Growing an Emerging Research University

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Abstract: *The emerging research college or university is one of the most formidable resources a region has to reinvent and grow its economy. This paper is the first of two that outlines a process of building research universities that enhance regional technology development and facilitate flexible networks of collaboration and resource sharing. Although the strategies described were undertaken at larger public research universities, the paper's analysis of the factors influencing innovation, alongside key research management interventions, provides a framework for adapting this process to fit the needs of a full range of educational institutions.*

Keywords: *research clusters, university research strategy, interdisciplinary research, innovation, competitiveness, regional economic development, open laboratory*

Introduction

When the first author was at New Mexico State University (NMSU), the president often stated that three types of universities would exist in the future: 1) those that have the resources to do everything and be great at everything, 2) those that are leaders in selected areas of teaching and research (often leveraging regional resources), and 3) those that focus solely on teaching. Given the need for economic development and revitalization and increasing global competitiveness, the authors believe that, contrary to prevailing thinking, many more universities and colleges across the country can, and should be of the second type; such universities should pursue increased involvement in research and development with their local communities. Through such outreach, they will become engines of economic opportunity and innovation in a way that enlivens the educational process and builds entrepreneurial leaders. Employers expect that graduates, no matter what their discipline, will have the experience and skill sets to function on the cutting edge of technology. This, then, is a set of papers that explores some of the most efficient and rewarding processes to achieve the goal of becoming a partnered research university or college. The authors will explore challenge- or theme-based interdisciplinary research cluster development, strategic hiring, open laboratories, and technology transfer – issues that are of most value to emerging research universities that want to become great research and educational partners; furthermore, the authors describe methods of implementing this change efficiently and in a timely manner.

The cluster-based approaches detailed in this paper are for those who have the desire to focus on developing points of excellence that raise the stature of their campuses and increase the capabilities of the surrounding community. Although this strategy can and should be highly inclusive, it involves a decision to emphasize some areas and not others. This approach is based on the experience that investing where the greatest synergistic strength exists within the surrounding community will best increase the support, funding, stature, and economic competitiveness of all partners. University leadership (i.e., board and president) must share the vision and show the determination and support necessary to pursue this strategy, culminating in the targeted dedication of resources. The potential results are remarkable if leadership is willing to take the risk. The authors of this article contend that emerging research universities are vital to developing partnerships with industry that not only enhance the discovery process, but also help to translate those discoveries quickly and efficiently (with real job creation) into creating and making things again (Grove, 2010).

Background

Rationale for Research Clusters and Becoming an Emerging Research University

A research cluster is a flexible and inclusive, team-based, multidisciplinary research structure that encompasses faculty, centers and departments, as well as outside partners in the community (including other universities) and is defined by a common theme or broad focus area inspired by a major 21st century challenge. These groups span across multiple academic departments and colleges within a university in a way that builds strategic areas of excellence around core competencies in research. In 2007, the National Academies released *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future*, a report that describes a "disturbing mosaic" of negative indicators spanning the nation's education, research, and economic sectors that, together, demonstrate the United States' lack of preparedness to compete effectively in the emerging global marketplace (p. 25). The U.S. has enjoyed a position of global economic leadership since World War II, but as Vest (2009), president of the National Academy of Engineering, noted, "[t]he time really has come to slay the dragon of complacency. There is little slack left. Other nations are not biding their time." The U.S. faces ever-expanding international competition for talented students and faculty, as well as scientists, engineers, and innovative industry entrepreneurs – the human capital that drives economic growth and national security. The National Academies' committee that developed the 2007 report argues that science and technology research and development hold the greatest promise for ensuring the United States' competitive advantage.

The follow-up report, *Rising Above the Gathering Storm, Two Years Later* (2009), laments that talk has not materialized into action. In the report, past National Science Foundation (NSF) Director Arden Bement bemoans the fact that, at such a crucial time, the "nation's colleges and universities have been particularly hard hit" (p. 10). Although it may be difficult for many to imagine the U.S. as no longer a leader in science and engineering innovation, as C. D. Mote, Jr., former president of the University of Maryland warns, "[t]he world is running away from us" (p. 13). The only sure means of enhancing U.S. leadership in an increasingly competitive global marketplace is a national educational strategy that produces a workforce capable of adapting to and thriving in an interdisciplinary environment of accelerated technological change and a relationship with industry that assures international competitiveness.

The American research university is the key to a sustainable national climate of innovation that will attract new industries and create new jobs, supply quality education to its citizens, attract top international talent, and lead the international community in the research and development necessary to address issues of global importance. As a core of knowledge-based resources, the American university functions as a site of collaboration for what Etzkowitz (2003) terms the "triple helix" of university-industry-government relations, which has become a proven method to leverage investments in research (p. 119). As Mintrom (2008) adeptly argues, the "general advancement of knowledge comes through research-based acts of discovery. This is why the research function of the university matters. It is through research that universities add to the shared stock of human knowledge" (p. 232). The team and challenged-based approach is one of the most effective ways to conduct research.

One medical research, team-based initiative has been compared to making a movie, in which producers bring together experts in different disciplines who are all focused on a common objective. Here, teams "[disrupt] the normal course of business across the medical research community" (Saporito, 2013, p. 32). In an effort to more quickly solve the complex interdisciplinary aspects of curing cancer, Stand Up to Cancer (SU2C) with Nobel laureate Phillip Sharp, is founding challenge-based teams that are aligned with Dr. Francis Collins' thinking. Collins, director of NIH, refers to himself as "strongly anti-silo, strongly pro-breaking down barriers, bringing disciplines together, building collaborations and building dream teams" (p. 33).

Research Clusters as a Foundational Construct for the Emerging Research University

A challenge for any emerging research university is how best to use the limited resources it has available to address the region's and nation's current gaps in education while undertaking a comprehensive effort to transform the collective research and development enterprise in a manner that increases its competitiveness and innovation capability. Fortunately there is considerable flexibility if one focuses on programs and research that cut across disciplinary and organizational boundaries. The greatest potential for new discoveries and the ability to craft a partnership with the local community exist here. This partnership thereby creates a unique outcome that is tailored to regional needs and capabilities, which can collectively be grown to an international competitive advantage. Crow (2007), president of Arizona State University, argues that such differentiation is key for emerging universities and is a competitive strategy that underpins his entrepreneurial vision of "the university as an enterprise" (p. 27). An approach that spans boundaries has the added benefit of leveling the playing field, to some extent, for new entrants and provides rich research and development opportunities for undergraduates and graduate students who have an orientation toward multitasking and synthesis.

Taking cues from successful academic/industry endeavors (such as Silicon Valley, Research Triangle Park, and Boston Tech Corridor) a cluster model groups education and research around broad, but relevant issues, such as energy and the environment, and helps to focus a university's discipline-based enterprise on global and multidisciplinary challenges. (See Appendix A.) Cluster models leverage local and regional strengths and resources to benefit the university and surrounding community. The model has strong support from the National Academy of Engineering and the Brookings Institute who recommend deep collaboration with new and various partners, such as those that might occur through regional clusters of innovation centers. How would this work? What is the benefit for faculty and students? How are research clusters defined in a way that is flexible, adaptive, and most effective?

For students, clusters represent education and training opportunities to work with faculty mentors on today's pressing issues: learning to work in teams; developing communication and critical thinking skills; and gaining hands-on experience working in the lab or field. For faculty, clusters represent an opportunity to learn and apply new concepts and theories across boundaries, to expand and refine current disciplinary knowledge, and to benefit from shared resources and networks of experts while working on the larger challenges of the 21st century. Interdisciplinary research is enhanced when conducted within the framework of clusters. A 2004 report of the National Academies' Committee on Science, Engineering, and Public Policy defined interdisciplinary research as "a mode of research by teams or individuals that integrates information, data, techniques, tools, perspectives, concepts, and/or theories from two or more disciplines or bodies of specialized knowledge to advance fundamental understanding or to solve problems whose solutions are beyond the scope of a single discipline or field of research practice" (p. 2). The use of clusters for this purpose represents a mechanism for focusing limited resources to produce measurable success.

New Mexico State University and the University of Houston: Cluster Strategies Employed to Advance the Research Enterprise

To demonstrate how research cluster concepts can be applied in practice, the authors' experiences implementing cluster strategies to grow the research enterprises of two universities, New Mexico State University (NMSU) and the University of Houston (UH), are detailed below.

New Mexico State University: 1996-2006

Research clusters at NMSU were defined as *constructs that are multidisciplinary, and which stimulate challenge-based groups of investigators;* New Mexico State (NMSU) first began exploring cluster-based approaches to research in 1996. The university's well-known research laboratory, the Physical Science Laboratory (PSL), played an integral role with the White Sands Missile Range in early rocket and space initiatives. It grew out of the physics department just after WWII and had a long history of successfully involving undergraduates in research. From the time of its founding, PSL was a trailblazer in projects (prior to cluster development) that broke down barriers and involved students in real-world projects. Faculty members and thousands of students were involved directly or indirectly in projects over the years; they worked together to take telemetry from V2 rockets using film, rulers, and calculators (later automating those processes with some of the earliest IBM computers) and developed the antennas and manned the satellite tracking stations that were critical to the Apollo space missions. The impact on lives was remarkable; at its greatest height, the laboratory employed over 700 faculty members, staff, and students. However, by the mid-1990s the laboratory had fallen victim to a sharply changing research landscape and was described by the then executive vice president and provost as "being in its 11th hour." Few resources were available and many feared that the laboratory that generated much of the campus' research would lose its remaining contracts and collapse. In response to this challenge, the first research clusters within the university environment were formed, and student/faculty partnerships with government and industry personnel were actively pursued.

It was not readily apparent what the laboratory's core research capabilities were or where the best opportunities for growth were, because of the changing marketplace and layoffs and retirements. The perceived strengths were mapped against potential opportunities for the next five to ten years.

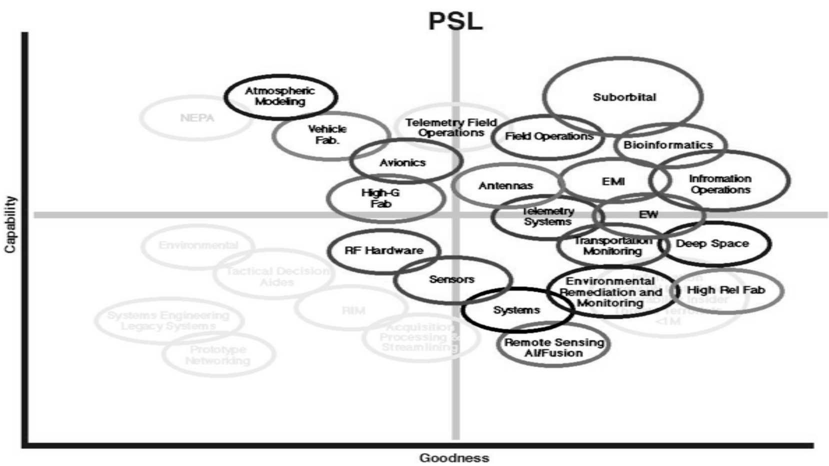

Figure 1. Capabilities and Opportunities (Birx and Finke, 1997)

Two important facts were extracted from a perceived strengths and opportunities (goodness) mapping exercise originally developed by Michael Porter (2004) (see Figure 1): (1) the laboratory, in a quest to survive, had been pursuing ventures for which it had little capability and for which there was limited prospect for growth of funding, and (2) new "clusters" of high research potential became apparent when mapping out NMSU capabilities (and those of the local community) with market needs. The decision was made, after some considerable discussion, to reorganize the laboratory into a series of clusters that best matched with opportunities to grow.

The clusters, based on aerospace, emerging technologies, and communications and information science, provided an approach to break out of the traditional discipline-based silos that had rendered the laboratory unable to change in an environment where change was essential to survival. They were matched to markets, capabilities, and the region's and potential partners' strengths. The clusters, by their very nature, had to be flexible, dynamic, and evolving. To accomplish this, the latest concepts of organizational theory (as presented by the NMSU College of Business) and complex systems (drawing on the resources of the Santa Fe Institute) were used. The guiding principles for the research clusters were: (a) that the greatest point of new discovery and exploration occurred at the edge of chaos (do not over-organize or control), (b) that clusters could self-form (within a framework of organizational structure and seeding), and (c) that leadership could be shared. The result was that within a year, the laboratory had halted its five-year decline and had started to grow again in a way relevant to the economic wellbeing of the community and state.

The cultural change took much longer. Some believed that the laboratory was being destroyed or they found the change unsettling. An early indication that the changes were having an impact occurred after a staff member stated that he no longer knew what to do when he came in each day. Until this point, few had asked, "Does what I'm doing make sense in the context of the challenges we face?" This statement resulted in the evaluation of the questions that were being asked. Were they the right questions?

In all, the cultural change took five years. In this endeavor, we were fortunate to have had substantial nonfinancial support from the university administration, the departments across the university's colleges, and particularly the college of business. The clusters helped the team determine who to hire, aided development of a critical mass around key strengths, guided investment of limited funds, and created opportunities to reengage faculty members and students. In fact, at one point, so many math faculty members became involved that the math department experienced a shortage of available teachers. To accelerate cluster development and assure maximum technology impact and translation to practice, the first vestiges of what would later be called an open laboratory model was used; it blurred the boundaries between NMSU and its partners and developed a cohesive team that drew on the strengths distributed across different organizations. This model concept, bolstered by a partnership with the U.S. Army Research Laboratory (ARL), a White Sands tenant organization, helped to reverse the Army lab's planned closure at White Sands and resulted in innovative products, one of which protected U.S. soldiers in Iraq and was named among the Army's (2008) "Top Ten Greatest Inventions of 2004."

Over the next decade, the laboratory not only survived, it more than doubled its annual research expenditures to $60 million. Programs were developed that involved undergraduates in applied research and theme-based education including an intelligence studies and remotely piloted vehicle program. When the provost sought to develop a Creative Media Institute that blended traditional theater, modeling, and simulation and animation, PSL played a key role in the technology input and integration (borrowing from the newly developed expertise in complex systems modeling) in this highly successful interdisciplinary endeavor. Should anyone wonder about the academic fallout, the impact of these programs on involved students, many of whom were first-generation college students, was startling. It brought to life their classroom education with relevant practice and it positioned them as leaders in their quests for employment in their fields. Finally, to speed the process of technology transfer and to provide an environment for more flexible research partnerships, we pioneered a successful technology incubator, the Physical Science Institute, that included venture capital companies on its board.

Having employed clustering concepts in a university research laboratory setting, it was not clear that the same concept would work across a university of many different departments and in a more faculty-driven environment. Fortunately, the initiative had the support of the president and provost. New Mexico State University, like the Physical Science Laboratory in past years, had been somewhat stagnant in research growth. The challenge was how the cluster model could be adapted to a university-wide setting. The first months were spent exploring with the faculty the strengths of the university community and the potential areas in which cluster capabilities attracted national and international research needs and funding availability. Many sessions were held with faculty groups after which their interest areas and research foci were grouped into clusters. The result of that analysis is presented pictorially in Figure 2 below. In 2004, the first university-wide research clusters were formed in Space and Aerospace, Border Issues, Information Sciences, Bio-Sciences, and Energy and Natural Resources.

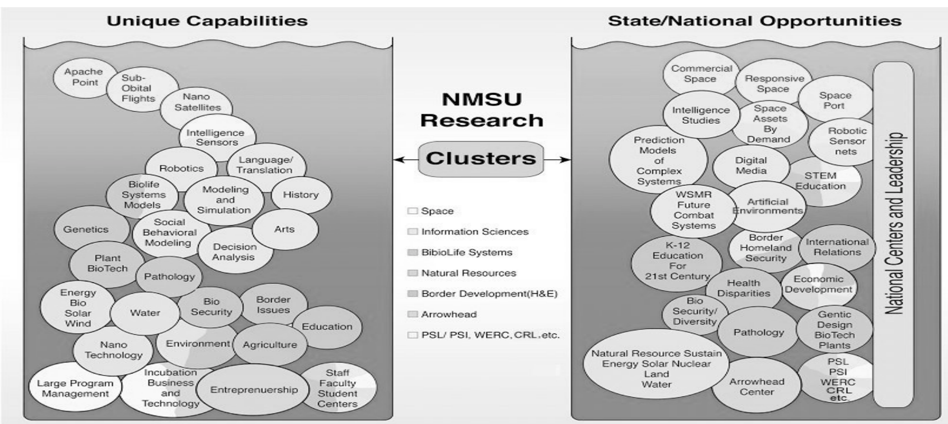

Figure 2. University Strengths and State/National Opportunities
(Birx, Egginton, Raad, Rivera, and McNiel, 2006)

Sá (2008) and Brint (2005) suggest that the limitations of the "disciplinary departmental nexus" hinder the successful implementation of interdisciplinary programs (Sá, p. 539). One of the alternative structures, recommended by the National Academies (2004), is a matrix management strategy for breaking down silos of the traditional departmental structure. The implementation of clusters that resulted was very much like a matrix in which the clusters focused on key strategic themes with the colleges and units that formed the pool of expertise (see Figure 3).

The president and provost of NMSU allocated funding, despite limited resources, for cluster mini-grants and support in the form of resources for administration and grant writing. Since NMSU faculty members had experience in developing larger initiatives as a result of years of support from the congressional delegation, developing clusters and larger joint projects was just an extension of that activity. The cluster members formed teams based on common

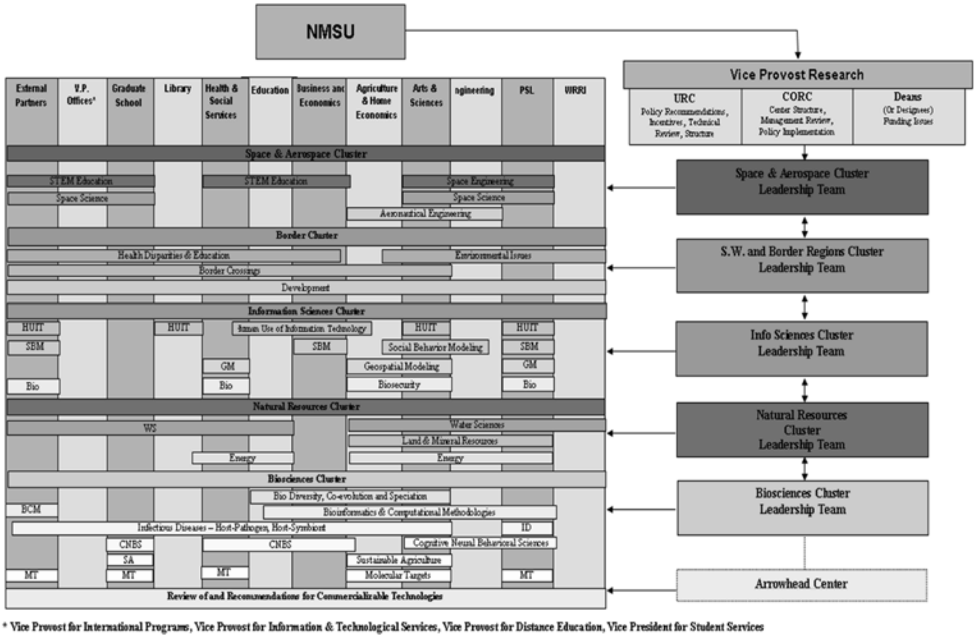

Figure 3. Matrix of Strategic Cluster Themes and University-Wide Pools of Expertise (Birx, Egginton, Raad, Rivera, and McNiel, 2006)

interests and built committees with flexible organizational structures. Pairs of leaders, in most cases, served for a year. This follows the ideas of Feller (2002), who advocated for the management styles characterized by *adhocracy*, a dynamic, flexible organizational form that shuns hierarchical control (p. 113).

Mini-grants were a boon to students who were engaged in the projects (along with faculty from multiple disciplines) and the focus that the clusters provided allowed the university to be represented to the funding community with cross-disciplinary strengths in key research areas. This cluster approach was useful in pursuing federal initiatives. When clusters of faculty researchers brainstormed on cross-disciplinary initiatives, the results were, at times, incredibly new and innovative.

As for any strategic goal on a university-wide level, faculty member leadership was critical. Research clusters were defined as “a concept that allows NMSU to frame and encourage administratively what is expected to be a largely faculty-driven and shaped process for evolving areas of NMSU strategic cross-disciplinary research, education, and service that builds on inherent strengths and resonates strongly with current and future community, state, and national needs” (Birx, 2005). The research office and accompanying web sites were restructured. In part, cluster development at both PSL and across NMSU accelerated research growth; in 2006, the level of research at NMSU peaked at an all-time high and NMSU moved from 125th (2004) to 99th (2006) in the NSF’s report on research universities.

Following the implementation of research clusters at NMSU, a rural-land grant environment, the cluster model was applied to a large metropolitan research university – the University of Houston (UH). However, each university faced different challenges, key drivers, and leverage points when implementing cluster development. UH was eager to move ahead in its research program and had a complement of outstanding faculty and research capabilities; it was just emerging as a top-tier research institution and faced the challenges of building critical mass in strategic areas. The opportunity arose to develop more fully the concepts of the open laboratory, cluster hiring, and more flexible approaches to technology transfer.

The University of Houston: 2006-2010

The University of Houston began the development and implementation of clusters in fall 2006. To a new research officer, the outstanding quality of the discipline-based programs and faculty was obvious. The level of individual success in sponsored and non-sponsored research was exceptional. Almost half of the research funding came from basic research grants with NSF and NIH. The previous administration had made significant progress in positioning UH as a research university, but the level of collaborative research was limited and growth had leveled. The overall strengths of the university and how they related to the community the university served (Houston) were unclear. Faculty members from various departments were surveyed, and the lack of clarity about the capabilities of the university community beyond departmental strengths became evident.

The first objective was to characterize potential common research and educational themes of interest to UH and the larger Houston community, similar to the process undertaken in New Mexico. Fortunately, a progressive Greater Houston Partnership, as well as the state of Texas, had already structured potential clusters through which the city and the region had existing or emerging strengths and the potential for growth. In a similar effort to the one undertaken by the Greater Houston Partnership, a mapping process (comparable to the figure on the next page) was used to look for areas of synergy and concentrations of research activities across the university and later, the university system (see Figure 4).

The six initial clusters outlined were Energy and Natural Resources, Biomedical Sciences and Engineering, Nano-materials, Complex Systems and Space Exploration, Arts and Human Enrichment, and Community Advancement and Education. They reflected considerable internal strengths and opportunities for partnership with the community. Houston is well known as a major energy and natural resources center, and it has the largest medical center in the world. NASA's manned space mission is headquartered in Houston, and complex systems are a key aspect of the evolving delivery and sustained life support systems for harsh environments. Moreover, materials and Nano-materials are regional strengths related to medical (e.g., drug devices and delivery) and energy needs (e.g., exploration and processing). The arts were very strong (both in the community and the university) and there had been considerable interplay between the university and the community to advance common causes in enriching community life, particularly education.

Maps of each of these six initial clusters were developed to show the interrelationships between the various topics of interest and faculty member research strengths in a manner relevant

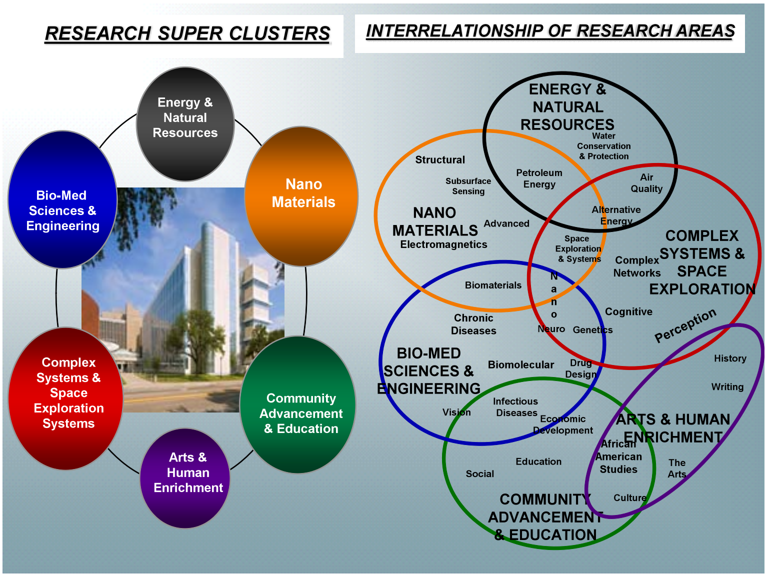

Figure 4. UH's Research Strengths (Birx and Boyko, 2007)

to both industry and sponsored research agencies. The cluster for Biomedical Sciences and Engineering (see Figure 5) was later strengthened when the College of Engineering founded the department of Biomedical Engineering.

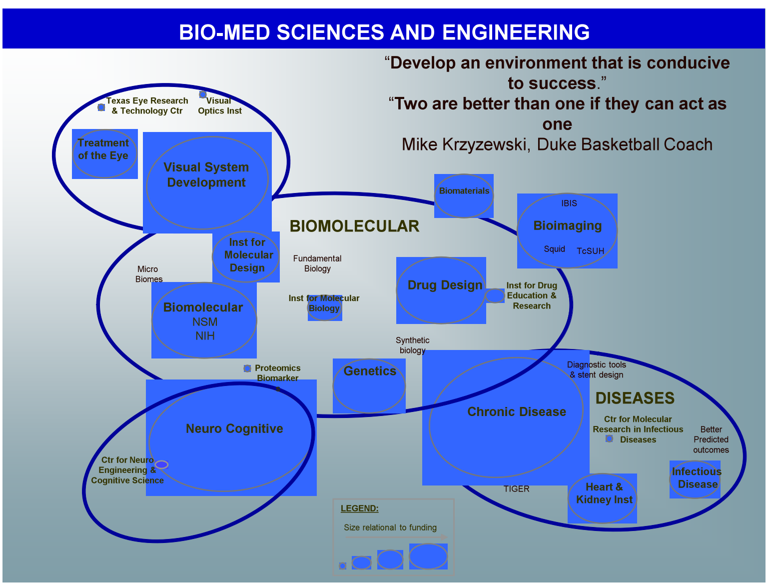

Figure 5. Interrelationships of Cluster Topics and Faculty Strengths (Birx and Boyko, 2007)

Implementation is always the biggest challenge in building research clusters, and the key pivot point for success is not always clear; therefore, a variety of approaches were pursued to shift the culture. While many universities have developed strategic plans that purport to encourage interdisciplinary research, many have failed to implement adequately the significant cultural and structural changes necessary for such a substantial transformation (Feller, 2002). To assist in this regard, The National Academies' (2004) landmark report, *Facilitating Interdisciplinary Research*, provides a comprehensive approach to promoting cluster-like research that targets a variety of stakeholders in the research enterprise, including researchers; educators; undergraduate and graduate students; postdoctoral scholars; academic institutions; public and private funding organizations; and professional societies. Many of these recommendations, such as fostering a collaborative research environment and providing faculty incentives and seed funding, were validated in the implementation of the UH research clusters (Figure 5-3, p. 87).

Initially, very limited new funding to develop clusters existed, so an inexpensive research seminar series was developed and featured individuals who had held key roles with funding agencies. The series brought together diverse faculty groups that might have common agency interests. Throughout the first year, cluster meetings included presentations on the value of research and topics of collective interests, as well as efforts to refine the funding announcement distribution (by cluster groups) and the internal grant process (to reinforce collaborative projects). This approach aligned with the guidance of Glied, Bakken, Formicola, Gebbie, and Larson (2007) who warned that collaboration at the planning level (courting faculty buy-in) is key to success.

Although the first year's progress was limited, the cluster model enabled focused investments and efficient communication across colleges and departments. As observed elsewhere, and noted in the National Academies' Report (2004), tenure-track faculty members, who were often most interested in this cluster-based approach to research, were discouraged from spending too much effort on cluster research projects as it could impact their chances of tenure and promotion; furthermore, associate and full professors often had already established their own research programs or were not engaged significantly in funded research. Although the promotion and tenure policies were not changed at UH, the experience laid the groundwork for tenure and promotion policy revisions at another institution, Penn State Erie, The Behrend College.

Activities that Nurtured Research Clusters and Leveraged Value

Multi-Investigator GEAR Grants. For years, UH's primary mode of investing in research development was through a competitive internal grants program offering New Faculty Grants, Small Grants, and a larger Grant to Enhance and Advance Research (GEAR). These individual grants ranged from \$3,000 and \$6,000 (for Small and New Faculty grants) to \$25,000-\$30,000 (GEAR), and totaled approximately \$750,000 per year. To spur the development of larger collaborative grants in strategic areas, a portion of the GEAR grant funding was dedicated to collaborative projects; the award was increased to \$50,000. Researchers who participated in GEAR-funded multi-principle investigator (PI) projects brought over \$15 million (2008-2011) in sponsored research awards based on approximately \$500,000 of UH investment. Although the much larger group of GEAR-funded, single-PIs has brought in a larger total amount in funding, PIs who received GEAR grants for multi-PI projects had an average return (in awards) per dollar over 40% greater than that of their single PI counterparts.

Positive side effects of cluster development emerged; the resources were more efficiently internally appropriated, grant announcements were targeted to faculty groups, agency program managers developed confidence in the team's competencies, and better decisions were made on equipment and limited submission grants.

Network Seminar Series. A group of faculty researchers interested in the cluster on Complex Systems requested sponsorship for a seminar series in complex networks that brought in researchers from around the country and encouraged faculty members from a variety of disciplines to discuss new books and papers on the subject. The cost was modest, around $15,000 per year, but the return on investment was considerable. Before the first author left UH, the group sent a detailed overview of grants that had resulted from joint research projects conceived from the interplay at these seminars and discussion sections. The results were striking, particularly considering the theoretical nature of the research and the inherently lower funding levels. From an investment of $30,000 over two years, $1.18 million worth of new funded research had evolved. This outcome reinforced the following elements of growing research funding: (a) large gains can be made with limited investment, (b) targeted institutional investment is critical, and (c) alignment of objectives with funding is of paramount importance. In addition to spurring proposal-writing activity, the collaborations forged in the network cluster resulted in the development of three new courses in mathematical biology: Mathematics of Evolution, Biostatistics, and Biological Physics and Networks.

Research Clusters as a Driver for Congressionally-Funded Projects.

Although earmarks are controversial and have become the subject of extensive discussion, they can be critically important. Congressional support is one of the few sources of substantial seed funding that is open to emerging research universities for big projects that can have significant long-term impact, but for which not enough data or experience to garner agency or industry funding exists. Research clusters became the basis organization of the federal agenda for research funding requests. Prior to cluster formation, most items for inclusion were brought by faculty members without regard to a strategic framework at the university level. The clusters enabled the framing of larger, more connected research concepts that resonated with congressional representatives and the community. The UH government liaison fully supported this approach. In FY2009, the project received almost $3 million in earmarks for programs in offshore wind, clean fuels, power generation, and cell differentiation synthetic biology. In FY2010, UH received $4 million for programs in offshore wind, carbon composite thin films for power, and teacher training and professional development.

Branding at the Super-Cluster Level. The concept of research clusters evolved into a university-wide branding strategy. Two of the original research clusters, Biomedical Sciences and Engineering, and Energy and Natural Resources, evolved into two super-clusters: UH Health and UH Energy. The university began to brand itself by focusing sponsored research and educational initiatives along these two over-arching themes. Later, UH Arts and UH Stars super-clusters were added.

Up to this time most of the UH faculty hiring was for assistant professors in areas believed, either by the college or department, to be essential for future growth or sustainability of their mission or interest areas. Very little, if any, focus was dedicated to (a) bringing in key faculty researchers that matched a university-wide strategy, and (b) building a team around key researchers (what would later be called cluster hiring). Similar to the University of Wisconsin-Madison's (UW-M) cluster hiring initiative in 1998 that provided "an alternative to departmentally based hiring practices and norms," UH sought to "enable the campus to devote a critical mass of faculty members to an area of knowledge that would not be addressed through existing departmental structures" (UW-M, 2008, pp. i and 3). For an emerging research university with a mission to impact the local economic development and move to a tier-one position within a five-year time frame, it was critical to focus on these key hires and to build the research enterprise by pooling resources and leveraging scarce startup dollars in order to have the greatest impact on research productivity.

The world's largest medical center is only few miles away from UH, which made bridging UH's basic science and engineering capabilities under the UH Health brand a natural choice. However, the gap between the basic research at UH and the medical research and applications at the Texas Medical Center limited the full potential of collaboration. Great partnerships with researchers in mechanical engineering existed, but UH did not have a biomedical engineering department initially, and the biology research had yet to evolve into a more medically-related focus on transgenic mice. The project was not without resources; the shell of a newly-constructed research facility sat unfinished in the center of campus and was available for build-out. The cost to finish this facility by building out the laboratories and other infrastructure would be at least $30 million, but it represented an exceptional opportunity to establish a world-class cluster in Biomedical Science and Engineering.

As Stahler and Tash's (1992) early survey of successful interdisciplinary programs revealed, "[t]he increase in new faculty hires in targeted fields, the provision of adequate research space and facilities, and the supplying of adequate equipment and start-up packages were viewed as key factors in rapid growth" (p. 22). The turning point for cluster research at UH was a series of two presentations made to the Board of Regents and the leadership of the university—the first of which included the initial presentation of the clustering approach to research. It was after the second presentation, which included an analogy that compared the shell of the newly-constructed research facility to a plowed field waiting to be cultivated, that the leadership saw the potential substantial growth in sponsored research income as well as the potential increased stature of the university.

After a significant presentation showing the potential growth in sponsored research, the UH chancellor allocated $6 million each year (for five years) to the UH budget. Then, with the support of the chancellor and the chair of the Board of Regents, the team developed a cluster hiring package valued at well over $20 million; it could be argued that a substantial part of the award would have occurred anyway in order to build out the facility and acquire the necessary research equipment. The Center for Nuclear Receptors and Cell Signaling was founded as a result of this funded cluster project.

The Center for Nuclear Receptors and Cell Signaling. The first cluster (Biomedical Science and Engineering) was built around several newly formed centers, one of which was the Center for Nuclear Receptors and Cell Signaling (CNRCS). An initial $7 million investment from the university was augmented by a $5.5 million award from the State of Texas' competitive program, the Emerging Technology Fund, and by $5.5 million from The Methodist Hospital Research Institute (primarily within its own facilities). The center focused its work on cell signaling in cancer, neurodegenerative diseases, and the immune system. Two recent large awards provided $3.2 million from the U.S. Environmental Protection Agency (EPA) to study in vitro and in silico models of development toxicity in embryonic stem cells and zebra fish, and $5.3 million from the Cancer Prevention and Research Institute of Texas (CPRIT) to study novel nuclear hormone receptor targets in prostate cancer. As of April 2011, eight tenure-track faculty members and seven research faculty members were employed at the center, with an additional two research faculty members in the hiring process when the first author left UH. While several smaller grants from the National Cancer Institute and the American Cancer Society were obtained, the largest awards at the time of this writing have been the EPA and CPRIT grants. Total sponsored funding associated with the CNRCS was $17.5 million as of April 2011.

Within one year, UH's success with the CNRCS began to have a significant halo effect, demonstrating the commitment of UH administrators and faculty to making the university a premier center for biomedical research and attracting leading researchers and institutions to join the UH Health initiative. One such case was the Center for Molecular Medicine and Experimental Therapeutics, which is comprised of a growing cluster of faculty researchers with close ties to several Texas Medical Center member institutions. The center is led by a tenured faculty researcher whose ground-breaking stem cell research will further help position UH at the forefront of a biomedical revolution. With funding for researchers' salaries provided by the Texas Heart Institute, the center has taken advantage of UH's developing biomedical research resources, expanded UH's relationships with area biomedical research institutions, and quickly turned the university's modest investment into just over $1 million in federal and state sponsored research awards. A second cluster-associated hire was an accomplished synthetic chemistry faculty researcher, who brought a proven track record of securing research funding from the National Science Foundation, National Institutes of Health, The Petroleum Research Fund administered by the American Chemical Society, and private industry, as well as a long-standing working relationship with the University of Texas Medical Branch (UTMB) at Galveston. This developing cluster has already secured over $2.5 million in research awards.

Impact of Cluster Initiative on UH's Research Profile

The sponsored research profile changed dramatically from 2006 to 2010 due to an increase in the submission of multi-PI and multidisciplinary proposals and their resulting awards. Figures 6 and 7 below show the increase in multi-PI awards $1 million and greater and $500,000 and greater, respectively. The number of multi-PI awards $1 million and greater increased by 60% from ten to sixteen from FY2006 to FY2010. The dollar amount increased by 74% from $15 million to $27 million over the corresponding time.

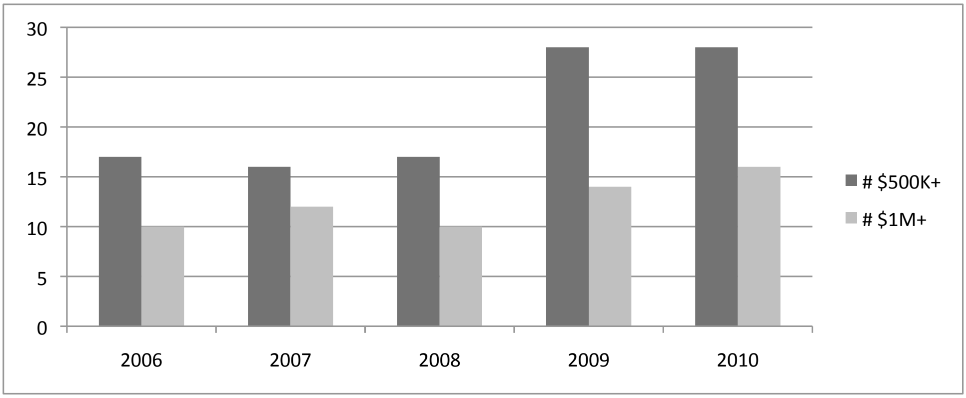

Figure 6. Number of Large Multi-PI Awards, FY2006-2010 (Fletcher and Ward, 2010)

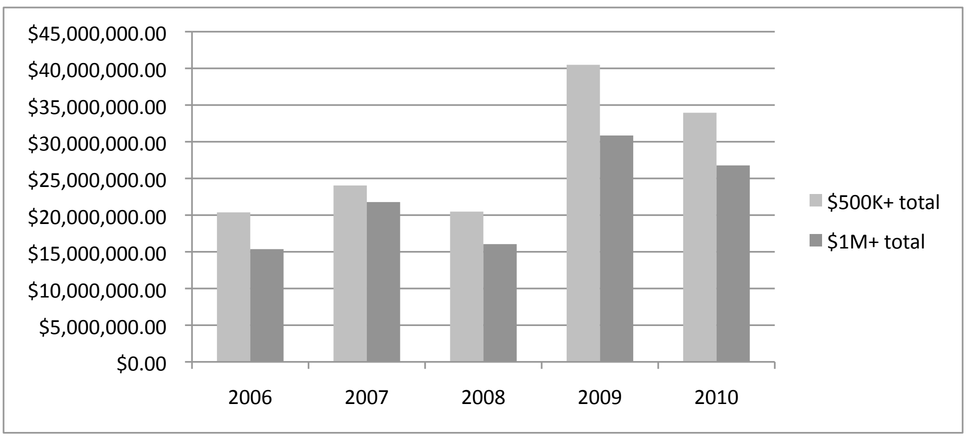

Figure 7. Amount of Large Multi-PI Awards, FY2006-2010 (Fletcher and Ward, 2010)

Figure 8 shows UH sponsored research activity (awards and expenditures) over the FY2000 to FY2010 time period. Research clusters were introduced in FY2006, but did not begin to take off for several years. UH benefitted significantly from the (American Recovery and Reinvestment Act (ARRA) initiatives, totaling $23 million in awards from FY2009 to FY2011 (this figure includes work UH undertook as a sub-recipient), in part because UH was well positioned to take advantage of this funding opportunity.

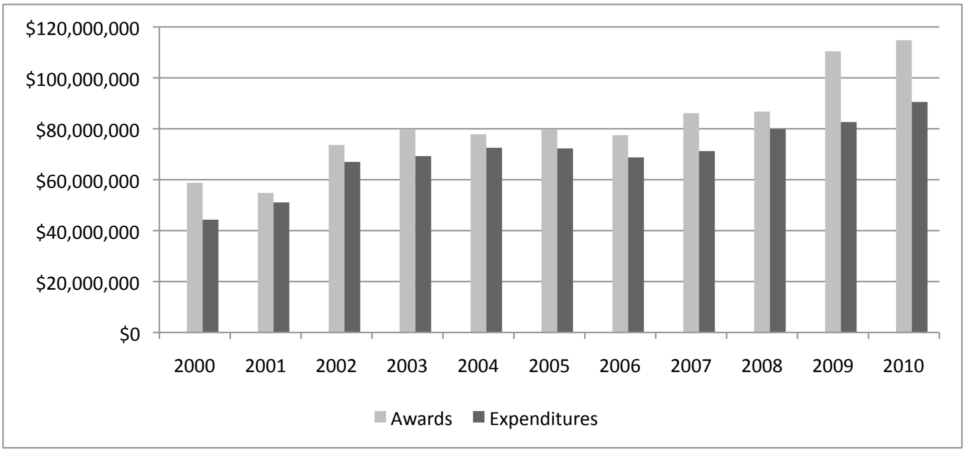

Figure 8. UH Sponsored Research Activity, FY2000-2010 (Fletcher and Ward, 2010)

The result of these and the other research initiatives by the chancellor was the designation of the University of Houston as a Carnegie Very High Research University in January 2011, for the first time in its history and less than five years after initiating research clusters.

Lessons Learned

Most of the challenges of the 21st century are interdisciplinary in nature, and transformational discoveries often occur at the interface of disciplines where different viewpoints yield unique insights. Organizationally, universities are often designed with discipline-based approaches to education and research. Centers, to varying degrees, are successful at integrating research areas; however, at times they become another layer of management that conflicts with and duplicates the traditional structure. There is great value in having a flexible organizational structure that can incorporate individual researchers, discipline-based structures, and centers without creating another layer of management. A cluster-based approach to education and research presents some unique opportunities to develop vibrant university-wide programs that are challenge-based and can also build on and integrate the strengths of the local community. In doing so, this process establishes unique capabilities and environments for discovery that are not already dominated by established universities or industries. However, there are hurdles to overcome.

Research clusters and university-wide strategic liaisons with the surrounding community represent a collective way of thinking that is sometimes foreign to academic environments. While the rewards can be considerable, one cannot move faster than the culture allows. Faculty ownership and communication are paramount to the success of cluster approaches, and this takes time to develop. Those most resistant to change are sometimes the ones most vested and successful in the current culture. While every opportunity to build the case for clusters was used and faculty input was regularly sought, less pressure was applied when an approach did not yield the results sought. Each university environment is different, and finding the leverage points that will make the greatest difference takes time, as does the development of a deep understanding of the communities (both internal and external) research officers serve.

One of the most significant challenges of the internal community is the traditional infrastructure of colleges and departments within a large university. In a relatively decentralized environment with strong college deans, there may be pressure to build strong departments within the individual colleges and to *not* focus on multi-college interdisciplinary initiatives. Ultimately, successful partnerships must be formed between the research officer and deans.

Successful cluster hires set an example, provide immediate returns, seed a capability, establish credibility, and serve as a focal point for individual research collaborations. It must be realized that they can be expensive initially and require a shared strategy and focus as well as more involvement at higher levels of administration than typical departmental hires. This can put a research officer in a difficult position. Combining cluster hires with incentives that involve the existing faculty members (from equipment to space, and internal grants to support funding for collaborations) is important to get the most benefit out of cluster hires. Clustering faculty researchers from different disciplines in common facilities around core equipment brought an immediate change in perspective that even surprised faculty. In the end, with the right mix, change is substantive and the results are striking.

Not all universities have the resources for cluster hires or even for multi-PI grants. Often, we did not have new faculty lines to offer to departments for cluster hires, and we needed to redirect existing open positions. Redirection can raise significant concerns from department heads who view these lines as allocated to the college and department – not the research office. Providing matching funds for start-up packages and other incentives ameliorated these concerns. Access to start-up funds and support from deans are important, as are successful hiring examples and future funded positions. At times when funds were very limited, we found that something as simple as providing resources for a seminar series focused on key interdisciplinary areas or co-locating faculty researchers from different disciplines (with common interest areas) were sufficient to form a successful cluster. A research cluster tends to span the university and the community and fosters a collective view of strengths and capabilities; therefore there is almost no segment of the administration that is not touched in some way. In fact, these clusters can evolve into and/or be major support elements for university-wide endeavors, such as UH Health and UH Energy at the University of Houston.

Clusters can be difficult to initiate, because they represent a significant paradigm shift and the leverage points and resources available differ. Cluster start-ups require significant upfront investment in (a) communications, (b) acquiring faculty input, (c) feedback and framing, (d) studying the university and community, (e) mapping out the clusters, (f) structuring the organization, (g) obtaining administration support, and (h) testing concepts and discovering the leverage points. Persistence and flexibility are key both in initiation and throughout the life of the cluster. Clusters are fluid and flexible, thus a natural entropy tends to break them apart over time and enables their restructuring or termination (if appropriate). Continued cohesiveness requires champions, central support, and sustaining mechanisms. There can be a great variety and adhocracy in the team structure and leadership of clusters, depending on the setting in which they exist.

The chancellors, presidents, Board of Regents, and most of our colleagues in administration were incredibly supportive of this endeavor at both NMSU and UH. However, it is easy to inadvertently create concerns and step on toes, particularly when significant resources are involved, when the time frame is short, and when one is framing the research agenda in ways that touch academic programs, funding allocations, and community perspectives of the university.

Faculty may have mixed feelings too, so it is important to demonstrate that clusters can have the unique aspect of membership and leverage that does not limit autonomy or individual research ambitions, but does provide resources and promote recognized communities. While clusters encourage the building of bridges and foster a mentoring and support environment (particularly for new faculty members), incentives are part of the grist that makes them work. Demonstrating that faculty clusters create a larger impact on the direction of research and institutional investment is important, as is the recognition of the incredible value of a wide range of disciplines often not considered in traditional funded research structures. These clusters must be inclusive and flexible, valuing a variety of disciplines, while at the same time creating shared focus and a critical mass of skills to solve efficiently and effectively major challenges of our century.

Conclusion

The authors have shown how cluster organization and focused investments and incentives can be effective means to achieve research growth while providing real value to a university's community. This approach is efficient and can be tailored to the investment funding and resources available. The challenges of substantially growing the research enterprise within the present financial constraints and in the globally competitive environment are considerable for emerging research universities. University stature (and hence student enrollment and financial support) is often highly correlated with research and scholarship. More importantly, research universities hold the expertise that has been and will be most critical in establishing a nation as the creator and maker of things that people want and need to maintain the standard of living to which we have become accustomed.

Emerging research universities have the opportunity, ability, and need to leverage the application and resource strengths of their regions in strategic areas to form globally competitive clusters. When funds are limited, funding agencies are likely to continue to invest in organizations that have the greatest expertise, longstanding reputation, and the least risk. Research universities that appear to have the least risk are those that leverage resources and build on complementary strengths and capabilities. While not all universities have a long-standing reputation in a discipline-based research area, the combination across disciplines creates a unique interdisciplinary strength that may vault emerging research universities to the forefront of a grand challenge area.

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Appendix

Table 1. Successful Cluster-Building Strategies of Top Research Institutions

Carnegie Mellon University	
Research Clusters	IT Computing & Security; Arts & Humanities; Energy & Environment; and Life Sciences[a]
Key Strategies	IDR integrated into university organization, research and teaching faculty Extensive fundraising campaign to promote and support clusters
Impact	Sponsored research revenues increased 73% in just ten years, from $170.3 million in 1998 to $296.1 million in 2008.[b]

Stanford University	
Research Clusters	Human Health; the Environment and Sustainability; International; Engaging the Arts and Creativity; and Improving K-12 Education[c]
Key Strategies	*The Stanford Challenge* (2006): a fundraising campaign and strategic plan to transform undergraduate and graduate education programs, establish large thematic areas that span disciplinary and interdisciplinary programs, new funding streams, and the construction of new research facilities.[d]
Impact	FY2006-2010: Raised $5 billion, new and updated teaching and research facilities, increased faculty lines and student aid.[e] Despite decreased federal aid and a recovering endowment, Stanford maintained a steady 15% increase in total research expenditures.[f]

Rensselaer Polytechnic Institute	
Research Clusters	Energy and the Environment; Biotechnology and the Life Sciences; Computational Science and Engineering; Nanotechnology and Advanced Materials' Experimental Media and the Arts. RPI's campus-wide focus on IT and Biotechnology is supported by a curriculum infused with entrepreneurialism and an extensive incubation program.[g]
Key Strategies	*The Rensselaer Plan* (2000): strategic hiring of "constellations" of senior and junior faculty, staff, and students to create a "critical mass of people" in support of strategically developed interdisciplinary research centers, such as the Center for Biotechnology and Interdisciplinary Studies.
Impact	Hired 234 new faculty members since 2000. Increased total research awards 110% in ten years, from $37 million in FY1999 to $77 million in FY2009.[h]

Massachusetts Institute of Technology	
Research Clusters	Energy, Cancer, Diversity, Global[i]
Key Strategies	An established culture of entrepreneurial collaboration, an "entrepreneurial ecosystem" supporting licensing and start-up ventures
Impact	"33,600 total companies founded over the years by living MIT alumni, of which 25,800 (76 percent) still exist, employing about 3.3 million people and generating annual worldwide revenues of $2 trillion, the equivalent of the eleventh-largest economy in the world."[j]

Arizona State University	
Research Clusters	Biodesign Institute, Global Institute of Sustainability, Flexible Display Center, Complex Adaptive Systems Initiative, LightWorks, Security & Defense Systems Initiative, Learning Sciences Institute, Institute for Social Science Research[k]
Key Strategies	*A New American University* (2002): an entrepreneurial university, strategic cluster hiring, redesign of research infrastructure, flexible university organization to encourage IDR, ASU Research Park[l]
Impact	TARU Total Research Expenditures National Ranking: 69 (2008), 76 (2007), 82 (2006), 95 (2005), 96 (2004); a 70% increase in research expenditures.[m]

[a] See Carnegie Mellon's Research web site: http://www.cmu.edu/research/projects/index.shtml

[b] CMU's *2007-2008 Annual Report*, p. 12. http://www.cmu.edu/finance/reporting-and-incoming-funds/financial-reporting/files/2008_Annual_Report.pdf

[c] See Stanford's Multidisciplinary Teaching & Research web site: http://multi.stanford.edu/initiatives/

[d] See Stanford's "The Stanford Challenge" web site: http://thestanfordchallenge.stanford.edu

[e] President John Hennessy's Annual Address to the Academic Council 2011 (Stanford University), http://news.stanford.edu/news/2011/april/hennessy-council-text-041511.html

[f] Stanford's 2010 Annual Report, p. 42. http://bondholder-information.stanford.edu/pdf/FY10_Stanford_University_Annual_Report.pdf

[g] See RPI's Research Constellations web site: http://www.rpi.edu/research/constellations.html

[h] See RPI's 2010 Fact Book, *The Rensselaerean*, http://www.rpi.edu/about/factbook/index.html

[i] See MIT's Research and Initiatives web sites: http://web.mit.edu/initiatives/ and http://web.mit.edu/research/

[j] Roberts, E.B. and Charles, E., *Entrepreneurial Impact: The Role of MIT* (MIT, 2009), p. 8. Retrieved May 2011 from http://entrepreneurship.mit.edu/sites/default/files/files/Entrepreneurial_Impact_The_Role_of_MIT.pdf

[k] See ASU's Knowledge Enterprise Development web site: http://ovprea.asu.edu/institutes

[l] Crow, M. M. (2007). Enterprise: The path to transformation for emerging public universities. American Council on Education. *The Presidency, 10*(2): 24-28.

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