up-to-date curricula for students of agricultural science and engineering. When it worked well, the integration of research, outreach and teaching created an upward spiral of progress.

Today, in the 21st century, we need to do something quite similar. As we approach the problem of spurring economic growth, we need to bring together research, teaching and outreach once again. To be successful, we need the "community" to be our partners in the endeavor. Today, the "community" is those engaged day-in and day-out in the real economy, which is to say business people. From the smallest new company led by an entrepreneur to the largest corporation faced with daunting global competition, we need to become partners for growth. Extending the metaphor of the land grant university as an engine of innovation, then it is through the business community that its power is transmitted to the wheels and provides traction in the real economy. The challenge of seeking to drive economic growth is too multifaceted for universities to attempt to take it on alone. Without broadly based partnerships with established businesses and entrepreneurs, we will not be successful. In an earlier era of our history, we would not have been successful in advancing agricultural progress without a partnership between our agricultural research and the agricultural practitioner in the field. This kind of a deeper partnership between the university and community we have dubbed "communivation" as shorthand for community-university partnerships for innovation.

Next, to organize our thinking and our action at the University of Missouri, we have developed a strategy consisting of five themes that will allow us to achieve our goals. These are as follows:

1. *Cooperate and collaborate rather than compete.*
2. *Grow our own entrepreneurs and innovators.*
3. *Be smart with intellectual property.*
4. *Unleash the power of the willing.*
5. *Don't be jealous; shamelessly borrow the best ideas of others.*

Each of these is essential to the overall strategy and they are explained as follows.

1. Cooperate and collaborate rather than compete. For decades, land grant universities have cooperated at the margins but they have mostly competed for research funds and revenue streams. As state appropriations have decreased, and student mobility has increased, these institutions increasingly compete for students from around the nation and overseas. Competition is often very good in that it drives toward higher efficiency and leads to better outcomes, but only up to a point. Today, in the University of Missouri System, it is to MU's advantage to seek ways to leverage all investments. One important way to do so is by cooperating with the other campuses at Kansas City, Rolla and St. Louis. As we seek to drive economic lift through better partnerships with the community, having access to and partners in the two largest urban areas of the state is invaluable. Capitalizing on the engineering strengths at Missouri S&T in Rolla, provides even more potential success. As partners, we can do much more for the benefit of the state than we can as mere competitors. In the same way, wherever and whenever possible, we seek to cooperate with all the public universities around the state of Missouri.

Cooperation within the University of Missouri System and the state of Missouri is better than mere competition. It also seems logical to seek greater cooperation among the top public research universities in the Great Plains region. As one example, consider the expenditures that must be made today to provide the kinds of tools that are required to do nanoscale science. Given the high cost of instruments, it makes sense to cooperate in seeking funding for such tools and to avoid duplication if sharing can be effective. Leveraging capital to the greatest extent possible is paramount today, and it will be going forward in time. From this perspective cooperation and collaboration are more necessary than optional.

2. *Grow our own entrepreneurs and innovators.* Missouri and the Midwest are wonderful places, but seeking to attract entrepreneurs to our regions and away from Boston, Austin and Palo Alto is not a winning strategy. On the other hand, many of our graduates would rather stay in their home state and region, but opportunities for them to do so may be limited. Hence, there is a real drain of talent from the Midwest toward the east and west coasts. If we can begin to foster entrepreneurship among our students, then we can begin to grow our own entrepreneurial communities up from the grassroots. To do this, we must put resources into new programs that foster entrepreneurial learning and that make it attractive for our graduates to stay with us and to build these communities. If we can begin to retain entrepreneurial graduates in our college towns, then we can over time begin to overcome the "management" gap and attract investment capital to our regions. To do this successfully, we must partner with our communities to create the entrepreneurial ecosystems that nurture and support the growth of seasoned entrepreneurs.

3. Be smart with intellectual property. Since the passage of the Bayh-Dole act, universities have been granted the ownership of intellectual property that stems from federally supported research. The act was a brilliant piece of legislation, because it moved the possession of the intellectual property from the federal agency that funded the research, to the university. Ownership created a financial incentive for the university to drive the invention to the marketplace, something the federal agencies had not done. The Bayh-Dole act, however, was never meant to chill the funding of research at universities by industry. In fact, one may surmise the authors of this legislation would have wanted the opposite to happen. Nonetheless, it is the case that for the better part of the last 30 years, most universities have had a rigid position on the disposition of intellectual property derived from industry-funded research. They often cite their interpretation of the Bayh-Dole act as the basis for that rigidity. That rigid stance is one of absolute ownership of all inventions, even if the source of the funding was from a private company. Universities also found it necessary to point out during the negotiation of a research contract that the cost of a license on intellectual property that might emerge ultimately would be set by the university. The university also asserted the right to license that intellectual property to a competitor if an agreement could not be reached with the original sponsor of the research. In some other cases, a bit more liberal position on licensing was taken. Often in industry-funded academic centers and consortia, all sponsors might be offered a royalty-free, non-exclusive license. It is the case that when asked, industrial research leaders will identify the argument over the disposition of the intellectual property as the number one problem they face in working more closely with academia. Therefore, the hardline approach that we have taken on intellectual property when working with industrial sponsors has diminished the number of collaborations that might have been.

It is impossible to determine accurately the amount of research *not done* between academia and industry in the United States over the last three decades because of this stance. With a more supple approach perhaps as much as three to four times *more* research could have been done over this time. Also, we cannot estimate accurately the value of the lost innovation that could have occurred had industry and academia been working more closely together. One wonders why in other regions of the world, most especially in Europe and more recently in Asia, cooperation and collaboration between industry and publically funded universities is both active and productive. One thinks of such schools as Eindhoven University and Delft University collaborating with Phillips and Royal Dutch Shell, or the Royal Institution in Copenhagen and Chalmers collaborating with Volvo as examples of healthy university-industry partnerships.

Aside from driving innovation, fostering collaboration between industrial practitioners and professors provides invaluable benefits to both. For the professors, many of whom may never have practiced their disciplines, these collaborations are valuable because they give them a chance to grapple with practical problems. The benefit is that they can bring this experience with them into the classroom, thus informing their teaching. At the same time, by working more closely with practitioners on particular problems, faculty researchers can identify new and important problems of a more general kind to work on that are fundamental in their nature. For industrial specialists, collaboration with scholars also reaps benefits. Academics are often at the leading edge of research in terms of theory, simulations and experimental methods. Thus industrial professionals, who collaborate with academics, can bring cutting edge approaches to bear on difficult problems encountered in practice. This can lead to breakthroughs and to more innovation.

Another benefit of collaboration of this kind is that it brings seasoned professionals together with students, which leads to sharing of experience. Coaching may take place that otherwise would not happen, and that mentoring can accelerate the effective performance of young professionals when they enter the workforce. When it comes to entrepreneurs in startup companies, all the same benefits and more accrue from them when they collaborate with academics. In fact, these collaborations are central to the growth of many technology-based entrepreneurial enterprises.

For all these reasons, we as universities are in the controlling position and we must reevaluate our stance on how we handle intellectual property. If we are to stimulate innovation and to have a real impact on economic growth, then land grant universities that receive state and federal funding should reconsider how they manage the formation and disposition of intellectual property. Whether we accelerate innovation and job growth within established companies or in new, startup companies through collaboration, we must do both since we have a broader social responsibility to help spur sustainable growth. Public research universities have a social responsibility to improve economic conditions for the benefit of the citizenry.

A more nuanced stance can be taken to the disposition of intellectual property. The more nuanced stance is in effect a new approach to intellectual property management.[v] In the first place, when it comes to industry-funded research, universities need not insist on owning intellectual property that may result from the research. In coming to this conclusion, consider the following points. Most research projects do not lead to invention disclosures, patents, licenses and revenue streams. Furthermore, even fewer industry-funded projects do so. Thus, when a university negotiates for ownership of intellectual property that may result from a research project, it is negotiating for something that does not yet exist and that probably will not come into existence.

This hardline stance over something that may not come to pass, (and usually does not) can result in the project never being undertaken. If, on the other hand, the contract negotiation does succeed, the project is undertaken, and actual funds will flow to that principal investigator. Even more, a successful research project creates a relationship between the faculty member and a sponsor that can be ongoing and beneficial for both. From many such relationships can begin a partnership between the university and the corporation that can pay much higher dividends than can imagined, but not real intellectual property.

Lastly, we must also keep in mind that whether an invention is disclosed to us or not, is ultimately a decision that rests with the principal investigator. The researcher may share the results publically as an article in a journal rather than disclose them as an invention. There is no university that would or should take action against such a decision maker. In industrial laboratories research management closely monitors results and progress. Disclosure to the public without permission would have dire consequences. By contrast at the university, administrators have little or no knowledge of that which is coming to fruition in a given faculty member's laboratory at any given time. Unless that faculty member divulges it to us, we do not know about it. Universities give faculty members tremendous latitude in making these decisions on their own, as is appropriate.

Therefore, at the University of Missouri, we created a process whereby the decision to negotiate or not for the retention of intellectual property is deeply informed by the faculty member *before* the negotiation begins. If the faculty member contends that there will not likely be intellectual property developed in the course of the research, then we do not negotiate for the sole rights to the intellectual property. Alternatively, if the faculty member does want us to retain the intellectual property that may issue from the research, we negotiate for those rights. If the faculty member is not sure how they want to proceed, which is sometimes the case, the new process catalyzes a deeper analysis with the technology management office. This analysis can lead to much better strategies for handling that faculty member's research and their intellectual property. The early inclusion of faculty in the decision-making process is a critical part of being "smarter" about intellectual property.

At the same time, we need to be even better about how we handle invention disclosures that we will not likely ever convert to a patent. Whereas some private and some public universities have enough revenue to file a patent application on almost any and all invention disclosures, most public land grant universities do not. Therefore, to be "smart with intellectual property," most schools will need to create a transparent rubric for making decisions on which disclosures that they will fund filings. The rubric should layout the areas of science and technology of highest interest to the university, and these areas should be tied logically back to the school's strategic strengths. Once established, this rubric must be shared widely on campus, so that the faculty members know what is likely to lead to a filing and what is not. With limited resources and the ever-increasing costs of patent filing and management, creating a rubric is not only logical, it is expedient and necessary.

Of course, at the same time, there needs to be some flexibility in the use of the rubric so that something truly novel outside of the areas of strategic strengths will not be squelched. Getting this detailed balancing act right is not and will not be easy, but it is a part of the art of managing an academic technology office with a limited budget. At the University of Missouri, not surprisingly, we view plant and animal sciences, nuclear medicine and new media as areas of strategic strengths and into which we will invest our limited funds. But we will remain open to and alert to the possibility of new products, processes and technologies stemming from any discipline or interdisciplinary research center on our campus.

When a disclosure is made that will not lead to a filing by the university, it is important to waive the rights to that property back to the faculty member to pursue privately. Again this is a part of smart practices around intellectual property management. The university can stand on its rights and not immediately move on a disclosure, but it should do this only under extraordinary circumstances. For instance, if there is reason to suspect that the results upon which the disclosure is based are not valid, or if the results appear to have been purloined. Another reason could be that the person making the disclosure is not in good standing with the institution. Under such circumstances, a disclosure may be held pending some other action. Otherwise, action should be take including waiving the disclosure back to the inventor makes good sense.

Finally, the ways that industry brings capital to the university to drive new technology and innovation to the market are in flux. In the past, large, well-established companies would often license a technology directly from the university, and then develop it within their laboratories and engineering organizations. Today this route is being taken less frequently. Instead, large corporations increasingly prefer to purchase a pre-revenue venture company that has developed the technology sufficiently to reduce the risk of making an investment too early. If this trend continues, then universities will need to support this new pathway to the market by taking equity in new ventures. Aligning capital from external investors for such ventures will also be part of the university's role as it works closely with entrepreneurs to take the technology to a more advanced stage that is closer to market.

4. Unleash the power of the willing. Faculty in many disciplines must be highly entrepreneurial by the very nature of their appointments and the expectations that their institutions have of them. To operate a well-funded and active research group in the sciences, in medicine or engineering takes no small amount of entrepreneurship and is not all that different from managing a small business. For the university researcher, the "customer" is the agency that provides the funding. The point is that many of our faculty members have strong entrepreneurial skill sets and strengths that have not been fully unleashed.

When it comes to creating an entrepreneurial entity, universities vary considerably as to the way they handle the activities of their faculty members so engaged. We need to rethink the messages we send with our policies and their implementation regarding work on technology transfer and entrepreneurship. It is the case that at most public land grant universities, our views about faculty entrepreneurship have evolved over the last decade. There is little doubt that they will continue to evolve over time, but in the meantime there are some basic practices to follow.

Perhaps the most important change we need to embrace is a change in our culture. We need to move from a culture that has been at best ambivalent to faculty starting new ventures to one that is more supportive and that values such activities. Many schools allow faculty to be more entrepreneurial today than in the past and others even support it with incubators and accelerators on their campuses. More than anything else, we as administrators need to speak plainly about entrepreneurship, what it is, why it is important and how best faculty members can pursue such activities. We need to invest in educating faculty (graduate students, and post-doctoral fellows) on issues that relate to the new environment in which research is being done. Most faculty members have not typically had the time to do so on their own. At the University of Missouri, we will be educating our faculty, post-docs and graduate students with three introductory sessions on intellectual property, entrepreneurship and industry funding. We call these meetings the "Let's Talk Series". Each session will run about two and a half hours but not more. We will have experts from around the campus and community give the participants the "what, why, how, when and where" about each of these topics. If participants want to learn even more, they are then provided maps to guide them to further resources. In the case of entrepreneurship, follow-on courses and boot camps will be offered for those who want to delve in and try this. At the end of the "Let's talk series," faculty members will know we are changing our school's culture, why we are changing it and how they can better align with it, if they choose to do so.

5. Don't be jealous of others and borrow their best ideas shamelessly. The idea of shifting a University's culture to one that is more open for innovation, more collaborative than competitive and more embracing of entrepreneurship can be daunting. It seems to be such a significant departure from the past. One can imagine that in the minds of many academic leaders, the risk of making changes of this kind may seem considerable. However, the risks are more apparent than real, more imagined than actual. Furthermore, the old business model for the public land grant university has run its course. There is no alternative to change, and we must find new business models. Change is all a part of that creative disruption process.

Bringing about change at most land grant universities will not be as intimidating as it may seem. The reason is that many schools have been making changes to how they operate and have been experimenting with new approaches for some time. Experiments that create new dynamics in support of the university's fourfold mission are underway at progressive schools such as Arizona State, the California System, Penn State, Minnesota and now the University of Missouri. Learning from these experiments is one way for other schools to reduce their risk as they also seek to make changes to their cultures and modes of operation. As schools do experiments, take some risks and learn, there should be more sharing of outcomes, amongst universities, especially among the public, land grant universities. For sharing to happen, university leaders need to be more willing to divulge information, and to embrace ideas developed other schools, to see if the idea will work at their university.

At the University of Missouri, we have borrowed approaches to managing intellectual property related to industrial contracts developed at Penn State and the University of Minnesota, and have adapted these for our use. We also will be engaged with the MIT Venture Mentoring System, in order to align the entrepreneurial assets that we have among our alumni and within our community. Similarly, when we see other good ideas at other institutions around the country or the world, then we will borrow them shamelessly.

Conclusions. The land grant universities have survived and thrived for 150 years. Our mission in the 21st century remains consonant with our past. At this point in our history and that of our nation, we are asked to do even more than before; we are expected to drive innovation to help the country achieve renewed prosperity through sustainable economic growth. To do this, is to be an "engine of innovation." To succeed at this, we need to bring our institutions closer to the real economy and to the business community. We need to do so locally, regionally, nationally and internationally. We cannot proceed with the same approaches that we have taken in the past. Instead, we need to test new approaches that will set the course for the land grant university for the rest of the 21st century. The new course will integrate the strengths of our past with entrepreneurship to bring forth more innovation from our research and scholarship than ever before.

Endnotes

i. In 1955, just six decades ago, the United States had an economy based on manufacturing. The top five employers were General Motors, US Steel, General Electric, Chrysler and Standard Oil. Today, the top five employers are quite different – they are Walmart, Yum! Brands, McDonalds, IBM and the United Parcel Service, now known simply as UPS. Our economy has shifted away from manufacturing. We can see how profound this shift is when we consider that the top five companies in the US based on their market capitalization are Apple Inc., Exxon Mobil, Google, Microsoft, and Berkshire Hathaway.

ii. http://en.wikipedia.org/wiki/Bell_Labs

iii. http://en.wikipedia.org/wiki/American_Recovery_and_Reinvestment_Act_of_2009

iv. https://www.starmetrics.nih.gov/

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Top Secrets to Growing University Research in Uncertain Times

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It is no secret that the budgetary environment for academic research funding has been more challenging than ever during the last six years. Flat federal funding for academic science and engineering research, increased competition and lower success rates for grants, heightened rivalry for top faculty talent and a larger burden of costs for research compliance make these uncertain times for university research. Despite these challenges, it is more important than ever that universities continue to grow their research enterprise.

Universities perform much of the basic research essential to the nation's long-term competitiveness, contributing to technology development and stimulating economic growth at the local, state and national levels. Unfortunately, recovery from the recession of 2008 has been slow, debt levels are high and the national budget deficit is huge, leading to an increased focus on cutting federal discretionary spending – the source of more than half of academic research funding.

Funding for Academic Research

The federal government has been the primary source of funding for academic research and development for more than 50 years[1]. In FY2008, the federal government provided approximately 60 percent of an estimated $51.9 billion of research and development funds expended by academic institutions[2]. While there have been increases in funding, and the numbers can be sliced and diced different ways, the main story is that federal obligations for science and engineering to universities and colleges have essentially been flat, even prior to the 2008 recession. Since the recession, sequestration has hit funding hard at some key funding agencies, especially the National Institutes of Health, where sequestration in FY2013 lowered appropriations by more than 5 percent or $1.55 billion below the previous fiscal year [3].

Federal expenditures for science and engineering academic R&D increased 4.5 percent from 2009 to 2012 compared to -0.6 percent from 2005 to 2008. But the higher growth rates in the later years largely reflect American Recovery and Reinvestment Act of 2009 (ARRA) expenditures. The 11.0 percent decrease in current dollars from FY2010 federal obligations ($35.3 billion to 1,219 academic institutions) reflects the absence of ARRA stimulus funds in FY2011. The last ARRA funds were obligated in FY2010 and accounted for 14.5 percent of FY 2010 S&E obligations to academic institutions. Universities reported $4.2 billion in expenditures funded by ARRA in FY 2011 and an additional $2.4 billion in ARRA expenditures in FY2012. The loss of ARRA funds has created a negative "cliff effect," with most academic institutions seeing their federal funding decrease during the last two years.

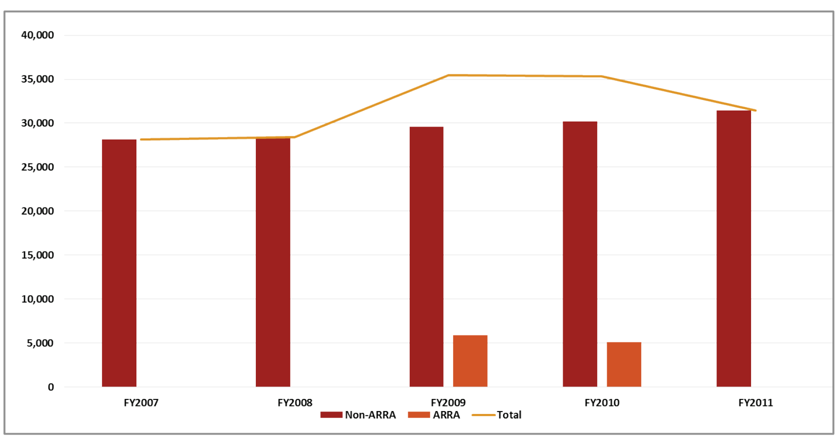
The NIH is by far the largest funder of academic research, providing about 56 percent of total federal academic S&E R&D expenditures in FY 2012. The National Science Foundation and Department of Defense are the next largest, each providing between 12 and 13 percent of the total funding. The Department of Energy, National Aeronautics and Space Administration and U.S. Department of Agriculture provided smaller shares of between 3 and 5 percent of the total in FY 2012[4].

Institutional and State Funds. Other sources of research funding also have been flat or faced reductions. In FY2012, institutional funds – self-funding – from universities and colleges comprised the second-largest source of funding for academic S&E R&D, more than 19 percent of the total, a number that has been fairly steady since 1990. This institutionally financed R&D also includes unrecovered indirect costs and committed cost sharing[4].

Public universities, which rely on state funding, have seen this source reduced as state economies struggle and non-discretionary budget spending grows. From 1992 to 2010, state appropriations as a percentage of public research universities' total revenue fell by 15 percentage points, from 38 percent in 1992 to 23 percent in 2010. At the same time, student enrollment from 2002 to 2010 increased 13 percent, and state spending per student failed to keep up. The result: state funding per enrolled student dropped 20 percent during this time and hit a 25-year low in 2011[6].

Together, these numbers add up to uncertain times for academic research funding that have wide-ranging effects on our institutions' research faculty and the nation's research enterprise.

Greater Competition for Fewer Dollars. Research is a growing part of the



Federal Academic S&E Obligations 2007-2011.
Source: NSF Statistics, NSF 14-309, "Federal Science and Engineering Obligations to Universities and Colleges Drop by 11 percent in FY2011," Michael Yamaner. Total Federal obligations for S&E US-wide in FY2011 was $128 billion.

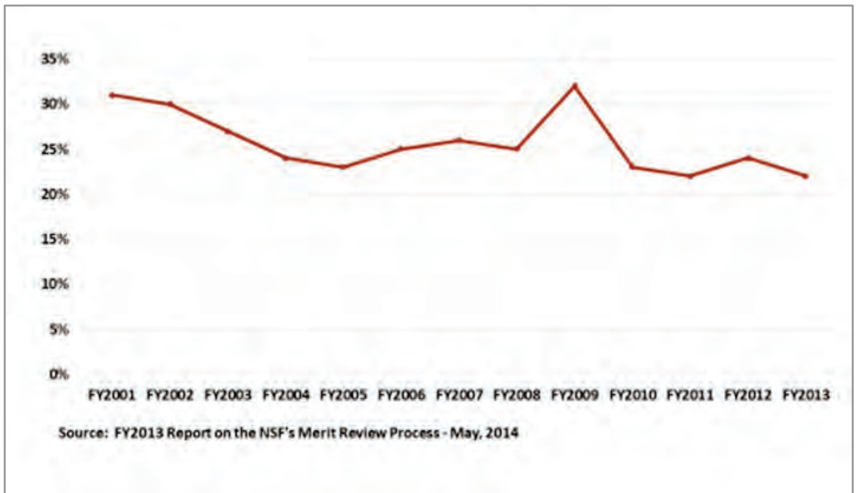
mission of universities, including those who may not have emphasized it in the past. Strong research programs are key to a university's reputation and attract talented faculty, students and donors. As universities push faculty to grow their research programs, more and more researchers are applying for the flat, or sometimes reduced, pool of funds. Competition for research funds has never been more intense, and funding rates are dropping.

The success rate for NIH R01 grants, the bread and butter of biomedical research, has dropped from 32 percent in 2001 to 17 percent in 2013 – an historic low. Nearly all NIH funding metrics, from the number of new awards, average size of awards and total amount of funding for research grants, declined in 2013 due to the 5 percent decline in appropriations due to sequestration [3].

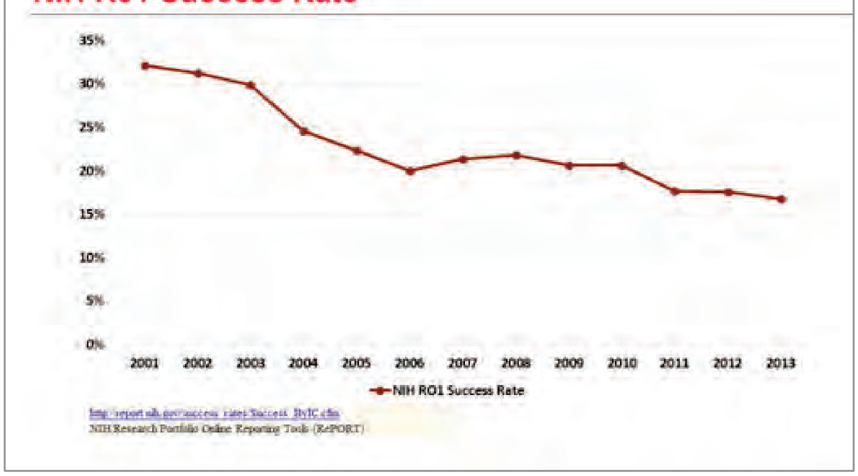
At NSF, the success rate for competitively reviewed proposals in 2013 was 22 percent, the lowest rate since 2001. The funding rate varies by NSF Directorate, from a low of 18 percent in Education and Human Resources to a high of 26 percent in Geosciences[6]. The average award total has been reduced – as has been the level of faculty summer salary covered by NSF awards.

The average number of months of salary support for individual Principal Investigators continued its 10-year decline and is now just over 0.8 months, down from 1.5 months in 2004. Additionally, during the last two years, the number of requests for proposals has declined, and some of the NSF programs have reduced the number of submissions from twice to once annually.

NSF Proposal Success Rates



NIH R01 Success Rate



These trends can have profound effects on a researcher's career. A scientist may not receive her first NIH R01 grant until age 40 or older, following several submissions and rejections. Researchers spend more and more time developing and submitting grants, with less chance of success. Thus, the demand for faculty who are well-funded or have shown the potential to bring in funding is increasingly intense.

Greater Competition for Talent. The quality of any research program depends on its faculty talent, and the competition for both talented faculty and students is intense. Institutions understand the value of proven, talented faculty who are visionary and have track records of establishing competitive, externally-funded research programs. These faculty can instantly enhance the research competitiveness and stature of an institution and can also provide leadership in successfully competing for large grants. There also is increased demand for entrepreneurial faculty who can translate research into technologies and solutions through partnership with clinicians, industry and start-up companies.

Recruitment and retention of faculty has become a top priority at most institutions, and this is driving increases in salaries and especially in start-up packages. Recruits are demanding larger packages as they recognize the competition among recruiting institutions and their own power to negotiate. In the life sciences, physical sciences and engineering, start-up packages can total more than $1 million for faculty in high-demand areas. This trend is not sustainable.

Successful Approaches for Building University Research

We have had good success in growing our research enterprise at the University of Nebraska-Lincoln during the last decade. In a recent 10-year span, UNL ranked seventh among all major U.S. research universities in the percentage growth in total NSF R&D federal research expenditures. We have used multiple approaches to achieve this growth, aiming for quick success in key areas and building for the longer term in other areas. Investments have to be made in many areas, ranging from faculty talent and centers of excellence, to infrastructure and partnership building. Data is invaluable in this kind of strategy, and one of our first investments was the development of NUgrant, an in-house research administration system used to manage all aspects of research activity.

What the UNL data tell us. At UNL, a small number of faculty earn the vast majority of the institution's research funding. During the last four years, 5 percent of faculty brought in more than 50 percent of UNL's federal research funding. Twenty-five percent of faculty brought in 90 percent of the funding.

The majority of our funding come in larger grants: 16 percent of research grants are for more than $1 million, but they account for more than 50 percent of our research funding. A majority of our top-funded faculty are affiliated with centers or major initiatives, but the largest percentage of our faculty have single grants rather than multiple or collaborative projects.

Single investigator-initiated grants vs interdisciplinary centers or program projects. The relative merits of funding agency support for individual investigator-initiated grants versus larger team science grants has been the subject of extensive discussion in the scientific community. The argument for investigator-initiated grants such as the NIH R01 is that these make up the strong investigator-inspired, fundamental research base that produces innovative ideas and major discoveries. Larger, team-science based approaches, it is argued, are required to address major societal challenges and are best supported through center and program project funding mechanisms.

Both approaches are needed, and the federal agencies maintain a balance. In 2013, NIH invested $2.799 billion in 769 research center grants and $14.9 billion on 49,581 research project grants (R01, R15, R21). NSF invested $1.2 billion in single PI grants and $2.1 billion on multiple investigator grants.

At UNL, our data show that half of our federal funding comes in grants of $1 million and larger, and a significant amount comes through grants to interdisciplinary teams and center grants. Our current large multi-disciplinary grants and centers include NIH Centers of Biomedical Research Excellence in virology, redox biology and obesity research; an NSF-funded Materials Research Science & Engineering Center in quantum and spin phenomena in nanomagnetic structures, a large NSF-funded project on the Large Hadron Collider and a USDA Coordinated Agricultural Project aimed at detecting and preventing E. coli infection throughout the beef production pipeline. All of these, and many of our other large projects, include partners from other institutions. These multi-institutional collaborations are critical to our ability to win large awards.

Like the federal agencies, we have to balance our investments in single investigator and inter-disciplinary centers and large teams. We have to invest in the future by hiring top junior faculty, nurturing their careers and building their leadership skills. At the same time, we are investing in centers of excellence through targeted hires, fostering collaborations with other institutions and the private sector, and building infrastructure to support research.

Faculty hires in Programs of Excellence. A decade ago, we decided that the best way to grow our research enterprise was to invest in a small number of areas where we were already strong or where we needed to be stronger to address research challenges important to Nebraska and the nation. Our Programs of Excellence funding and other funds enabled us to hire new faculty, both senior and junior, in these targeted areas. Multi-disciplinary cluster hires enabled us to build strong teams in a short time. Areas in which we have invested central resources include materials and nanoscience, atomic and molecular physics, virology, early childhood education, water and food security, computational sciences and digital humanities.

Developing faculty leadership. Key to building successful research programs are visionary faculty who are also willing to lead faculty teams and pursue collaborative research. We support junior faculty leadership development through our Research Development Fellows Program, a focused year-long experience of formal and informal learning sessions designed to help early stage investigators conceptualize project plans, interact effectively with program officers, identify funding opportunities, plan and draft effective grant proposals and develop an understanding of the proposal review process. We also provide a variety of targeted workshops for faculty, including those on successful proposal writing, faculty career development award programs, interacting with specific agencies like the Department of Defense and strategies for integrating research and education to achieve broader societal impact.

Research Competitiveness Support. In today's tough budget environment, proposals have to be top quality with innovative ideas that are well presented. We created an office that provides support to faculty from idea generation to facilitating team building and external review of proposals prior to submission to funding agencies. This mechanism is very much utilized and appreciated by faculty, especially for large multi-investigator grants. Our faculty have benefited from these services, which have increased their funding success. This focus on enhanced grantsmanship also includes developmental assistance with graphics and generation of grant proposal budgets.

Shared Facilities. The traditional model for faculty hires provides start-up packages to purchase equipment to be located in the faculty member's laboratory. Often this equipment is not accessible to other faculty. Our approach is to require that multi-user equipment be placed in department-wide or university-wide shared instrumentation facilities. During the last three years, we have built four such shared instrumentation facilities. A few examples:

- *The Volte-Keegan Nanoscience Research Center*, which houses a shared instrumentation core facility to support our faculty research in nanoscience and materials science. The building was partially funded through a competitive ARRA grant

from the National Institutes of Standards and Technology. The 32,000-square-foot facility is equipped with clean room space and equipment for making and characterizing nanomaterials provides centralized research facilities for more than 80 physics, chemistry, engineering and other faculty members.
- *The Extreme Light Laboratory* is home to one of the nation's leading programs in laser research and has created an extensive infrastructure, including the Diocles laser, one of the world's most powerful compact lasers, delivering up to 1 petawatt of power. In 2014 a new specialized laser Archimedes, housed in a facility designed for multiple research

teams added to our capabilities. The multi-user facility was funded by ARRA funds from NSF and the laser was funded through an Air Force Research Laboratory grant. The Extreme Light Laboratory is a truly collaborative effort, created through investments from UNL, the state of Nebraska, DoD and NSF.

- *The Center for Brain, Biology and Behavior* features shared research areas that encourage faculty collaboration, state-of-the-art equipment and a unique partnership between UNL research and athletics that deepens the university's growing expertise in concussion research. Other Center research ranges from uncovering the biological underpinnings of political leanings and the nature addiction to exploring the heritability of social attitudes and language development. It is one of the only labs in the world to simultaneously capture functional magnetic resonance imaging (fMRI), record brain electrical activity and track eye movement. The Center, which occupies half of a more than 50,000-square-foot addition to UNL's Memorial Stadium, is adjacent to the Nebraska Athletics Performance Lab, a collaborator on joint health and performance initiatives. NAPL provides shared facilities for investigating the impact of training interventions and nutrition on performance and recovery, assessing the biomechanical impact of performance on the athlete's body, harnessing biomarkers in saliva and blood to guide training, and developing technologies to reduce injury and improve performance.

Faculty engagement. Communication and engagement with faculty is absolutely critical to research success at UNL. The UNL Research Advisory Board, made up of top researchers from disciplines throughout the university was established in 2001. The RAB has provided crucial advice on the research agenda and in defining what is most important to faculty success. An early suggestion that has paid big dividends was to build connections among faculty through interdisciplinary faculty retreats in targeted thematic areas. The most recent retreat, held in May, 2014, involved more than 275 faculty from across campus, featured nationally recognized speakers and talks and "quick pitches" by UNL faculty, panel discussions, networking activities and breakout sessions focused on thematic areas developed in conjunction with the RAB members[7]. At the conclusion of the retreat, a new seed grant program designed to facilitate competitiveness for external funding was announced. These retreats have proven essential to build faculty connections and stimulate the level of cross-disciplinary collaboration and innovative thinking needed for long-term funding success.

Conclusion

In the current budgetary environment, research universities face a number of significant challenges related to the pursuit and capture of external funding, including the recruitment and retention of top faculty talent. This concept paper highlights some of the strategies that have enabled UNL to mitigate these challenges and maintain its research growth and progress. Data-driven decision making, emphasis on individual investigator and team-based projects (including multi-institutional and interdisciplinary efforts), targeted hiring and infrastructure investments, and focused research and faculty development resources represent some of the strategies necessary to maintain market share and facilitate academic R&D in the face of stagnant or diminishing extramural funding. Strategies such as these represent but a few of the secrets to success that may be adopted – in whole or in part – by other institutions seeking to enhance their research profiles in these uncertain times.

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A newcomer's view of research administration in uncertain times

Sarah Nusser, Vice President for Research, Iowa State University

For many years, faculty have faced considerable uncertainty in their research funding environments as well as increased requirements in managing research. In response, researchers have evolved their programs to take advantage of changing research priorities and funding availability, and have learned how to couple fundamental research with a good management plan, compliance and outreach activities, and an explicit focus on broader impacts.

In many ways, the public university experience is not so different from that faced by researchers. State investment and federal funding are at best volatile and more likely to be shrinking; we are experiencing increased scrutiny of our administrative, educational and research practices; and the role of research is also being reframed as part of the broader creative and translational process of innovation.

Like our faculty, we must evolve to meet this challenge. When I joined the Office for the Vice President for Research, we began evaluating the research environment at Iowa State University from the perspective that being responsive to change offers an opportunity to improve how we operate. For example, the focus on accountability sets the stage for developing a research culture that actively commits to ethical behavior. The push for embracing the full innovation chain enables us to more fully express our applied research and consider a much broader set of research sponsors.

At this point in our thinking, we are working with a few basic tenets to help us move forward. First and foremost is the importance of a diversified portfolio in managing volatility in funding opportunities. The second focus area is preparing our faculty to respond to opportunity as it arises. A third and trickier consideration is managing risk in the research and development process as funding sources, regulatory guidelines, and commercial opportunities expand. Finally, serious strategic planning and effective resource management are required to meet our goals.

This paper briefly reviews four examples that illustrate how these themes are shaping our thinking.

Range of focus in research development (increasing diversity and engaging opportunity)

We tend to invest heavily in the star researchers and research-intensive colleges, departments, and programs where the return on investment is most significant. However, there are pockets throughout the rest of the university that have the capacity to engage in higher levels of sponsored funding. For example, some faculty and research groups are active in niche disciplines that may not become a major university priority, but for which funding is available and the competition for funds is not as intense as it is at NSF and NIH (e.g., federal statistical agencies support statistical methods development for national surveys).

Some of these researchers may lack the knowledge required to identify funding sources and develop successful proposals, as is often the case with new assistant professors in research active domains. This problem is readily addressed by existing faculty development programs, outlined in C. Rajan's paper in this volume. They may also face cultural barriers (e.g., negative perceptions of seeking funding, particular research area or funding sources not valued by colleagues), which can be trickier to address.

Supporting proposal development and award management (increasing diversity and opportunity, reducing risk, improving how we function)

Funding streams are becoming more diverse and complex. Today, a large portion of a grant proposal consists of administrative elements that document the capacity of the university and research team and address compliance and regulatory matters. In addition, engaging with larger proposals requires a massive coordination effort.

ISU has a distributed and heterogeneous network of pre- and post-award support. Some colleges and centers have well-developed grant proposal and award staff capabilities. In other parts of campus, available support varies in relation to an academic unit's resource base, which may not be large if grant activity is historically low. Central support for the proposal development process is largely limited to contracted staff and consulting support from VPR staff on larger proposals. To complicate matters, government, industry, and nonprofit/foundation agreements enter the sponsored programs system from three distinct administrative units, which can be confusing to researchers and supporting staff.

We are contemplating a mixed strategy to fill gaps that exist in campus grant support and reduce the burden in preparing and administering sponsored funding. To assist academic units with limited grant support, we are creating a shared pre- and post-award service that will be available to individuals, research groups, and academic units. We are also developing a proposal support system that will serve researchers who wish to submit moderate to large proposals that require good planning and execution and involve interactions with partner institutions. This will be supported with a combination of dedicated ISU and temporary contract staff to address variation in demand for services.

Anticipated benefits of this initiative include more efficient administrative processes in submitting grants and higher quality proposals. We also hope this reduces the barriers for capable faculty to submit proposals for sponsored funding. This concept could be extended to include other services that represent challenges for funded research, such as preparing position descriptions to support hiring as soon as an award is made.

Embracing the innovation chain (increasing diversity and opportunity, reducing risk, improving how we function)

The innovation paradigm links fundamental research to commercial opportunity and is well suited to the land-grant university mission. However, preparing our researchers to engage with the full processes is not without its challenges: we hire researchers for their creativity in knowledge development, and they may not carry an interest in entrepreneurship or commercialization or wish to navigate the contrasting interests of industry and academia.

To address these issues, we are discussing how we evolve our culture and support activities that foster commercialization of research outcomes. This work is being conducted in partnership with ISU's Vice President for Economic Development and Business Engagement. Our main activities have focused on two areas: (1) initiating pilot programs to better understand what training is needed in order for our faculty to be successful in translating their research to commercial applications, and (2) determining what to prepare for as an institution in order to manage risk in the translation process. In our first pilot project, we are recruiting faculty who are interested in entrepreneurship and initiating a mentorship program with local business leaders and angel investors. From this experiment, we hope to identify what kind of support is needed to more efficiently spawn commercial products and businesses from our research efforts. Our second project is designed to help us understand appropriate roles for personnel with dual commitments in conducting research and engaging with start-ups. We are working with a center that has spun off a handful of start-up companies to identify which roles arise and how we wish to separate the academic and business functions to avoid conflict of interest. Finally, we are discussing structures needed to connect industry to campus researchers to address the emerging research needs of businesses.

Responsible research and conduct (reducing risk, improving how we function)

In recent years, the burden, complexity, and risk associated with research conduct and compliance have steadily increased. These forces demand a more coherent approach than we currently have. Fortunately, the ability to investigate and address noncompliance and misconduct works well at ISU. We are now discussing how to address campus culture more broadly to increase researchers' understanding and commitment to responsible research conduct.

Our main work thus far has focused on understanding the landscape and its challenges. The dynamic, conflicting, and arcane regulatory environment makes it difficult for researchers to understand and engage with this responsibility, particularly given their intense workload. Our office also faces issues in keeping abreast of new changes to regulations and evolving roles of faculty (e.g., via start-ups). It can be especially complex to balance the forces of keeping compliance procedures simple and uniform and thus potentially too restrictive versus tailoring the procedures to specific research settings and resolving the resulting confusion and workload associated with a more flexible approach. As we migrate to new software systems for compliance committees, we have an opportunity to evaluate our processes and see if we can reasonably address these forces.

Ultimately, we need to more actively engage campus in a discussion of research ethics and increase our training opportunities for researchers. This work is still ahead of us.

Anticipating New Directions in Human Subjects Research

Michele Kennett, Assistant Vice Chancellor for Research, University of Missouri

Human subjects research, highly regulated and overseen through the Institutional Review Board, is still viewed by many as a barrier to research. The question is, how we can as institutions, move from being the barrier to research to aiding in creating a culture of compliance?

Challenges

Today, research and academia face an ever-growing number of challenges. The changing funding environment is at the top of most lists. With decreased federal funding there is increased competition for research dollars and increased look to industry to remain competitive.

Institutions face challenges in dealing with the increasing number and complexity of regulations. These unfunded mandates provide both fiscal challenges and challenges in implementation in an environment where investigators are already feeling the burdens. Even potential changes to the regulations, such as has been suggested by the Advanced Notice of Public Rulemaking (ANPRM) proposing to revise the human subjects regulations, creates an unknown which may benefit the research environment but might also bring increased burdens to the institution as well as the investigator.

Increased complexity of contracts creates challenges, extending timelines for study implementation in an already competitive environment. Contracts may have to go through countless sets of negotiations over items ultimately inconsequential to the institution. Integrated systems of contract review with timely weigh-in need to be developed to cut down the turnaround time and move contracts on in a timely fashion.

Difficulty recruiting subjects poses another challenge. Adequate feasibility analysis needs to be conducted to determine that the population is available to be recruited. Investigators need to take into account for the amount of work that is involved in recruiting subjects – "build it and they will come" rarely works in the research enterprise. You need to create relationships, revisit those relationships and put a significant amount of elbow grease into the recruitment and retention of research subjects. In addition, if you do not have a strong culture of research you have to educate the community you are recruiting from. The community needs to understand the value and availability of research.

Inadequate research training, poor mentoring of new researchers, research coordinators without appropriate skills to carry out a research protocols and lack of professional compliance staff, all cause inefficiency in the research enterprise and leads to dissatisfaction and frustration.

How do we respond?

We must be proactive not reactive, balance accountability and risk management and understand the needs of the investigator. We need to rethink the way we do business. Many times we get stuck in the mindset that we have to do it this way because we have always done it this way. We have forgotten why or if there ever was good justification for doing it that way. Times have changed, we need to rethink and reanalyze our interpretations - are they still good, or do we need to adjust? Many in human subjects protections are currently rethinking several areas, one is the reliance on a single IRB in multicenter trials. In some places this has been off limits, either it was reviewed at the institution it was being conducted at or it was not done. Today, many are rethinking this position and facilitating multicenter research through a single IRB. Another area being explored is the option for equivalent protections in human subjects protections. Federal regulation dictates the regulations applied to federally funded research but flexibility is possible in non-federally funded research, provided it provides equivalent protections. This may lead to a lessening of the burden for some types of research i.e. research in schools. Metrics are another way to show the value of what we do in human research protections, today's electronic systems allow us to track and quantify the many activities that go into human subject protections. Metrics allow us to calculate time from submission to approval and identify where delays occur. We can determine the portfolio of studies by funding type, type of subject, or regulatory status - giving a much better picture of what a human subjects protection program does.

How do we help investigators?

We need to help investigators understand what the rules are, when the rules apply, whom they apply to, and what the consequences are. Investigators often do not have the toolbox that would allow access to pertinent information directly related to their research needs. A toolbox would allow investigators to access information needed for IRB submission, forms and templates, FDA regulations, and guidelines on how to navigate the human subjects research experience. There is generally no one-stop shop for regulatory compliance, but today with technology available to us, the ability to create a more centralized place for investigators and compliance staff to interact is possible. Technology can allow submission of a protocol for IRB review, access to conflict of interest disclosures and reviews by biosafety and radiation safety all within the same system. We need to make the most effective and efficient use of time and effort in order to meet the needs of both the institution and the investigator.

Building Research Capacity and Infrastructure

Chitra Rajan, Associate Vice President for Research, Iowa State University

The last seven to ten years have been very challenging for universities: we have seen a growing scarcity of resources for research due to decreases in federal funding and reductions in state support. At the same time, research administrative costs have been increasing, as greater resources (including staff time) are required to handle the growth in compliance, accountability and reporting requirements. Greater investments are needed to maintain, let alone grow funding streams in these uncertain times and the administration of research has become more complex. Public support for higher education institutions is on the decline, and universities are expected to demonstrate their relevance in terms of their abilities to solve complex societal problems.

During this time, Iowa State University (ISU) witnessed a period of rapid growth in its external funding; during a period of 5 years (2008 – 2011), sponsored funding increased from $274 million to $365 million (after peaking at $385 million during the ARRA funding years). Prior to this period, from 2005-2008, sponsored funding had been decreasing and so the university made some deliberate and calculated decisions that helped not only reverse the downward trend but increase the level of funding to unprecedented levels. Although ISU's approach was neither new nor unique, it is nonetheless worth recounting some of these strategies since it underlines the importance of institutional investments in research administration and infrastructure (broadly defined), without which, research capacity cannot be built and research advancement cannot take place.

Despite severe cuts in state funding over a 3 year period, ISU was able to make critical investments, develop new programs, and improve processes and overall efficiencies. Some of these efforts are described below:

1. Institutional strategic investments were made in a few critical areas: bio-economy, vaccine development and delivery, integrated health, and HPC. Criteria for identifying these strategic priorities included (i) the existing base or at least, pockets of excellence, in the proposed area that included a critical mass of researchers with senior faculty leadership; (ii) the theme/area would address scientific/economic/social challenges that required broad-based interdisciplinary approach; (iii) there were clearly defined focus areas within the themes where ISU was seen as capable of providing leadership and setting the research agenda and/or had collaborative networks

with other institutions that were recognized as world leaders in that area.

2. New faculty hires (cluster hires); these were inter-departmental and inter-college hires with the objective of developing interdisciplinary expertise. It was also meant to reinforce a culture of collaboration by sending a clear message that the university supports and values interdisciplinary research. Many of these cluster hires were at the entry level (assistant professors) and very few at senior positions mainly due to financial reasons. These junior hires were paired with senior faculty who are known for their collaborative work in order to provide them with the mentoring in cross disciplinary work.
3. A strong commitment to provide excellent research support services and facilities that are needed to enable research excellence and knowledge transfer. These include sponsored program accounting and administration; responsible research and compliance; core facilities and laboratories. The former and current VPRs held 'listening sessions' that helped us identify the impediments and challenges that researchers faced with respect to any aspect of research administration and plans to address the issues/obstacles have been in progress. Most notably, the VPR Office has stepped up the resources available to help faculty submit grant proposals and manage awards by offering comprehensive menu of research development and support services chain (identify funding opportunities; proposal preparation and submission; project management and compliance; reporting and closeout), thereby making it easy for faculty to develop, prepare, and submit grant proposals by reducing administrative or clerical work. The VPR Office and the Office for Sponsored Programs Administration also provided several training and workshops for support staff in departments and centers to upgrade their skills in grant preparation and post-award and project management.
4. Develop the capacity and capability to deal with the growth of compliance requirements' complexity and intensity. The VPR Office has been helping create a culture that promotes compliance, research integrity and ethical conduct by incorporating awareness at all levels. There has also been greater efforts to help researchers and staff understand and deal with these requirements and at the same time, develop efficient and proportionate processes to meet compliance and reporting requirements so that they do not become unduly burdensome for researchers.
5. A broad plethora of professional development programs for all researchers – faculty, staff, postdocs and graduate students – are offered each year to help early career researchers gain grantsmanship and research administration related skills. In addition, and in collaboration with the Provost Office, new mentoring programs were developed that were based on a 'distributed model' that involved department chairs and senior faculty. The goal was to allow faculty at every stage of their career, and

in all disciplines, to flourish and develop. The creation of a grants office to assist arts and humanities faculty obtain external funding is perhaps most noteworthy. This office helps identify funding opportunities for specific projects, assists faculty members with proposal development and submission, and trains them to become eventually self-sufficient. The VPR Office uses the limited submission internal competition to provide targeted support and maximize the chances of success (example, internal peer reviews of grant proposals and manuscripts, assistance with proposal coordination for large grants, and sharing of best practices from previous successful grant proposals).

6. Although most cross-disciplinary interaction occurs spontaneously, the VPR Office proactively facilitated team formation by providing thematic contexts for cross-disciplinary interaction based in large part on emerging new opportunities. These efforts helped develop multidisciplinary communities that were well-equipped to address problems demanding diverse expertise. This was also a time when the President and Provost Offices were willing to invest their own resources to foster an environment where openness to cross-disciplinary interaction was recognized and rewarded through campus-wide discussions on tenure and promotion criteria.
7. In an effort to build interdisciplinary research capacity, a seed fund program was re-introduced. The importance of investments in developing new or 'tuning up' existing research programs cannot be overstated. The VPRED Office used to have a modest budget for seed grants, but it was lost during the budget cuts. Using some limited amount of funds, a new and revised seed grant program was introduced that extended beyond the traditional planning grants and/or pilot projects from yesteryears. The primary goal of these new seed grants was to build new cross-disciplinary research themes. Some of the colleges offered their own 'venture capital' funding to build large inter-disciplinary teams. After surviving three years of severe state budget cuts, the VPR Office began to offer funds to meet other needs such as (i) seed funding to gather pilot data for NIH grants, (ii) graduate student funding – especially to support training grants – and required co-supervision from faculty in different colleges; (iii) build collaborations with industry partners (both contribute for a pre-commercialization phase); (iv) small grants for junior faculty teams -- junior faculty partner with junior faculty in another discipline and have a senior faculty as mentor; and (v) modest funds for inter-disciplinary seminar programs, conferences and workshops.
8. A deliberate strategy was adopted to broaden our funding sources and target specific programs within traditional funding agencies that had been beyond our reach until that point. In particular, the focus was on large center grants were targeted and ISU was

awarded 7 large center grants during this period.

9. By partnering with other units, the VPR Office helped expand ISU's engagement with industry through an integrated team approach, making it easier for companies to work with ISU as well as for researchers to communicate their expertise and interests to industry. At this time, there was strong institutional support from the top to these efforts, which demonstrated a commitment of the university leadership to corporate relations. ISU created an 'industry relations team' by bringing together professional staff who were distributed in different offices across campus (in subsequent years, additional staff were added to this team). This team's goal was to work with internal and external partners to build corporate engagement (overcome barriers); provide one point of contact for the corporation, build awareness of university programs and strengths, identify each company's strategic needs and match those needs with the university's strengths and strategic priorities, and generate new leads and prospects. Specifically, the industry relations team was expected to gain knowledge about faculty strengths and research capabilities in specific areas that would be of interest to targeted industries (example, aerospace, biofuels, food, agro-based, pharmaceuticals) and communicate those strengths to corporate partners. Once an area of mutual interest is established, the team was expected to close the deal by working with appropriate offices to develop contracts and agreements in a timely manner. They would also help with the stewardship of the projects: correspondence, annual reports, site visits focused on showcasing the work done and recognition/appreciation to promote the collaborations.
10. The VPR Office helped provide leadership in building strategic alliances regionally and nationally -- with other universities, national laboratories, and industry. With each partner, we identified prospects where strengths are complementary and synergistic and where combined effort offers exceptional potential. While many of these collaborations were driven by partnering needs for large center-based solicitations, others were deliberately cultivated to develop broad-based engagement (as with industry) or to enable sharing of key infrastructure and equipment that made it easier for ISU to compete for equipment grants.
11. Last, but not least, and especially now under the new VPR, there is a strong commitment that all support service units under the VPR Office will be well managed, service-oriented, and responsive to faculty needs. Staffing for many of the critical research support offices such as sponsored programs administration and responsible research has increased, making it easier for these units to keep up with the growth in the volume and complexity of sponsored funding contracts. There are resources now for staff professional development and a

cultural shift that emphasizes consultative decision making, and continuous self-assessment and improvement.

CONCLUSION

The VPR Office played a proactive role in anticipating emerging themes and areas for new funding, in building capacity, and developing a research portfolio that capitalized on ISU's position of leadership in targeted areas. Even during periods of budget cuts, the university identified institutional resources that were flexible and deployable for capacity-building in areas of emergent research excellence. By building on existing strengths, and working across and between disciplines, ISU was able to see growth in external funding from a range of sources across the breadth of the university's research activity. A few lessons are noteworthy: (1) it is critical that research universities develop a plan to diversify their funding portfolio to hedge against the vagaries of external funding; (2) make selective, strategic investments even in difficult times; (3) develop long-term sustainable plans for programs and units; (4) although it may be politically unpopular to do so, discontinue support for unproductive and under-used programs and units; and (5) be willing to take some calculated risks.

Clinical Research: New Frontiers

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Clinical research is undergoing significant changes due to both technological advances and new visions about clinical research by the NIH and PCORI, two major funders of health related research. An often quoted statistic is that on average new discoveries have taken 17 years to make their way into common practice. All acknowledge this is far too long. Both NIH and PCORI recently have created and funded large programs aimed at doing clinical research better and more efficiently so that discoveries are brought to patient care and improve the health of the public more rapidly. In 2006 and 2007 we provided initial information about the status of the long standing General Clinical Research Center (GCRC) program supported by NIH for over 40 years and the then newly launched Clinical and Translational Science Award (CTSA) program designed to subsume and replace the GCRC program (Barohn, 2006; Barohn and Aaronson, 2007). In this report we provide an update on these and other programs that are aimed at improving clinical research as we know it.

First, we briefly discuss the CTSA program funded by the National Center for Advancing Translational Sciences (NCATS) at NIH and describe the current status of *Frontiers: The Heartland Institute for Clinical and Translational Research*, the CTSA program headquartered at KUMC. Second, we discuss the NeuroNEXT program, a consortium program funded by the National Institute of Neurological Disorders and Stroke (NINDS), NIH, and for which KUMC is one of 25 funded site participants. Third, we discuss PCORI and the PCORI Clinical Data Research Network (CDRN) and identify several individual clinical research projects funded by PCORI. KUMC was awarded one of 11 CDRNs earlier this year, one of the authors of this paper (Barohn) is the principal investigator of a specific comparative effectiveness clinical trial also funded by PCORI earlier this year, and KUMC investigators have been successful in obtaining additional clinical research grants from PCORI.

The Clinical and Translational Science Award (CTSA) Program

The CTSA program is a signature program of NIH (https://www.ctsacentral.org). With a budget of $475M annually it is the largest single program funded by NIH. Initially established under the former National Center for Research Resources, as identified above, it is now managed by the new National Center for Advancing Translational Science (NCATS).

When first launched, the purpose of the CTSA program was to establish a transformative and integrated academic home for clinical and translational science. Each site was required to have a number of key function areas or cores and was allowed to propose unique novel methods programs drawing on strengths of the applicant organization. Funding formulas varied over the years since 2006 when the first CTSAs were funded. *Frontiers: The Heartland Institute for Clinical and Translational Research* was funded in June 2011 for $20M over five years and became part of what is now a 62 site national consortium.

Frontiers: The Heartland Institute for Clinical and Translational Research. The Frontiers program, headquartered at KUMC, is a regional program (http://frontiersresearch.org). From its inception we were committed to advancing aspirations of making the Kansas City area a major hub for life sciences research. We reached out beyond KUMC and the University of Kansas Hospital to the other local academic health centers and their affiliated hospitals. Today, five academic institutions (KUMC, KU-Lawrence, KUMC-Wichita, UMKC, and KCUMB) and 10 health care institutions (see Table 1) comprise the Frontiers program. Investigators from all of these sites are eligible to apply for and use Frontiers resources.

Table 1. The Frontiers network of academic and health-delivery institutions

Academic partners	Health system partners
University of Kansas Medical Center - Kansas City University of Kansas Medical Center - Wichita University of Kansas - Lawrence University of Missouri-Kansas City Kansas City University of Medicine and Biosciences	The University of Kansas Hospital, Kansas City, KS. Wesley Medical Center, Wichita Via Christi Health, Wichita Veterans Administration Medical Center, Kansas City St. Luke's Health System, KS and MO Children's Mercy Hospitals and Clinics KS and MO Truman Medical Center, Kansas City, MO. Swope Health Services, Kansas City, MO. Center for Behavioral Medicine, Kansas City, MO. Center for Practical Bioethics

Among the successful programs under the Frontiers umbrella is a pilot study funding program. It is increasingly competitive to obtain extra-mural funding for research and having solid, supportive data from a pilot study has become essential for success with such funding. Since our initial funding in 2011, we have had four annual rounds of Requests for Proposals. Across these four years, we received 294 applications and funded 71 projects to investigators from Children's Mercy Hospital, KU-Lawrence, KU-Wichita, UMKC, and St. Luke's Health System, in addition to investigators from KUMC. Pilot study funding for a project has varied from $20-30K for each project.

For the Frontiers pilot study program we have used reviewers from across all Frontiers sites and have invited other units and programs that have pilot study funding to award to join our process for review and funding decisions. Each year we have modified our process in response to past years' experience. We now use an approach where the peer reviews of applications are taken to a funding council composed of representatives from the Frontiers sites and from other programs/units with pilot study funding to award. Combining the review and funding decisions of several programs has enhanced efficiency, reduced redundancy, and extended awareness and knowledge of the breadth of clinical and translational research across our institutions. The investment in these pilot studies has been substantial. For the 71 projects funded so far, $1.1M came from the CTSA grant and $685K was contributed as 'cost-shared' funds from other programs (the KUMC Research Institute, the K-INBRE program, an American Cancer Society grant program at KUMC, the KUMC Diabetes Center and departments of internal medicine, neurology, and physical therapy & rehabilitation sciences, KU-Wichita, UMKC, and Children's Mercy Hospital.)

While some of these pilot studies were recently funded and are currently ongoing, we already have seen substantial return on the investment of pilot study funding. Two R01s have been awarded by NIH to investigators for projects based on their pilot study work and one other pilot study recipient anticipates receiving funding for an R01 this fall. In addition, one NIH R03 has been awarded to an investigator who received Frontiers pilot study funding for preliminary work and one large PCORI grant has been awarded to another Frontiers pilot study recipient. These four funded projects amount to over $3.2M in extra-mural research funding.

In 2013 the Frontiers program launched another program to provide a smaller amount of funding on a more flexible basis than the annual call for the formal pilot study program. Dubbed the Trail Blazer program, this opportunity allows for obtaining that last bit of data needed for a competitive extra-mural research grant application or for an opportunity to capitalize on an existing funded project and extend its work toward an additional area of inquiry. These applications may be submitted at any time and undergo an administrative review. While applicants may ask for up to $5K, often less is requested or awarded. In its first 18 months, 45 applications were received for Trail Blazer awards and 33 were funded for a total investment of just over $88K. All Trail Blazer recipients commit to submitting an extra-mural grant application within 12 months. While it is still too early to see return on our investment in these Trail Blazer awards, two recipients used their Trail Blazer funding to extend work on their active NIH R01 grants.

Another major component of all CTSAs is education to train the next generation of the clinical and translational workforce. To this end, the Frontiers program established a Clinical and Translational Education Center (CTREC) to coordinate and manage several specific training programs. The CTREC currently offers a pre-doctoral clinical research training program (TL1), a post-doctoral mentored clinical research scholar program (KL2), and a post-doctoral fellows and junior faculty Clinical Research Curriculum Program. Trainees in each of these programs may complete a formal Masters in Clinical Research degree (MS-CR). The Clinical Research Curriculum Program primarily provides tuition assistance so that these post-doctoral fellows and junior faculty may take classes required for the MS-CR degree. Tuition costs also are covered for the TL1 trainees and the KL2 Scholars.

The TL1 program is a year-long program that provides institutional support to students in clinical doctoral programs who are seeking a practical introduction to clinical and translational research. Students selected for the TL1 program take this year out of their regular degree program, thus extending their training by one year. The Frontiers TL1 program has supported four students each year from the KU Schools of Medicine and Pharmacy, and from KCUMB.

The KL2 program offers institutional support for mentored career development of investigators who have recently completed professional training and are beginning a career in translational and/or clinical research. It is generally a two-year program that involves a 75% time commitment with salary largely covered by the Frontiers CTSA grant. Commitments from the scholars' home departments were obtained to cover up to 25% salary so that each scholar would have the requisite 75% dedicated time for their research training and experience. This cost-sharing allowed us to support six KL2 Scholars in each of the two cohorts of Scholars thus far. While the second cohort only recently started their training, two of the first six Scholars already have garnered independent funding for their research—one was awarded an R01from the National Cancer Institute at NIH and the other received a Blue KC Health Outcomes Grant.

The Frontiers program also provides other resources to support investigators. While we are not describing all of these in this paper, it is worth noting that Frontiers serves as a matchmaker for finding colleagues or mentors and provides a forum in which investigators may brainstorm their research ideas or get specific feedback on developing grant applications. This has shown to be a very valued resource. In the words of one investigator, recently funded by NIH for an R01, and who did not receive any specific funding assistance from Frontiers but did take advantage of our collegial assistance: "I can't sing the praises of the CTSA enough for the help it provided to us."

Network for Excellence in Neuroscience Clinical Trials (NeuroNEXT)

While the CTSA program is "disease agnostic", some of the categorical institutes at NIH have established national consortia specific to their institute's focus areas. NeuroNEXT is one such consortium or network supported by the National Institute of Neurological Disorders and Stroke (NINDS) (http://www.neuronext.org). It was created to expand the capability to conduct clinical studies in neuroscience. One of the authors of this paper (Barohn) is the principal investigator of the NeuroNEXT program at KUMC and chairs a formal CTSA/NeuroNEXT committee to promote synergy between these two programs.

The goals of NeuroNEXT are fourfold. The first goal is to test promising therapeutics in Phase II clinical trials, using biomarkers when available, and to generate results that may support moving forward with a larger Phase III trial using a Go/No-Go decision process. The second goal is to accelerate drug development through an established clinical trials infrastructure. In addition to funding the 25 sites that comprise the NeuroNEXT network, NINDS also funded a Clinical Coordinating Center at Mass General Hospital and a Data Coordinating Center at the University of Iowa to provide this clinical trial infrastructure. Through these entities, the NeuroNEXT network has the flexibility to take advantage of opportunities that emerge and to foster sharing of expertise in different diseases across the 25 network sites.

The third goal of the NeuroNEXT program is to decrease the cost of conducting trials and the time between trial design and trial completion. Two mechanisms that support this goal are the use of a central IRB and standard master trial agreements for all studies conducted through the NeuroNEXT program at the 25 sites in the network. The fourth goal is to coordinate efforts between the public and private sector and test the best therapeutics coming from both academic and industry investigators. To this end, NINDS leverages their existing relationships with academic investigators, industry investigators, and patient advocacy groups (Kearney, et al., 2014).

Through the NeuroNEXT program, KUMC is currently involved with four studies. These studies focus on four diseases. The first involves looking at biomarkers in spinal muscular atrophy. The other three are intervention trials involving multiple sclerosis, myasthenia gravis and stroke.

The PCORI Clinical Data Research Network (CDRN)

The Patient-Centered Outcomes Research Institute (PCORI) was established as part of the federal Affordable Care Act and authorized by Congress to fund and disseminate research on the best evidence available for patients and health care providers to make the best decisions about health care. It has a very substantial budget and has become a major player in the clinical research arena. One large program launched by PCORI is the PCORnet. The PCORnet is composed of both a clinical data research network (CDRN) and a patient powered research network. In this paper we address the CDRN program.

In January 2014, KUMC signed a $7M contract with PCORI for the 18 month Phase 1 part of PCORnet as one of 11 funded CDRNs (R Waitman, KUMC, PI). Called *The Greater Plains Collaborative* (GPC), our CDRN involves seven states and 10 institutions (see Table 2) from Minnesota to Texas—all of which are home to the greater prairie chicken, our namesake and mascot. Nine of our 10 sites also are part of a local CTSA program. While some other CDRNs are at institutions with CTSAs, we believe the GPC has done the most to integrate and create synergy between these two large national programs.

The overall goal of PCORnet is "to improve the nation's capacity to conduct clinical research by creating a large, highly representative national patient-centered network that supports more efficient clinical trials and observational studies" (http://www.pcori.org). A key concern for PCORI is involvement of patients and other stakeholders in all phases of clinical research involving people—from idea conception to study design and implementation, data analyses and interpretation, and dissemination and implementation of treatments shown to be most efficacious. This is based in the PCORI commitment to supporting research "that will be useful to patients and other clinical decision makers by ensuring that their questions and concerns are the focus of our work." (Selby, et al, 2013).

The specific role of the CDRN program in PCORnet is to harness the rich data currently residing in electronic health records (EHRs). The GPC views the CDRN program as a test of the nation's multi-billion dollar investment in EHRs. While EHRs are increasingly present in hospitals and health care practices, there has been little quantitative evidence for determining the degree to which EHR data can be used to assess clinical effectiveness. Given the diversity of EHRs, there also are many challenges to establishing the interoperability and common language standards needed to conduct research across institutions using different EHRs. Technical issues involved in establishing the GPC and working with our 10 sites are discussed elsewhere (Waitman, et al., 2014).

Table 2.The Greater Plains Collaborative (GPC) is a network of 10 leading medical centers in seven states.

State	Medical Center
Kansas	University of Kansas Medical Center
Missouri	Children's Mercy Hospital
Iowa	University of Iowa Healthcare
Wisconsin	University of Wisconsin-Madison
	Medical College of Wisconsin
	Marshfield Clinic
Minnesota	University of Minnesota Academic Health Center
Nebraska	University of Nebraska Medical Center
Texas	University of Texas Health Sciences Center at San Antonio
	University of Texas Southwestern Medical Center

While it is too soon to have any specific outcomes from the GPC to discuss here, we do want to identify that the GPC will be working within the PCORnet on three specific conditions. All applicants for a CDRN were required to select one common condition, one rare disease, and to agree to work on obesity as an all-CDRN focus area. After consulting with our community stake-holders through our respective CTSA community engagement core function areas, the GPC selected breast cancer as our common condition. For our rare disease we selected amyotrophic lateral sclerosis (ALS), commonly known as Lou Gehrig's disease, because of the expertise we have in this specific rare disease.

Last, we introduce two independent projects recently funded by PCORI to illustrate the types of research that PCORI supports. Patient Assisted Intervention for Neuropathy: Comparison of Treatment in Real Life Situations (PAIN-CONTRoLS – R Barohn, PI) is comparing four different drugs used to treat neuropathic pain to see which is most effective. The other study, Smoking Cessation Versus Long-Term Nicotine Replacement among High-Risk Smokers (E Ellerbeck, PI) is comparing two different methods for smoking cessation in patients with chronic obstructive pulmonary disease (COPD.) Both studies are ongoing and both actively sought input and involvement of patients in designing the studies—resulting in changes and additions that made the studies more relevant to the patients affected by these conditions. These are just two examples of how this new funding resource is allowing our investigators to conduct practical comparative effectiveness studies in our region and to do so in partnership with the people whose health we hope to improve.

In sum, collectively, the CTSA program, the institute-specific research networks like the NeuroNEXT program, and PCORI for both its ambitious PCORNet program and its general portfolio of supported health outcomes research are driving a new frontier in clinical research. Central to this new frontier is collaboration across disciplines and institutions, within and outside academia, with industry and the public sector, including patients, advocates, and policy makers. The shared hope is that through such collaboration we can more rapidly and more rigorously find answers to the questions that matter most for achieving a healthier public.

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Can research inform us about the efficacy of University STEM education?

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Accountability for Student Learning and Its Potential Effects on the Public Research University: Creating more effective models for science, mathematics, engineering and technology (STEM) education represents one of the perennial problem/opportunity scenarios for the future of U.S. public research universities. Trends since the 2007 recession show enrollment in STEM fields on the increase [1], which provides a ready-made response for universities engaged in discussions of their contributions to regional and national economic development. However, improving the retention of students in STEM majors has been a longstanding challenge for universities. Based on recent discussions it appears that many states intend to incorporate student retention, including retention in STEM majors, as a metric in the evaluation of the efficacy of public university performance. [2]

Resulting institutional efforts to improve the quality of STEM instruction and learning outcomes of STEM students will provide an opportunity for public research universities to broaden the scope of the university research mission through the application of rigorous, quantitative social science research methods to our own efforts to drive educational improvement. Employing the methods and metrics of research to studies of undergraduate STEM curriculum change may insulate public research universities from specious arguments that our education and research activities are something other than indivisible aspects of our mission, and from the even more destructive argument, promulgated by some, that the research activities of public research universities detract from our role in teaching undergraduate students. [2]

Over the past 15 years, the increased climate of accountability around the use of taxpayer funding has come to rest on the U.S. public higher education system. Key accountability metrics commonly embraced by both State governments and organizations influencing national higher education policy include both student retention in college and time to degree. [3] These metrics present challenges for traditional models of university STEM instruction, which are perceived to contribute to higher than institutional average attrition from the ranks of STEM majors.

In a ground breaking 1999 study, Seymour and Hewitt examined the motivations of students who leave degree programs in STEM majors, but go on to complete university degrees in alternative academic fields. [4] The study related a number of the factors contributing to this attrition to characteristics of traditional

STEM curricula: Overwhelming amounts of vocabulary, perceptions of poor teaching, and loss of interest in STEM subject matter. These factors relate to some of the challenges facing U.S. Engineering programs, where degree obtention rates of 60 percent represent a national average. [5] Given the current focus on degree completion and time to degree as metrics for university success, these challenges could, if left unaddressed, become a threat to the structure and mission of public research universities.

Research on the nature of human learning has provided a window into effective solutions to these challenges. Many instructional models that accommodate a broader range of learning student learning styles, improve success in learning and increase student engagement with subject matter are based on the cognitive development theories of Piaget. [6] Flipped classroom and peer instructional models which are intended in part as vehicles for enhancing student success and self-efficacy are based on constructivist learning theories. Constructionist instructional models tend to be more student-centered than traditional direct instruction methods. (Interestingly, recent asynchronous instructional methods, including massively open online courses (MOOCS) may, but often do not, employ constructivist-derived learning models.)

While constructionist learning models hold promise for generating improvements in metrics such as time to degree and degree obtention in STEM majors, they are likely to be relatively expensive in terms of supportive infrastructure and faculty opportunity costs. Furthermore, rigorous educational research studies are usually required to unequivocally establish a connection between constructivist based course interventions and improvements in specific, desirable learning outcomes.

In order to demonstrate both to the Academy and to external stakeholders that STEM curriculum changes are actually having the effect we anticipate, we need to consider whether public research universities should systematically turn the tools of rigorous quantitative and qualitative research inward to study the instructional changes being driven, in part, by a culture of increasing accountability. Though this path would increase the cost of implementing curriculum innovation, it would also provide a range of benefits for our institutions, including:

- Development of a broad, new area of multidisciplinary scholarship that is only practicable on a large scale in research universities,
- Creation of a vehicle that allows faculty who have largely shifted their focus to teaching and learning to contribute more broadly to the scholarly life of the university,
- Validation for the university community about the efficacy of the human resources and dollars expended on these efforts, and
- Development of ready-made talking points for accountability discussions with external stakeholders.

Most top-flight public research universities began to take steps to support faculty efforts to create a scholarship of learning as a follow on to the Boyer report [7], and some have developed extensive, nationally recognized expertise in this area. [8] The key questions we must ask about applying these capabilities to studies of STEM curriculum change are: Can rigorous quantitative educational research answer fundamental questions about the efficacy of university curriculum reform, what are anticipated institutional commitments and costs for these studies, and what are reasonable boundaries for the implementation of such programs?

Commitments and Costs for Educational Studies

Among the most daunting challenge of conducting high quality institutional studies of curriculum change is the rigor of designing experiments that will provide meaningful answers to our questions. Collecting a data set that provides adequate statistical power to study all targeted subcategories of learners, maintaining 95 percent confidence limit standards, cleaning and analyzing data sets with large numbers of variables, ensuring the statistical similarity of control and treatment cohorts in an environment of quasi-experimental design (most institutions and faculty are uncomfortable with random assignment studies), and ensuring compliance with human subjects (IRB) requirements all add to the commitment made when undertaking this type of analysis.

A compounding factor associated with such studies is that creating and implementing a relatively straightforward curriculum innovation in a single course, together with designing a course evaluation and collecting and analyzing student outcome data can easily comprise the topic of an entire doctoral thesis. This timeline is problematic for studies of STEM curriculum innovation in research universities where primary interests may lie in longitudinal questions relating the influence of large-scale curriculum change to post-graduate outcomes. Such studies require an extended timeline and more careful research design than studies of a single innovation in an individual course. Achieving this goal would require long-term collaborations among faculty teaching STEM courses, capable quantitative and qualitative educational researchers, and full time university staff dedicated to providing continuity in the study.

Appropriate longitudinal evaluation of curriculum change can be relatively expensive. Guidelines for budgeting evaluation studies in NSF curriculum innovation programs call for commitment of as much as 15 to 20 percent of the total project budget. In larger more comprehensive curriculum innovation projects, this can amount to hundreds of thousands of dollars for a longitudinal evaluation. While quality analyses of student outcomes can be built into university courses for a far lower level of cost, the magnitude of resources required to carry out these studies requires a degree of surety that the study will provide useful outcomes for the institution, as well as careful consideration of the scope and objectives of the study.

Potential Applicability and Utility of Educational Research

First and foremost, we need to ask whether rigorous scientific studies of learning innovations in STEM curricula can provide useful insights into benefits for our students. My own scholarly STEM discipline, Chemistry, is a good context in which to address this question. Traditionally structured university Chemistry curricula have many of the characteristics identified as problematic for student retention in STEM majors in the original work by Seymour and Hewitt: Chemistry courses are built upon abstract concepts, are laden with vocabulary, and require facility with algebra and more advanced mathematics from the outset.

Moreover, over the first three years of study, the Chemistry curriculum swings from algorithmically based material, to subjects requiring substantial memorization, and on to material where calculus becomes the lingua franca. Opportunities to create a synthesis of these different perspectives on the nature of Chemistry often do not occur until the senior year of undergraduate study, or even well into the graduate experience. The initial two years of the undergraduate chemistry sequence have the unfortunate reputation of being gatekeeper courses.

These factors make the Chemistry curriculum a useful test bed for studying whether the application of rigorous educational research methods to the study of new and modified STEM curricula can inform us about improvements in student learning, attitudes and motivation. The three brief examples that follow will illustrate this is possible and that such studies can also yield interesting, unexpected insights.

In my group Dr. Danielle Barker recently pursued a study of whether asynchronous mathematics learning tools built using a constructionist educational framework would improve student performance and self-efficacy in a freshman chemistry course for science majors. [9] Facility with algebra and algebraic reasoning are among the most critical skills required for success in freshman chemistry courses; consequently, these are topics that tend to be emphasized in the initial weeks of Chemistry instruction.

The fact that standardized examinations developed by the American Chemical Society indicate this area to be a weakness in up to 30 percent of our students has tended to reinforce the early coverage of chemistry-related algebra concepts. Unfortunately, subjects such as significant figures, ratios, and negative logarithmic scales are scarcely the most charismatic and integrative aspects of the discipline of Chemistry. Dr. Barker's study was intended to determine whether these subjects could be covered asynchronously, and whether this change might enhance student achievement and self-efficacy in the course. Students participated in a series of 40 online chemistry oriented mathematics tutorials over the course of the first semester.

Studies of student achievement showed that benefits were dependent on student persistence though the majority of the units. Students persisting through the tutorials showed nearly a full grade point improvement over a control group and half grade point improvement over students receiving traditional in-class math concept instruction. (Note: Students who persisted through 35 or more units started the program with demographic and academic characteristics that were indistinguishable from the class as a whole.) Students completing the tutorial also showed sustained higher levels of self-efficacy with respect to chemistry content knowledge than their peers.

Ms. Linda Myers is currently concluding a study of whether peer-led undergraduate supplements (PLUS), group work problem-solving assignments coordinated by a trained student leader, improve student achievement in freshman chemistry. These learning tools are related to peer-led team learning (PLTL) and process-oriented guided inquiry learning (POGIL) strategies that have been successfully employed as active learning supplements to lecture and laboratory experiences in other contexts. [10, 11] Ms. Myers' studies show that students persisting in weekly PLUS session show a 14.5 percent improvement on chemistry examinations over comparable peers. This result is moderated by gender, with male students experiencing higher benefits than female students. Interestingly, the cohort of pre-pharmacy students in the course showed no overall benefit from participation in PLUS sessions. Based on prior academic performance, pre-pharmacy student can be categorized as being among the most academically capable of the major-cohorts in freshman chemistry.

Finally, Dr. Deblina Pakhira has examined whether the common practice of allowing students to choose whether to enroll concurrently in Organic Chemistry lectures and laboratories has any effect on student learning and achievement in these classes. [12] This project relates to an ongoing study of whether practicing components of the discipline of chemistry within the laboratory benefits student learning.

We were surprised to discover that students choosing to enroll concurrently for the lecture and laboratory, and students who enroll first in the lecture course and then enroll in the laboratory in a subsequent semester begin Organic Chemistry with statistically indistinguishable demographic, academic, and motivational characteristics. Despite these initial similarities, Dr. Pakhira's 3-year study demonstrated students choosing concurrent enrollment during the first semester Organic Chemistry course showed a quarter grade point average advantage in achievement over their colleagues enrolled in only the lecture portion of the course. During the second semester course, this advantage increased to a half grade point for students choosing concurrent enrollment. Moreover, students concurrently enrolled in lecture and laboratory showed higher longitudinal motivation and self-efficacy regarding the Organic Chemistry course sequence.

Recommended Boundaries for the Evaluation of Curriculum Reform Efforts

As these examples show, it is possible to gain useful, sometimes surprising insights from rigorous evaluation of curriculum reform efforts. However, the resources required to conduct such studies on a large scale should lead us to engage in a careful consideration of the circumstances that justify an intensive evaluation of STEM curriculum innovation. The following list identifies some of the characteristics that might reasonably trigger a need for institutionally supported longitudinal STEM curriculum studies:

- True novelty in curriculum design, instructional practice or application of technology,
- Networks of STEM curriculum change across multiple courses or disciplines that together are intended to create a broader impact on student learning and outcomes,
- Curriculum interventions that require substantial investment of institutional resources,
- Experiments in curriculum change that are part of a broader, national reform study,
- Changes that may have high stakes consequences for students, faculty and instructors, and the institution, and
- Efforts to engender longitudinal (post-graduation) advancements in student knowledge, skills and abilities.

Finally, we need to consider the range of questions we should strive to address through institutionally supported research studies. The following are examples of big picture questions that should drive our curiosity in this area:

- At what threshold of curriculum change (class component, course, core education program, major curriculum) do we observe the onset of specific desired benefits in student learning and success in degree programs?
- Have curriculum innovations created noteworthy enhancements in student ability to obtain and apply new knowledge, skills and abilities in future professional endeavors?
- Beyond performance in individual courses, what are the key educational metrics that we want to promote...increased retention in majors, reduced time to degree, improved rate of degree attainment, etc.?
- How have curriculum changes influenced retrospective student perception of educational value?
- What degree of improvement in student learning, perception and attitude is sufficient to justify a specific level of institutional investment in curriculum innovation?
- Is the institutional commitment to longitudinal research on STEM curriculum innovation contributing to expanding the productivity of STEM and education faculty researchers?

Given the stresses that external accountability is exerting on university budgets and faculty researchers, it is to our advantage to demonstrate that resources aimed a STEM curriculum enhancement are providing the anticipated benefits for our students. We have the tools of research at our disposal, faculty who could benefit professionally from partnering in such studies, and the need to move away from an anecdotal narrative for evaluating the efficacy of educational change. This process can contribute to protecting the diverse, interrelated missions of public research universities and provide a narrative for engaging a sometimes-skeptical public in the discussion that the research and educational missions of the university are indivisibly linked.

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Pakhira, and Ms. Linda Myers whose thesis research is highlighted in this work. I also wish to thank Ms. JoAnn Williams (OIRP) for her work with obtaining KU institutional data. Portions of this work were supported by the National Institutes of Health (NIH IMSD R25 GM062232-08).

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Department of Defense Research Funding: Opportunities, Idiosyncrasies, and Risk Analysis

Kurt Preston, Associate Vice Chancellor for Research, University of Nebraska

Since World War I the federal government has funded universities to perform research in the defense of the nation[i]. World War I saw the invention of armored vehicles, chemical weapons, and submarine warfare; the broad use of combat aircraft; and the industrial production of explosives through the development of the Fritz Haber process for ammonium nitrate production. As a result of this modernization, American universities and their associated laboratory facilities became involved in defense research.

What World War I initiated, World War II perfected. The nation's colleges and universities produced many of the scientists and engineers that would produce radar, sonar, and the first nuclear weapons. By the end of the war, the Endless Frontier was recognized as a frontier requiring full involvement by the defense community.

Over the last 70 years, the leaders of the DoD understood that our universities and the research they produce are key to accomplishing the DoD mission: to protect the American people and advance our nation's interest.

Federal Research Budget

The federal research budget is a component of federal discretionary spending.

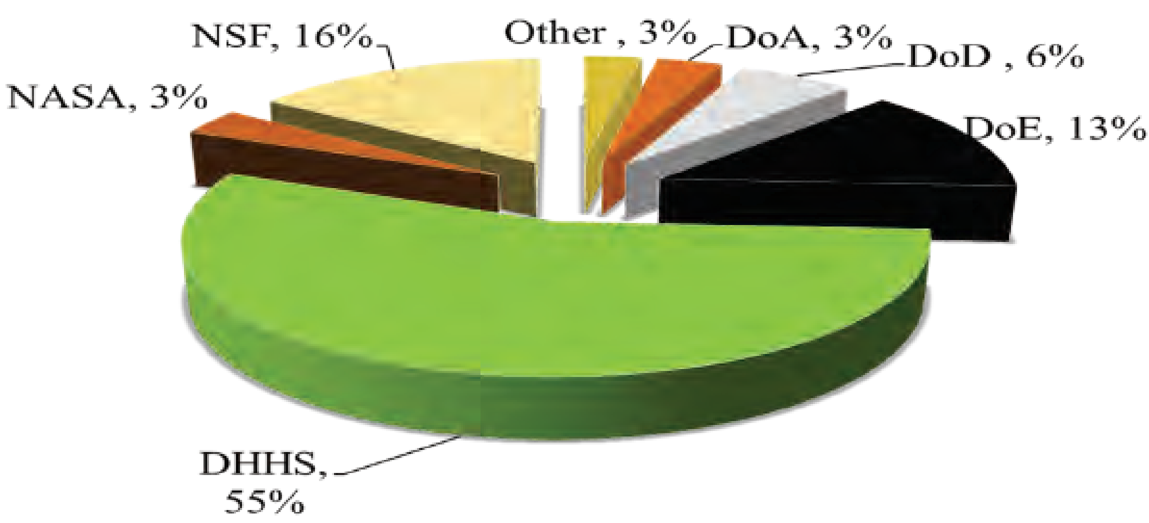

Figure 1. Federal Budget for Basic Research by Agency

In Fiscal Year 2011 it totaled $134 billion. 51% of the total budget is allocated to the Department of Defense. As a result, there is often the misplaced assumption that the Department of Defense correspondingly funds about half of the research performed at the nation's research universities. The fact of the matter, which will be described in detail below, is that most of that 51% is not spent on University related research but on the development of DoD relevant systems.

When the federal budget for basic research is examined by agency, a second picture emerges (Figure 1). Over half of federal basic research is funded by the Department of Health and Human Services (DHHS) through the National Institute for Health (NIH.) The NIH budget takes up 55% of the nation's federal basic research funding followed by the National Science Foundation (NSF) at a distant second at 16%. The Department of Defense is not even third on the list. That position is held by the Department of Energy (DoE) at 13%, followed by the Department of Defense (DoD) at 6%, with the Department of Agriculture (DoA) and the National Aeronautics and Space Administration (NASA) both at 3%[ii].

Notwithstanding the relative modest proportion that DoD basic research funding takes in the federal budget, there are some disciplines, such as engineering, where the DoD basic research funding effort comprises a significant portion of its resourcing. Mechanical engineering, electrical engineering, and aeronautical engineering respectively receive 80%, 61%, and 35% of their federal basic research funding through the DoD.

If not in basic research, where does the defense portion of the federal science and technology budget wind up? The Research, Development, Testing, and Evaluation (RDT&E) budget in fiscal year 2014 totaled $67.52 billion or more than about half of the federal science and technology budget. To understand the budget in detail, however, one must be familiar with budget activities which comprise the Planning, Programming and Budgeting system (PPBS), the system which organizes the RDT&E budget:

Planning, Programming and Budgeting System (PPBS), Budget Activities[iii]

Budget Activity 1, Basic Research. Basic research is systematic study directed toward greater knowledge or understanding of the fundamental aspects of phenomena and of observable facts without specific applications towards processes or products in mind. It includes all scientific study and experimentation directed toward increasing fundamental knowledge and understanding in those fields of the physical, engineering, environmental, and life sciences related to long-term national security needs. It is farsighted high payoff research…

Budget Activity 2, Applied Research. Applied research is systematic study to understand the means to meet a recognized and specific need. It is a systematic expansion and application of knowledge to develop useful materials, devices, and systems or methods. It may be oriented, ultimately, toward the design, development, and improvement of prototypes and new processes to meet general mission area requirements. Applied research may translate promising basic research into solutions for broadly defined military needs, short of system development…

Budget Activity 3, Advanced Technology Development (ATD). This budget activity includes development of subsystems and components and efforts to integrate subsystems and components into system prototypes for field experiments and/or tests in a simulated environment. ATD includes concept and technology demonstrations of components and subsystems or system models. The models may be form, fit and function prototypes or scaled models that serve the same demonstration purpose. … this category do not necessarily lead to subsequent development or procurement phases, but should have the goal of moving out of Science and Technology (S&T) and into the acquisition process within the future years defense program (FYDP). Upon successful completion of projects that have military utility, the technology should be available for transition.

Budget Activity 4, Advanced Component Development and Prototypes (ACD&P). Efforts necessary to evaluate integrated technologies, representative modes or prototype systems in a high fidelity and realistic operating environment are funded in this budget activity. The ACD&P phase includes system specific efforts that help expedite technology transition from the laboratory to operational use. Emphasis is on proving component and subsystem maturity prior to integration in major and complex systems and may involve risk reduction initiatives...

Budget Activity 5, System Development and Demonstration (SDD). SDD programs...are conducting engineering and manufacturing development tasks aimed at meeting validated requirements prior to full-rate production... Prototype performance is near or at planned operational system levels. Characteristics of this budget activity involve mature system development, integration and demonstration..., and conducting live fire test and evaluation (LFT&E) and initial operational test and evaluation (IOT&E) of production representative articles...

Budget Activity 6, RDT&E Management Support. This budget activity includes research, development, test and evaluation efforts and funds to sustain and/or modernize the installations or operations required for general research, development, test and evaluation. Test ranges, military construction, maintenance support of laboratories, operation and maintenance of test aircraft and ships, and studies and analyses in support of the RDT&E program are funded in this budget activity...

Budget Activity 7, Operational System Development. This budget activity includes development efforts to upgrade systems that have been fielded or have received approval for full rate production and anticipate production funding in the current or subsequent fiscal year.

Of the seven activities, it is only in Budget Activity 1 that universities are generally funded. Most often they will be funded from the Army Research Office (ARO), the Air Force Office of Scientific Research (AFOSR), the Office of Naval Research (ONR), or the Defense Advanced Research Projects Agency (DARPA.) The funding will come almost exclusively in the form of grants to the Universities awarded through Broad Agency Announcements (BAAs).

Broadly speaking there are three types of BAAs. The first type is the annual broad agency announcement which describes the research interest of the respective offices and their program managers. For the faculty member pursuing DoD research funding for the first time, the annual broad agency announcement is a critical document to review before contacting the program manager in their respective discipline.

Program managers take great care in crafting the program descriptions found in annual broad agency announcements because there are two inherent mutually exclusive goals in their message. On the one hand, the program manager would like to describe the program in sufficiently narrow terms so that a practitioner in the discipline will understand the technical goals and objectives in some detail. On the other hand, the program manager seeks to describe their program in a broad manner that practitioners with unique approaches to relevant technical problems will be encouraged to submit their ideas.

The second type of BAA is one that is topic specific. It is difficult to predict when the topic specific broad agency announcement may be posted to grants.gov or at agency websites. The topic announcements often result from internal discussions in which senior leaders in the

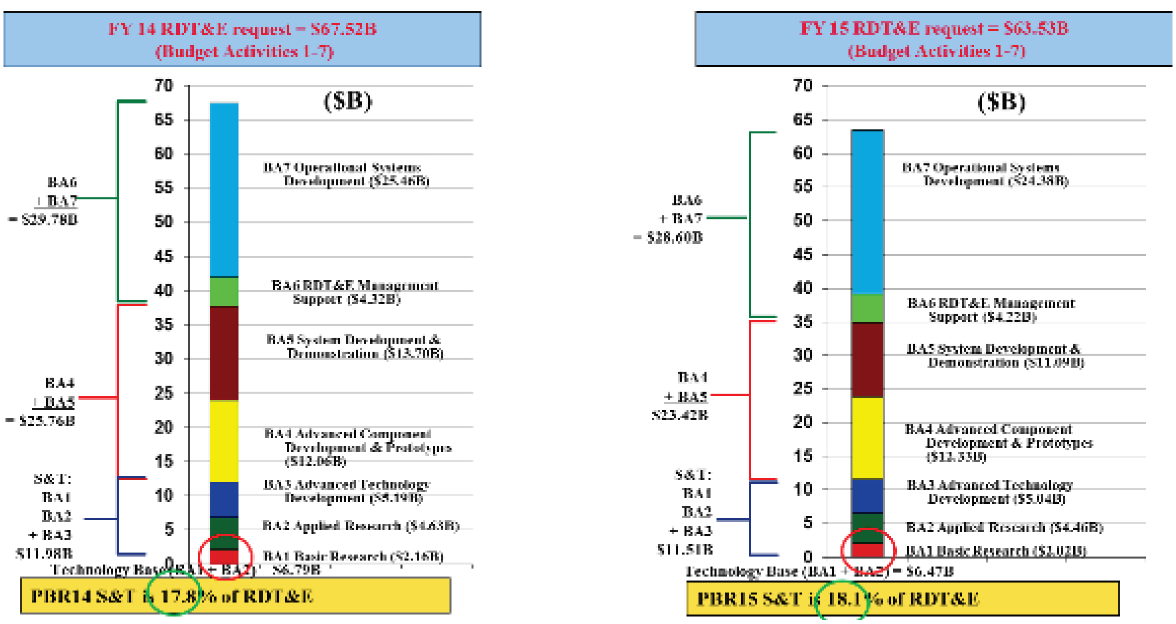

Figure 2: DoD FY 2014 and 2015 RDT&E Budget Request Comparison[iv]

DoD science and technology enterprise determine that a particular topic area warrants extraordinary focus due to rapid advances in the discipline, perceived technological risk, or a myriad of other factors.

The third and final type of broad agency announcement is the recurring announcement which, as the name implies, is advertised at set intervals, often annually. The Defense University Research Instrumentation Program (DURIP) announcement is an example of an annually recurring announcement. It is often released to the public in the fall, September or October, with winners announced in February or March just before funding from the new annual budget is released to the research offices.

Although Budget Activity 1, basic research funding, is the most common type of funding received by colleges and universities, it represents but a small portion of DOD research funding.

Figure 2 describes the budget requested by the President and submitted to Congress for DoD RDT&E budget in fiscal years 2014 and 2015. In both years, the RDT &E budgets were approximately $65 billion with basic research receiving the smallest portion (red block and circle), approximately $2 billion. The largest proportion in both years went to operational system development, Budget Activity 7. Also noteworthy in Figure 2 is the observation that science and technology funding, which includes budget activities one through three, proportionally increased from FY2014 to 2015. One interpretation of this increase is that it reflects the intent of the senior leadership to avoid an erosion of basic and applied research funding in the face of a very difficult budgetary climate.

Drilling further into the budget, Figure 3 provides a breakout of the science and technology funding across the "Services" (the Army, the Air Force, and Navy), DARPA, other agencies, and the Office of the Secretary of Defense (OSD.) DARPA possesses the largest overall science and technology budget at $2.793 billion; however, the largest single basic research funder is the Navy at $576 million.

Two Highly Differentiated Funding Modalities

The take away message from examining the DoD RDT&E budget is that there are two highly differentiated funding modalities. The first modality is the basic research mode in which one finds grants awarded, largely to research universities, through the vehicle of a broad agency announcement (BAA.) In the basic research environment the secret to funding is to propose high risk, high payoff research that creates a scientific foundation for future DoD capabilities. The second modality funds applied research and advanced technology development. In general terms, there is an inverse relationship between involvement by universities and maturity of the technology. The further one departs from basic research, the smaller the proportion of funding is likely to be found going to a college or university.

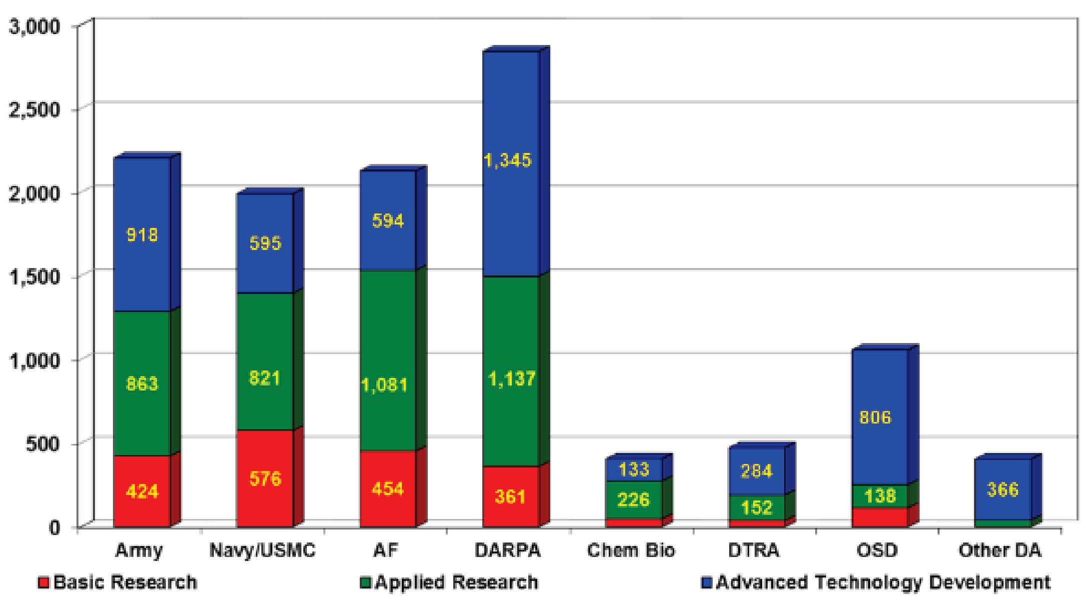

Figure 3. Total FY 2015 Science and Technology request which is $11.51 billion.

There are exceptions to the general rule such as University Affiliated Research Centers. Fourteen UARCs have been established by the DoD to focus on areas of science, engineering, and technology possessing particular importance. UARCs may receive sole-source funding or may compete for science and technology development work across the budget activities. Each UARC is unique in both its core competencies and structure. Some have been in existence since World War II. The newest, the National Strategic Research Institute (NSRI) affiliated with the University of Nebraska and established under the auspices of USSTRATCOM, is two years old. The DoD seeks only to establish UARCs when there is a need that can be uniquely filled by the core competencies found in that university.

Idiosyncrasies

The take away message for a university research faculty member is that there are two modes of DoD science and technology (S&T) funding. The first, basic research, is designed to engage the university research faculty member. The second mode, the rest of the (S&T) funding, rarely benefits university research faculty members unless they lead or find themselves in a team focused on applied DoD problems. It is critical that the faculty member understands in which mode they are pursuing funding. There is no better way for a research faculty member to undermine their proposal to a basic research program manager than to focus on

		Likelihood of Award		
		High	Medium	Low
Positive Impact to the Institution	High	~~Congressional Earmark.~~	National Quality Sophisticated, DoD Networked Team.	High Quality, DoD Networked Team.
	Medium	ID/IQ or other continuance of contracted > 6.2 research.	***Networked MURI team encouraged from whitepaper***	***MURI team encouraged from whitepaper***
	Low	***Encouraged DURIP /HBCU/MI Proposal from QPI***	***Encouraged Single Investigator Proposal from a QPI***	***Shot in the Dark Proposal***
(Italics denotes basic research activities)				

Figure 4: Risk Analysis. The items in italics represent those activities associated with the DOD basic research program and open to individual faculty members or a team of faculty members. The Quality Principal Investigator (QPI) referenced is principal investigator that is performing high-impact research relevant to the DOD and willing to engage the DOD basic research program managers in the discussion of the research interest. Shot in the dark proposals are those in which no attempt has been made to discern the interest of the relevant DOD program manager.

applications, talk about what they will demonstrate, or insist that they know how to improve a system. Applications, demonstrations, and systems are all outside the realm of basic research in the DoD context.

Competitive Environment

At the university institutional level, the question then becomes where does DoD research funding fit into a university's overall strategic and operational planning, especially when this planning is occurring in uncertain times. The answer to this question comes from risk analysis. Since proposal development is a resource intensive process, the institution must balance the potential for positive impact against the likelihood of successful award.

Figure 4 provides a simple initial approach to such risk analysis. In the past, congressional earmarks were probably the awards which possessed the highest potential to produce a positive impact at the institution and the highest likelihood of award. Even in their heyday, however, congressional interest or earmark projects were a very small fraction of total basic or applied research budget. Today, absent earmarks, the highest likelihood of producing a positive impact at the institution are the development of sophisticated, networked teams of national quality researchers performing research of interest to the DoD. These teams must integrate university researchers and corporate technology developers to provide DoD technology development pathways. These are the types of teams that are often funded in DARPA efforts.

Networked teams are also critical for success in pursuing Multidisciplinary University Initiative (MURI) projects. In the case of a MURI, the teams are generally academic researchers networked across disciplines and institutions. At approximately $1.25 to $2.5 million per year, however, MURI's are insufficient to form the foundation for an institution's research program. They certainly are welcome and important for an individual faculty member or teams of faculty members, but the level of resourcing is such that they are in addition to, but not the basis of, a university research enterprise.

An opportunity with the potential for medium positive impact to the institution and a high likelihood of award is for the university to be part of the team contracted for research beyond basic research (BA 2 [aka 6.2] or higher). These applied research efforts, however, can pose significant challenges for the university. These challenges often include high administrative burden and intellectual constraints that come from export control and other restrictions when working on DoD applied research projects.

Conclusion

DoD research funding has a place in planning for future research in public universities in uncertain times. However, the DoD is not the principal source of research dollars to colleges and universities. It is a distant fourth behind NIH, NSF, and DOE. Absent a unique relationship created by either a UARC or other contract, it is unlikely that DoD research funding would form the basis for funding the University research enterprise. Nonetheless, the DoD basic research program provides a vehicle for university principal investigators to be involved in the defense of the nation through their research activities.

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Building upon Existing Research Strengths in Uncertain Times: Analytical Chemistry and ISU

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The chemical sciences have been a research strength at Iowa State University for several decades. Departmental rankings among state institutions and research expenditures are two criteria used to determine this strength. Both the cost and space requirements to start a new chemistry laboratory, as well as competition for existing faculty, are challenges that need to be considered in order to maintain a vibrant chemistry department (as is the case for many others). The challenges of uncertain funding require new and innovative, as well as traditional, approaches to maintain research strengths in a highly competitive environment. Some strategies are proposed herein using an analytical chemistry case example.

Background. The field of chemistry is traditionally divided into five divisions: analytical, biochemistry, inorganic, organic, and physical. Undergraduate chemistry majors usually complete survey courses in each of these areas. Analytical chemistry is a measurement science: the focus of analytical research is to both develop new and improve existing methods of analysis to measure qualitative and quantitative information. A majority of students who earn a B.S. in chemistry in the United States will enter graduate school or industrial employment. Analytical chemists represent the largest group (14.8 percent) of employed members of The American Chemical Society [1]. This highlights the need to maintain a vibrant analytical chemistry faculty.

Analytical chemistry, as a defined scientific field, has a historical foundation dating back to roughly the turn of the 20th Century. Then, it was as an applied field focused on methods of analysis for the steel and iron industries [2]. The discipline thrived through World War II for two primary reasons: measurement needs for the Manhattan Project and petroleum analyses [3]. Analytical chemistry at Iowa State University has strong connections with the Department of Energy's Ames Laboratory, a national laboratory located on the ISU campus, as early as the 1940s. Improved techniques developed by Ames Laboratory and ISU chemists enabled the production of about 2 million pounds of uranium metal ingots, a vital material used by the U.S. military during the war effort [4]. The connection between ISU's analytical chemistry division and Ames Laboratory lasted well beyond WWII. In the intervening decades many universities were shrinking or eliminating their analytical divisions; ISU continued to invest in this research area. In 2004, there were five analytical faculty at ISU and 31 total (tenured or tenure-track) faculty in the department. The analytical division was ranked 5th in nation for analytical chemistry, and was generally recognized internally and externally as a strength [5].

Competitive start-up funds and space requirements for a research group are the most significant challenges to maintaining research strengths in the chemical sciences. The average start-up package for an assistant professor of chemistry for 19 selected universities across the Midwest does not statistically vary by division (Figure 1). The average start-up package across all divisions is roughly $810,000 for an assistant professor, excluding associated costs for renovating space [6]. The average start-up package for a senior faculty member is approximately $1.7 million excluding renovation costs [6]. Many research groups have unique space needs and considerable renovation costs may be associated with hiring a new faculty member.

While the start-up costs in the chemical sciences are high, the average yearly research expenditures in the chemical sciences for 19 selected universities across the Midwest are $18 million per department (Figure 2) [6]. Federal funding represents a majority of the research expenditures as reported for the years 2011-2012. Industrial-funded research expenditures represent about 10 percent of the total.

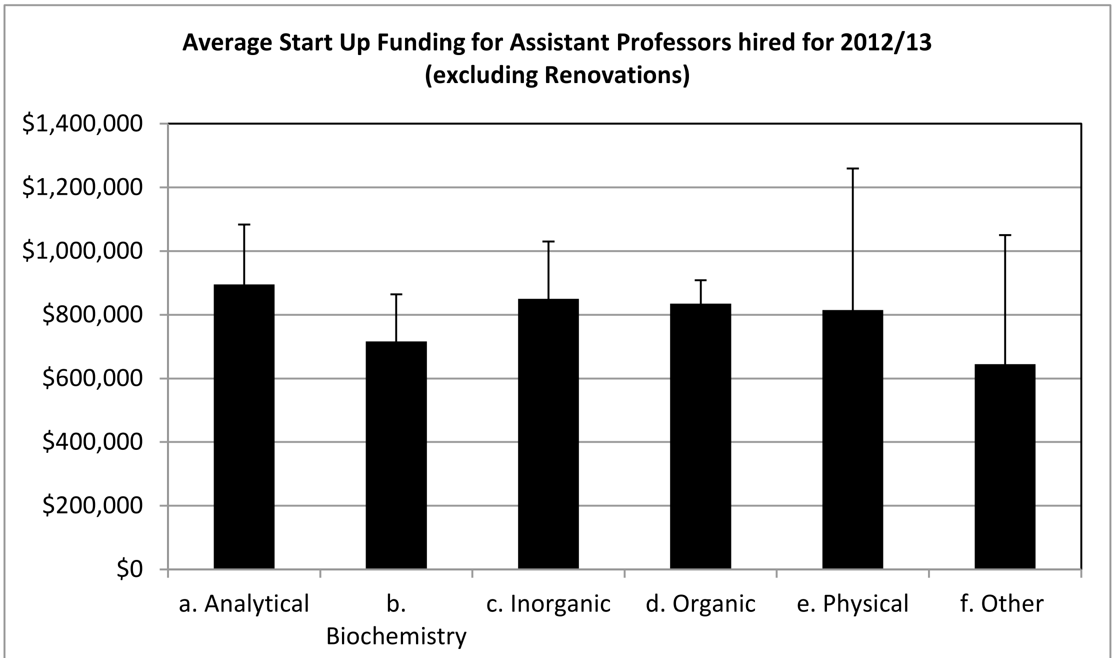


Figure 1. Citation Midwest Chairs 2012-2012 Survey including information from University of Chicago, University of Illinois-Chicago, University of Illinois-Urbana Champaign, Indiana University-Bloomington, Iowa State University, University of Iowa, Michigan State University, University of Michigan-Ann Arbor, University of Minnesota, University of Nebraska-Lincoln, Northwestern University, University of Notre Dame, Ohio State University, Penn State University, University of Pittsburgh, Purdue University, University of Washington, Wayne State University, University of Wisconsin-Madison.

Selected Strategies for Maintaining Research Strengths in Uncertain Times. In times of uncertain state and federal funding for research, maintaining research strengths should include innovation. The following suggested considerations and approaches for maintaining research strengths are not exhaustive. They are presented here in the context of the

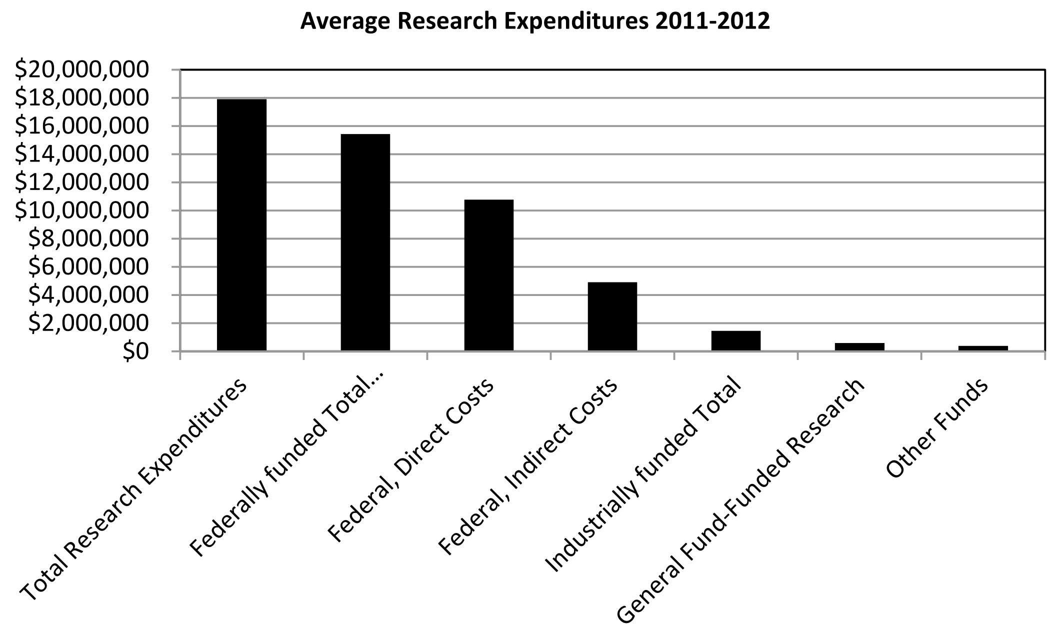


Figure 2. Citation Midwest Chairs 2012-2012 Survey including information from University of Chicago, University of Illinois-Chicago, University of Illinois-Urbana Champaign, Indiana University-Bloomington, Iowa State University, University of Iowa, Michigan State University, University of Michigan-Ann Arbor, University of Minnesota, University of Nebraska-Lincoln, Northwestern University, University of Notre Dame, Ohio State University, Penn State University, University of Pittsburgh, Purdue University, University of Washington, Wayne State University, University of Wisconsin-Madison.

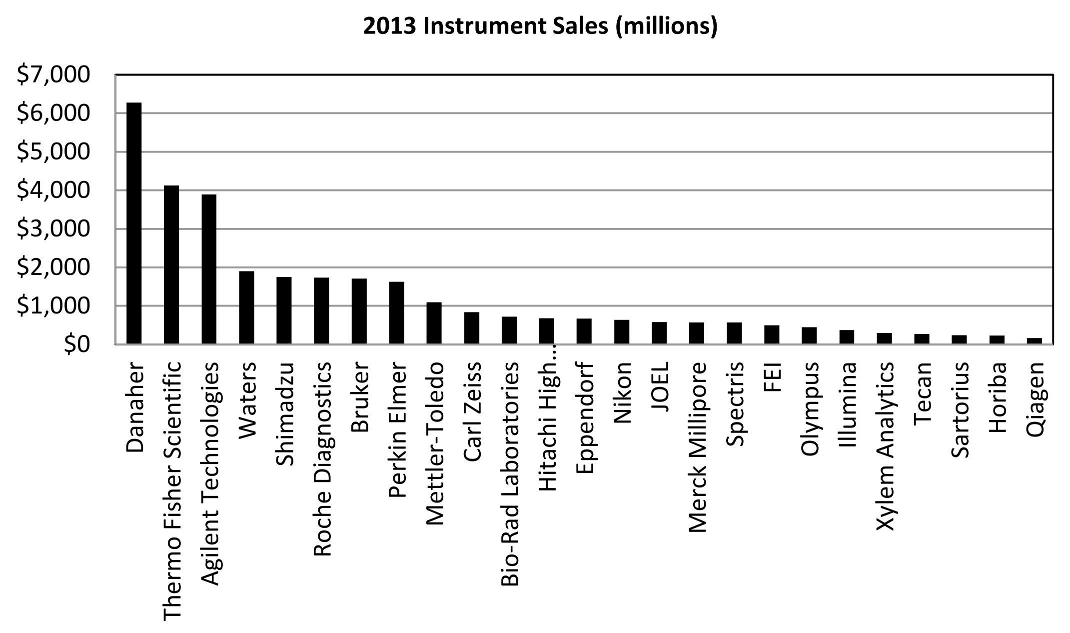
field of analytical chemistry. Most should be applicable to other research fields.

In times when funding sources are increasingly emphasizing the importance of documenting the benefits of funded research projects, strategies to justify the benefit of a scientific project, department or field should be prominently advertised to numerous audiences. To this end, it is useful to define a few examples of fundamental research and technological advancements benefiting society, the scientific endeavor, and the field. Within the field of analytical chemistry, examples are numerous. For example, in the 1970s, Dr. Leland Clark of Yellow Springs Instrument Company developed the Model 23 Glucose Analyzer [7]. This was the first whole-blood glucose meter, and predecessor to blood glucose analyzers used today by millions of diabetics to monitor and manage their disease. The Model 23 Glucose Analyzer, a technological advancement that can't be overstated in importance, measured roughly 16.25 inches by 13 inches by 8.375 inches [8]—it was not a portable unit. Over the ensuing years, numerous measurement advancements were made; today, accurate, portable blood glucose meters fit in the palm on one's hand and some continuously monitor in vivo glucose [9].

On a more local scale, the two main objectives of the Smith research group are: (1) to measure the organization and dynamics of cell membrane components, and (2) to demonstrate Raman spectroscopy analyses of biomass, enzymatic catalysis, and thin films. These objectives are accomplished through a combination of measurements, instruments, and methods development. The instruments being developed focus on improvements to traditional optical microscopy approaches. Optical microscopy is used to image objects that can't be visualized by eye. The spatial resolution, meaning the ability to image increasingly smaller objects, is limited by the diffraction of light. Typical optical microscopy techniques have a limit of a few hundred nanometers. To put this in context, the diameter of a human hair is about 90,000 nanometers, much larger than the diffraction limit. However, many biological and materials samples have important spatial scales of tens of nanometers or less, and these can't be measured with traditional optical microscopy techniques. There are other (e.g., electron) microscopy techniques with a finer spatial resolution. But these techniques don't often allow dynamic information to be measured. One can't measure and obtain information about processes as they happen. The Smith laboratory focuses on developing optical microscopy techniques that get around the diffraction limit of optical microscopy, thus enabling dynamic processes to be measured in smaller and smaller spatial scales [10-11]. This has applications to medicine (e.g., pathology), biology, materials science, and many other fields.

Industrial connections are increasingly seen as an important source of funding and partnership in times when obtaining federal funding for basic research is a growing, unnerving challenge. These connections make particular sense for applied research projects that may offer a shorter-term payoff in the form of developed products or new measurement techniques. In 2013 analytical instrument sales for the top 25 sellers was approximately $32 billion (Figure 3) [12]. Reported values of 4.2-19.5 percent of sales from selected manufacturers have been reinvested in research and development [12]. There is existing evidence for the successful partnership between industry and academic departments with analytical chemistry divisions. For instance, the University of Texas at Arlington partnered with Shimadzu (ranked 5th in instrument sales) to develop the Shimadzu Institute for Research Technologies on the UT Arlington campus. Shimadzu Scientific Instruments donated $7.5 million as a corporate gift and $3 million as an in-kind gift of instrumentation [13]. Named endowments, donated equipment for departmental use, and the use of equipment at remote sites may be beneficial approaches for fields in which analytical measurements are taken.

Since a significant amount of start-up funding in analytical chemistry is devoted to scientific instruments, collaborative hires whereby shared equipment (e.g., nuclear magnetic resonance, mass spectrometers) can be built into a competitive start-up package may be a useful approach. The careful planning of shared university (center) equipment purchases may also alleviate need for a portion of start-up funds for new faculty members, and the entire university community might benefit from the addition of on-site equipment experts. Finally, there is a need to have easy access to shared university (center) equipment that is easy for the community to locate on campus. This may reduce the need for an individual faculty member to possess selected instrumentation, make it easier to find out what is available on campus when negotiating start-up packages, and avoid duplication of instrument purchases across units on campus when multiple units may share instrument time.



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Investing in junior faculty members has several benefits. If adding faculty to a department, an $810,000 average start-up package for a junior-level hire makes more economic sense than a $1.7 million offer. Of course, one must expect a longer term payoff that may not be as certain as hiring a senior faculty member. But, there is also a benefit of building loyalty to the university, to provide resources and mentoring that will have a future impact. Part of building loyalty also means investing in the leadership skills of junior faculty through dedicated programs and opportunities, as well as highlighting the appreciation for junior faculty's contributions to the university.

Finally, it is necessary to invest time and money in advertising the unique strengths within and outside one's own organization. Seminars and local conferences have been the traditional route for achieving this. Many funding mechanisms are making a transition to emphasize interdisciplinary teams. Forming well-situated teams requires knowledge of strengths; to be included in these teams, a department's strengths must be commonly known. Highly collaborative fields, such as analytical chemistry, may be an effective route to establishing partnerships both within and outside an organization. For example, as stated by Jonathan Sweedler, the current Editor of *Analytical Chemistry*, "In all processes, whether in engineering, science, or medicine, you need quantitative numbers to optimize the goals [14]." Analytical Chemistry is well suited to make connections in the field of medicine, environmental monitoring, energy, agriculture, basic biological sciences, and engineering. In other words, teams that target all the major federal funding sources.

In closing, existing research strengths at public universities in uncertain times may not remain strengths unless the university invests both time and money to maintain them. This may be accomplished with traditional as well as innovative strategies. Leadership from all levels will be key to successful implementation of these strategies.

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Enhancing the Success of Early Career Faculty in STEM Fields During Uncertain Times

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Early-career faculty face numerous challenges when working to establish an upward professional trajectory, particularly those in STEM fields. Almost without exception, federal resources for basic and applied science have diminished since ARRA (American Recovery and Reinvestment Act) funding ended. As a result, the academic careers of many early-career faculty may be in jeopardy, particularly since federal grant funding is usually expected for tenure in STEM fields, and is often essential for conducting scientific research. Currently, many programs at NSF and NIH remain at funding levels that are at or below 10%.

Clearly, this presents some national challenges in determining how federal funding can be leveraged to maintain our national standing as a leader in scientific research. Alberts et al. (2014) recently laid out specific recommendations for how this may be achieved at the level of graduate training. This also presents local challenges within universities, since the investment in tenure-track faculty is often substantial (particularly in STEM fields), and the loss of faculty members through tenure denials is far from ideal.

In this article, I will not attempt to tackle the national problem of scientific funding since it is well beyond the scope of my own experience and expertise. Rather, I will provide practical ideas and insights into how academic leaders can help early-career faculty members attain their highest potential, as well as meet the current standards for achieving tenure at research institutions. These recommendations are based upon practices that had a positive outcome in my own career, as well those of my closest colleagues who have become highly successful faculty members in their own right. Some of my recommendations come with little to no cost, whereas others may require resources and time on behalf of university leaders.

Although much of the success of early-career faculty is driven by their own desire to work hard and succeed, the university can also play a major role in facilitating the success of these faculty members. This is certainly true in my case, and I will provide insights as to how the University of Kansas helped me attain my goals. I have had a successful early through mid-career path, while raising two children with the support of a spouse who was also a faculty member in the biological sciences. I maintained continuous funding for my research through NSF, including a CAREER award. I also received the Presidential Early Career Award for Scientists and Engineers (PECASE) in 2009. I was also fortunate to have received an endowed position at the University of Kansas for early-career faculty, the Wohlgemuth Faculty Scholar Award, through a private donation. I have worked with the National Academy of Sciences as a Kavli Fellow for both the Arab-American and Japanese-American Frontiers of Science Programs.

These professional successes were due in part to an innate drive that many scientists possess to answer important questions, as well as the commitment to work hard to achieve these goals. Importantly, these successes were also due to factors beyond my own personal drive and ambitions, through a willingness by my university (University of Kansas) to provide tangible support at vulnerable points in my career when I needed resources and/or time to remain competitive in the realm of grant funding and research. These successes were also due in part to the mentorship of several senior faculty members and administrators that helped me to understand how the university works, and to make informed choices about how I spent my time and how I approached my scientific endeavors. Below I will describe several strategies taken by the University of Kansas that aided me, as well as my colleagues, in moving through the early faculty ranks. The majority of my closest colleagues include my spouse, as well as women faculty members in the biological sciences who also have substantial family responsibilities (e.g., raising of children, assistance with elderly parents, spouses who are also scientists), and who have been highly successful at receiving grant funding, gaining tenure, receiving national awards, and publishing articles in prestigious journals. My ideas in this article are based on my own perspectives, as well as information that I gathered from numerous discussions with my closest colleagues on successful strategies for elevating the productivity and success of early-career faculty.

Practical Strategies for Enhancing the Success of Early-Career Faculty Members in STEM

1. Short-term teaching release to enhance the momentum of early-career research programs

Early-career faculty members are generally hired with traditional 40-40-20% (Research-Teaching-Service) appointments, and most already understand (or quickly learn) that course development and teaching are very time-intensive processes. This has become even more relevant over the last several years as more efforts have been made to flip courses and to reform approaches to STEM education. In my experience, the vast majority of early-career faculty members are committed to providing high quality teaching in their courses, and many invest time in teaching that extends well beyond the typical 40% appointment. When taken to an extreme, this can have negative consequences (sometimes disastrous) on the research programs of early-career faculty, particularly if the faculty member is unable to refocus their time through their own efforts, or from advice of a close mentor or departmental chair. Thus, an important component of the early-career transition is to effectively manage time, and be efficient at achieving an appropriate balance between research, teaching, and service. Department chairs should be quick to address these issues if they are not being achieved by early-career faculty.

There are, however, times when early-career faculty members would greatly benefit from teaching release for short periods of time (1-2 semesters) in order to enhance their research programs, and this may be essential to their success. This is not a recommendation that is intended to correct poor time management or work ethic, and these are rarely problems for successful early-career faculty members. Rather this recommendation is in response to the increased demands that are placed on early-career faculty members to produce competitive grant applications that will rank among the top 10% in the country (to allow for funding). In addition, this is necessary for developing research programs to a stage where funding is more likely, which includes publications in top-tier journals that are also becoming increasingly more competitive. In other words, I am referring to the needs of early-career faculty who are excelling at teaching and research, and would greatly benefit from additional time to devote to research. These are faculty who are most likely to produce a strong return on an investment made in their time.

My recommendation for short-term course release is based on two main factors: (1) it is difficult to attain one's first research grant from federal sources, and (2) it is even more difficult to compete for a renewal of ongoing research. Generally, in many STEM fields, faculty members are granted teaching release for their first semester in order to set up their research laboratory and this is a highly recommended practice. Teaching release may also be applied in cases of pregnancy and other family emergencies- and again, this policy is not only wise, but may be critical for the health of the individuals involved. Here, however, I am recommending teaching release for early-career faculty to attain the momentum needed to sustain a long-term research career, and this may be best applied in mid- to late stages of the pre-tenure period. This recommendation comes when hours invested in research can range from upwards of 40-60 hours/week. This approach can also be coupled with the availability of bridge and/or seed funds that help promote acquisition of preliminary data for grant proposals. To allow for teaching release without adversely affecting students, there may need to be a temporary redistribution of teaching duties within a department. Such an approach allows for increased momentum of an already high-quality researcher, and this ultimately benefits students, since faculty members can bring the results of their own research into the classroom and can train undergraduate and graduate students in the practice of research within their laboratories through grant support.

A previous Dean of the College of Liberal Arts and Sciences at the University of Kansas implemented this approach with an amazing level of success. A number of early-career faculty members (approximately 7) requested teaching release from the Dean during a meeting to discuss how the early-career experience could be enhanced at the University of Kansas. Following agreement from the departmental Chair, the Dean granted permission for a one-semester course release for each early-career faculty member. This release was implemented across several years in order to allow for full coverage of courses. The outcome of this approach was the funding of two NSF CAREER awards, a PECASE award, and three additional NSF research awards. Together, these successes also directly benefitted students at the University of Kansas since grant resources were ultimately used to support undergraduate and graduate research in faculty labs. Thus, when short-term investments are made to enhance time for research among promising early-career faculty, the outcomes can be dramatic, long-term, and beneficial to all constituents involved.

2. Opportunities for networking among early-career faculty to enhance research collaborations

The arrival of new faculty members (at all ranks) brings a multitude of new talent and expertise to a university campus each year. In many cases, new faculty arrive with knowledge of the newest challenges and approaches in their respective fields, as many had previously been focused on research and scholarship. Oftentimes, early-career faculty are eager to develop close networks with other colleagues that may be in different, yet complimentary fields. This may facilitate the formation of large multi-disciplinary teams that will eventually be highly competitive for large grants. Development of these networks can be particularly strong within new cohorts since all are adjusting to new positions at a new university, which presents a number of challenges that are best shared and discussed. In addition, these early-career networks can last many decades, and strong networks within cohorts can facilitate retention of faculty over the long-term.

There are relatively simple, yet highly effective, approaches that can be implemented to facilitate networking within new faculty cohorts. One approach that worked quite well at the University of Kansas when I arrived in 2003 was a series of introductory receptions for new faculty. These involved a number of units on campus such as the Chancellor's Office, the Provost's Office, the Kansas University Center for Research, Endowment, International Studies, a variety of centers, and Athletics. They included many different venues and styles, such as an informal buffet lunch, an evening reception with drinks and appetizers, as well as a tailgate party and tickets to a football game. These receptions tended to be well done, informal, and facilitated faculty interactions by having new members introduce themselves and provide a description of their scholarship/research. Then time was allotted for new faculty members to meet each other and to discuss their research in a social setting. By the time this series of receptions was completed at the end of the first year, most new faculty members knew each other well, and some had even begun to collaborate on research projects. There were also many lasting collaborations that initially developed from these receptions and that persist to the present day, and these groups often recall that it was simply a few "get-togethers" that allowed them to compile such highly productive teams.

Most likely, these receptions were initially meant as simply an informal welcoming tool, although in the end these produced some very notable outcomes.

I will expand on some of my own experiences with early networking as a result of these events. At several receptions, it became clear that a number of new faculty (at both early- and mid-career stages) had strong expertise in climate change research. This ranged from areas involving geology, biology, and the social sciences. In response to this, the new faculty quickly organized as a team within the first two years to acquire funding from the W. M. Keck Foundation for development of a stable isotope facility that is required for climate change research in a number of fields. It is important to note that since hiring is usually done at the departmental and/or college level, it may not be obvious that new faculty from different academic units will be complimentary.

Thus these events are critical to allow for the organic organization of highly effective multidisciplinary research teams. I firmly believe that the successful Keck proposal would not have materialized if these new faculty receptions had not occurred. In addition, I have written two separate grant proposals with faculty colleagues outside of my department whom I met at these receptions. A number of my other colleagues have built similar collaborative projects following these early interactions as well. In my view, this is a very simple and inexpensive approach to enhancing multi-disciplinary collaborations beginning at the early stages of a faculty member's career. This likely worked because these receptions allowed natural bonds to build between faculty members rather than forcing these interactions, and faculty discovered that they did not have to look outside of the university to find the collaborative expertise that they needed for their research. Furthermore, faculty members in their first year tend to be more open to considering collaborations with other colleagues, and quite frankly, this is a time when faculty are more likely to attend university functions before becoming more isolated in their own departmental and lab environments.

3. Engagement with the university through strategic service

Service expectations typically comprise 20% of early-career appointments at research-oriented universities. At the national and international levels, service by early-career faculty can be quite prestigious and should be encouraged, particularly when it involves serving on grant panels, STEM education reform, editorships, and planning national meetings or symposia. Along with this, service is required at the university level, and I will mainly focus on those types of service commitments here.

Within departments, there tends to be a movement towards minimizing hours spent conducting service for early-career faculty, mainly because this allows for greater time for teaching and development of research programs. I strongly agree with this practice, as the demands on early-career faculty can be overwhelming, and teaching and research productivity will be more heavily scrutinized when tenure decisions are being made. Thus, it is critical that for the service component that does exist, it should be carefully selected by/for the early-career faculty member such that these efforts are of value to both the university, and the faculty member alike. In several cases that I have observed at the University of Kansas and a number of other universities, early-career faculty were placed in service commitments that were not particularly important to the faculty member, or to the university for that matter. Such service committees tend to be characterized by ineffective leadership, unproductive meetings, and few tangible outcomes. Although these were most likely honest attempts to "protect" the early-career faculty member from "excessive" service, this may place the faculty member in a position to develop poor leadership skills through example, may prevent potential access to senior faculty and administrative leaders, and may result in early-career faculty members devaluing the role of service on a university campus. Furthermore, when service resides only at the departmental level, the university loses the potential for new perspectives from its early-career faculty at higher levels. Thus, I would argue that service commitments need to be selected carefully for all faculty, but especially for early-career faculty members who have limited time to devote to these endeavors, yet have the highest potential to benefit from them.

During my pre-tenure years, I was engaged in numerous university committees that began with my election to the University Athletics Committee, and that grew to university strategic planning for research, trustee for the Kansas University Center for Research, and a number of Dean and Director search committees. In looking back, I likely overcommitted my time to university service, although I would never trade this experience due to the benefits it provided me. First, I became more effective at national service in my own field following service on these university committees. This was particularly obvious to me as I chaired the Frontiers of Science Program for the Japan-American Program (Kavli fellow) and helped to plan the Arab-American Frontiers of Science program. These programs require a high level of sensitivity in working with people from different cultures, as well as a high level of organizational skills, and I acquired these skills while working with senior faculty members at the University of Kansas through university service commitments.

In addition, I was able to gain mentors at the highest faculty ranks (e.g., distinguished professors) as a result of serving on university committees. In a number of cases, these distinguished faculty members guided me to make better choices in my professional development, and were effective at helping me to more effectively manage my time. I am indebted to the mentors that I met through university service for helping me to become a better faculty member and to be more highly engaged within the administrative structure of my university. Such interactions also facilitated my involvement in the University of Kansas C-CHANGE IGERT program that was sponsored by NSF (PI: Joane Nagel) and that allowed me to gain a multi-disciplinary perspective on climate change issues through inclusion of the social sciences. All of these benefits were attained from having been active in authentic service roles at my university at a relatively early stage, and these have benefitted me to the present day.

4. Internal recognition for achievements made at early-career stages

Early-career faculty are often highly anxious about the prospects of gaining tenure, and this occurs among the most successful of STEM faculty in my experience. I would argue that too much energy is expended at this stage in worrying about tenure, and this is counter-productive for making progress in teaching and research, especially in uncertain times. This is also not beneficial to the health of the individual or the families involved.

To help rectify this problem, early-career faculty require excellent senior faculty mentors, and these mentors need to be clear if deficiencies exist that may block the candidate from gaining tenure. The mentor should then work with the early-career faculty member to overcome these deficiencies as soon as possible. On the other hand, when early-career faculty are thriving, and are clearly on a trajectory to gain tenure, it is imperative that faculty mentors convey this information to the candidate as well. There tends to be a culture within many departments that is hesitant to recognize achievements made at the early-career ranks. Perhaps this is because there are concerns that positive feedback in early stages of the pre-tenure period could eventually be used against the university if tenure is not granted. However, one needs to realize that competition at the national level for gaining grants and for getting research published in top-tier journals far exceeds the challenge of acquiring tenure at most universities when considering the success rates of each (although these factors are obviously not independent of each other).

As a result, the combination of excessive pressure while competing at the national level, matched with lack of positive feedback at the departmental level, can have severe negative consequences on the physical and mental health of early-career faculty. I therefore recommend that department chairs as well as senior faculty mentors be clear and fair at both ends of the spectrum by alerting early-career faculty when tenure is truly in jeopardy, while simultaneously recognizing the achievements of those that are likely to attain tenure and that are excelling in the pre-tenure period.

Along with excellent mentoring at the departmental level, the university can also provide mechanisms for recognizing outstanding achievements made at early-career stages among its faculty. For example, endowed chairs at the pre-tenure stage may be highly beneficial for retaining faculty through enhanced resources for salary and research, and may serve to elevate the confidence of such faculty members as future university leaders. Such endowments may also allow early-career faculty to get to know their donor in some cases, and these individuals may serve as additional mentors and sources of support for the early-career faculty member. In addition, early-career faculty members should be considered for university teaching and research awards, and their major accomplishments should be highlighted in media releases made by the university when appropriate. Overall, this allows the early-career faculty member to recognize that they are valued within the university, particularly when external pressures at the national level for research funding are possibly more intense than they have ever been. This may also allow a university to retain their best early-career faculty, and this is absolutely critical during uncertain times.

In conclusion, I have laid out a number of practical solutions (some obvious, maybe some not so obvious) that may be highly beneficial for enhancing the success of early-career faculty in STEM fields. If I have achieved my goal, readers who are early-career faculty should be shaking their heads in agreement that these represent at least some of the major issues (and solutions) that confront them. I also hope that I may have reacquainted readers that have not been in the early-career stages for some time with some of the challenges that they experienced in the past, and introduced them to some new areas of concern and strategies for overcoming these concerns. My greatest hope is that this article will promote increased dialogue among administrators and faculty at a variety of career stages concerning the challenges that confront early-career faculty in order to enhance the success of future cohorts of STEM faculty at research institutions in the United States.

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37 Years an Academic Scientist

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The basis for this brief paper is my 20 minute presentation at the Merrill Advanced Studies Center conference "Planning for Future Research in Public Universities in Uncertain Times" that was held July 16 – 18, 2014 in Nebraska City, Nebraska. These are uncertain times; indeed, aren't they all? As Heraclitus observed "one does not step into the same river twice." Change is time itself, and as such, we should embrace it; we should use it. How can we use these uncertain times to our advantage? I think that by being more prepared for change, we gain an advantage over our rivals. To be prepared for change we must learn from the past and plan accordingly for the future. That is my purpose here.

I began my career as an academic scientist in August 1977, 37 years ago. I began as a tenure track assistant professor of physics at Kansas State University. As a professor, one has two major missions, teaching and research. Added to these is a smaller service component. In this paper I will use my experience as an academic scientific researcher to gain a perspective of the state of academic research today and how we got to where we are.

The majority of my first grants were funded by the NSF. This is consistent with the fact that I trained to be a scientist, not an engineer or applied scientist. Looking further back, I trained to be a scientist because I grew up in the 50's, only a few decades after the revolutions in physics, quantum mechanics and relativity theory. My junior-high mind clearly saw that scientists, driven by simple curiosity, could revolutionize not only our world view but lay the foundation of modern technological wonders as well. Looking at summaries (abstracts) from those early grants one immediately sees the lack of Intellectual Merit and Broader Impacts categories now mandated by the NSF. One might say that back when I started my career, NSF only cared about intellectual merit, and it was assumed the reader was smart enough to find that in the abstract without a category. I guess they saw it like I saw it in the 50's, that is, good science was enough, the rest, broader impacts, would follow. Indeed, it was the National *Science* Foundation, wasn't it?

My most recent grant funded by NSF (2013) has the Intellectual Merit and Broader Impacts categories. Without these categories explicitly included, grants are returned without review (regardless of the scientific quality). Reading the summary reveals more differences. My early summaries only talked about the science and its implications for science. The most recent grant summary discusses global climate change (the research will study light scattering by aerosol particles), integrating research with teaching, a summer workshop for teen women, involvement of undergraduates in research, an upper level undergraduate course on light scattering, talks at high schools, mentorship of ACS Project SEED students, and writing of a monograph on light scattering. Whew! Tell me again, how many hours are there in a day? So the point is that in 1978 I proposed to do good science while in 2013 I proposed to do good science and a whole bunch of other stuff too.

A well-known change that has occurred through my years is the probability of getting a grant funded. As above, I will use NSF as an example. Figure 1 is from a recent article in Science [1]. It shows the funding success rate for astronomers over the past quarter century has steadily declined from 48% in 1990 to 15% in 2013, a drop of over a factor of three. That is a drastic fall off and anyone would agree that a one in eight probability of funding is quite desperate. This problem is not limited to astronomers; it's endemic throughout the sciences. However, astronomers, like all scientists, I believe, are resilient, as indicated by their collective response to this dire situation. They submitted grants three times more often!

My own funding success rate tells a similar story. My NSF Fastlane site shows that I'm successful on about 15% of my grant requests over the past few years. How did I respond? I wrote more grants.

It's good to have a solution in hand, writing more grants, but writing more grants takes time away from the reason why we write the grants, doing more science. I also think that preparing to do all the outreach and teaching activities gets in the way of the science. Half of my job (and my passion) is teaching and I really don't need NSF to insist I pay attention to it.

The universal decline in science funding leads to the irony that we all owe our prosperity and our health prospects

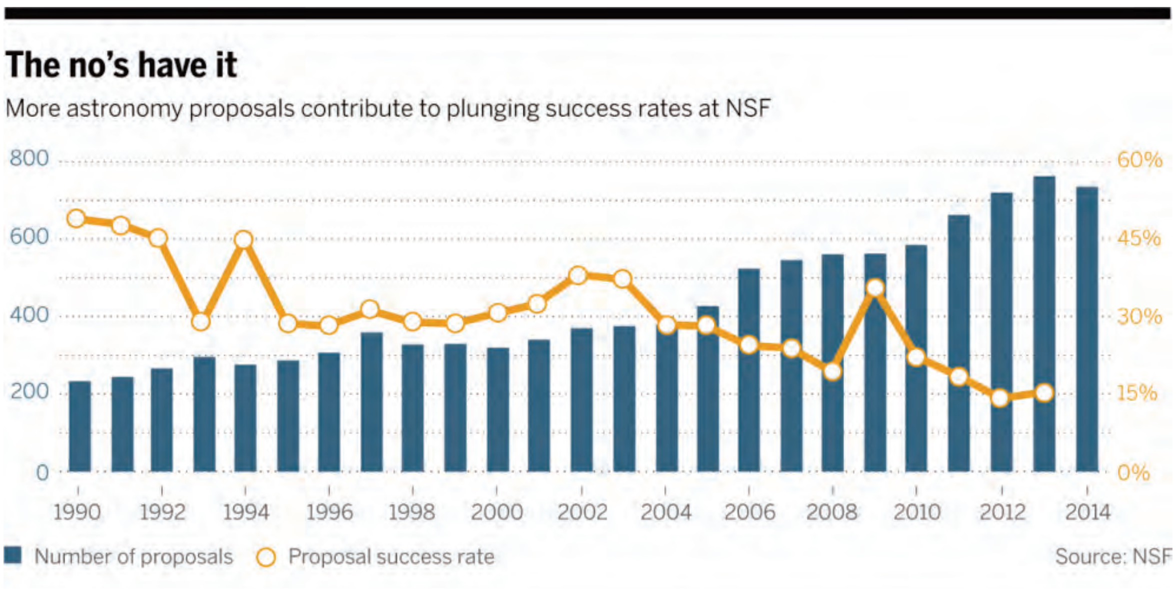

Figure 1. Funding success rate and number of proposals submitted for NSF astronomy programs since 1990. [1]

to advances in the sciences. NIH Director Francis Collins stated in recent testimony to Congress, "Our nation has never witnessed a time of greater promise for advances in medicine." Yet NIH's budget for fiscal year 2014 (FY14) is 11.7% below the FY04 peak [2]. I write this article at a desk top computer with orders of magnitude more power than the mainframe computer that I used for my first scientific researches as an undergraduate at the University of Nebraska in the late 60's; a computer that occupied a large room. We all know this but many of us don't seem to recognize that if this prosperity is to continue we must support the sciences as much as ever.

So what do we academic scientists do in this dire situation? How can our universities help us win the grants to keep our researches going?

Let me itemize things that are either necessary or would be very helpful for single or few investigator grants:

- Solid infrastructure is the foundation. I need a plethora of diagnostic equipment that are too expensive and require too much expertise to run and money to maintain by a single investigator. Things like electron microscopes, XPS and X-ray diffraction. It is the university's role to provide these devices, man them with expert operators and provide for their continued maintenance.
- The university should also have in place outreach connections across a wide range of venues such as K-12 schools, community colleges, minority institutions, civic groups, museums, etc.
- It would be very useful to have readers to read drafts of our grants and give advice. Readers who know the current trends and buzzwords, the ins and outs of the funding agencies.

Through my 37 years there has been an unmistakable trend for research to be performed in collaborations. I see this as part of a more general trend for group activities. For example, we now identify peer instruction as a viable teaching method and encourage our students to work on their homework in groups (So much for the rugged individual). The other undeniable trend is for interdisciplinary or multidisciplinary research. Funding agencies and others claim that modern problems are too complex for a single investigator or a single discipline (I guess we long for the good ol' days when problems were simple and straightforward). So, like it or not, we find ourselves aspiring to win big grants for lots of money involving many researchers. I have led a handful of such grant efforts and with those experiences, I can itemize things that are either necessary or would be very helpful for multi-investigator grants:

- A coordinator from the pre-awards office who knows all the ins and outs of organizing and constructing large multi-investigator grants. This person advises the group during grant construction, works alongside the PI, and perhaps more than anyone reads the RFP!
- A secretary for the PI during construction. The PI no doubt has his or her own research and teaching responsibilities that cannot be neglected.
- As for single investigator grants (and perhaps even more needed) outreach in place: K-12 schools, community colleges, minority institutions, civic groups, museums, etc. In addition, big grants typically stress diverse student

recruitment and connections to minority institutions.

- Solid infrastructure is the foundation.
- A technical writer. The PI and CoPIs will write the science, the technical writer will make sure it is communicated very well.
- Readers who know the current trends. Perhaps people who have served on previous review panels. Much like all universities have congressional liaisons they should also have funding agency liaisons. These are not lobbyists. Rather they are liaisons in the truest sense: people who foment mutually beneficial interactions by knowing the needs of both parties very well.
- Institutional Assessment ability. Very often major grants propose novel programs to advance science, teaching or outreach. Such programs need assessment to determine their efficacy.
- Administration for big grants. Once the grant is awarded (oh happy day!) it must be managed. The scientists want to be in the lab doing the science, I assume, so managers need to be found to run the non-science part of the grant.
- Last but not least, a record of collaborative previous work.

Although I list it last, a record of collaborative previous work is the first requirement to improve the chance of success. How is such a record acquired? Certainly research collaborations are born, one way or another, all the time. Sometimes such collaborations fit the request for proposals (RFPs) and those collaborations can adapt to the RFP and submit a viable proposal. Most of the time, however, the fit is imperfect and adjustments need to be made in research direction. Even more often, with major RFPs, the collaborative group is smaller than the scope of the RFP. This leads to the collaborative group "beating the bushes" to find other researchers who might add to and complete the team to fit the RFP scope. Beating the bushes is much easier if the university has a detailed database of the research interests and capabilities of the faculty. And such a database warrants a bullet.

- A detailed data base of the research interests and capabilities of the faculty.

Collaborations might not exist to satisfy the objectives of a particular RFP, yet the objectives could well align to partial extents with a variety of faculty. Thus it would seem wise if the university could anticipate RFPs. This can be done by looking at previous calls for proposals and the programs that stimulated them. For example, NSF has for years funded Materials Research Science and Engineering Centers (MRSEC). It would be wise to plan ahead of the next RFP by assembling a group of researchers who might contribute to a MRSEC. Led by senior faculty a research agenda could be outlined. Then a crucial step would be to gain a significant record of collaborative previous work. Such work needs to be funded and the university should fund it with seed moneys. These moneys would pay for students, for the entire degree cycle, materials and supplies and some travel. Such a seed grant is an essential investment a university must make if it is to compete effectively for major grants. Thus I add another bullet.

- Seed grants to gain a record of collaborative previous work must be supplied by the university.

Another use of seed money is to prepare a failed but worthy major grant request for the next opportunity for funding. We all know that to win grants one must often try and try again. Use the reviewer's criticisms, address them with more research to support a hypothesis or develop a technique. And the university should make the investment to do this.

Who should fund our work?

A growing funding source is the private sector. Corporate entities based on technology need research to create new and competitive products. However, there are many cultural differences between the corporate and academic worlds that need to be overcome or dealt with. These differences are not insurmountable if a philosophy of mutual benefit is kept in mind. This is a huge and detailed topic that I know only a little about so I will stop here.

I think universities should plan to support their own research by proper management of the intellectual property (IP) their faculty produces. This appears to be a growing realization but still awakening. Younger professors are much more aware of IP than I was 37 years ago, and so am I! We need to ensure that production of IP is seen as valuable to the academic world and an indication of scholarly success when evaluating faculty for tenure and promotion. We also need to have active research offices that continue to encourage the production of IP as well as publications from the faculty. These research offices also need to develop strategies for help faculty produce more IP and how to effective license it once produced. Most generally, IP has to become part of the culture of the university.

A novel idea is to use our teaching abilities to create capital. Yes, I know, that's been called tuition, but I mean something more. We can produce "classes" that would have general appeal to the public. These could be Nova-like productions on science, or interesting presentations in the arts or humanities. These presentations, either singly or as a series (a class), would be available on line for a price. This is much different than the many MOOC style classes available for free on the internet. We would be selling intellectual entertainment, not knowledge nor degrees.

From the societal or governmental point of view, I propose the future should heed the past. Most academics know very well the prescience of Vannevar Bush who wrote *"Science the Endless Frontier"*, a letter to the president [3] that laid the foundation for the NSF and set the tone for other government funding agencies. Bush foresaw that curiosity based science was both part of human nature and the necessary foundation for technical advances. Academic science has thrived for nearly 70 years as a result. Although funding from such agencies is getting more difficult, as described above, the agencies are not going away yet. Hence the federal government will still be a significant source of academic research funding, especially following the advice above.

We must also recognize we are not as powerless in influencing the federal budget and the public perception of academic research as some of us seem to think. In a recent editorial in *Science* [2] John Edward Porter, a former U.S. congressman and chair of Research!America argued that "we must convince the public and our representatives that cutting research is not a pathway to deficit reduction; it is a pathway to increased health threats, lost lives, and economic insecurity". And yet, Porter points out "there has been little outreach by scientists to the public to help them understand how science contributes to better health, job creation, and global competitiveness." Furthermore he writes "Scientists remain largely invisible to the public"

You would think professional teachers (which we academics are the *other* 100% of our time) would be terrific at communicating these important messages to the public. Well maybe we are, but we rarely try. Let's try.

We can try, Porter suggests, by writing op-eds and letters to the editor of local newspapers about the latest scientific breakthroughs and their implications for society. We can volunteer to speak at local organizations, chambers of commerce, junior high and high schools about our work or the latest discoveries. We could offer to be a scientific advisor for candidates or create and serve on science advisory committees.

Finally, I believe we should not forget that we have the opportunity to profoundly influence the future every class day by teaching the value of science to our students. By letting them know that we not only teach but do research as well. By being good and reasonable people to win their respect and thus ensure our arguments gain efficacy. What we do in the classroom might not have an effect overnight, but it will certainly change the future.

References

[1] J. Mervis, Just one proposal per year, please, NSF tells astronomers, *Science* 344, 1328, 20 June 2014.

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[3] V. Bush, Science the Endless Frontier, a July 1945 report to the president, United States Government Printing Office, Washington: 1945.

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Notes