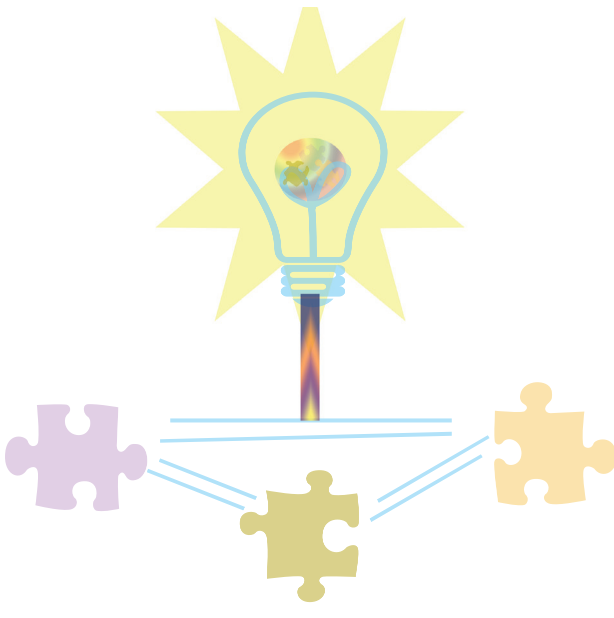
INNOVATION U 2.0

Reinventing University Roles in a Knowledge Economy



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Foreword

No one realized ten years ago how prescient *Innovation U* would be. Back then, the words economic development and universities rarely appeared together. Now, many economic developers include universities in their asset portfolios, and a large number of university officials purposefully interact with their local economies. *Innovation U* should not claim sole credit for this shift; it can, however, claim to have raised awareness in a few critical groups and helped build momentum for critical policies.

Innovation U 2.0: Reinventing University Roles in a Knowledge Economy enters a very different world than its predecessor. Government officials are questioning the role of universities in society. The economic underpinnings of higher education, for universities and students, are stressed. Federal support for research is uncertain. Never have so many raised so many questions about the value, purpose, and impacts of higher education, at least in contemporary times.

Amid all these questions, the strategies and practices encapsulated in this book present some answers. Innovation U institutions dramatically depict universities as creators of intellectual capital and economic growth. They show paths for universities to follow for larger impacts on their region. The cases are not exhaustive, and certainly there are omissions. Volumes could be written about each university, and many others are accomplishing remarkable feats.

Dr. Lou Tornatzky and his colleagues—fueled not by remuneration, but by an intense belief in the economic power of universities—should be commended for their dedication and quality product. Dr. Tornatzky recently retired from Cal Poly, and this project caps an illustrious career as a teacher, manager, and researcher in all things in technology and policy.

Scott Doron
Director
Southern Technology Council
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The State Science and Technology Institute featured a digital version of the report in its online newsletter, and sponsored a Webinair to present the project to its large constituency.

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Denis Gray was one of the authors on the 2002 *Innovation U* book, but regrettably took a pass on being a co-author on this project. Nonetheless, over the past 18 months he has provided logistical, intellectual, and political assistance that has gone beyond the call of duty and expectations of friendship. He also was a significant contributor in the key Introduction and Summary chapters, and co-designed and participated in the Case Selection process.

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Introduction*

The suggestion that US universities do more to pursue and optimize the potential usefulness of the results of taxpayer-funded research is not an acclamation that US universities have failed. Instead, it is a suggestion that they can improve and, in doing so, better advance economic growth and human welfare. Paraphrasing from elsewhere in this article, better than it was is no excuse for failing to pursue or even achieve as good as it could be.

— John E. Tyler III,
Redeploying Bayh-Dole: Beyond merely doing good to optimizing the potential in results of taxpayer-funded research

This book is a selection of twelve case studies of exemplary, innovation-producing universities in the United States—what they do and how they came to be. The universities are exemplars not only in the creation of innovation, but also in terms of outcomes that have economic impacts (e.g., inventions, industry partnerships, or entrepreneurial startups). The purposes of this introductory chapter are several-fold: (1) to describe prior case study work that was a precursor to this book; (2) to articulate the need and value of the current project; (3) to highlight key assumptions and goals; (4) to describe why and what the team looked at in each university case study; and (5) to describe case selection and analysis methodologies that were used, as well as ones that were avoided, and why.

Innovation U - 2002

Twelve years ago a slim paperback volume was completed and widely distributed by the Southern Growth Policies Board (SGPB),[1] located in Research Triangle Park, North Carolina. It was entitled *Innovation U. New University Roles in a Knowledge Economy*. The heart of that book was twelve brief case studies of research universities that were doing bold and novel things to foster technological innovation within the institution, as well as to enable technology-based economic development within their region, state, and beyond. That book of cases was the last product that came out of a multi-year research project supported by the National Science Foundation (NSF), and hard copies of the report were distributed to partners of SGPB as well as nationally to leaders—presidents, provosts, chief research officers, deans—of the 100 largest (by research expenditures) universities in the US. It was also distributed to public officials and business leaders who had interests in regional economic vitality. Various follow-on activities ensued, primarily via invitations from universities themselves, as well as from state or regional organizations interested in fostering

* *This chapter was written by Denis Gray, Elaine Rideout, and Louis Tornatzky.*

knowledge-intensive, high-growth industry in their area. To our great satisfaction, the dissemination trail endured for nearly a decade, as SGPB continued to post the document on its website, with several thousand takers over the years.

There was also one important lesson distilled from the original project that bears repeating here. The 2002 cases demonstrated that a group of universities, that were nationally prominent centers of excellence in their traditional roles of undergraduate and graduate education, research, scholarship, and public service, could *also* be nationally prominent in intentionally fostering technological innovation.

Rationale for a New "Innovation U" Project

Over a decade later the original *Innovation U* research team, plus several allies and supporters, decided that the time was ripe for a new look at America's "Innovation University" landscape. A number of developments, including changes in government Science Technology and Innovation (STI) policies and programs, maturation of certain innovation strategies, and the changing trajectories of some of the schools we included in the 2002 *Innovation U*, convinced us of the need to take a second look at what universities are doing to promote technology-based economic development (TBED). These developments included:

Growing Consensus on the Important TBED Role Played by Universities. During the past decade the chorus of voices highlighting the important role universities can and should play in promoting innovation and ultimately technology-based economic development has grown larger. It would not be an exaggeration to say that every major policy report that deals with national technology-based competitiveness, as well as many scholarly papers on the topic, have highlighted the importance of an intentionally engaged university sector.[2] For instance, the National Research Council's *Research Universities and the Future of America* report concludes: "As America pursues economic growth and other national goals, its research universities have emerged as a major asset—perhaps even its most potent one."[3] Recently, the influential Information Technology Innovation Foundation issued a short policy brief, *25 Recommendations for the 2013 America COMPETES Act Reauthorization*. By our count, fourteen of the twenty-five recommendations were directly or indirectly targeted at university practices and performance. Sometimes these issues are discussed as "triple helix," or in Europe as "Mode 2 Universities."[4] Regardless of the label or the messenger, the message has been clear: *Universities can and should contribute to innovation and technology-based economic development*. However, as Tyler suggests in our opening quote, they cannot rest on their laurels, and they need to figure out how to perform better than they have been. With this updated volume, we hope to contribute to this discussion.

Changes in the Government Science Technology Innovation Policy and Funding Landscape. As we argued in our original volume, university innovation efforts can be either enabled or constrained by federal and state STI policies and programs. For instance, some of the most successful universities in our first volume took advantage of innovation-focused federal programs, and had synergistic relations with state STI agencies. However, the landscape of federal and state STI policies and program has evolved, and the opportunities for partnering have changed, in some ways dramatically.

At the federal level, interest in and support for university-based activities that foster innovation and economic development have increased significantly over the past decade.[5] For instance, the National Science Foundation (NSF), known primarily for its role in funding basic research, has expanded support for a range of industry partnering programs, including the Industry/University Cooperative Research Centers program and the Small Business Innovation Research program. At the same time, NSF's Industrial Innovation and Partnership Directorate has launched several new and promising commercialization-focused activities, including the Partnerships for Innovation initiative and the I-Corps Program (designed to promote university-based entrepreneurial start-ups). Other federal agencies have implemented new initiatives that include a prominent role for our nation's universities, including the Commerce Department's "i6 Challenge," which created proof-of-concept centers involving universities and research consortia, and the National Network for Manufacturing Innovation, which will create regional hubs based on public-private partnerships. In short, the federal science research funding system has changed, and this has worked to support more Innovation U thinking and acting. Historically, federal government support of University research has emphasized basic science. That approach derives from a linear model of the innovation process, as well as an assumption that "market-failure" explains why private R&D research has gravitated away from the early Bell Labs model, in which basic science could take years to have an impact on the bottom line.[6] Recent federal S&T funding has begun to embrace "innovation policy" principles that create new opportunities for willing universities.

At the state and local government levels the landscape is much more complex and dynamic, despite funding for more general economic development programs having fallen 40% since 2009. Nonetheless, as the State Science and Technology Institute has documented, spending for technology based economic development by states grew by 11.3% between 2010 and 2011.[7] According to a recent NSF report, state expenditures for research and development to support state agencies totaled $1.4 billion in 2011,[8] with roughly a third of this amount going to universities via R&D contracts and other transactions. Another $3.8 billion of state government expenditures went directly to universities in support of academic research activities. There are tremendous opportunities for ambitious and proactive universities that include support for applied and basic research, entrepreneurship initiatives, science related manpower development, cluster and regional technology efforts, and a range of industry partnerships. Reinforcing the importance of this mechanism, the National Governor's Association recently listed, "Raising expectations for universities to bridge the gap between research and commercialization," as one of the top trends in state economic development for 2013.[9]

Not surprisingly, some universities have been more proactive and astute than others in capitalizing on both the expanding federal opportunities, and the changing mosaic of innovation-focused opportunities at the state level, to support their technology innovation objectives.

Maturation of Innovation Strategies. In 2001-2002 university innovation programs were mostly focused on faculty research, industry partnering, and enabling faculty licensing. The most notable change in the past decade has been a significant expansion of programs for *student entrepreneurship*—both curricular expansion (classes, minors and majors) and a co-curricular phenomenon (e.g., centers, accelerators, institutes, pitch contests, clubs, seed funds). Entrepreneurship education is now a significant component in virtually all major universities, and in many smaller institutions as well, and was singled out as a particularly important target of opportunity in a recent report on university-based technology commercialization by the US Department of Commerce.[10] There are simply more students than faculty members in a university who want to do entrepreneurship. Economic dislocations have also led students to seriously consider non-traditional career paths. Entrepreneurship education curricula and co-curricula activities can engage thousands of students and many alumni and have the potential to have an impact on local economies. We feel this development is significant enough to warrant a focused examination in the current volume.

Churn Among the Top Performing Universities. Innovation performance data (e.g., inventions, industry partnering, entrepreneurial start-ups) among the top-100 schools gets better every year, and some schools have made large improvements.[11] Nonetheless, in the years since the first volume was published, some of the exemplary program innovations that attracted our attention have withered or gone away at various institutions. In retrospect the durability of cultural and operational leadership support that fostered these innovations may not have been as strong as we assumed. Causes varied, but included innovative university leaders being hired away, followed by other key operations people, and innovation performance gains (i.e., technology transfer indicators) leveled out. We learned that "routinization,"[12] or the permanence of the schools' novel programs and activities could not be assumed, and was a critical factor in sustaining innovation performance. We also observed that "boundary-spanning" approaches to overcome the disciplinary silos of academia were important aspects of both innovation routinization and sustainability. (The importance of boundary-spanning activities cannot be overstated and thus is reiterated in three of the five subheadings describing each case study in this volume). And finally, it became apparent that some institutions not covered in the original volume were attempting to follow J. E. Tyler's opening dictum to "pursue or even achieve as good as it could be" (sometimes with considerable success), and deserved a closer examination.[13]

In sum, all these factors argued for a fresh examination of universities that were being successful at technology innovation and related outcomes. In recognition of the lessons learned with regard to longevity and sustainability, the current study's second look is based on different and more structured methods of case selection than the earlier study (see case Selection Methods and Procedures section below).

Our Assumptions and Goals

Given the level of interest the policy and economic development communities have recently expressed in the role universities can and should play in technology-based economic development (TBED), and recent recommendations "to work with the higher education community to develop a national program to identify, recognize and celebrate exemplars of 'economically engaged' universities,"[14] it is not surprising that a number of groups have produced "best university" lists and best practice reports. These have included: quantitative-based rankings of top performers (but lacking any explanation of why and how they excelled); contextually disembodied "best practices" for a specific domain of practice (e.g., STEM education); and skimpy case studies that basically describe a university success story in some domain of TBED.[15] While we believe all of these products are valuable and contribute to the ongoing dialogue on what universities can and should do, in this volume we have taken a slightly different tack to showcasing exemplary universities based on a number of key assumptions, as follows.

Innovation U's Must be Understood as Organizational Systems. Based on what we learned producing the original *Innovation U* volume, our personal experiences since that volume was published, and our interactions with stakeholders who read and tried to implement the lessons contained in that volume, we are convinced that a high performing Innovation U is more than a collection of well-intended incentives and practices, but is a product of a well-designed, led, and implemented organizational system.[16] Relevant drivers include institutional history, heroic individuals who alter an institution's trajectory, organizational culture that may be reinforced by the attraction and/or selection of a certain type of faculty member or student, and synergies achieved across a wide range of complementary organizational structures, policies, and practices. While individual practices can and do matter, we believe real impacts happen when all (or at least most) of the parts of the university's organizational subsystems are tuned to work synchronously toward a common objective—promotion of technological innovation and delivery of value to society. Importantly, as our cases will illustrate, there is more than one path to achieving this end. As a consequence, we have tried to provide our readers with contextually rich, holistic case studies that allow one to come away with a coherent story of how and why these universities may be different from their institutional peers. Consistent with this view, we highlight five key organizational subsystems (described in the next section) in all the cases included in the volume.

Size Doesn't Matter As Much as One Thinks. One criticism of *Innovation U* in 2002, based on the schools that were included in the cases, was that it appeared to suggest that only the largest research extensive universities could become high performing Innovation U's. While this was not our intent, we think it was a fair criticism. In fact, this concern was partially addressed later on in a colleague's fine report that highlighted several successful smaller universities.[17] While the current volume still focuses on the top 100 research universities, our revised selection methodology, which relied on both quantitative and judgment-based criteria, was stratified to ensure heterogeneity across the research-funding spectrum. This has ensured that some smaller institutions, which were "punching above their weight class" in terms of technology transfer, start-up creation, and industrial research, were included in our case examples this time around.

Achieving Harmony between Resources and Goals and Methods. When one is tackling a research project as ambitious as the current one with fairly limited resources, you need to makes difficult choices about project goals and methods. This was certainly the case for *Innovation U 2.0.* For instance, many of you will read our report on exemplary innovation universities and question why University "X" or "Y" was left out of our case list. The truth of the matter is we almost certainly could have included several more universities in our list of top performers, but we simply did not have the time and resources to do so. We apologize to those meritorious universities that were left out of our report and simply assert that the twelve universities that we chose to examine are a *representative and interesting subset of these high performers.* A second issue relates to whether the data collection methods we chose to use—basically qualitatively and quantitatively informed descriptive case studies—will allow us to confidently assert a causal relationship between the structures, policies and practices we highlight and the outcomes achieved by these schools. The answer is: we cannot make such an assertion. Since we did not pursue a methodological strategy—multiple case comparisons—that would allow testing and rejection of various counterfactuals about the causal relationships in play, we cannot confidently assert institution-level causality. While the scholarly side of our professional personas salivated at the prospect of conducting such a study, there were a number of reasons such a study was impractical.** However, the most compelling reason was that the amount of resources we would need to conduct such a study, and the time needed to secure those resources and to do it right, were well beyond the scope available to our project team. Thus, we acknowledge that the institutional strategies and practices that we highlight as important and instrumental in this report are closer to well informed working hypotheses than proven principles, and we welcome follow up work by colleagues who would like to test these assertions in a more rigorous methodological fashion. With these key assumptions made explicit, our goals are similar to those stated in our initial volume:

- To describe and define, in broad categories, what constitutes university partnering, engagement, and entrepreneurship in terms of technology-based economic development;
- To objectively identify a small but diverse group of universities that are considered exemplary in those categories of partnering;
- To describe what those universities are doing differently from their peers in terms of specific organizational practices, policies and programs.

**To verify this quantitatively would mean testing the counterfactual case, which after much discussion among the larger project team, we decided not to do. To go down that path would have involved a matched quantitative comparison between innovative universities (our exemplary case study sample of 12) and a parallel sample of "non-innovative" universities drawn from the same selection tranches. These kinds of analyses can and are performed in a wide variety of settings. However, they are most viable methodologically when a very small number of explanatory variables are involved, and where each should easily yield quantitative indicators, which was not generally the case here. This may explain why, to the best of our knowledge, no one has completed such an analysis. Further, the purpose of this book is not to point out and compare winners and losers. Many fine universities may nonetheless be yet in a developmental stage when it comes to innovation production. Some of the ingredients of an Innovation U as described here have vastly different time frames across cases and in fact, all of the cases have a large historical component. How does one devise a metric that will give weight to extraordinary leadership episodes that span decades? What happened in 1940 at MIT with the founding of the RadLab was very influential on what MIT became. So too were the steps taken by a Carnegie Institute of Technology president in 1967 to merge with the Mellon Institute and become Carnegie Mellon University. Yet building these historical events into a more quantitative analysis would have been challenging. Nonetheless, some of the qualitative factors teased out by this case-study analysis may well lend themselves to a future more quantitative counterfactual analysis.

Sources and Processes of University Innovation

In FY2011[18] US universities conducted just over $65 billion of research, and the top 100 (in terms of research scope) performed about 80% of that. Of the $65 billion, 62.6% came from the Federal government and 4.8% was provided by business. The majority of expenditures (57.2%) were focused on the life sciences, with engineering second (15.4%). For most faculty members most of the time, and in virtually all academic units (departments, colleges), the most important desired outcomes of all this research was not technological innovation. Typically the goal of university research is to test theory-driven hypotheses, and thereby add to a field of knowledge. This is how basic science mostly works. Sometimes, where a faculty researcher is part of a larger "grand challenge" with other researchers, the potential for real world applications may be more apparent and the work is more interdisciplinary in nature. Most exciting and valued is when findings from typical puzzle-solving faculty research ("normal science") end up challenging an existing body of theoretical concepts and assumptions in a non-incremental way; these are the "paradigm shifts" that lead to academic awards and acclaim. This is what the majority of faculty members in scientific fields aspire to throughout their careers.[19]

For the most part, core university activities are focused on two things: (1) new *knowledge development* via basic and applied research; and (2) knowledge *dissemination* via scholarly publication, teaching, and student advisement. Generally, when universities talk about what they do and of what they are proud, they come back to these core activities.

Nonetheless, over the last few decades universities have become increasingly and directly involved in *technological innovation*. New knowledge development becomes technology development when the theoretical ideas and research findings of normal science are transformed into replicable devices or processes. It becomes technological innovation when those devices and processes move into the larger society and delight, advantage, utility, or benefit is realized by adopters. The complex processes by which technological innovation occurs has been described by a robust literature[20] which we need not summarize here. However, there are organizational variables and issues that are particularly important in enabling universities to promote technological innovation.

Our case analyses focused on *five key problems or opportunities* related to major organizational subsystems that universities need to address in order to be more effective in technological innovation:

- **University Culture: Goals and Aspirations.** For a university to expand its activities beyond the core traditional goals of education, scholarship, and service, it must explicitly articulate and endorse the additional goals and aspirations that underlie innovation activities. Technological innovation, as an activity that links to the private sector and moves beyond normal university work, needs to be legitimated.

- **Leadership.** University leaders and administrators must, in effect, proclaim to the campus and external community, that: "Yes, we are going to be good at technological innovation, and this is what we are going to do often, publicly, preferably with some passion, and via leading-by-doing." This is the difficult, action-forcing part of an enabling university culture.

- **Boundary-Spanning: Entrepreneurship**. Universities aspiring to technological innovation must be active and imaginative in fostering entrepreneurship among students, both in the classroom and in other settings, as well among faculty members. Entrepreneurship needs to be brought into academic disciplines as a legitimate part of learning and action.

- **Boundary-Spanning: Industry and Community Partnering.** Technological innovation, from theory to practice, works better if there are policies, practices and support for moving research and action beyond the traditional disciplinary structures as well as crossing the boundaries between the university and the "external" private sector world.

- **Boundary-Spanning: Technology Transfer.** A professional and robust technology transfer function will enable the protection and legal translation of innovative research findings into commercially viable intellectual property, its licensure and its successful launch, via both startups as well as industry partnerships.

The above few paragraphs briefly summarize the challenges that universities must address to be technologically innovative, and implies some reasons for why some universities may have difficulty "out there" in the world of business, industry, and society. Our 12 case studies are organized around the five *key problems and opportunities* (and the strategies, policies, and practices universities have used to address them) that we have concluded are important in fostering university technological innovation, as follows:

University Culture: *Goals and Aspirations*

Most large organizations state what they are about and what they aspire to be. These are found in strategic planning documents, mottos, and goal statements, and reflect important values in the organization. Many differences in the propensity to "do technological innovation" are reflections of a long-established organizational culture.

So what do we mean by "organizational culture?" For the most part we follow the 40 years of thinking of Edgar H. Schein[21] on what constitutes this phenomenon. To Schein and others in this field, organizational culture exists in several layers, is difficult to change once established, and influences how people do their work and what kind of work is valued. Culture defines what work we hold in esteem and how we think of or construe our environment. For example, organizations have physical and behavioral *artifacts* that characterize work settings and practices. At another level organizational cultures are characterized by *values* that connote what is considered worthy work and what not so much. Then there are *assumptions and beliefs* that operate at a more cognitive level, and might define how we think about a problem and what data points will be utilized.

While all this seems somewhat straightforward it gets complicated when one is trying to tease out the characteristics of universities that are excellent at technological innovation versus those that are not. One problem is that universities are not unitary organizations. Each of the colleges, departments, and centers/institutes that constitute the organizational building blocks of the large American university are also tied to a field of inquiry or expression, each with its own methodological assumptions and value systems, with much less attention given to sorting out feelings, values and behaviors related to novel activities like patenting things, for example. So how do universities, such as our case sample of technological innovation exemplars, emphasize and celebrate technological innovation and also accommodate the historic emphases of major league academia?

For want of a more elegant term, we are hereby advancing the *lagniappe*[22] concept. Those readers who have visited New Orleans will understand the metaphor. We are hypothesizing that our study sample of technological innovation exemplars has essentially expanded its menu of what they do well, by doing "just a little extra." While retaining their national prominence in research, scholarship, and excellent undergraduate and graduate education, they have chosen to also, and concurrently, be good at entrepreneurship, technology commercialization, industry R&D partnering, and all the rest. Moreover, they have evolved ways to tune their cultures so that all those disparate endeavors co-exist and sometimes even mix into a true *lagniappe* model of organizational functioning. These universities exhibit the type of organizational culture Lacatus characterized as *enterprise*, consisting of firm policy (particularly related to promoting innovation) but loose operational control, focus on market, external opportunities, and relationships with stakeholders.[23] In this book we will explore how and why some universities were able to build cultures that inculcated innovation and entrepreneurship seamlessly, while others evolved only with great difficulty.

Leadership

According to a recent Forbes article, being a university president may be the toughest leadership job of all.[24] At their best, university presidents are characterized as "disruptive innovators" who must lead through collaboration and cajoling, and not control. But most universities most of the time select their managerial cadre—presidents, provosts, vice presidents, deans, department chairs, and non-academic managers—from among people who have risen to prominence and visibility in the world of traditional academia, and followed the norms and mindsets thereof throughout their career. However, many of the policies, structures and activities that might enable technological innovation are not always aligned with the traditional functions and goals of universities and require a disruptive innovator.

Those schools that are exemplars in fostering technological innovation are very likely to have had a sequential cadre of effective "innovation leaders." For example, they may have presidents, deans, chairs, and professors who over the course of their careers have been effective and productive leaders in technology-oriented business. Some may have started a world class company during a sabbatical year[25] and then returned to be an excellent academic administrator. These represent a growing cadre of university leaders who embrace "market logic"[26] and support the growth of entrepreneurship, technology transfer, and university-industry research, as well as the more traditional functions and activities of academia, and most of them are also exemplars in traditional academic activities.

In our cases we looked for, and sometimes found, examples of innovation leadership like the following: (1) people in positions of authority who were experientially rich and knowledgeable about the "terrain" of technological innovation (in plain English, they may have done it themselves); (2) proven leaders and effective managers in accomplishing the traditional core goals of the university, as well as having the expertise and mindset to "make things happen" more generally; (3) personal "boundary spanners" in terms of their ability to move back and forth between different organizations and disciplines, and between the world of academia and the world of practical innovation and business; and (4) people who got things done and stayed-the-course in one or a few places as opposed to academic careerists or job hoppers.

Our cases of exemplary universities highlight examples of innovation leadership. They describe personalities and career paths, how these leaders foster technology innovation in their universities, and suggest how such individuals might be more frequently discovered and supported in the context of large and sometimes hide-bound universities.

Boundary Spanning: *Entrepreneurship*

Historically, the key activity of universities is to *convey knowledge* to students, typically via readings, class lectures, modeling, lab instruction, and discussion, especially at the undergraduate level. More advanced (i.e., graduate) students learn and apply the methods, procedures, and associated epistemology for creating *new knowledge*, such as via graduate theses or dissertations. Much of this has a limited link to technology innovation, except when a student project may point directly to an innovation with real world applicability.

However, when the focus of instruction is *on* innovation processes, such as in entrepreneurship education, technological innovation may be accelerated. Over the past decade entrepreneurship education has become among the fastest growing curricular foci in the US.[27] This has manifested itself in entrepreneurship majors or minors within particular colleges (e.g., often in colleges of business or colleges of engineering), or various combinations of academic majors and minors in other colleges or across colleges and majors. The evidence that this kind of curricular exposure enhances technological innovation or entrepreneurial ventures after graduation is encouraging but inconsistent, and seems to be a function of discrete program features.[28] However, it does seem to get students at least thinking about their futures within a larger framework of entrepreneurial options.

There are two associated trends in entrepreneurship education that are having major impacts on real-world technological innovation. One is the increased participation of graduate students in *curricular* entrepreneurship programs that are accelerating their involvement in founding roles in startups. A second is the rapid growth of *co-curricular* programs in entrepreneurship, for both undergraduates and graduate students. Co-curricular participation includes: forums; competitions, ranging from pitch contests of a few minutes to semester-long team business planning competitions; student incubation services; field trips; business mentors; summer work-study; clubs; and on and on.

The curricular and co-curricular activities related to entrepreneurship are burgeoning nationwide. This is a major change from the situation we observed a short decade ago and based on its diversity and potential impact, one we felt deserves expanded coverage in this volume.

Boundary-Spanning: *University, Industry, and Community.*

Much of the work of technological innovation in research universities tends to occur at the boundaries of, or in parallel to, its traditional structures and systems. The traditional mission and normal work of universities occurs in the context of departments, colleges, units of academic governance and long-established systems of rewards and advancement. One can devote and nourish an entire very successful career in academia and spend most of that as a solo professor in an academic department, teaching and advising graduate students' theses and dissertations, doing research and publishing, executing grants and engaging one's "invisible college" of like-minded colleagues.[29] However, in order to promote technological innovation one needs to rub shoulders if not actively engage in what has become known as "team science" both within the university and with external stakeholders.[30]

Of the $65 billion of reported university research expenditures in FY 2011 around 5% involved industry support, and this has declined a few percentage points from a few years prior. There are many channels for companies to work with talented faculty, such as via consulting during the academic year and over the summer break. In addition to industry- sponsored research projects, technology-based companies also connect to universities via research parks, labs, research centers and institutes, many with industry advisory committees. Some centers or institutes are heavily facilities-based where significant investments have been made in state-of-the-art instrumentation made available to a range of users, often from different disciplines. One of the most important characteristics of these structures from a technological innovation perspective is that they enable *multidisciplinary* and *interdisciplinary* science.[31] Depending upon the nature of the research foci, the work of a center may cut across departments or even colleges in terms of staffing and student or faculty involvement. Why is this boundary-spanning important?

The reason is that technological innovation in the so-called "real world" rarely is confined to the concepts, methods and assumptions of a single discipline. When talented people from different epistemologies and conceptual mindsets are brought together around an important problem, the range of potential solutions gets bigger. Moreover, technology-based companies tend to organize their R&D workforce around problems and markets, not exclusively around disciplines. They often seek out university research entities that enable wider participation across the institution.

In terms of our case analyses we spent considerable effort documenting how our universities encouraged, enabled and implemented team-based multidisciplinary boundary-spanning centers, institutes, labs, or programs. One crude outcome index of how much attention is focused on this issue is the *number* of such entities across the entire university. Another case variable considered was the extent to which involved companies had a significant financial and substantive decision-making role in the programs that are established.

We also looked at the extent of "center-enabling" capacities at an institutional level. These might involve university-level research management staff working with faculty members as they engage potential industry partners and build center research programs. Some universities have created senior positions and staff organizations whose responsibility it is to "make things happen" in the areas of industry research, innovation partnerships, government relationships, and community engagement. The expectations and titles vary across campuses, but this kind of centralized expediting or "treaty-making" activity is increasingly found in universities that want to do better at technological innovation.

Boundary-Spanning: *Technology Transfer*

Although the creation of intellectual property is only one manifestation of a university engaged in promoting innovation, it is a very important one.[32] Following the passage of Bayh-Dole legislation in 1980 every US university had the responsibility—and new opportunities—to work with faculty innovators in assessing the commercial potential of their inventions, protecting the intellectual property embedded therein, and developing commercialization paths for the faculty invention. The latter have ranged from direct licensing to a company or non-exclusively to companies, working with the faculty member (or student) to develop a more entrepreneurial path to commercialization, or in some cases to "turn back" the control of the invention to the inventor. Statistics for the field have been captured for decades by the Association of University Technology Managers (AUTM). In its recent FY 2012 report,[33] responding institutions claimed totals of 14,224 new patent applications, 5,145 issued US patents, 6,372 licenses and options executed, and 705 startups formed. Over most of the history of university involvement in technology transfer these indicators have been moving upwards for the "industry," although there were many schools that started late and haven't quite caught up, as well as a few exemplars that have been leaders since the beginning. Several of the latter are in our case sample, and some got started before Bayh-Dole was even passed.

The universities in this volume have well-run, generously staffed and mission-intensive technology transfer offices. They instruct, encourage, and support campus inventors, regardless whether the inventors are faculty, staff or students. The variance in technology transfer performance across universities is considerable; all of the cases described in this volume employ myriad creative strategies in support of their faculty and student inventors. Those approaches can be replicated; exemplary offices are very willing to give away their secrets. In our university cases we will describe some of their replicable policies and practices via which their peers can do better.

We trust that the "five boxes" of factors that contribute to a viable *Innovation U* will enable the reader to navigate the dozen cases here. However, if the reader is an action-oriented individual, who really wants to take what is written here and embark on a change process in a favorite university, the first thing that should be done is to visit or talk with innovation leaders at several of our universities. It will be a somewhat disconcerting but still enlightening experience. What will be discovered is that in reality, the five boxes or factors that have structured our cases do not entirely reflect reality in that they are not really *separate*. If you visit, or get on the phone, you will find that the people in technology transfer are probably working closely with research centers and labs on licensing opportunities, the individuals who are managing the network of entrepreneurship programs can count on someone in the president's office to be the featured speaker at a forthcoming incubator event, an advancement campaign in the planning stage is benefiting from advice from industry partners, and so on. Eventually, you will discover the extent to which an Innovation U is a living phenomenon that captures the attention of many people, and the most interesting challenge that confronts the prospective change agent is to figure out who those people are in his or her university, and get them in the same room, on many occasions, to scheme up the future.

Case Selections: *Methods and Procedures*

As noted above, this volume attempts to improve upon the "panel of experts" sample selection technique employed in the first version of *Innovation U* by using a multifaceted multistage selection process. In summary, all case study universities were selected from a diverse population of high performing research universities. Universities were stratified based on research funding. Raters selected cases based on a combination of quantitative and qualitative judgments about the influence of the institution's organizational strategy and practices on producing those outcomes. The following specific procedures were followed:

- A national Project Advisory Committee was convened of eight individuals, whose current work and careers were solidly congruent with the aims of the project. The Committee included practitioners, researchers, former university senior managers, and generally individuals who were knowledgeable about the project focus. Dr. Louis Tornatzky and Dr. Denis Gray, as leaders of the research team, participated in the Committee selection process as well. Thus 10 knowledgeable individuals from across the US made the "picks" of the schools that would constitute the case study sample.

- Candidate universities were drawn from the top-100 universities in terms of NSF research expenditures in FY2010, plus a sub-sample of smaller less research-intensive institutions that nonetheless had reputations as innovators, and had excellent normalized outcomes metrics as well (e.g., invention disclosure "batting averages")

- The candidate universities were organized into tranches of 10 institutions, starting from the top of the NSF list in terms of research expenditures.

- For each tranche of 10 schools, Project Advisory Committee members were provided with three performance data points: (1) a normalized measure of invention disclosing; (2) a normalized measure of industry research funding; and (3) the number of startups. These metrics were developed using NSF data as well as Association of University Technology Transfer (AUTM) statistics. In effect, every university in a tranche was doing about the same amount of sponsored research, but there were significant disparities in innovation outcomes. Within each tranche, judges were free to "vote" for up to 3 schools.

- After adding up the vote tallies, the study sample consisted of the top 12 vote getters and included: Arizona State University; Brigham Young University; California Institute of Technology; Carnegie Mellon University; Clemson University; Georgia Institute of Technology; Massachusetts Institute of Technology; North Carolina State University; Purdue University; Stanford University; University of Florida; and the University of Utah. The voting was surprisingly consistent across the 10 judges. Thus 5 schools got either 9-10 votes (out of a possible 10), and another 6 schools received 7-8 votes.

- This is a distinguished sample of schools even considering traditional academic metrics. Six of these schools were in the original *Innovation U* sample from 2002.[34] Also, of the 12 schools in the sample, 7 were in the 25 Top American Universities in their multivariate scorecard, 3 were in the 26-50 grouping, and one was among the top 50 publics.[35]

How to Read This Book; *Who Should Read this Book*

We do have some suggestions: first of all, you have read this chapter so you have some sense of the logic of the analysis and approach, and what we are trying to convey. Second, you might want to read the book straight through and look at each case as a complete and separate analysis, which will tell you about this school and not much else. Third, you might want to skip around and look at a particular topic (e.g., Leadership) in all the cases and see if that kind of immersion best meets your interests. Finally, the last chapter briefly summarizes some of the more interesting and/or surprising commonalities and differences we found across the twelve cases, and offers suggestions about what policymakers and university leaders can do if they want to enhance their own innovation footprint. The book will have succeeded, from our perspective, if we are able to provide interested parties with a path to ideas, best practices, policies, and tools that they can implement in their own settings, to better create and realize the kind of innovation that produces new companies, new jobs, and other beneficial economic outcomes.

There are several important audiences for the book. One of course are university leaders, administrators and governing boards, who have aspirations for their institution to become more like an Innovation U as we have described in these cases. Second, are change-oriented university faculty members (or department chairs, or deans) who think that they and their colleagues could be making a bigger innovation-based difference in their units, and are motivated to lobby their administration to emulate some of the exemplary policies and practices described in the cases. Third, are leaders in technology-based industry, whose relationship with universities may not get much beyond hiring their graduates, or making occasional gifts in advancement campaigns. We hope that the examples here will be motivational to seek out richer, longer, and more mutually beneficial relationships. Fourth, and perhaps most important, are elected and appointed public officials whose knowledge about how universities work may be based on their undergraduate experience of decades past, and who might get ideas from these cases about how their alma mater *can work differently,* and to the greater benefit of the commonweal. Universities represent major government and private expenditures, but those expenditures can be much more targeted, have greater impacts on economies, and citizens' life chances, and in word be more *innovative*.

Endnotes

[1] Southern Growth Policies Board has been around for several decades as an economic policy think tank connected to public and private leadership in the southern states. Early in its history it established a division called Southern Technology Council (STC) which had a comparable agenda, but focused more on science and technology related issues. The original *Innovation U* book was an STC project, but by dint of the familial relationship between SGPB and STC it was a creature of both.

[2] A few representative reports and papers that have made this argument include: PCAST (2012, November). *Report to the President, Transformation and Opportunity: The Future of the U.S. Research Enterprise.* Washington, DC: Executive Office of the President, President's Council of Advisors on Science and Technology; The Science Coalition, *Sparking Economic Growth: How Federally Funded University Research Creates Innovation*, New Companies and Jobs, Washington D.C., 2010, www.sciencecoalition.org/successstories/fullReport.cfm; National Advisory Council on Innovation and Entrepreneurship (2011, April). *Recommendations to facilitate university-based technology commercialization.* Washington, DC: Department of Commerce; Tyler, J.E. (2011). Redeploying Bayh-Dole: beyond merely doing good to optimizing the potential in results of taxpayer-funded research. *Journal of Technology Transfer*, published online: 10 September 2011; Shaffer, D.F. and Wright D.J. (2010). *A new paradigm for economic development: How higher education institutions are working to revitalize their regional and state economies.* Albany, NY: The Nelson Rockefeller Institute of Government, University at Albany, State University of NY.

[3] National Research Council (2012). *Research Universities and the Future of America.* Committee on Research Universities, Board of Higher Education and Workforce, Policy and Global Affairs, Washington, DC: The National Academies Press.

[4] For instance see: Mowery, D.C. and Sanpat, B.N. (2006). Universities in national innovation systems. In Faberberg, J., Mowery, D.C. & Nelson, R.R. (Eds.) *The Oxford Handbook of Innovation.* Oxford, UK: Oxford University Press.

[5] Some of these initiatives both launched and planned can be found in: PCAST (November, 2012). *Report to the President, Transformation and Opportunity: The Future of the U.S. Research Enterprise.* Washington, DC: Executive Office of the President, President's Council of Advisors on Science and Technology.

[6] See Lundvall, B.A and Borras, S. (2006). Science, technology and innovation policy. In Faberberg, J., Mowery, D.C. & Nelson, R.R. (Eds.) *The Oxford Handbook of Innovation*. Oxford, UK: Oxford University Press.

[7] State Science and Technology Institute (2013). Trends in technology-based economic development: Local, state and federal action in 2012. Westerville, OH: SSTI.

[8] NSF Social, Behavioral and Economic Sciences (2013). State government R&D expenditures increase 11.3% from FY 2010 to FY 2011. Washington, DC: NSF (NSF Info Brief 14-300).

[9] See NGA website: http://www.nga.org/cms/home/nga-center-for-best-practices/center-publications/page-ehsw-publications/col2-content/main-content-list/top-trends-in-state-economic-dev.html; accessed on December 13, 2013.

[10] National Advisory Council on Innovation and Entrepreneurship (2011, April). *Recommendations to facilitate university-based technology commercialization.* Washington, DC: Department of Commerce.

[11] See: Association of University Technology Managers. (2013). *AUTM U.S. Licensing Activity Survey: FY2012.* Deerfield, IL: Association of University Technology Managers.

[12] See: Yin, R.K. (1979). *Changing Urban Bureaucracies*. Lexington, MA: Lexington Books. This is the classic description of how, over time, new organizational practices and policies being "routinized" into standard and accepted ways of doing business.

[13] Tyler, J.E. (2011). Redeploying Bayh-Dole: beyond merely doing good to optimizing the potential in results of taxpayer-funded research. *Journal of Technology Transfer*, published online: 10 September 2011.

[14] National Advisory Council on Innovation and Entrepreneurship (2011, April). *Recommendations to facilitate university-based technology commercialization.* Washington, DC: Department of Commerce.

[15] For example see the following reports or links: Office of Innovation and Entrepreneurship, Economic Development Administration (2013, October). *The Innovative and Entrepreneurial University: Higher Education, Innovation and Entrepreneurship in Focus.* Washington, DC: U.S. Department of Commerce; Innovation Excellence, Best US Universities for Innovation Transfer: http://www.innovationexcellence.com/blog/2011/12/14/best-us-universities-for-innovation-transfer/; University Economic Development Association, Awards for Excellence 2012: http://universityeda.org/value-to-members/best-practice-sharing/awards-of-excellence/awards-of-excellence-2012-finalists/.

[16] Resnick, D. P. (2012). Innovative Universities: When Why and How? *Journal of Educational Planning and Administration.* Volume XXVI, No.2, April, 331-341.

[17] Innovation Associates (2007). *Technology transfer and commercialization partnerships.* Washington, DC: Innovation Associates (based on NSF Grant No. EEC-0413603).

[18] National Science Foundation, National Center for Science and Engineering Statistics, FY2011. *Table 14. Higher education R&D expenditures, ranked by all R&D expenditures, by source of funds: FY2011. Table 15. Higher education R&D expenditures, ranked by all R&D expenditures, by R&D field: FY2011.*

[19] Thomas Kuhn's rich description of this process is still a classic. See: Kuhn, T. (1962). *The Structure of Scientific Revolutions.* Chicago, Ill.: University of Chicago Press.

[20] There is a large literature that has attempted to summarize these conceptual and empirical issues, for example: Tornatzky, L. and Fleischer, M. (1990). New York: Lexington. Ch 2; p. 9-25; Marinova, D. and Phillimore, J. (2003). Models of Innovation. In Shavinina, L.V. (2003). *The International Handbook of Innovation*. NY: Elsevier. p. 44-54; Pavitt, K. (2006). Innovation Processes p. 86-114. In Fagerberg, J., Mowery, D.C. & Nelson, R.R. (Eds). *Oxford Handbook of Innovation*. New York: Oxford University Press.

[21] Schein, E. H. (1990). Organizational Culture. *American Psychologist*, Volume 45, No.2, 109-119, February; Schein, Edgar H. (2011). *Organizational Culture and Leadership*. 5th Edition. New York: John Wiley and Sons; Schein, Edgar H. (2009). *The Corporate Culture Survival Guide.* New York: John Wiley and Sons.

[22] The term has Cajun ancestry, and is often used in Louisiana to connote "give a little extra", like the baker's dozen of pastry.

[23] Lacatus, M. (2013). Organizational culture in contemporary university. *Procedia – Social and Behavioral Sciences*, 76, 421-425.

[24] Asghur, R. (2013, November 15). The toughest leadership job of all (and it's not what you think). *Forbes*.

[25] A fascinating non-technical article was published in *The New Yorker* ("Get Rich U" by Ken Auletta) that focused on Stanford and the notable leadership behaviors of its current president (and serial entrepreneur) John Hennessy. Retrieved from http://www.newyorker.com/reporting/2012/04/30/1204

[26] Berman, E. P. (2012). *Creating the Market University*. Princeton, NJ: Princeton University Press.

[27] Finkle, T.A, Kuratko, D. F., Goldsby, M. G. (2006). An examination of entrepreneurship centers in the United States: A national survey. *Journal of Small Business Management*. Vol. 44(2), 184-206.

[28] Rideout, E. and Gray, D. (2013). Does Entrepreneurship Education Really Work? A Review and Methodological Critique of the Empirical Literature on the Effects of University-based Entrepreneurship Education. *Journal of Small Business Management*, Special Issue: Measuring the Impact of Entrepreneurship Education, 51(3), 329-351.

[29] This book is not about that world, except for the fact that faculty members' involvement in technological innovation usually derives from a very successful academic career. Moreover, faculty members who diversify their careers by getting involved with industry partnerships, starting companies, or commercializing inventions often end up having larger and more diversified academic careers. Robert Langer, discussed in the MIT case, is a great example.

[30] Interest in and support of a move toward a more team and interdisciplinary model of conducting research within universities, often referred to as "team science," has grown in both academic and policy communities. For a scholarly review of this topic see: Stokols, D., Hall, K.L., Taylor, B.K. and Moser, R.P. (2008). The science of team science: An overview of the field and introduction to the supplement. *American Journal of Preventive Medicine*, 35, S77-S93; National Institute of Health supports an internal and external effort to promote team science. Retrieved from: http://ombudsman.nih.gov/collaborationTS.html

[31] Gray, D.O., Boardman, C. and Rivers, D. (2013). Cooperative research centers as government policies, industry strategies and organizations: Emerging theory and practice for technological innovation. In Boardman, C., Gray, D.O. & Rivers, D. (Eds.) pp. 3-33. *Cooperative Research Centers and Open Innovation: Policies, Strategies, and Organizational Dynamics of the New Science and Engineering Management.* NY: Springer Press.

[32] Office of Innovation & Entrepreneurship Economic Development Administration (2013, October). *The Innovative and Entrepreneurial University: Higher Education, Innovation and Entrepreneurship in Focus.* Washington, DC: U.S. Department of Commerce.

[33] Association of University Technology Managers. *AUTM U.S. Licensing Activity Survey: FY2012.* Deerfield, IL: Association of University Technology Managers. August, 2013.

[34] The following six universities were also included in the first version of *Innovation U.*: Carnegie Mellon University, Georgia Institute of Technology, North Carolina State University, Purdue University, Stanford University, and the University of Utah.

[35] The Center for Measuring University Performance. *The Top American Research Universities. 2010 Annual Report.* Arizona State University, Tempe, AZ. Retrieved from: http://mup.asu.edu

Arizona State University*

Arizona State University (ASU) has developed in a context of superlatives. For example, it is one of the largest universities in terms of enrollment in the United States and is located in one of the largest states that has also experienced some of the fastest population growth in the country. ASU also has a President who has arguably published and commented the most among any current academic CEOs about new paths that a university should be taking to address the challenges of the 21st century.

The initial precursor to Arizona State University—the Territorial Normal School at Tempe—was established in 1885,[1] when Arizona was a territory, and 27 years before it became a state. The Normal School era was focused almost entirely on two-year teacher training, and led by a principal, John Mathews, who stayed for 30 years. When the Normal School was founded the Arizona territory had a population of less than 70,000. Between statehood in 1912 and 2010 the state experienced continued double-digit population growth during each decade, most notably in the period between 1940 and 1960. Many found themselves in Arizona as members of the military, or as producers of war goods, and had remained or returned to the state later on. Many were of course attracted to trading six months of winter gray for many more months of sun.

The climb of the Normal School to university status, and a more technologically oriented mission, was slow and occurred well after statehood. In the 1920s admission requirements were strengthened (needing a high school diploma) and Tempe Normal School became Tempe State Teachers College and began offering a 4-year degree. Enrollment was still less than a thousand. In the 1930s the school sought and achieved its first accreditations and began offering a masters degree (in education). Enrollment was still in the low thousands during the depression years, but accelerated after World War II. Governor Osborn approved a name change to Arizona State College in 1945, as the school began to accommodate the growth spurt enabled by the GI Bill. Temporary housing called Victory Village was erected to accommodate married veterans with kids, as enrollment increased from 553 in 1946 to 4,094 in 1949. During the 1950s, the school fought (and mostly won) the battle to become a more expansive university, adding colleges of Applied Arts and Science, Liberal Arts, Education, and Business and Public Administration.

The next step, to university status, involved a large-scale petition effort and statewide campaigning by students, alumni, and faculty members (including the participation of Frank Kush, a very successful football coach[2]), leading to a ballot initiative in the November 1958 election. Opposition was

** This case was written by Elaine Rideout, Drew Rivers, and Louis Tornatzky.*

apparently significant from University of Arizona advocates. Proposition 200 passed by a 2 to 1 margin, and the school became Arizona State University by executive order in December of 1958. ASU has always been a "striver" institution that has reinvented itself many times and still does.

During the half-century since becoming ASU the institution has grown in both student headcount (72,500 in Fall, 2011), stature, and mission richness. Enrollment was 26,425 at the Tempe campus in 1970, and 37,248 in 1980. ASU total enrollment of 42,952 in 1990 now included a West Campus student body of 4,150. Ten years later in 2000, the 50,365 enrollment included the Main campus, the West Campus, and also a new Polytechnic Campus. By 2010, the enrollment had been expanded by the addition of a Downtown Campus, which had grown from 6,229 in 2006 to 17,551 four years later.

These various campuses are not simply replicas of the Tempe main campus. Each campus expresses novel goals and visions, serving distinct markets with different educational services and R&D activity, but all within the larger themes that define ASU.

One area that has changed most profoundly in the 50-plus years since alumni, faculty, and students rallied in support of university status is that ASU has grown from modest beginnings to be a significant research and technology performer. ASU received its first external research grant in 1956, in the Department of Physical Sciences, and awarded its first PhD degrees in 1963. As recently as 1992 ASU was reporting $69.3 million in research expenditures, which placed it at 90th nationally, barely in the magical "top 100" of research institutions. Seven years prior, this total had been only $28.9 million, thus it had doubled in a relatively short time period.

In FY2011 the university reported[3] research expenditures of $355.2 million, mostly concentrated in engineering and the life sciences, and ASU had moved to a rank of 62nd. Rising from 90th to 62nd in 20 years is a notable accomplishment and the pace of R&D growth seems to be still increasing. Self-reported data from ASU indicate that the current total is closer to $400 million.

In addition, the ASU faculty has gone through a significant period of intellectual enrichment. Among the over 1,800 tenure track faculty members, and the thousand research professors and clinical professors, are found the following: two Nobel laureates; six Pulitzer Prize awards; a MacArthur Fellow; 11 members of the American Academy of Arts and Sciences; 11 members of the National Academy of Sciences; nine members of the National Academy of Engineering; 21 IEEE Fellows; 25 Guggenheim Fellows; five Sloan Research Fellows: three Royal Society Fellows; 65 AAAs Fellows; two members of the Institute of Medicine; four members of the National Academy of Education; eight American Council of Learned Societies Fellows; and 19 Alexander Von Humboldt Foundation Research Prize winners.

At an institutional level, ASU has also increasingly received rating and ranking accolades. Thus in *U.S. News & World Report's* 2013 "Best Graduate Schools" rankings ASU is noted for its programs in law, education, business, public affairs, and fine arts.

University Culture: *Goals and Aspirations*

Perhaps more than any other institution in this volume, Arizona State has had the opportunity to be led by a chief executive whose professional *raison d'etre* and scholarly work has been so focused on innovation and the role of the university in the larger society. To really understand ASU one has to understand the impact of Dr. Michael Crow, who became president in 2002. The reconfiguration of ASU as a new breed of metropolitan research university pervades nearly every aspect of the institution, and follows from Crow's thinking and writing about the *New American University,* which are explained below.

Foundations and Context of the ASU Re-design. As an alternative approach to the design and operations of a large research university, the thinking of Crow (and others) is particularly at odds with the so-called "Gold Standard" model that dominates mainline thinking about how American research universities should operate. Some of the features of the Gold Standard derive from the German university model of the 1900s, that was championed by American institutions such as Johns Hopkins at the time, and rapidly became the norm among elite universities. Some of the key features included a discipline-based structure, highly selective admissions practices, a focus on theory-driven discovery, an emphasis on quantitative methodologies, polite disengagement from the everyday world, and limited concern for social and economic applications of research and scholarship.

While Crow had been developing and implementing many of his ideas about alternatives to the Gold Standard model prior to coming to ASU, the Arizona situation presented an environment for implementing change in a much larger context. Within Arizona and greater Phoenix, ASU faced increasing social and financial challenges that while nominally "external" were seen by the Crow administration as an important impetus for change. These included an under-performing K-20 education system, explosive population growth, challenges in immigration and social services, and a reliance on the state of Arizona for the lion's share of its funding. In 2010 the Phoenix metro area ranked 14th in the US with population of 4.2 million people.[4] Phoenix placed among the top five metropolitan areas in population growth between 2000 and 2009, jumping 33% in the period.[5] However, unlike many other metropolitan research universities, ASU is the sole bachelor's degree granting university in the metro area, and therefore bears significant educational responsibility.

The term "ossification" is often employed by Crow to describe the general lack of variation in institutional designs among American research universities. A globally competitive market place, diminishing public investments in education, and the increasing specialization of knowledge, make the Gold Standard model even less viable.

Implementing the *New American University* model at ASU has redefined innovation and entrepreneurship in a university context. This has included dramatic innovation in the organizational configurations of majors, departments, and colleges, along with the flourishing of entrepreneurial mindsets on how faculty can strike out in different intellectual directions to better serve students and communities. Innovation is not just the next process after scientific discovery in some linear model, but it also connotes the redesign of organizational systems and curricula. Entrepreneurship in the Crow model surely applies to the building of startup private companies, but equally important is its application in the reinvention of social systems to do science and education differently.

The ASU University Design Team: Goals and Aspirations. As a sounding board for the change processes launched by President Crow, in 2002 a University Design Team (UDT) was established. This was a campus-wide group of administrators, deans, and distinguished faculty, with a mission to provide input to the process of re-conceptualizing and redesigning ASU as a New American University. This led initially in 2004 to a widely circulated report from the Office of the President[6] (*One University in Many Places*) that has been supplemented and expanded over the past several years. Although the basic premises and goals of the vision have remained relatively constant between 2004 and 2010 the "design imperatives" have been softened to "design aspirations."[7] They are change goals for what is happening operationally at ASU.

The New American University is to be egalitarian in its admissions practices, solutions-focused, and generally designed to maximize social impact. Crow often characterizes the New American University as having breadth of functionality and an outward or external focus. The New American University was to be outcomes driven, innovating in new products and processes within an entrepreneurial mindset. Most importantly, the New American University was to be innovative and entrepreneurial about its *own structures and processes*. The expectation was that the New American University was to be experimenting with itself at the same time it was offering unprecedented opportunities for students, faculty and staff to sample new combinations of intellectual substance. So, the vision from the perspective of 2004 was:

> *… an institution that measures its academic quality by the education that its graduates have received rather than the academic credentials of its incoming freshman class; one at which researchers, while pursuing their scholarly interests, also consider the public good; one that does not just engage in community service, but rather takes on major responsibility for the economic, social, and cultural vitality of its community.*

Four University goals and eight design aspirations serve as guideposts for the ongoing re-creation of ASU. While the exact wording has undergone changes, the four basic goals as re-stated by President Crow in a 2010 paper are:

1. Access and quality for all;

2. Becoming a National comprehensive university by 2012;

3. Establish national standing for colleges and schools in every field;

4. Enhancing our local impact and social embeddedness.

Eight "design aspirations" reflect the vision of the New American University and function as guides for the many activities that have been undertaken over the past decade. Crow introduced these in his 2002 inaugural address and repeated them in the *One University in Many Places* report. They have remained a consistent element of the change process at ASU:[8]

1. Embrace the cultural, socioeconomic, and physical setting of the institution;

2. Become a force for societal transformation;

3. Pursue a culture of academic enterprise and knowledge entrepreneurship;

4. Conduct use-inspired research;

5. Focus on the individual in a milieu of intellectual and cultural diversity;

6. Transcend disciplinary limitations in pursuit of intellectual fusion;

7. Socially embed the university, thereby advancing social enterprise development through direct engagement;

8. Advance global engagement.

So, how did the goals and aspirations framework—along with subsequent policies, urgings, and intentional directives—change the organizational environment at ASU? To stretch an analogy, ASU moved from Eastern Europe circa 1949 to a bubbling modern market economy of ideas and actions. The Gold Standard of the university model is structured primarily around disciplinary traditions of permissible inquiry and preferred methodologies, circumscribed within impermeable boundaries, and captive to the *status quo* or incremental change at best. To stretch these analogies a bit more, and following Kuhn's analysis of the structure of paradigm-changing scientific revolutions,[9] the ASU redesign initiative, with its emphasis on transcending disciplinary limitations, embracing the community and economic setting of the institution, and conducting "use-inspired research," seems an ideal environment for creating entities or "enterprises" that are transdisciplinary and paradigm-changing in nature.

To institutionalize a culture of academic enterprise, ASU introduced a range of programs, policies, initiatives, and structural elements. These changes are conceived within an innovation systems framework, involving the alignment of design elements across multiple levels, from transdisciplinary departments to programs and policies that motivate use-inspired innovation among students and faculty university-wide, to external boundary-spanning units (like Arizona Technology Enterprises, ASU's technology transfer unit) and start-up accelerators (like Venture Catalyst) that connect the university to local and national businesses.

ASU as a Federation of Colleges and Schools. To support agility and rapid decision-making and to encourage organizational entrepreneurship, ASU undertook a bold redesign of its colleges and departments, essentially flattening and distributing the organizational structures. This redesign process focused on four main objectives:

- To build the university around strong entrepreneurial colleges and schools;
- To devolve intellectual and entrepreneurial responsibility to the level of the college and school;
- To create a design that allows colleges and schools to grow and prosper to the extent of their intellectual and market limits;
- To create a federation of unique colleges, schools, academic departments, and interdisciplinary research centers ("colleges and schools") as the foundation of the premier metropolitan research university of the twenty-first century.

The ASU redesign has organized departments into a "federation of schools and colleges" or a "school-centric" model.[10] A college or school is now "a unit of intellectual connectivity between faculty and students organized around a theme or objective." These definitions seem flexible, referring to intellectual connectivity rather than something more structural. In some schools and colleges faculty members organize around "faculties" rather than departments. Each faculty member may choose a primary and secondary faculty group. At the graduate education level, faculty members could be part of several faculty groups in which they are qualified to supervise graduate work; faculty members are not limited to a single department. When this graduate education model launched in 2007, ASU noted a 72% rise in listings of graduate faculty available to supervise in doctoral programs across the university as departmental participation expanded.

Some departments were fused with other departments or dismantled altogether. For example, the College of Human Services was de-established with departments dispersed to other colleges and schools. Traditional departments such as biology, sociology, anthropology, and geology were eliminated or reconfigured. Ultimately 23 interdisciplinary and transdisciplinary colleges and schools emerged. For example, the School of Sustainable Engineering and the Built Environment was formed from elements within the Department of Civil and Environmental Engineering and the School of Construction.

Further, each college or school is responsible for its own entrepreneurial and innovation activities, and competes nationally and internationally with peer colleges and schools. This effectively diffuses these programs beyond engineering and business schools. For example, the College of Nursing and Health Innovation offers a Master of Health Care Innovation degree that "is designed to bring together information from innovation and change theory, leadership, entrepreneurship, application technology, and system-design programs, to create innovative solutions to the challenges in health care."

At the campus level the design process aimed to create "one university, many places" with a diversity of schools and campuses of "equal quality and aspiration." Each campus is comprised of related but distinct colleges and schools, with little hierarchy across campuses. The UDT recognized the importance of language in shaping culture, and has been deliberate about referring to campuses by name rather than using a traditional nomenclature like "main" and "satellite." ASU's four campuses include Tempe, Polytechnic, Downtown Phoenix, and West. Each is special in its own way, but the structures and substantive compositions of each has generally followed the goals and aspirations established at the onset of the ASU change process.

Despite the intentional diversity across the university, evidence of ASU's overall mission, goals, and design aspirations can be found in the language of how colleges and schools describe themselves. While units have been empowered to pursue entrepreneurial and intellectual goals, elements of the New American University model seem to color the mission and goals of each organization, signifying a shared culture and sense of purpose across campuses, schools and units. What is not transparent is the extent to which these rich program descriptions reflect the reality of how programs actually operate.

Leadership

In an institution of 72,000 students, thousands of faculty and staff, and four campuses there are many examples of leaders and leadership being played out. Nonetheless, the transdisciplinary and outward reaching culture of ASU is reflected in many key leaders and teams. Further, there is evidence of leaders with a history of intrapreneurship and/or entrepreneurship.

President Crow's philosophy of universities as enterprises, and key contributors within innovation systems, is reflected in his leadership history. At Columbia University he was Professor of Science and Technology Policy in the School of International and Public Affairs, and also served as Executive Vice Provost responsible for Columbia's research enterprise and technology transfer operations as well as interdisciplinary program development. While at Columbia, Crow showed a strong orientation toward technology transfer, boundary-spanning partnerships, and education expansion. According to the *Columbia News* article announcing his departure,[11] under Crow's leadership Columbia consistently ranked in the top three among US universities on income from patents and licensing. Crow played instrumental roles in creating several research centers and institutes, including the Columbia Earth Institute and the Center for Environmental Research and Conservation, as well as the Center for Science Policy and Outcomes in Washington, a think tank dedicated to linking science and technology to societal outcomes. Crow was also instrumental in developing Columbia's online education strategy.

Leaders at ASU show similar qualities. The dean of the College of Technology and Innovation also leads one of the college's cross-sector collaboratories, and has a history of working with private sector organizations on innovation and technology issues. Similarly, the dean of the School of Engineering and the dean of the School of Business each have backgrounds that involve positions in industry, with the later having co-founded a successful start-up. The dean of the Walter Cronkite School of Journalism and Mass Communication created the Knight Center for Digital Media Entrepreneurship, the Cronkite Institute for High School Journalism, and the New Media Innovation Lab. He also expanded the school's student television newscast, led the design of a new undergraduate curriculum, and developed a new intensive professional master's program.

Teams and boards of directors also exhibit a transdisciplinary and cross sector orientation. The University Design Team involved faculty members and administrators from across ASU's various departments and its four campuses. The executive team at the technology transfer office, Arizona Technology Enterprises (AzTE), has extensive experience in the private sector in areas of research and licensing for the life sciences and physical sciences. The CEO of AzTE is an accomplished patent attorney and former colleague of Crow from Columbia University. The Board of Directors for the ASU Foundation includes a mix of successful entrepreneurs, high-level industry executives, and ASU administrators. Similarly, the Board of Directors for ASU's Research Park—a 320-acre park that offers business training, cooperative research, and contract research services to corporate residents—is a balance of public and private sector leaders.

The ASU model is perhaps this review's richest example of how to build an Innovation U from scratch—from the top down via inspired and charismatic leadership. The approach required the creation of a campus-wide entrepreneurial "ecosystem" that would encourage and nurture the emergence of radical innovation at both the individual and institutional levels.

> *By making the university into an entrepreneur itself and thereby empowering every level of the university community to be entrepreneurial, we have modeled behavior for other higher education*

> *institutions and become a place that empowers individuals to be entrepreneurial.*
>
> —ASU website

How did a huge university transform itself to create a culture of innovation permeating its entirety? The approach involved five critical strategies:

- Create the structural landscape—the new organizational structures (more than 31 new colleges and schools created in the last 7 years), new facilities, spaces, and collaborations;
- Expand interactions, networking, communications, and connectivity both internally and with the outside world;
- Adapt quickly to changing opportunities, and the needs and concerns of students and faculty;
- Recognize and reinvent failures, and be responsive to new and emerging industries;
- Link new knowledge to action in the real world;
- Embrace a portfolio of experimentation approach: seed a thousand flowers to see which bloom most brilliantly.

Illustrative of all of the above, four years after Crow took office ASU's financial commitment to entrepreneurial reinvention met the matching-fund requirements for a grant from the Ewing Marion Kauffman Foundation, America's premier foundation supporting university-based entrepreneurship. The Kauffman Campus award gave ASU the critical resources needed to catalyze the process of bringing entrepreneurship out of the business and engineering schools to infuse it campus-wide. Six years afterwards that infusion of entrepreneurship education has made inroads at the college, department, program, course, and individual actor levels. For students, entrepreneurship at ASU is like learning a new language via the total immersion method—many avenues exist for any student to gain the entrepreneurial knowledge, skills, and connections they need to pursue new ideas to address global challenges (sustainability, access to education, quality of life, etc.).

Boundary Spanning: *Entrepreneurship*

Of all the university reinvention at ASU the no-one-path-fits-all approach to entrepreneurship education is singularly novel. Other universities create majors and minors and degree pathways. ASU has institutionalized the reality that any knowledge area "provides a base for innovation." Entrepreneurial skills give you the freedom and the support to fill the voids you see in your community—whether those voids are cultural, technological, social or economic.

Entrepreneurship education at ASU is comprehensive because it takes a pipeline approach to entrepreneurial development. At each stage in the journey an innovation takes from idea to execution, there are structures, knowledge, and resources to facilitate that journey. For example, student ideas are cultivated in courses and seminars where instructors provide entrepreneurship education by building the capacity to innovate into their curricula. Students work with scholars from any number of programs and departments organized around pressing issues, with a focus on radical innovation and entrepreneurship. For students developing a plan of action there are workshops, experiential learning opportunities, and starter grants. For students ready to launch a venture there are grants, office space, training, and mentorship. Once the venture is launched, students, faculty, and community members have the support and assistance of incubators/accelerators and business support services. In sum, entrepreneurship education at ASU involves equal focus on three approaches:

- *Curricular.* Course-based learning related to getting a credit, completing a major or a minor, or meeting a degree requirement;
- *Co-Curricular.* Activities that are offered or enabled by ASU organizations but which are generally separate from courses and degrees (e.g., a club, a business plan competition);
- *Extra-Curricular.* This includes activities that may be "outside the walls" in location and are likely to be "real business" in terms of intent and desired outcomes.

Curricular Programs

ASU appears to be the only university that requires all entering freshmen to take an introductory entrepreneurial course (ASU 101: The ASU Experience). The course introduces students to ASU and to New American University concepts, and "plants the seeds of interest" that might encourage students towards entrepreneurship.

ASU offers dozens of entrepreneurship courses, depending on the particular listing. The following are illustrative and notable examples:

- *Social Entrepreneurship.* Offered by the Nonprofit Leadership and Management Department and taught in downtown Phoenix, it's an in-depth study of social entrepreneurship, including how ideas are formulated, constructed, and implemented. It includes experiential learning in developing a social enterprise plan.
- *Entrepreneurship for Engineers.* The Fulton School of Engineering offers a variety of courses to undergraduate engineers interested in innovation, technology, product development, entrepreneurship, and intrapreneurship, including: Launching a Technology Venture; Intellectual Property for Technology Ventures; Operating a Technology Venture; Entrepreneurship Practicum; and Engineering Projects in Community Service (EPICS). In the latter, EPICS classes partner student teams with not-for-profit organizations locally, nationally, and globally to promote social entrepreneurship and technology-based innovation. In addition, the Fulton School of Engineering is one of twelve US universities to offer the Grand Challenge Scholars program to undergraduate engineering students. Students select a grand challenge area, conduct research, enroll in an interdisciplinary curriculum, take Entrepreneurship for Engineers, participate in a global experience, and do a service-learning project.
- *GlobalResolve.* The College of Technology and Innovation offers a Product Design for the Developing World course that engages ASU students in projects that directly improve the lives of people throughout the world. ASU students and faculty collaborate with international universities, residents of rural villages, local governments, financial institutions, and non-governmental organizations (NGOs) to develop and disseminate no-tech, low-tech, and high-tech solutions that address pressing public health or environmental needs. Past successful ventures to launch from GlobalResolve include Daylight Solutions, which created the Aura

Light, a device that uses the waste heat from cooking embers to create electricity.

- *InnovationSpace/Collaborative Design Development.* The Herberger Institute for Design and the Arts offers a course that brings together ASU students from business, engineering, industrial design, and visual communications design to create sustainable, socially responsible, useful and economically feasible products for large and small clients. One such partnership has involved the Phoenix Fire Department, which participated in the creation of a new generation of self-contained breathing apparatus, or SCBA.

- *Innovation Advancement Legal Clinic.* ASU students in law, the sciences, engineering and business help community entrepreneurs commercialize technologies.

- *Digital Media Entrepreneurship.* The course is a dual offering of the School of Management and the Cronkite School of Journalism and Mass Communication. Students become familiar with the latest developments on the digital media landscape while learning the essential principles of entrepreneurship necessary for them to forge their own sustainable niche within it. The course is a part of the Knight Center for Digital Media Entrepreneurship, and has its own lab and office space in the digital media wing of the Cronkite School's new state-of-the-art complex in downtown Phoenix.

- *Certificates.* Certificates in entrepreneurship are offered by the W.P. Carey School of Business (Automotive Entrepreneurs and Leaders, Knowledge of Entrepreneurship and Innovation, Small Business and Entrepreneurship), the Ira A. Fulton Schools of Engineering (Technology Entrepreneurship), and the Lodestar Center for Philanthropy and Nonprofit Innovation in the College of Public Programs. In addition, the Certificate in Knowledge Entrepreneurship and Innovation, which provides entrepreneurship training from basic to advanced, is offered to students of all majors.

- *Degrees.* Undergraduate degrees in entrepreneurship are offered in arts, design, engineering, business, and healthcare. Specifically, the W.P. Carey School of Business confers the Bachelor of Science in Management (Entrepreneurship); the College of Technology and Innovation (Bachelor of Science and Minor in Technological Entrepreneurship and Management); and the Herberger Institute for Design and the Arts (Bachelor of Arts in the Arts or Bachelor of Arts in Design Studies). Graduate degrees in entrepreneurship are offered by the School of Letters and Sciences (Doctor of Behavioral Health); the Ira A. Fulton Schools of Engineering (Master of Science in Engineering with a concentration in Enterprise Systems Innovation and Management); and the College of Nursing and Health Innovation (Master of Science in Clinical Research Management and Master of Healthcare Innovation).

Co-Curricular Programs

- *Edson Student Entrepreneur Initiative.* All students who take entrepreneurship courses at ASU may build on that work by entering the ASU Edson Student Challenge. Both undergraduate and graduate students can apply for and win grants ranging from $1,000 to $20,000 to help develop and launch their business, social, or non-profit ventures (the mini-grant Entrepreneur Advantage Project). Edson winners (20 each year) are also provided office space in the Edson Accelerator, which is located in the SkySong innovation facility. To date, over $1 million has been awarded to student teams with innovative venture ideas. Over the last six years, 102 student ventures and projects have been funded and 19 companies have been formed from ASU inventions and technologies.

- *ASU Innovation Challenge, Health Innovation Challenge, and p.a.v.e.* The two Challenge programs and the Performing Arts Venture Experience (p.a.v.e.) are funding competitions for undergraduate and graduate student teams who have an innovative idea that could "make a difference in our local or global community." The Arts program provides both students and faculty with resources to pursue arts entrepreneurship. Students can win grants of $500-$5,000. The Health and General Innovation challenge programs award transdisciplinary student teams with the best ideas for addressing social, cultural, or economic challenges. Student proposals must include a workplan, a budget, and support from a willing faculty mentor. Students can win up to $10,000.

- *Sun Devil Entrepreneurship Network.* This program links local small businesses with the student talent base at ASU. Interns of all majors and interests learn professional skills and gain work experience working with professionals and entrepreneurs.

- *Student Clubs.* Two active clubs are the Entrepreneurs@ASU student group and the MBA Entrepreneurship Society. The former unites students from all majors who are interested in entrepreneurship, and hosts events and activities to promote entrepreneurship among the student body, broaden student skillsets, and widen student networks. The latter provides a conduit for MBA students to access entrepreneurial resources, network with prominent community entrepreneurs, and share ideas.

- *Innovation Advancement Program and Lisa Foundation Patent Law Clinic.* The Sandra Day O'Connor College of Law sponsors both programs, which provide legal and consulting services to students seeking counsel. The Clinic provides student entrepreneurs with patent prosecution, licensing, and litigation services.

- *BioDesign Impact Accelerator.* Hosted by the Biodesign Institute, this accelerator facilitates the development of valuable innovations by nurturing new technologies through key stages of development and moving them into the private sector once they are viable.

- *The Spirit of Enterprise Center.* This Center is located in the WP Carey School of Business. It engages student teams with community entrepreneurs to address ongoing challenges/opportunities and celebrates entrepreneurship by hosting annual Spirit of Enterprise Awards.

Extra-Curricular Programs

In 2010 ASU launched a Venture Catalyst program based at the new *SkySong* facility in Scottsdale. This is described on the ASU Foundation website as "an international business and innovation center" that has been designed "as a global focal point for technological innovation, cross-disciplinary collaboration and expansion of world trade." It is also:

> *...creative architecture [that] accommodates 1.2 million square feet (112,000 square meters) of high-tech commercial office space, displays of tenants' most innovative technologies, multimedia-rich pedestrian areas, retail space, restaurants and 324 beautifully designed apartments. SkySong's tenants can live, work and play in this creative, connected enclave.*

The facility itself is a rich venue for collaboration among students, faculty, community members, prominent entrepreneurs, and corporate executives. The facility supports ventures of every size and stage of development and serves all-comers including faculty and student ventures. ASU student companies in the Edson Accelerator, for example, initially receive help from a "first mentor" from the Venture Catalyst team members, who are also based on-site.

The Venture Catalyst program is led by an Assistant Vice President for Innovation, Entrepreneurship, and Venture Acceleration. This person had started two companies, advised others, worked in venture capital, was Director of a Venture Accelerator in Dublin and joined ASU in 2011.

Key program components and programs of Venture Catalyst in the first full year of operations at SkySong include the following:

- *Edson Accelerator.* The Accelerator offers funding, office space and mentorship to student entrepreneurs and faculty. Core support of the program was enabled by a $5.4 million gift.

- *Furnace Accelerator.* This starts with a competition that is open to entrants from anywhere in the US focusing on technology-based ventures where intellectual property is a key part of the value proposition. Winners must locate their enterprise for a six-month acceleration process at either SkySong or facilities at Northern Arizona University. The winning teams receive: $25,000 in cash; a dedicated acceleration process; access to mentors; fast-track licensing arrangements with the institution that is the source of the technology; and access to co-working facilities.

- *Techiepalooza.* An intensive networking event that involves speakers, panels, networking, and up to 500 attendees over an intensive 7-hour period. ASU sponsors draw heavily from career centers and services across the campus locations.

- *Rapid Startup School.* The program is open to entrepreneur teams and follows the Lean Launch Pad approach developed at Stanford University. It is conducted over 9 weeks, with each short class session supplemented by 10-15 hours in the field. A military, defense, and veteran version of the program is also offered to teams with background and startup ideas that are focused on the defense industry.

- *Entrepreneur Office Hours.* This appears akin to "entrepreneur in residence" programs in which a seasoned entrepreneur is made available for a set number of hours and student entrepreneurs make appointments for a problem-solving session, but here the entrepreneurs are members of the Venture Catalyst staff.

- *Matching Startup Companies with Senior Management Talent.* This program activity helps place senior (15 years or more) management talent in early stage ventures that need help with a particular problem. The placements are assumed to be 6-36 months in duration with compensation negotiable. Positions being filled would be at the level of Chief Executive Officer, Chief Financial Officer, Chief Technology Officer, and Senior Board member.

Boundary Spanning:
University, Industry and Community

ASU's goal of enhancing local impact as well as its design aspirations like leverage our place, transform society, be socially embedded, and engage globally, are integrated into the mission statements, programs, and initiatives across many of the university's organizational units. This section of the report will focus on community partnerships that are not particularly focused on student entrepreneurship per se.

According to ASU's *Community Connect*—the portal to ASU's community connections—"Arizona State University has 491 community outreach programs in 174 locations, offered by 121 different units, totaling 753 outreach opportunities." Several examples of ASU's boundary spanning efforts and initiatives appear below.

- *College of Technology and Innovation (CTI).* CTI operates five collaboratories that "bring faculty, students and external partners together to solve real problems, build the workforce of the future and develop innovative solutions." These collaboratories offer local, regional, and national partners consulting services, professional development, and training services. For example, the Aerospace and Defense Research Collaboratory involves a partnership with General Dynamics to test new border control and homeland security technologies. The Conservation and Renewable Energy Collaboratory is a partnership with the Salt River Project (an energy provider in the Phoenix metro area) to award grant funding for research and professional development in renewable energy fields. Other efforts under the CTI umbrella include the GlobalResolve Program described above. Locally, CTI has partnered with the City of Chandler (where CTI and the Polytechnic Campus are located) to create the Chandler Innovation Center. In addition to providing access to ASU courses, the Center offers multi-purpose engineering and proof-of-concept lab space.

- *College of Public Programs.* The outward focus of this college is described clearly in an address by the dean:

> *Across the four schools and nine research centers that make up our College, we are preparing students for lives of community engagement and service while faculty pursue use-inspired research aimed at making our communities more prosperous, healthy, and resilient.*

Several examples back up this statement. The Lodestar for Philanthropy and Non-profit Innovation has a mission "to build the capacity of the social sector by enhancing the effectiveness of those who lead, manage, and support nonprofit organizations." The center was founded as a collaboration between ASU and the W.K. Kellogg Foundation and works with local and regional foundations and businesses. Through research and education, the Center provides non-profit leaders with knowledge and tools to improve their effectiveness in the community. Other examples include the Center for Urban Innovation, which promotes innovation in governance, policy, and management of urban neighborhoods; the Morrison Institute for Public Policy which provides policy research to "inform, advise, and assist state, business, and community leaders"; and the Partnership for Community Development which empowers local community members to develop solutions to issues that affect their quality of life.

- *Mary Lou Fulton Teachers College.* One pressing impetus for change at ASU was the extent of under-performing K-12 education across the state. The Teachers College is addressing this problem through several projects and initiatives. The ASU Teach for America partnership provides support and training for teachers who commit to teach in high-need urban and rural public schools for two years. The partnership won the ASU President's Medal for Social Embeddedness in 2008. The Sanford Inspire Program is dedicated to providing professional development and training on best practices in teaching, as well as finding innovative approaches to teacher recruitment and preparation. The America Reads Program partners with local schools and community centers to pair children living in low income areas with ASU students who provide tutoring, mentoring and other skill development assistance.

- *Herberger Institute for Design and the Arts.* The mission of the institute is "to educate future designers to shape collaborations, synthesize complexity, and catalyze transformation for public good." This mission is operationalized through several community-oriented programs. For example, the Performance in the Borderlands Project seeks to enrich the "understanding of the diversity of cultures and artistic traditions in the region" by sponsoring performances, lectures, workshops, and public discussion. Urban Sol is an interesting collaboration between Institute scholars and the "urban artist culture of DJs, MCs, graffiti artists, and dancers." The Lyric Opera Outreach Performance program presents annually a series of musicals and operas to K-12 students. After each performance students can engage in discussion with musicians, dancers, conductors, and other performers.

- *Mayo Clinic Partnership.* Collaboration between ASU and the Mayo Clinic dates back to 2002-2003. The original collaboration resulted in the launch of the ASU College of Nursing and Health Innovation, which provided ASU nursing students with clinical training and the Mayo Clinic with a significant recruiting pipeline. In 2010 the partnership expanded enterprise-wide for the Mayo Clinic, creating opportunities for a host of new educational and research collaborations between the partners. Emerging initiatives include the construction of proton-beam facilities for the treatment and research of cancer, and a concussion assessment and management initiative to develop concussion-screening tools for ASU athletes. As part of the new agreement, ASU's Department of Biomedical Informatics will relocate to the Mayo Clinic campus in Scottsdale, Arizona.

- *Global Institute of Sustainability (GIOS).* ASU launched the GIOS in 2004, and in 2007 the Institute established the first School of Sustainability in the US. GIOS covers research, education, business practices, and global partnerships, with a mission to address the grand challenges of sustainability. The

Institute focuses particular attention on urban centers. For example, the Decision Center for a Desert City conducts research and develops tools to inform decisions regarding the future sustainability of the Greater Phoenix area, and the Energize Phoenix project is transforming a 10-mile stretch of Phoenix's light-rail system into a Green Rail Corridor.

- *LightWorks.* This program is a R&D partnership that brings light-inspired research at ASU under one strategic and organizational framework to leverage ASU's strengths in this area. There is a particular emphasis in renewable energy fields including artificial photosynthesis, biofuels, and next-generation photovoltaics.[12] LightWorks connects with more than 20 research centers across ASU, all engaged in renewable energy research, like biofuels and solar power. For example, the Arizona Center for Algae Technology and Innovation (AzCATI) partners with about 20 public and private-sector organizations and provides research, testing, education, and training services to the algae industry and research community.

- *Ira A. Fulton Schools of Engineering: Industry-University Cooperative Research Centers.* Among the more novel boundary-spanning industry research partnerships at ASU are those that involve financial support from business partners working in a consortium format. One very significant example is ASU's success in the National Science Foundation's Industry-University Cooperative Research Centers (I/UCRC) program. ASU has several of these Centers, most of which are based in the Fulton School. They include:

    - *Power Systems Engineering Research Center*. Arizona State is the lead university among 13 collaborating institutions. The research program is focused on the national electrical energy system, and has over three dozen Center Members from both private and public sectors.

    - *Water and Environmental Technology (WET Center)*. The WET Center has been in operation since 2009 and currently is involved in 23 research projects, conducted by scientists at three universities. The research program is focused on water quality and the problem of emerging contaminants.

    - *Center for Embedded Systems (CES)*. ASU is the Director of this Center with Southern Illinois University as Co-Director. Fourteen companies, from a variety of industries, participate in the Center, which focuses on engineering and materials issues related to computing systems that perform sensing, control, and communication functions, often at the nanoscale, within larger systems.

    - *Net-Centrics System and Software (NetCentric)*. This Center serves 16 member companies, primarily from the computer and software engineering sectors, and focuses on research to restructure software and systems for networked and cloud-computing environments.

    - *Center for Excellence in Logistics and Distribution (CELDI)*. ASU is a Co-Director participant in a consortium of eight universities that serves 30 member companies and organizations. It focuses on logistics and distribution, including intelligent systems, systems analysis, supply-chain modeling and material flow design.

- *Telecommunications (Connection One)*. This Center, in operation since 2002, involves five universities and a number of private sector and federal government partner organizations. It focuses on various problems dealing with RF (radio frequency) technology and wireless communication systems.

Boundary Spanning: *Technology Transfer*

In most universities an office of technology transfer—or equivalent nomenclature—has the lead responsibility in invention commercialization and development issues, often reporting to a Vice President for research. At Arizona State things are different in a couple of ways.

To begin, roughly 10 months after Michael Crow was inaugurated as President of ASU in July of 2002, Arizona Technology Enterprises (AzTE) was organized as an LLC under Arizona state law, as a subsidiary of the newly reorganized and renamed ASU Foundation (now the ASU Foundation for a New American University). Dr. Crow served on the Board of Directors of AzTE from 2003-2009 and has apparently served continuously on the Board of Directors and Board of Trustees of the ASU Foundation for a New American University—which has oversight of AzTE. Having a robust, productive, and entrepreneurial technology transfer function at Arizona State has been a high priority.

How does AzTE differ in terms of the organization and functioning from the average technology transfer office? For one, both the governing board and the professional staff have deep technology-based enterprise development experience and success. Consider the AzTE Board of Directors: its Chair had a very successful career in increasing tenfold the valuation of an early stage semiconductor company, and also started several ventures; every board member has experience in starting, investing, or growing successful technology companies; every board member has an advanced degree, mostly in technical disciplines; several board members have experience in university leadership or oversight.

The staff of AzTE has comparable talents. All have deep experience in corporate and/or university settings in intellectual property law, licensing, technology management, venture development, and entrepreneurship. The team has several PhDs, MBAs, JDs and collectively over 100 years of technology commercialization experience, and their credentials and performance have grown since the onset of the Crow administration.

The operation of AzTE is embedded in a business mindset, not seeing itself as a routine service function for the faculty. Operating as a separate corporate entity may help this. Its interactions with and support of faculty are premised on deal potential, which may be found in a license arrangement with an established company or fostering a start-up. AzTE will release an invention to a faculty inventor if it doesn't appear to meet long-term mutual interests of the university and the inventor.

For startup ventures the office policy is "no requirement of burdensome upfront licensing fees," but the office will be attentive to technical milestones and royalty payments. The overall philosophy of the office seems to be less focused on maximizing value to the University, and more on rapid dissemination of ASU inventions and discoveries into the market.

The services and functions of the AzTE office seem to be very comprehensive and user-friendly. The website (http://www.azte.com/) is very accessible for both companies and faculty (or student) inventors. Thus there is a straightforward 4-page Faculty Primer on Intellectual Property as well as an excellent non-bureaucratic overview on Working with AzTE, with linkages to basic intellectual property information, and how office activity will unfold. For potential licensees and investors, the website has links to very informative (and succinct) Industry FAQs, and a summary of Standard Agreement terms and practices of the office. Users can then conduct an online Technology Search of over 300 technologies available for licensing, with the majority from the life sciences, (notable for an institution without a medical school). Most credible technology transfer offices have these functions, but they are very good at ASU. The disclosure rate at ASU is rising across the board, particularly in areas such as energy, reflecting ASU's large number of energy-related faculty members. Between 2004 and 2009 the energy-related disclosure rate increased ten-fold.

In fact, the formation and procedures of AzTE, as opposed to the prior organization and procedures of the technology transfer function, have yielded significant increases in disclosures, licenses/options, startups, and patents. The FY2012 data[13] from the Association of University Technology Managers are instructive. Thus, ASU had 239 invention disclosures on a research base of $385.9 million, which is a very commendable normalized "batting average" (one disclosure for about every $1.6 million of research). Similarly, ASU realized 80 licenses and options in FY2012, as well as five startup companies and $1.9 million of license income. ASU is doing very well in technology transfer performance, and is likely to continue to improve given the many organizational and programmatic innovations described in this chapter.

Summary and Parting Comments

Arizona State University is clearly an institution focused on innovation. However, it differs in some interesting ways from many of the other case studies in this volume.

For one, ASU is an example of a university that went through a top to bottom, across the board, organizational change process that has gone on for just over a decade. In addition, the notable initiatives in entrepreneurship, technology innovation, and community partnering were not simply grafted onto an existing structure of colleges, departments, centers, programs, and activities. ASU is perhaps the purest example of concurrent engineering of both innovation systems and the structures and operations of the university itself. Said another way, the various innovation and entrepreneurship activities that have been invented and implemented at ASU assumed and demanded parallel changes in how the university works. There are many examples of this in the case chapter.

The second most critical way that this case is somewhat of an outlier is the extent to which the change process has been consistently and longitudinally driven by a conceptual model and a set of precepts, assumptions and working hypotheses. The model of the New American University articulated by President Crow has captured the attention of many in the national university community. It also has become the road map to many of the changes that have occurred at ASU as well as the preview of coming attractions in the years to come. The extent and variety of writings on the part of Dr. Crow aspire to be, in effect, a field guide on how to change or build a university in order for it to be responsive to the innovation needs of present-day America. The body of work emanating from Dr. Crow is impressive; so too are the dramatic changes at ASU over the past decade linked to that body of work. It is yet unclear how the dramatic and positive changes at ASU would continue to flourish if their philosopher-in-chief departed.

Depending on one's personal philosophy or politics, ASU today is perhaps the most dramatic example of a huge public university—with all the fiscal and ideological uncertainties that complicate its mandate—taking on the extraordnary task of lending a hand in addressing the problems confronting the "external" society while also energizing the "internal" functions of the institution. In fact, in the "aspirations" articulated by Dr. Crow nearly a decade ago, these action objectives are joined at the hip. So, ASU is not just a story of trying to make a university more innovative; it is also an ongoing drama of how to leverage positive change in the larger society by doing smart and needed things inside the university that link to that real world. While all of the cases in this book have many examples of real world activities and connections (these were part of the case-selection criteria), ASU differs in the extent to which that mandate is written down in an organized body of work and acted upon daily.

In closing, the ASU approach also acknowledges a bit more forcefully something about the real world that every entrepreneur knows, but that many public institutions (governments, schools, universities) fail to acknowledge. Entrepreneurs recognize and even embrace the fact that innovative entrepreneurship is a high-risk activity and failures occur. One possible advantage that ASU may have as a very large institution is the ability to mount more trials and experiments and learn from the process.

Endnotes

[1] Many of the historical highlights reviewed here are derived from DeLuse, S.R. and Bates, D.E. (2012). *Arizona State University.* Charleston, S.C: Arcadia Publishing.

[2] Frank Kush was not the only a successful football coach but also played an important role in a postwar climb of the campus to a larger role. In the 1950s, Michigan State University came into being (with the keen opposition of the University of Michigan) on the heels of a nationally prominent football program, a meteoric postwar rise in enrollment and a lot of state capital maneuvering by a politically adept president, John Hannah.

[3] National Science Foundation, National Center for Science and Engineering Statistics, FY2011. *Table 14. Higher education R&D expenditures, ranked by all R&D expenditures, by source of funds: FY 2011. Table 15. Higher education R&D expenditures, ranked by all R&D expenditures, by R&D field: FY2011.*

[4] U.S. Census Bureau. *Table 20. Large Metropolitan Statistical Areas—Population: 1990 to 2010. U.S. Census Bureau, Statistical Abstract of the United States: 2012.* Retrieved from http://www.census.gov/compendia/statab/2012/tables/12s0020.pdf

[5] Koebler, J. 10 Metro areas with the largest population growth. *U.S. News & World Report.* Retrieved from http://www.usnews.com/news/slideshows/10-cities-on-the-growth-track

[6] Office of the President. Arizona State University. (2004, April). *One University in Many Places. Transitional Design to Twenty-First Century Excellence. The President's Response to the University Provost's Recommendations Regarding the University Design Team Report.* Retrieved from http://www.asu.edu/president/udt/UDTwhitepaper.pdf

[7] Crow, M. M. (2010). *The Research University as Comprehensive Knowledge Enterprise: A Prototype for a New American University.* In Weber, L. E. & Duderstadt, J. J. (Eds.). *University Research for Innovation.* Paris, France: Economica.

[8] *Ibid.*, pp. 216-217.

[9] Kuhn, T. (1996). *The Structure of Scientific Revolution.* 3rd edition. Chicago: The University of Chicago Press.

[10] Crow, M. M. *The Research University as Comprehensive Knowledge Enterprise: A Prototype for a New American University. op cit.,* pp. 217-218.

[11] Columbia News. (2002, March 29). *Michael Crow Leaving Columbia to Becoming President of Arizona State University.* Retrieved from http://www.columbia.edu/cu/news/02/03/michaelCrow.html

[12] ASU Lightworks. Overview. Retrieved from http://asulightworks.com/overview.html

[13] Association of University Technology Managers. (August, 2013). AUTM U.S. Licensing Activity Survey: FY2012. Deerfield, IL: Association of University Technology Managers.

Brigham Young University*

The precursor to Brigham Young University was Brigham Young Academy, established in 1875 on one acre in downtown Provo. In 1891 the school moved to a larger site in the city. In 1903 the Academy became Brigham Young University, with expansion in facilities, enrollment and educational programs. While BYU added graduate programs throughout the 20th century (1st doctoral program in 1957) it remains primarily a teaching-focused rather than research-focused institution. In 2011 graduate students accounted for roughly 10% of a total enrollment of 32,900 across a wide range of departments. Of note, BYU ranks highly as a PhD "launch pad" institution; based on 2004-2008 NSF data it was right behind UCLA in the number of bachelors graduates that go on to successfully complete doctoral programs.

Top undergraduate majors (in rank order for Fall 2011) are Exercise Science, Management, Psychology, English, Elementary Education, Accounting, Communications, Computer Science, Public Health, and Political Science. While perhaps not expressed in degree program preferences, BYU has major facilities and wide participation in the visual and performing arts. BYU performing groups have been involved in 13,600 shows in 50 states and 100 countries since the early 1970s.

Not surprisingly some of the highly enrolled majors got higher rankings from various ranking organizations: #1 in Accounting, as per *Wall Street Journal*; #3 in both undergraduate and Masters Accounting by *Public Accounting Report*; #3 in undergraduate accountancy by *U.S. News & World Report*; #7 nationally in the completion rate of students admitted to a PhD program, and who enroll, by *U.S. News & World Report*; and graduates with least debt, by *U.S. News & World Report*. Also, notable for this paper is the #4 ranking by *Entrepreneur* magazine of the graduate entrepreneurship program.

It should also be understood that BYU is part of and sponsored by The Church of Jesus Christ of Latter-day Saints (LDS) and has been since the early part of the 20th century. That fact drives many facets of academic life at BYU. For example, for a graduate school application to be considered it must have received an unconditional endorsement from an LDS bishop or BYU chaplain.[1] By the same token, in a more reaching-out context, those same graduate students once admitted are encouraged to participate in Inspired Counsel devotional or forum sessions, as well as receiving a heavy concentration of faculty mentoring during their program experience. Per Fall 2011 enrollment data, 93% of students were from the US, and 98.5% were LDS by religious affiliation. The

** This case was written by Louis Tornatzky, Elaine Rideout, and Elizabeth Ann Pitts.*

balance of non-US enrolling students come from a very wide variety of countries, reflecting to some extent the international scope of LDS missionary activity. A majority of male students and a smaller fraction of female students take a two-year break from their degree programs to work as missionaries somewhere in the world. The student tie with LDS is also reflected in the significant tuition reduction for LDS-member enrolled students.

While not usually a vehicle to promote student involvement in entrepreneurship or industry, the scope of the BYU internship program is likely an important contributor thereto. The BYU Internship Office has campus-wide responsibilities in this area, and coordinates with the 107 department-level internship coordinators, each of which has responsibility for developing a very structured syllabus for its internship experience. Nearly 10,000 BYU students do an internship every year, and according to the Internship Office their average starting salary is $6300 higher than their peers, and their chance of having a job offer at graduation doubles. Internships are organized throughout the US and in a number of international settings. Of note, there is one internship activity—the Utah Startup Marketplace (USM)—that is linked to entrepreneurship opportunities. At USM the dozens of booths are manned by early-stage companies looking for talent, either in the form of internships (paid and unpaid) or employment. USM is organized and supported by several on-campus organizations as well as community-based partners such as the Utah Technology Council, Silicon Slopes, and the Association for Information Systems (AIS).

While BYU is not a research-intensive university as might be assessed by the scope of sponsored research, other research and scholarly activities are common and not reflected in those data. Student projects, mentored by faculty members, are frequent and ambitious. The Office of Research and Creative Activities (ORCA) manages a competitive small-grant program in which awardees can receive funds to work with a faculty mentor on a mutually agreed upon project. The student must write the proposal and negotiate a working relationship with a faculty member. In addition to these nominally funded efforts there is a much larger number of faculty-student mentoring efforts. The relatively low student-faculty ratio at BYU appears to facilitate these relationships.

Both students and faculty members must adhere to the BYU Honor Code, originally developed in the 1940s and expanded later on to cover a range of discouraged or prohibited activities, encompassing dress, alcohol consumption, sexual activity, and other issues. Violation of the honor code can result in removal from BYU for students and negative tenure decisions for faculty. Not surprisingly, BYU has ranked as Princeton Review's #1 "stone-cold sober" school for 15 years running—an achievement its students celebrated on Twitter with the hash tag #soberisthenewcool.

This brief, mostly statistical, profile of BYU draws a picture of a rich college learning experience for its students, enabled and structured by the LDS church, that turns out successful students (who don't leave prematurely), and who then graduate and go on to rewarding careers and lives.

However, this idyllic picture has few obvious links to the theme of *Innovation U*. What is it about LDS teachings and philosophy that seems to enable technological innovation, commercialization of science, and entrepreneurship?

University Culture: *Goals and Aspirations*

The organizational culture of BYU, and the ways and extent to which it encourages innovation-related activities, are inseparable from how the LDS looks at these issues as a religious body. Thus the BYU Mission Statement, as guided by the LDS church, emphasizes both the religious and the secular. Here are the first few sentences:[2]

> *The mission of Brigham Young University —founded, supported, and guided by The Church of Jesus Christ of Latter-day Saints—is to assist individuals in their quest for perfection and eternal life. That assistance should provide a period of intensive learning in a stimulating setting where a commitment to excellence is expected and the full realization of human potential is pursued.*

That leads to a statement of the Aims of a BYU Education. Each of the following is elaborated in a separate section of what a BYU education should be: (1) spiritually strengthening, (2) intellectually enlarging, (3) character building, and leading to (4) lifelong learning and service. The subsequent text elaborates these themes, and if one extracts the frequent mentions of the LDS tenets, it describes a rich, disciplined, and ethical approach to a liberal arts education.

The difference between these statements from an LDS-linked BYU, and what might come from another religious order or a non-religious university, is that LDS sees normal life—including business—as just other venues for doing the work of the church. A recent *Business Week* makes the point[3] that:

> *To Latter-Day Saints, opening megamalls, operating a billion-dollar media and insurance conglomerate, and running a Polynesian theme park are all part of God's work. Says Quinn: "In the Mormon [leadership's] worldview, it's as spiritual to give alms to the poor, as the phrase goes in the Biblical sense, as it is to make a million dollars."*

The point being made is that these situations are just venues to make real the service values that are embedded in the religion. They are settings in which the skills and moral lessons that are imparted through the religion, and in the classroom, can be exercised. Part of the LDS view of things is tied to building the kingdom of God on earth, now or in the future. And building the kingdom of God at BYU is considered a measurable enterprise. As Dean of Students Vernon Heperi put it in BYU's 2011 annual report for campus life:

> *Just as our students connect information into a meaningful whole and acquire personal ownership of their knowledge, after study, thought, and prayer, we have moved forward to bring learning outcomes and their assessment into our ownership, to integrate them into the full body of our work.*

Plenty of evidence bears out his claim. University publications feature charts, graphs and numerical data to quantify everything from the number of hours that students volunteered in the center for service and learning (126,151 in 2010, with an estimated economic impact of over $2.6 million) to the average number of job offers per management school student seeking employment (.92 in 2010, a figure BYU aims to nearly double by 2015). Expected learning outcomes for every college, department and program are posted online in an easily searchable format at www.learningoutcomes.byu.edu. The site advises students that reviewing these goals will help them "see the big picture of the knowledge and skills" that they will be able to apply upon graduation, while recommending that professors review outcomes regularly in order to "identify areas of strength and weakness… improve student learning…and…contribute to ongoing accreditation." Similarly, a typical line in the annual report reads: "As the survey results were analyzed, the IS Office learned that we needed to focus more attention on…" and so on.

In short, BYU's goal is to provide a rich and diversified educational experience that moves graduates into lives of doing good in the real world, including the world of science, innovation, and associated business, and some outside the LDS would argue that the latter is much more explicit than implicit. Nonetheless, the institution holds itself accountable for achieving its goals by measuring them in objective increments. And from the start, it prepares students for what is perhaps one of the most entrepreneurially daring enterprises that a young person can undertake: serving as missionaries.

While at the institutional level references to goals that speak to the primary foci of this book—technological innovation, entrepreneurship, invention—are mostly non-existent, at the program level (college, activity, center) they are fairly robust. For example, in the Ira A. Fulton College of Engineering, one of its "five key areas" for student emphasis articulates the following:

> <u>*Innovation*</u>
>
> - *Students understand processes by which innovation can be enhanced and have practiced these in a technical environment.*
>
> - *Students are ready to guide innovative change within an organization.*

There is also a Student Innovator of the Year competition that appears to get significant attention in the College.

In the Rollins Center for Entrepreneurship and Technology, within the BYU Marriott School of Management, the expected Outcomes of student involvement are very clear:

> <u>*We Want Students To:*</u>
>
> - *Learn about leadership, innovation, technology and entrepreneurship;*
>
> - *Practice leadership, innovation, technology and entrepreneurship skills;*
>
> - *Establish actual ventures, especially tech-oriented and scalable ventures.*

The Rollins Center also goes on to articulate Values that should be held by students including:

> *Creativity and innovation—a 'pioneering spirit' that pervades the BYU culture.*

The Brigham Young University Technology Transfer office (TTO), which has campus-wide responsibilities, has a simple set of Objectives that are consistent with both a technology innovation mindset as well as the larger goals of the University:

> *The BYU Technology Transfer Office has been established to help faculty, students and staff commercialize any technology or product developed through their association with the university.*

And why will the TTO pursue this goal? Here is where the operational goal ties to the larger goals of BYU:

> *While the primary focus of the BYU faculty is teaching, research and other scholarly activities, often the products of scholarship have applications as products or services beyond the gates of the academy. Under most circumstances these intellectual properties can only be utilized by society if they are made into commercial products and sold by a company with a profit motive.*

As a footnote to this section, college sports enthusiasts have debated whether BYU's football team has a "missionary advantage"—in other words whether the two-year hiatus that students take to do missionary work results in a more mature, more capable team. We also wonder whether this advantage might apply to a variety of off-the-field successes, including a successful technology venture career. It seems reasonable to assume that a successful missionary in the field is not only goal-focused, but also able to adapt to new and unforeseen circumstances and viewpoints. In addition, BYU's emphasis on missionary work means that foreign language learning becomes a high priority. Over 50 languages are taught on a regular basis, and the university has the capacity to offer classes in an additional 30 languages if student demand for them is high enough. As a result, seven out of every 10 students speak a second language, among the highest percentages in the country.

Leadership

For every other case study in this volume the authors have been able to identify and describe significant leadership behaviors and identify a few specific leaders, typically at the level of senior administrators (president, provost, VP for research) who moved the rudder of their university toward the mix of organizational behaviors that we have considered as fostering innovation. After looking extensively and intensively at Brigham Young, we have concluded that this is difficult or impossible to do at this university. In contrast to the typical university, BYU staff, faculty, students and administrators are much more homogenous in terms of their goals and aspirations. Sure, the chemical engineering professor may have less to discuss substantively with the choral director and vice versa, but they will both pretty much share the goals and aspirations discussed above.

Yet people will stand out in terms of being more visible or effective in enabling and instructing the processes of technological innovation, and we finally concluded three things: (1) that the phenomena of innovation are in effect "hard wired" into the culture and history of the institution; (2) that the phenomena of innovation leadership, as alluded to above, is most robust at the program level (college, activity, center) and can be demonstrated by the backgrounds of key leaders at that level; and (3) that innovation leadership at BYU gets a tremendous boost from linkages with the rich network of technology innovators and entrepreneurs both regionally and via the LDS more generally.

For example, in the Ira A. Fulton College of Engineering, the senior leadership is rich in background experiences to enable substantive instruction and behavioral modeling in an innovation context. The Dean is the co-author of a commercial optimization software package, used at companies and universities worldwide, and received a Design Automation Award from ASME. An Associate Dean and Professor of Mechanical Engineering, with expertise in design, has overseen 250 graduate and undergraduate design projects:

At the Rollins Center for Entrepreneurship and Technology, the Managing Director has started and harvested three companies, and currently serves in a leadership capacity in several others. The Academic Director had a leadership role in a Provo startup. Another faculty leader of the Center (a BYU graduate) started a company that went public, achieving a $35 million market capitalization and 1,500 employees. The Rollins Center also benefits in terms of leader assistance via the Entrepreneur Founders, a network of 140 entrepreneurs who contribute financial support (an initial contribution of $15K and a sustaining donation of $5K). They also give lectures, mentor students, arrange internships, and help develop teaching materials and opportunities.

In the BYU Technology Transfer Office, the Director has a rich multiyear (going back to 1973) involvement in technology-based ventures. This has included roles as founder (nine startups), investor and fund developer, and participation in various federal and state programs fostering entrepreneurship and technology commercialization. Other staff members in the office have rich experiences as mangers in or founders of technology-based ventures (over 20). In a manner similar to the work of the Rollins Center, the TTO also benefits from an Entrepreneurship in Residence function, composed significantly of Provo-based technology entrepreneurs that help the office to evaluate the promise of emerging technologies. Also, via social media such as LinkedIn the office is able to connect with a much larger group of individuals, many BYU grads, who are potential licensees of BYU inventions. All of these are excellent examples of how to enhance de facto leadership talent in technological innovation by reaching beyond the campus.

Boundary Spanning: *Entrepreneurship*

Entrepreneurship is all about the ability to pursue opportunity without regard to the resources in hand. One explanation for the surprising level of student entrepreneurship at BYU most likely lies in the BYU culture. Mission statements at both the School of Management and the College of Engineering and Technology specifically include objectives for students to understand innovation processes and practices and be prepared to guide innovative change within an organization. The Marriott School's website alludes to nurturing, in each student, the "pioneering spirit" that pervades the BYU culture, with the help of the larger entrepreneurship community that surrounds and supports scalable ventures.

The low student-staff ratio, LDS apprentice-style traditions, nurturing mentors, and formal boundary spanning university structures, programs, and processes is consistent with recent research showing that social and mentoring networks are critical facilitators of small business creation. BYU's strong network of extraordinarily active alumni (the Founders and Young Founders organizations) shower student entrepreneurs with attention, sharing resources and expertise, in order to demonstrate "by selfless example" the "joy of giving back." In addition to one-on-one mentoring the Founders make charitable donations for scholarships, competitions, and activities, and participate in formal social and networking events including annual retreats, semi-annual conferences, and many other activities.

Entrepreneurship curricular and co-curricular opportunities abound at BYU. They involve students and mentors from across the campus, as well as from the contiguous business community. They come in many flavors, disciplinary mixes, reward structures and timelines. Their richness contributes to BYU being an Innovation U.

Curricular Programs

BYU offers a number of degree programs, certificates, and courses in entrepreneurship at the undergraduate and graduate level, including an entrepreneurship emphasis, minor, and major for business undergraduates, a minor in social innovation, and an MBA major and minor in entrepreneurship. In 2012, the Princeton Review ranked the BYU MBA entrepreneurship program third in the country. In general, the curricula covers technology issues and opportunities, basic entrepreneur skills, creating new ventures, managing new ventures, financing new ventures, mobile application development, entrepreneurial marketing, venture capital investing, and due diligence. The success of BYU students' post-graduation venture sustainability, and their team success in university competitions external to BYU, are attributable (according to one faculty informant) to the customer development curricular approach. Student teams repeatedly test and validate their ideas with actual customer prospects and then iterate and adapt their business plans based on the feedback they receive until they've arrived at a final model.

Experiential course offerings include a course in Mobile App development, and an MBA field studies class where MBA/MPA and occasionally students from other disciplines work on a company -sponsored innovation project. In addition a 3-year accelerated joint degree (MBA/MS) in mechanical or manufacturing engineering is offered that requires acceptance to both programs. The program provides students with the management skills of the MBA program and advanced training in engineering. Courses teach specific expertise in product and process development through projects, industrial interaction, and research in development and interdisciplinary methods. Other non-course activities supplement the class experiences.

Co-Curricular Programs

The Venture Mentoring Services program of the Rollins Center for Entrepreneurship and Technology (part of the Marriott school) is one such formal activity. Students sign up online and select their desired mentor from a list. (They must complete minimal market analyses and patent searches on their idea before the session). The alumni mentors come from a variety of fields and are experienced in business leadership, entrepreneurship, management, or venture/angel investing. Many of the mentors live in the local Provo metropolitan area. A one-time (up to an hour) one-on-one advisement session is offered either in-person or via BYU's online mentoring portal. A second, more robust mentoring program is offered to student teams who are advanced enough to enter into campus entrepreneurial competitions such as the New Venture Challenge/ Business Plan Competition, Utah Student 25

Business Plan Competition, Student Entrepreneur of the Year, International Business Model Competition, Mobile App Competition, Omniture Web Analytics Competition, Crexendo, and the Online Marketing Competition. The teams do not select team mentors; Rollins faculty advisors, usually three per team, assign them. The mentors typically meet with teams an hour a week for several weeks leading up to the competitions. Mentors also receive training in using the BYU mentoring portal software, which facilitates scheduling and tracks the mentoring process.

While the Rollins Center is a center for student entrepreneurs at BYU it also supports a number of boundary spanning efforts, effectively connecting student entrepreneurs with alumni, and sponsoring a number of events such as the Entrepreneurship Week activities, a lecture series, and the aforementioned competitions. BYU's New Venture Challenge is one of the largest internal business plan competitions in the nation, with up to $130,000 awarded in cash and in-kind prizes. The Rollins Center encourages students from across the campus to form ventures and enter the competition. This year a new initiative by the Center—the Weekly Idea Pitch and Super Saturdays—culminated in a record number of eighty-two final business plan submissions. Throughout the year the Rollins Center received more than 1,000 ideas from more than 100 teams in weekly pitches, workshops, and other events.

Another novel boundary-spanning approach, unique to BYU, employs connecting experiential entrepreneurship with students' LDS missionary trips abroad. A number of students have leveraged their evangelical work into sales and customer development skills. Students have returned from a mission trip with a new product idea to support needs in the developing world.

The Rollins Center is led by multidisciplinary faculty members with entrepreneurial, business, and technical (computer science, chemistry) backgrounds. While new efforts are being made to pull multidisciplinary student teams together, student groups themselves are the primary drivers of interdisciplinary collaborations at BYU. For example, the Engineering and Technology Startup Club, "Venture Factory", meets monthly at BYU's Ira A. Fulton College of Engineering and Technology. Students from any discipline, as well as community members, bring and present their new ideas and receive constructive feedback from the College's faculty and other student club members.

The Venture Factory student leadership team and faculty advisers select particularly promising ideas, and even hire engineering and business students to work on the projects. The Venture Factory is designed to run like a non-profit, creating products that become profitable and that then aid in financing future Venture Factory projects. The college helps support the Venture Factory because it not only allows students to innovate and apply their learning, but also provides students with a hands-on paid internship opportunity. It also is a venue for improving presentation skills via student and faculty feedback.

Other student clubs include: Collegiate Entrepreneurs Organization (CEO) club, Association for Systems Management (ASM) club, Web Startup Group, the MBA Tech Academy, Student Intellectual Property Law Association, and the Social Startup Group. Interestingly, club meetings and other student entrepreneurship activities do not seem to be centrally located in a campus incubator but are spread around among University labs, classrooms, and the Wilkinson Student Center.

There is one interdisciplinary co-curriculum program that is particularly noteworthy. The Crocker Innovation Fellowship program is for top students at BYU with a good idea. Students apply for the fellowship (20 winners) and receive support from five leading faculty and a cohort of students, along with a $4500 stipend to support their projects. The students learn design thinking, entrepreneurship, agile software, and innovation practices. They work for an innovative company during the summer, develop their own innovations during the fall semester, and are provided additional funding, equipment, and lab space as needed.

A critical part of the Crocker Initiative is the development and cultivation of its alumni network. Alumni have the opportunity to network with leaders in the innovation ecosystem and with prior Crocker Innovation Fellows, provide feedback on the program, and eventually give back to the program via mentoring, funding, employment, or even providing projects that will allow future generations of Crocker Innovation Fellows to continue learning by experience.

There is another recognition type program that involves virtually all the institutions of higher education in the state—Utah Student 25. It is designed as a competitive recognition program in which there is an opportunity to be named one of the top-25 student enterprises in the state, be recognized at an Award Gala, be featured in *Utah CEO Magazine,* and get media attention across the state. Presumably, the Student 25 winners will have more opportunities to connect with investors, potential partners, and customers. Utah Student 25 finished its third year of competition in 2012.

Boundary Spanning: *University, Industry and Community*

The Office of Research and Creative Activities (ORCA) is the research management function of BYU, including relationships with funders, faculty researchers, labs and centers, and undergraduate research activities. In FY2011 BYU reported[4] $37.1 million in research expenditures, with the largest fraction ($24.2 million) coming from the Federal government. Interestingly, business accounted for $4.7 million, or 12.8% of total expenditures. That is definitely on the high side, relative to national averages across all universities, which are around 5%. By R&D field, the lion's share of research was conducted in engineering (32.3%), followed by the life sciences (19.7%), non-science and engineering fields (19.3%) and physical sciences (15.6%).

Consistent with the university's emphasis on undergraduate research activities, ORCA sponsors an annual competition to select projects involving a student and a faculty mentor. Each student receives $1500 to cover project expenses. During the 2011-2012 academic year ORCA awarded $450,000 to 321 undergraduate student for their research projects, and in parallel awarded $1.4 million to 71 faculty members for projects involving undergraduates. To enable faculty proposal activity and grants, ORCA also offers a range of workshops, including: grant writing, proposal preparation, using NSF Fast Lane, and finding funding opportunities.

BYU hosts over 50 centers and institutes across the university, most prominently in the humanities, social sciences, and life sciences. BYU also participates in four NSF Industry-University

Cooperative Research Centers (I/UCRC) in partnership with much larger, more research-intensive universities, a fact that is notable in its own right. They include: the Center for High-Performance Reconfigurable Computing; the Center for e-Design; the Center for Friction Stir Processing; and the Center for Unmanned Aircraft Systems. This is a major accomplishment for a university of its size in terms of the scope of graduate education programs and sponsored research.

Boundary Spanning: *Technology Transfer*

In a 2009 article,[5] the Technology Transfer Office at BYU was labeled as "Brigham Young's Entrepreneur Factory." Particularly noteworthy at BYU is the "hit rate" of starting companies based on university inventions per research dollar, the relative frequency of invention disclosures per research dollar patent applications and patents issued per research dollar spent, licenses and options per research dollar, and license income. The annual reports of the Association of University Technology Managers (AUTM) bear this out year after year. The current FY 2012 AUTM report[6] is illustrative. Looking at the hit rate of invention disclosures filed relative to research expenditures, BYU's batting average is about one disclosure for every $351,000 of expenditures! That rate is phenomenal. So too is the number of licenses and options executed during the year (34), which rivals the volume achieved by universities ten or more times the size of BYU in terms of research expenditures. There are a couple of potential explanations. For one, the Technology Transfer Office has a Director, Mike Alder, who is an experienced venture investor and a serial entrepreneur. Second he has a complement of professional staff that for the size of the university's research portfolio is large. Third, operations are also enhanced by student interns and gratis advice from community volunteers.

BYU Technology Transfer is a very well organized, professional organization that is very effective in identifying, evaluating, protecting and moving faculty inventions into business applications. It runs like a disciplined small business within the university context. The focus of the office's licensing activity encompasses arrangements with existing companies, as well as startup situations. Licensing arrangements offer inventors a generous 45% share in revenues, although the faculty inventor can opt to dedicate all revenues to support her/his research program. When the inventor does assign that share of income to his research account, then BYU will match that amount from its share of the proceeds.

Inventions that come to the attention of the TTO tend to cluster in a small number of domains. Chemistry accounts for over half of inventions, followed by engineering, the life sciences and computer systems/software. As noted above the invention disclosure rate per unit of research spending is very high. Of approximately 1600 faculty members at BYU there are about 200 who are active inventors, and 50 who are very active.

A notable example of the businesslike mindset of BYU Technology Transfer Office is its internal quantitative performance benchmarking of several typically used metrics. Unusual is the office's practice of normalizing outcomes and making them publicly available in an easily understood visual format on its website. One can find, for example, quantitative and graphical information on: invention disclosures per million dollars of funding; patent applications per million dollars of funding; startup companies formed per million dollars of funding; licenses and options per million dollars of funding; and license income per million dollars of funding. The graphical presentations also include BYU's standing and numbers compared to the leading universities in the country. There are several first places, which is highly commendable and very unusual for a university with the modestly sized sponsored research portfolio of BYU.

The Technology Transfer Office website is easy to peruse and search, and fairly customer friendly. The function is staffed with people with business experience, which on a staff person per unit of research funding basis is more than adequate. The Office works closely with academic units across campus that are involved in ancillary activities. For example the College of Engineering and Technology runs a Capstone Program in which, for a $20K fee, a company can work with a student team and a faculty advisor to solve an engineering-related technology problem; the sponsor company will have the rights to any intellectual property that will result. A prominent theme of the office is "serve the faculty" and be flexible in interactions with partners.

As noted above, the de facto staff of the BYU Technology Transfer Office is significantly enhanced by the extent to which the office and the university are connected to leaders in the Provo regional economy. Provo is a burgeoning technology cluster community that includes a number of people with ties to BYU, and who are willing to help out in terms of providing guidance and support for BYU Technology Transfer. For example, the Office meets annually with its counterparts at the University of Utah and Utah State University to share best practices and solutions to common problems. While for reasons of LDS policy the university takes no money from state government, the Technology Transfer Office works with its licensees to compete in the state-funded Technology Commercialization and Innovation Program (TCIP). TCIP mimics the Federal Small Business Innovation Research program and gives grants to technology-based startup companies.

The "technologies available" portion of the BYU Technology Transfer website is easy to search, and organized by areas of science and technology. Notably, the number of available technologies has increased significantly as the office has ramped up its operations and staffing over the past several years. Information is provided about the invention in non-disclosing terms, the potential market (s), patent status, the inventors, licensing status, and a contact person in the Office. There also appears to be a great deal of "walking and talking" around the campus, engaging faculty members and students alike.

In closing this section it should be noted that prior to 1996 the Technology Transfer Office also had responsibility for the licensing and commercialization of "creative works," typically instructional materials such as video, music, art, and some software applications. Since BYU has a rich tradition in these areas, in terms of curriculum, performance, and associated creative products, the BYU Creative Works Office (CWO) was established. Much of invention in this area is typically protected by copyright, but it emerges from many disciplines and departments, such as the School of Music, the Department of Theater and Media Arts, and other units.

In addition to managing the intellectual property protection most appropriate to these activities and products, the Creative Works Office also developed a dissemination and sales strategy. Originally the CWO functioned as the assembler and marketer of these diverse products, starting with a printed catalog sent to 160,000 BYU alumni. This was replaced by an online approach, with the campus bookstore functioning as the order fulfillment entity, for a 15% share. Incentivizing the bookstore seemed to work well, and has expanded the reach and visibility of the campus; an entrepreneurial solution for an entrepreneurial place.

Summary and Parting Comments

BYU, while a unique university on some dimensions that would be impossible to replicate elsewhere, also provides many examples of good practices that could be applied to any university. Discounting the religious and associated cultural context, many practices are notable and replicable. For instance, a campus that is not research-intensive can have a very productive technology commercialization operation if it operates with more of a business mindset and more aggressively engages leaders in its business community. So too is it possible for a "small" university to effectively work with its more nationally visible counterparts in conducting industry-university cooperative research centers. The delivery of a wide range of entrepreneurship curricular and co-curricular programs is possible, if program innovation and community involvement are cooperatively harnessed in the effort. It remains unclear whether a campus like BYU could be as productive as it is in the technological innovation arena if it were not located in the fairly energetic innovation culture of Provo and the State of Utah, but there are many wise and clever policies and practices at BYU.

Endnotes

[1] Graduate Studies. Brigham Young University. (Updated 2012). *Policies and Procedures Manual, Section B: Policies.* Retrieved from http://graduatestudies.byu.edu/sites/default/files/graduatestudies.byu.edu/files/files/policies/b_section_ppm.pdf

[2] Brigham Young University. *BYU Mission Statement.* Retrieved from http://aims.byu.edu/p/missionstatement

[3] Winter, C. (2012, July 18). How the Mormons Make Money. *Bloomberg BusinessWeek*. Ms. Winter describes the wide-ranging current investments and enterprises of the LDS church, as well as economic matters being a significant theme among the early revelations of the 19th century founding history.

[4] National Science Foundation, National Center for Science and Engineering Statistics, FY2011. *Table 14. Higher education R&D expenditures, ranked by all R&D expenditures, by source of funds: FY2011. Table 15. Higher education R&D expenditures, ranked by all R&D expenditures, by R&D field: FY2011*

[5] Wong, V. (2009, December 7). Brigham Young's entrepreneur factory. *Bloomberg Business Week*.

[6] Association of University Technology Managers. (2013). *AUTM U.S. Licensing Activity Survey: FY2012.* Deerfield, IL: Association of University Technology Managers.

California Institute of Technology*

The California Institute of Technology, an institution that emerged from very modest origins 120 years ago, was recently named the world's top university by the *Times Higher Education* ranking of the leading universities in the world—and for the third year in row. Selection criteria included research, teaching, citations, international outlook and industry engagement. The selection methods included a survey and analysis of published papers among other approaches.

This outsized ranking is astonishing for such a small institution. With a 2012 freshman class of 264, Caltech is a quarter the size of MIT's freshman class, which is also small by comparison with its peers reviewed here. And yet if one were to point to places where the modern post-industrial world originated, Caltech would be on the short list.

For those familiar with Caltech's meager origins this seems a leap. In 1891 a wealthy philanthropist named Amos Throop founded a small school in Pasadena, and named it Throop University. Two years later, it became Throop Polytechnic Institute, and for several years the college offered a wide range of subjects albeit with an emphasis on vocational outcomes including instruction at the high school level. Between 1906 and the 1920s the Institute came under the influence of several key individuals: George Hale, director of the Mount Wilson Observatory, was named a Trustee; Arthur Noyes, a chemist from MIT, was instrumental in early development; as was physicist Robert Millikan who began to spend time at the Institute as director of physical research. Hale, Noyes and Millikan—the "triumvirate"—were active in the steady scientific evolution of the fledgling school prior to and during WW I when the three worked in Washington to support the defense effort. By 1920 the school had become the California Institute of Technology, had secured a significant endowment, and was building a new approach to scientific education. The triumvirate, having cut other ties, were in leadership positions in the evolving Caltech, with Millikan as administrative head as well as Director of the Laboratory of Physics.

During the 1920s and 30s the Institute evolved into a small (in student headcount) but exemplary university that focused on the physical sciences (particularly physics and chemistry) and engineering. Its reputation was further enhanced by a growing research portfolio (mostly funded by philanthropy and private foundations) as well as the appearance of internationally known visiting scholars. All of these became part of a continuing tradition. So too did the tradition of linking Caltech's fundamental science to its practical implications for important societal problems and challenges. The latter was expanded several-fold

* *This case was written by Louis Tornatzky, and Elaine Rideout.*

during World War II and thereafter, with work on various weapons systems, radar and the establishment of the Jet Propulsion Laboratory (JPL).

During the 1950s the history of Caltech was also closely tied to the history of the development of the semiconductor industry, and thereby of Silicon Valley itself, and much of the modern world as we know it. Caltech/MIT alum William Shockley, Nobel Prize winner and co-inventor of the transistor, left Bell Labs to start the first semiconductor company with financial backing from Arnold Beckman, also of Caltech lineage. Included among his early hires were Caltech's own Arthur Noyes and Gordon Moore, (PhD, 1954), two of the "gang of eight" who eventually left Shockley to launch their own startup, Fairchild Semiconductor. Later, Moore went on to found Intel, where he became well known as the author of "Moore's Law," which still holds today (that computer processing speed tends to nearly double every two years). The semiconductor industry spawned hundreds of companies, and the region grew and prospered by attracting the best and brightest, and also by the attraction of capitalists (Sequoia Partners and Kleiner-Perkins, for example) and other industry suppliers and service providers. Much of the enormous new wealth that was generated was plowed back into the region via regional investment VC funds and independent startups. Area universities benefited indirectly, by attracting the best and brightest faculty and students, and directly with industry and individual endowment funding. For example, in 1986 Arnold and Mabel Beckman donated $50 million to Caltech. Approximately a decade later, Gordon and Betty Moore established the $16.8 million Gordon and Betty Moore Laboratory of Engineering. In the early 2000s the Moore's bequeathed an additional $600 million to the University.[1]

Despite, or perhaps because of these propitious beginnings, California Institute of Technology remains small in student and faculty head count but internationally pre-eminent in a number of science fields and a hotbed of technological innovation. Early work in Vitamin C, the Richter scale plus associated instrumentation and brain hemisphere studies are all part of the school's heritage. There are relatively few students[2] at Caltech, 978 undergraduates and 1,253 graduate students, served by a faculty of 300, which is supplemented by 600 research scholars, many who are post-docs. Over the years many honors have been bestowed on Caltech faculty and researchers: 32 Nobel Prizes; 56 recipients of the National Medal of Science; 110 members of the National Academies; 12 National Medal of Technology Recipients; and 94 members of the American Academy of Arts and Sciences. This is extraordinary for a faculty base of a few hundred.

Even more extraordinary is the record of research performed relative to that base of faculty members and research scholars. In FY 2011[3] NSF statistics Caltech reported $377.5 million in R&D expenditures, which placed them 58th in the country. Not so good? Actually, quite commendable when one considers the relatively small number of faculty plus research scholars. It suggests that on average each faculty member is somehow associated with over $1 million in research. By comparison, the school just above Caltech on that list, performs $378 million in research, but has over five times the number of faculty members as Caltech. That school ranked #2 nationally on the same list, with $1,279 million in research, does it from a faculty base of approximately nine times the size of Caltech. Not to belabor these statistics too much, since definitions of "faculty" differ somewhat from place to place, but it cannot be denied that the California Institute of Technology has a very productive faculty in term of research and development and also attracts very talented graduate students and post-doctoral researchers.

Where many schools might sit back and rest on their laurels, Caltech continues to maintain its edge. So how does that happen? This quote from Jean-Lou Chameau, President of Caltech, perhaps captures the key themes that we will elaborate in more detail in the balance of this case discussion:

> *Our people, both on campus and at JPL, practice collaboration over competition. Our interdisciplinary environment allows engineers to talk to biologists, biologists to work with physicists, and computer scientists to partner with social scientists. It teaches our students our core values: respect, risk-taking, intellectual curiosity, and integrity. And it gives our staff the freedom and opportunity to act not only as support but also as mentors themselves to our students and our faculty, accelerating the Institute's progress and increasing its impact on society. Our commitment to excellence and to each other's success makes Caltech special.*

They also do it by having areas of expertise, and individual talents, that are among the best in the world. In *U.S. News & World Report's* recent rankings Caltech is #1 in chemistry (2010), #2 in chemical engineering (2012), and 5th best university in the US (2012) with best graduate programs in chemistry, earth sciences and physics (2012). There are many other accolades.

University Culture: *Goals and Aspirations*

One might expect that a modestly sized (in headcount) faculty and student community, with outstanding intellectual credentials, would have the potential to have a very focused set of goals and aspirations. Many universities have a difficult time in zeroing in on these topics—not Caltech.

Here are its current Mission Statement and Research Priorities in just over 100 words:

> ***Mission Statement***
>
> *The mission of the California Institute of Technology is to expand human knowledge and benefit society through research integrated with education. We investigate the most challenging, fundamental problems in science and technology in a singularly collegial, interdisciplinary atmosphere, while educating outstanding students to become creative members of society.*
>
> And:
>
> ***Research Priorities***
>
> *Caltech researchers are known for scientific inquiry that is bold and innovative and impacts society. Our investigators pursue high-risk, high-reward research to advance technology, theory, and both fundamental and applied science. The Institute's many cross-disciplinary research centers and institutes support the kind of collaboration that develops powerful ideas and addresses global challenges.*

So much has been captured in these short, dense statements. Caltech will focus on very big problems. Its work will span the gamut from theory-informing science to socially impactful technology and applications. It will pull together large collections of people, from many disciplines and perspectives, who will be mutually respectful and focused on the problems at hand. And as it does its work it will engage its students in the most intellectually challenging problems of the day. Note that while the word "entrepreneurship" does not appear in either the mission statement or research priorities, both focus on the uses of technology and science (whether fundamental or applied) to solve global problems and serve humanity.

How Caltech works, and how its goals and aspirations play out is illustrated by looking closely at the six substantive research priorities that define the work agenda:

- *Energy*. Per the Caltech website, "more than 20 Caltech faculty members lead energy-focused collaborations that leverage the Institute's programs in engineering, chemistry, chemical engineering, physics, nanotechnology and information science." The energy portfolio encompasses generation, storage, transmission, and conservation.

- *Earth and Environment*. "More than three dozen Caltech faculty members" execute a portfolio of research that includes Earth's origin and evolution, global climate, atmospheric chemistry and physics, seismology, and instrumentation. Much of this work also involves the Jet Propulsion Laboratory (JPL), a NASA-funded research and development laboratory that is operated by Caltech, and involves collaboration with the U.S. Geological Survey.

- *Medical Science*. Over 50 faculty members and research scholars are involved in a wide-ranging program of R&D that is focused on new materials and devices intended to transform medicine. The research portfolio includes diagnostics and devices, molecular machines, microbiology, neuroscience, systems, and synthetic biology.

- *Information Science*. About 70 professors are involved in this priority area that is "revolutionizing information technology by discovering the fundamental mathematics and physics of information systems and processes."

- *Advanced Materials and Nanoscience*. A number of Caltech researchers are developing "novel materials and devices with superior properties." The problem domains include health and medicine, electronics, energy, quantum information science, and materials optimization.

- *The Universe***.** This area involves over 80 Caltech investigators, including scientists at JPL, plus a number of collaborating scientists at NASA, the University of California system, the U.S. Geological Survey, the European Space Agency, and several other universities that are prominent in this area. This focus on expanding our understanding of the universe includes emphases on the cosmos, the quantum universe, galaxies, stars, black holes, and planets.

While these six Research Priority areas represent compelling questions and problems at the frontiers of human understanding, it should be re-emphasized that Caltech's goals and aspirations are all about talented people finding innovative solutions as well. This seems to be happening on several levels at Caltech.

For example, in the Energy area alone: a National Medical of Science winner is leading an increasingly successful search for nontoxic catalysts for splitting water using sunlight; a Draper Prize winner has invented a process to evolve enzymes for the production of biofuels; a Nobel laureate has invented a catalyst to enable the production of high-performance resins for wind turbines; a MacArthur fellow is utilizing novel applications of fluid dynamics to increase the power harvest of wind turbines; an Eni Award winner has led the improvement of an ultrathin solar cell that significantly improves light absorption. Comparable exemplary individual accomplishments exist in each of the other five Research Priority Areas.

Given the individual accomplishments in research and application outcomes it should not be too surprising that there are comparable levels of excellence in all aspects of research, including securing resources to perform the work. It was noted above that, on average, Caltech faculty members are receiving more research funding from all sources than are their counterparts at other institutions. Exploring this a bit more, we looked at the mix of research funding sources. As per NSF data, in FY2011 Caltech reported $377.1 million in research expenditures, and of this 90.8% came from the Federal government, with 4.4% coming from nonprofit organizations, and a very modest 2.1% of the total from business.

Looking more closely at data on Federal funding at Caltech[4] we can derive additional conclusions. Two Federal agencies account for the over $165 million of total contract and grant funding: the National Science Foundation ($100.2 million) and the National Institutes of Health ($65 million). The Department of Energy and NASA are tied for third at $37 million each. So how does the goal of research excellence break out in terms of Caltech versus the rest of the university community? In teams of the "batting average" for NSF proposals submitted over Fiscal Years 2004-2010 Caltech's hit rate is 10.7%, which is higher than the average for all other universities; the comparable hit rate advantage for NIH proposals is 8.7%, which is again higher than the average of all other schools. The Division at Caltech that accounts for the largest share of proposals (and hits) is Physics, Math and Astronomy.

Before leaving the research proposal and award topic, it is useful to point out that compared to most of the other case examples in this volume, Caltech is lower in the percentage of research funded by companies. It may be that the Caltech model of industry funding is more along the corporate gift or "partnership" model, rather than the "portfolio of contract research" approach, or the multi-partner center model, such as the NSF Industry-University Cooperative Research Center approach. If that is the case, those monies might be assigned to the Nonprofit funding source in the NSF tables. In 2011 Caltech named an Assistant Vice President for Institute Corporate Relations, and later on announced a $10 million gift from Dow, mostly dedicated to graduate student support as well as funds for the Resnick Sustainability Institute.

To close this section on Goals and Aspirations, here are excerpted comments from Ares J. Rosakis, (Division Chair of Engineering Applied Science) on what Caltech is all about.[5] The bolded sections are emphases from Professor Rosakis not from the authors of this chapter:

> *...I encourage you to think about the Engineering and Applied Science (EAS) Division and Caltech's greatest*

> *achievement—**the creation of new schools of thought**. These schools of thought reflect our combined achievements and excellence in both research and education.*

And more:

> *First, by design, we don't cover all areas of engineering and applied science. We dynamically choose only the ones that we consider the most important, and we are ready to retire the ones that are not intellectually stimulating. Our faculty do not represent a continuum of research interests and specialties. We are in the words of my old Caltech mentors, Professors Jim Knowles and Eli Sternberg, **a collection of isolated singularities**. However, in order for these isolated areas of excellence to be effective, the second principle has to be introduced. This principle dictates that the barriers between disciplines, departments and even divisions remains very low so that both faculty and students can cross them, if they wish, without spending unnecessary energy. This is a principle that is also shared throughout the Institute and necessitates the existence of a truly interdisciplinary culture in which turf and labels become secondary to intellectual exchange. Other major engineering schools speak of the value of interdisciplinary research; our difference is that we have practiced it since our founding over 100 years ago.*

Leadership

Many individuals currently in positions of authority throughout the Institute enable the Caltech culture, goals, and aspirations described in the previous section. As described below, for a faculty that numbers less than 300 there are a surprising number of leadership venues, particularly the centers and institutes that are perhaps the primary vehicle for executing the Caltech vision. In addition, while this is a case description of the current Caltech, amazing visionary leaders that stayed long and did much have blessed the Institute throughout its history. Jean-Lou Chameau, the current President, was preceded by David Baltimore, a Nobel Laureate, and a long line of chief executives who added to the vision of scientific excellence tied to real-world importance that began with Robert Millikan, who served as Chair of the Executive Council (equivalent to president) from 1921 to 1945. Millikan (also a Nobel Prize winner) was perhaps the primary shaper of the legacy handed down to President Chameau.

Jean-Lou Chameau became Caltech's president on September 1, 2006, and he has benefited from strong leadership mentors as well as the organizational cultures of prior postings. For example, while finishing his PhD at Stanford, Dr. Chameau co-authored a journal article[6] with a Stanford professor, Wayne Clough, who within two years was on his way to Virginia Tech, where he moved from professor to dean within a decade, and then was a very successful Georgia Tech president (as described in the Georgia Tech case in this volume).

There are also many examples of Dr. Chameau's early talents in leadership. After Stanford he was a faculty member in civil engineering at Purdue, where he was asked to lead a very talented but apparently irascible group of faculty members and enable them to pull together.

As described by Chameau in a LA Times article:[7]

> *When I finished my PhD at Stanford, I took a position at Purdue, in a very good research program. I was in a research group of very senior faculty members, very good in their field, but they could not get along. One day, the department chair said, 'You know, your colleagues – I'm tired of them. They're like children. There's only one thing they agree upon, and that is that they seem to be able to work with you. I'm making you in charge of the group.' Since I was still young and foolish and didn't know better, I agreed to it. That's the beginning of this career in administration. I enjoy doing my own work, but also realized that I am more and more rewarded personally by seeing the successes of others.*

And so it went from there. Chameau ended up heading the Geotechnical Engineering program at Purdue, and in 1991 was asked to lead the School of Civil and Environmental Engineering at Georgia Tech, where later on he re-united with Wayne Clough, who became President in 1994. In 1995, after a stint as president of a geotechnical consulting company, he was named a Georgia Research Alliance (GRA) Eminent Scholar. The GRA endowed chairs are dedicated to individuals who have carved out careers that metaphorically have one foot in early-stage science and another in "real world" applications. In 1997 Chameau was named Dean of the College of Engineering at Georgia Tech, one of the largest in the country, before becoming Provost in 2001. Throughout his career at Georgia Tech he significantly emphasized the linkages between science and applications via enhancements in policy, program and mindset.

It should also be mentioned that Stanford, Purdue and Georgia Tech were selected by two independent panels for inclusion as exemplary cases in the 2002 predecessor[8] to this volume, as well as in this volume. Dr. Chameau spent large portions of his career at all three institutions. A strongly held assumptionof this book is that the prevailing cultures and values of universities cling to the mindsets of attentive people who pass through.

So how does the leadership philosophy of an engaging, arguably brilliant and visionary president like Dr. Chameau get expressed substantively at Caltech? One useful example of that mindset was expressed in a co-authored article by him on "the transformative impact of fundamental scientific research."[9] The basic point of view is that Caltech's pursuit of large, high-risk and complex basic science problems has the most potential to make the most significant differences in solving real-world problems. The argument assumes a technology transfer and commercialization function that has "trusting, collaborative relationships with the scientists" and that there is a "natural give and take between basic and applied research" as well as strong linkages to undergraduate and graduate education. It also cites the work of the late Donald Stokes[10] who argued for "Pasteur's quadrant" and "use-inspired" basic research and bringing together the world of science and the world of applications. As are a lot of things at Caltech these concepts are often better understood by example.

Boundary Spanning: *Entrepreneurship*

Technology entrepreneurship, which requires a diverse range of skills (organizational, financial, management, marketing, product design and development, for example) as well as deep technical expertise, can be considered a quintessential boundary-spanning phenomenon. Nonetheless, university entrepreneurship programs are frequently centralized, usually within a business school. One of the more interesting and noteworthy characteristics of Caltech is the extraordinary level of student entrepreneurship that occurs in spite of not having a business school. Caltech alumni have started an estimated 400 companies, according to statistics published by the student entrepreneur club. With no entrepreneurship silo in the form of a major or department at Caltech, student entrepreneurship seems to live anywhere and everywhere on campus, arising organically from within the six global challenge areas and permeating Options and Divisions.

Curricular Programs

Academic majors at Caltech are known as Options and there are roughly two dozen to choose from, with some specialized sub-choices within options that expand the menu. Students must choose an Option by the end of their freshman year. While there is no Entrepreneurship Option at Caltech, students can avail themselves of a sequence of three entrepreneurship courses within the Business Economics and Management Option of the Humanities and Social Sciences Division. These courses arose from a single engineering class taught in the 1990s (E102) by John Baldeschwieler, a very distinguished chemist (National Medal of Science winner) who also holds the informal Caltech record for leading the most startup companies. Dr. Baldeschwieler also is a convincing witness in his oral history for the dramatic cultural changes at Caltech over his long career[11] that have enabled Caltech to be a more entrepreneurial place. In his view, as the post Bayh-Dole period played itself out, and as industry research labs disappeared and scientific posts became harder to find in academia and the private sector, more and more graduate students, post-docs, and occasional undergraduates began to pursue careers based on technology start-ups.

The course that Professor Baldeschwieler pioneered has been picked up and expanded into a three-course group by Professor Ken Pickard,[12] that now incudes: E102 *Entrepreneurial Development*; E/ME 105 *Engineering Design of Products for the Developing World*; and E/ME 103 *Management of Technology*. Development support has also come from the NSF Partnerships for Innovation Program. That program provided fellowship support for participants from Caltech, USC, UCLA, and the Art Center to work together in teams to commercialize promising technologies coming out of all four institutions. While that program ended, the curriculum that was developed, lessons learned (such as the value of mentors), and the inter-campus partnerships survive to support today's entrepreneurship offerings. Today all three courses are team-based and assume deliverables that are analytically dense and rely heavily on interactions with "real world" people as well as readings. E102 assesses the viability of yet-to-be commercialized Caltech technologies and students build a business case around them which could lead to a viable company. E/ME 103 is designed for students considering working in technology companies, startups, or interested in going to business school. Student teams either assess a technology or technology field or perform an innovative capabilities consulting audit for an existing technology company. The early partnership with the Art Center in Pasadena evolved into E/ME 105, which teams Art Center design students with Caltech students on location in a third-world country (frequently India, as many of the participating students are of Indian descent). The students travel to the host country, observe and experience the needs of the community, and then return to school with ideas, designs, and new solutions and technologies to address these needs.

While these three course offerings provide a formal introduction to entrepreneurship, for the most part learning about entrepreneurship happens naturally as students' book knowledge and experiential learning grows over their individual courses of study. In virtually every class there is the expectation and opportunity for hard-nosed research projects, which have a way of morphing into something that has a glimmer of commercial potential. Stories abound at Caltech of research groups working on a wide range of experimental and theoretical research projects and spinning out new companies, as faculty and graduate students build new applications leveraged off earlier discoveries.

Co-Curricular Programs

In addition to coursework and formal opportunities, a number of mostly student-run programs and activities have filled the role of entrepreneurship education and information sharing at Caltech. The Caltech Entrepreneurship Club (http://caltecheclub.tumblr.com/) modestly "aims to provide aspiring Caltech entrepreneurs with the knowledge and connections to help launch the companies of the future." A large part of its approach involves introducing aspiring entrepreneurs to the regional network of supportive infrastructure in which Caltech is embedded. This includes partnerships with Caltech's Office of Technology Transfer, Idealab, the Pasadena Angels, SoCalBio, TechZulu, LARTA, both USC and UCLA business schools, and other groups fostering entrepreneurship in the region. Entrepreneurship Club activities include:

- Business plan competitions
- Field trips such as to Silicon Valley and San Diego
- Entrepreneurship boot camps
- Entrepreneurship Seminar Series
- Networking events, including the large network of Caltech alumni entrepreneurs

One organization that has been particularly visible and helpful is Pasadena Entretec, founded as a member-based organization in 2000, which offers networking events, training workshops, and leads to financing and connectivity among a membership of 275 companies, units of governments and higher education institutions. Enabling the recruitment of talent for startups is a primary focus of its "in the trenches" work. Its primary geographic focus is the Pasadena area, which makes it a significant partner of Caltech and JPL.

One program that has probably received the most national play recently, because of its support by the National Science Foundation, has been the Innovation Corps training program originally developed and co-taught by Silicon Valley veterans Steve Blank and Jon Fieber. It involves an intensive 5-day Lean Launch Pad boot camp offering at NSF-sponsored institutions. Thanks to the efforts of the Caltech Entrepreneurship Club and its faculty advisors, Lean Launch Pad is being offered on campus. A more traditional, but equally important, kind of offering by the Club has been a series of lectures labeled *Startup Law 101* and offered by DLA Piper, a prominent law firm that has a significant business presence in entrepreneurship. Another club activity this year was a field trip to *Space X*, the space travel startup, for a tour and a discussion with Elon Musk, founder of *Space X* (also co-founder of PayPal and Tesla Motors, and Chairman of SolarCity).

One interesting thing about the Caltech Entrepreneurship Club is the composition of the officers, which consists of undergrads as well as a healthy percentage of doctoral candidates and post-docs. This suggests that entrepreneurship as a career path is much more on the short list of options for this cohort at Caltech, perhaps more so than at other institutions (echoing Dr. Baldeschwieler's comments from ten years ago).

Extra-Curricular Programs

The Caltech/MIT Enterprise Forum is part of a national network of events, modeled after ones pioneered by the MIT Alumni Association in Cambridge and New York in the 1970s. The Forum is co-sponsored by the Caltech Industrial Relations Center and the alumni associations of Caltech and MIT. It is a monthly event during the academic year, typically involving a panel of speakers, networking and often food. Topics include entrepreneurial issues, such as finance, marketing, and business planning, discussed by experts and practitioners. Companies are featured and new opportunities in life sciences, entertainment, medicine, energy, IT, and tapping into global markets are identified.

The Forum is currently under the leadership of a Founding Executive Director of Pasadena Entretec, and operates an ambitious agenda of events. In addition to providing practical support for local entrepreneurs both in and out of academia, it brings connections to UCLA, USC, and business leaders across greater Los Angeles.

Another example of Caltech's regional boundary-spanning efforts in entrepreneurship is a three-year project, First Look West (FLoW), supported by a U.S. Department of Energy grant secured by the Resnick Institute, in partnership with USC and UCLA. FLoW builds on an existing five-year business plan competition organized by the three southern California technology-intensive universities, and others in the western region, in an effort to produce clean technology businesses. Specifically, the funds will support student groups, including Caltech's Entrepreneurship Club and Engineers for a Sustainable World, in their efforts to start new businesses around green energy technologies. The program culminates annually with a western region student business plan competition (seven western states and two Pacific territories) focused on clean energy solutions, with winners awarded cash prizes and a chance to compete for a National Grand Prize. The initial competition, held in the spring of 2012, drew 100 student teams from 34 universities in 12 states.

An illustration of how the different parts of the entrepreneurial infrastructure, and individuals of disparate disciplines and levels of training, can come together was recently described on the Caltech website that features Campus Life and News.[13] The story, *How to Grow an Entrepreneur*, opens with two students participating in a Caltech class project that involved building a house to compete in the 2011 Department of Energy Solar Decathlon. Their contribution was an iPad-based energy control app that seemed to pique the interest of people who toured the house. The two inventors concluded that there was a need and potential market for "active monitoring" of energy use in a home. One of the students had served as President of the Caltech Entrepreneurship Club, and the two original inventors expanded their team with recruits from the Club and made further technical improvements to the technology. They then competed in FLoW (above) and although they didn't win, they got many suggestions on how to sharpen the technology and the business model. From that experience, they then participated in the Lean LaunchPad (above) five-day boot camp, and received significant feedback from potential customers and partners. As a follow-up the team is now working with several Caltech faculty members who are providing technical advice about the app, significantly enhanced by testing it in their own homes. The most recent step was admission to the Los Angeles CleanTech Incubator, with office space, wireless, ongoing coaching, and the benefits of comparing notes with other tenants of the incubator. There seem to be many stories like this at Caltech.

Finally, it's worth noting the expanded role of other Caltech organizations in promoting and supporting entrepreneurship education in a university with no business school. Caltech librarians, for example, take an active role, lecturing in classes and speaking at student club events. The library offers a Business Resources workshop in researching businesses and industries, conducting market research with business databases, business planning and business resources for engineers.[14] One of its workshops, on the patenting process, is conducted by members of the staff of the Office of Technology Transfer (OTT). Unlike many universities, the OTT is robust enough to critique and support student patenting and business plan development, as well as faculty invention. Even more significant, the OTT's Grubstake program, a fund raised by university alumni, allows student teams as well as faculty to apply for an award of $50,000 to support a promising startup. (More about this program below).

Boundary Spanning: *University, Industry and Community*

Each of the six Priority Areas of research mentioned above has a range of boundary-spanning structures and processes, labeled by Caltech as Research Centers and Partnerships. Sometimes they involve industry relationships, sometimes they involve other major R&D performers, sometimes they involve connections to major government research agencies and uniformly, given the culture of the university, they involve participation of faculty, graduate students, and post-docs from across the university. We will not describe each, but will attempt to focus on those that seem to have more participation and support. For purposes of continuity, this section will parallel the order of Priority Areas as above:

- *The Joint Center for Artificial Photosynthesis.* This is a Department of Energy Hub, that is budgeted for $122 million over five years, involves over 120 scientists and engineers, and includes Lawrence Berkeley National Lab as a lead partner, as well as working relationships with Stanford, UC Berkeley, UC Santa Barbara, UC Irvine, UC San Diego and the Stanford Linear Accelerator. The Joint Center also serves as a hub for other DOE research teams across the US. The program leverages recent advances in chemistry, materials, and nanotechnology.

- *Light-Material Interactions in Energy Conversion.* This is a DOE Energy Frontier Research Center, which involves scientific collaboration with Lawrence Berkeley National Laboratory, and the University of Illinois at Urbana-Champaign. The Center is “creating new methods and architectures for complex photonic materials for solar energy conversion”. The vision is to enable “light conversion to electrical and chemical energy with unprecedented efficiency.”

- *Powering the Planet Center for Chemical Innovation.* This is supported under the NSF Center for Chemical Innovation Program, and focuses on the production of fuel from sunlight, with emphases in oxidation catalysts, reduction catalysts and solar capture and charge separation. There are several university partners including: Wisconsin, MIT, Penn State, Wisconsin and Texas A&M.

- *Center for Bioinspired Wind Energy.* In the rich tradition of Caltech science going in the direction where ingenuity takes it, this center seems to have morphed into a component of a parent Center for Bioinspired Engineering. Nonetheless, in the wind area work is underway on more efficient designs of vertical-axis wind turbines and wind farms, partially inspired by the spatial arrangements of schooling fish. Related work proceeds on flow control systems and bio-inspired propulsion that mimic the shape and kinematics of flying and swimming animals. This is a great example of how the interdisciplinary culture of Caltech enables the leapfrogging of concepts and findings across research problems.

- *The Ronald and Maxine Linde Center for Global Environmental Science.* Founded in 2008, the Center’s research is wide-ranging in terms of problems, methods, and settings, but all are addressing questions of past and future global climate change. Examples include: measuring the isotopic composition of iron in the ocean to explore its impacts on marine plants; measuring, via satellite, movements and height changes of ice sheets to potentially predict eventual ice loss; studying lignocellulose degradation by termite gut microbiota; and winning the Reinventing the Toilet Challenge issued by the Bill and Melinda Gates Foundation.

- *Terrestrial Hazard Observation and Reporting (THOR).* Launched in 2010 via two major gifts, the THOR mission is to study, in an interdisciplinary approach, how to anticipate, prepare for, and address large-scale natural hazards. This includes floods, wildfires, earthquakes, and extreme weather. Current lines of work include the Caltech Virtual Shaker, which will be a gateway to a global database of building and bridge models, plus a capacity to analyze their performance under earthquake shaking via a high-performance computing cluster (HPCC).

- *Seismological Laboratory/Southern California Seismic Network (SCSN)/Community Seismic Network.* These facilities and research activities encompass Caltech’s longstanding, since the 1920s, work in geophysical phenomena tied to community earthquake information. Research foci include: earthquake early warning, engineering seismology, geodynamics, and earth structure. Work by SCSN in monitoring earthquakes in Southern California involves a close partnership with the U.S. Geological Survey, as well as working relationships with several University of California campuses, the National Science Foundation and FEMA. The Community Seismic Network (CSN) is an ongoing effort to provide 1,000 community volunteers with in-home sensors, and thereby to enable creation of denser block-by-block Shake Maps.

- *Tectonics Observatory (TO).* Founded a decade ago via a private grant, the TO has been involved in a multidisciplinary program of research addressing the question of how and why the earth's crust and lithosphere are deforming over timescales ranging from seconds to millions of years. Research involves both laboratory science as well as field data gathering across the world; projects typically involve collaboration with researchers from other institutions.

- *Beckman Institute.* Endowed in the 1980s by the aforementioned Arnold Beckman, the Beckman Institute (BI) mission is "to invent methods, instrumentation and materials that will open new avenues for fundamental research in the chemical and biological sciences, and to provide technological support for these activities." It is particularly focused on "early development of research thrusts too innovative or too 'high-risk' for the regular sources of research support…" Organizationally, the BI operates across the Divisions of Caltech as a research facility and research-enabling organization. There are three major programs in the BI: five Facilities that provide instrumentation and methodologies across the campus, including within the BI; the Pilot Program, which accepts proposals annually for study projects (1-3 years, up to $200K annually); and nine Resource Centers that carry out research, develop new methods, instrumentation and materials, and maintain and operate facilities.

- *Annenberg Center for Information Science and Technology.* This initiative is an investment in facilities as well as an intellectual framework that will guide work among individuals in several associated disciplines. In 2009 the Walter and Leonore Annenberg Center for Information Science and Technology was opened. Comments from the Chair of the Engineering and Applied Science Division framed the mission:

  > *We have gathered people from computer science, physics, biology and bioengineering, economics, applied mathematics, computation and neural systems, applied physics, control and dynamical systems, and electrical engineering to think together about the fundamental theoretical underpinnings of information as well as it practical applications…*

- *Kavli Nanoscience Institute (KNI).* The Institute is fostering cross-disciplinary collaborative research in nanoscience, with emphases in nanobiotechnology, nanophotonics, and large-scale integration of nanosystems. Its core research staff of over two dozen draws from physics, materials science, applied physics, electrical engineering, aeronautics, biology, geobiology, chemistry, mechanical engineering, bioinspired engineering, computational mathematics, information science, and technology. Recently reported accomplishments include the development of microscale accelerometers and the creation of a mechanical device that can measure the mass of a single molecule.

- *Materials and Process Simulation Center (MSC).* The MSC is one of the more long-lived centers or institutes at Caltech, as well as one with the most continuity in leadership, and a distinctive model of sponsorship and agenda-setting. The Director, William Goddard, is a Professor of Chemistry, Materials Science and Applied Physics. The objectives of the MSC are:

  > *To develop methods required for first*

principles multiscale multi-paradigm based predictions of the structures and properties of proteins, DNA, polymers, ceramics, metal alloys, semiconductors, organometallics and to apply these methods to design new materials for pharma, catalysis, microelectronics, nanotechnology, and superconductors.

In contrast to many other centers at Caltech, the MSC has been supported primarily by industry funding. At any given time, upwards of 10-12 industrial companies have supported the center, along with various R&D groups within the federal government that have a particular interest and mission in technology transfer. The Beckman Institute also provides logistical and some financial support for the MSC. Two levels of industrial participation have been used. Corporate Associates of the Center ($35K annually) attend an annual MSC workshop, receive reports and reprints of publications, and establish contacts with graduate students. Corporate Participants will directly fund (or co-fund) one or two specific projects ($120-200K per year), and have a much more extensive working relationship with the postdocs, MSC scientists, and MSC Corporate Advisory Board. Various approaches to proactive technology transfer are built into MSC operations

- *Caltech and JPL.* Caltech and the Jet Propulsion Laboratory have what might be described as a separate-but-together relationship. JPL is a division of Caltech, was founded with Caltech scientists, but is a NASA-funded facility, primarily focused on space exploration and related research and development. There are joint appointments that tie the two organizations together and over 200 collaborative projects have been conducted. Substantive collaboration is conducted through five NASA facilities at Caltech: the *Infrared Processing and Analysis Center*; the *NASA Exoplanet Science Institute*; the *Spitzer Space Telescope Science Center*; the *NASA Herschel Science Center*; and the *Galaxy Evolution Explorer Science Science Center*. The extent to which these relationships have resulted in technological innovations with commercial applications is unclear.

One factor that is unclear from this discussion of various centers and institutes (plus others that were not discussed) is the modalities of direct private-sector participation. One, the *Materials and Process Simulation Center (MSC)*, seemed to have significant financial and substantive involvement on the part of private industry, although many others have considerable substantive involvement. This pattern of engagement contrasts with many of the cases in this volume. There are several possible explanations for this history. One might be the disciplinary mix of Caltech, particularly the prominence of some disciplines that have limited traditions of engagement with business. Other reasons might be the extensive focus on—and startling success in—theory-driven fundamental science. Universities differ on this for many reasons. Nonetheless, Caltech has been very successful in moving science-based innovation into the world via technology transfer, as per the next section.

Boundary Spanning: *Technology Transfer*

As noted in the introductory section of this case, Caltech has a commendable record in terms of research funding per faculty member. Its batting average in terms of various technology transfer indicators is equally excellent. Illustratively, based on FY 2012 AUTM statistics,[15] the Office of Technology Transfer (OTT) worked with some fraction of the 300 Caltech faculty members and 600 research scholars, to execute 37 licenses or options, 136 issued patents, 588 patent applications, 343 invention disclosures, and 7 startups. No other major university can claim that level of productivity per faculty headcount. If one looks at similar indicators, albeit computed per unit of research expenditures, the normalized statistics are equally impressive when compared to other universities. How does this happen, particularly when one realizes that Caltech did not have a technology transfer office until 1995, well past the founding bubble of new technology transfer offices that followed the passing of Bayh-Dole in 1980?

One answer can be found in all the cultural and leadership factors described above. Caltech is a university that does cutting-edge, basic science but also with an eye to solving the big problems that confront society. Its history, particularly its more recent history, and its leadership have reinforced this mindset. It has also led to a technology transfer organization that has amiable and mutually supporting relationships with faculty and students. An important operating principle seems to be spending a lot of time with inventors, working closely with them throughout the technology transfer process, and trying to maximize the commercialization potential of their research.

A second answer can be found in the staffing of OTT, which is technically deep and very experienced. The Licensing Team is composed of eight professionals, and the Administrative Team consists of seven individuals. Of note, Larry Gilbert is a Senior Director on the Licensing Team, and has the distinction of being a founder, over 30 years ago, of what is now the Association of University Technology Managers (AUTM). He came to Caltech from MIT. Fred Farina is the Chief Innovation Officer at Caltech and the Executive Director of OTT. Previously he worked as a research engineer in the GPS field and as a patent officer in industry. He is a Caltech graduate, with an MS in Electrical Engineering. The rest of the licensing team has similar backgrounds of formal certification and private-sector experience.

The OTT will work with faculty inventors to orchestrate a licensing relationship with an established larger company, when the nature of the invention and relevant markets suggest this is the best strategy; there is a parallel and strongly preferred path to technology transfer where the entity taking the invention to market is a start-up company. When working with an established company the typical outcome is a license agreement that compensates Caltech for patenting expenses accrued in developing the intellectual property, plus royalties and other fees based on some formula mutually agreed upon. The licensing agreement will also preserve publishing rights for the faculty inventor, and specify various commercialization milestones. Examples cited by OTT include "licensing the automated DNA sequencer to Applied Biosystems and the JPL MEMS gyroscope to Boeing Hughes."

However, there is a strong impetus both within OTT and among Caltech faculty inventors to take an entrepreneurial approach to commercialization. Here the typical transaction vehicle will be an option (usually 12 months) with the startup, specifying milestones such as raising development funds sufficient to last up to two years, a modest option fee, moderate equity for Caltech, significant equity for the inventor(s), technology development milestones, and the like. This kind of arrangement can take some time to play itself out and OTT staff will articulate a road map for the faculty inventor. Caltech has had equity in over 80 startup companies since 1995 when OTT was founded. As an excellent culture building practice one can peruse thumbnail descriptions of these startups on the OTT website, and see how they have blossomed. One of the descriptors is "current status" and for many of the spinoff companies there will be a "Acquired by XYZ Company" note. An operating premise of the OTT focus on startups is that a "reasonable success rate over a 10-year period will add $50 million to the Caltech general funds." OTT describes its program strategy as enabling "two bites of the apple." That is, enable startups that allow faculty inventors to acquire significant equity and downstream payouts, and then assume that many of them will make significant turnaround donations to Caltech.

One activity that is being executed by OTT to facilitate inventors developing an idea is the Technology Transfer Grubstake Program. This is an endowed fund to provide grants of "about $50,000" to better support faculty and student entrepreneurs/ licensees in their efforts to move an idea along the path to viable commercialization. Proposal guidelines include:

1. *Be brief.*

2. *Be specific.*

3. *Identify and describe a specific problem in need of a better solution (s). Does the solution have application to the problem in general?*

4. *Describe what you have done to date that relates to a possible solution to the problem.*

5. *What are the present commercial techniques for solving the problem?*

6. *Describe a plan or protocol for solving the problem that is target-specific.*

Summary and Parting Comments

The Caltech case is an example of a small, elite university that has leveraged its distinguished history of basic science excellence into a campus-wide innovation culture that is having huge impacts on regional economies as well as commensurate impacts on some of the largest problems confronting American society. In 1993, while chairman of the board at Intel, Gordon E. Moore said, in a talk at Caltech:

> *Most of what I learned as an entrepreneur was by trial and error but I think a lot of this really could have been learned more efficiently. At a place like Caltech, broadening the curriculum to include some instruction in business...would certainly be useful....But a technical education is probably the best start for an entrepreneur in a high-tech business. Don't change the basis of what you do well. For Caltech, what it does well is train the best scientists and engineers in the world. My advice to Caltech is this: help students a bit if they want to move in entrepreneurial directions, but don't change the basic nature of a Caltech education.*

Perhaps one secret to Caltech's success is that it has taken the above advice of one of its most famous alumni. They still don't have a business school. But they have broadened their curricula to include some business entrepreneurship instruction, and they have enrolled their sizable and diverse institutional resources in the cause of creating an entrepreneurial culture and ecosystem, but one aligned with their mission of discovery. As a result, entrepreneurship is organic at Caltech. It naturally spans boundaries, perhaps because there is no business school. Recall that this operational approach fits perfectly with the Engineering and Applied Science Division Chair's observation that innovation requires "the barriers between disciplines, departments, and even divisions remains very low so that both faculty and students can cross them if they wish." The interdisciplinary culture at Caltech "necessitates that turf and labels become secondary to intellectual exchange."

This offers the intriguing possibility that the placement of a boundary-spanning discipline (entrepreneurship) within a business school silo may actually inhibit technology entrepreneurship, especially to the degree that turf issues prevent the collegial interaction of the entrepreneurship students with the technical science and engineering students and faculty. Many current thinkers in entrepreneurship (including the Kauffman Campuses Program) suggest that technology E-ed is best centered outside of business schools. Recent research suggests that while business skills indirectly support entrepreneurial creation (startups, new products/services), the greater impact comes from supportive entrepreneurial networks and ecosystems. It may be easier to teach business skills to scientists and engineers than it is to teach science and engineering to business students. Universities that integrate entrepreneurship into technical schools may see improved entrepreneurial production over those attempting to integrate science and engineering into business schools.

The Caltech experience is also an interesting story of important shifts in the organizational culture and mindset of an institution; Caltech of today is different from the Caltech of the 1980s. In fact, the Caltech of that era was somewhat of a laggard in getting involved in the technology transfer activities enabled by Bayh-Dole, much less than the growth of the faculty and student culture of entrepreneurship of the last decade or so. Nonetheless, there is no doubt that Caltech is now a leader in all the organizational, leadership, and cultural ingredients necessary to address innovation, entrepreneurship, as well as the grand challenges of science.

Endnotes

[1] Moore, G. E. (1994). The Accidental Entrepreneur. *Engineering and Science, Summer.*

[2] These are from *At a Glance*, based on the 2010-2011 academic year at Caltech.

[3] National Science Foundation, National Center for Science and Engineering Statistics, FY2011. *Table 14. Higher education R&D expenditures, ranked by all R&D expenditures, by source of funds: FY2011. Table 15. Higher education R&D expenditures, ranked by all R&D expenditures, by R&D field: FY2011.*

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[11] Baldeschwieler, J. (2003) John Baldeschwieler Interview by Shirley K. Cohen. Pasadena, California, January-February, 2001. Oral History Project, California Institute of Technology Archives.

[12] As this case was being written, all three classes are being taught by Ken Pickard, Visiting Professor of Mechanical Engineering, who has a PhD in Physics from the University of Pennsylvania, and an extensive corporate and entrepreneurship background. He has been affiliated with Caltech for over 12 years.

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[14] Ramachandran, H., Toot, L. and Smith, C. (2002). Developing E-Business Information Without a Business School. White paper presented at Special Libraries Association (SLA) 2002 Conference.

[15] Association of University Technology Managers. (2013). *AUTM U.S. Licensing Activity Survey: FY2012.* Deerfield, IL: Association of University Technology Managers.

Carnegie Mellon University*

Carnegie Mellon University (CMU) is a small private university of 12,000 students (half undergraduates, half graduate students) and 1,400 faculty that is located in Pittsburgh, Pennsylvania. The University began as the Carnegie Technical Schools in 1900 with a $1 million donation made by industrialist and philanthropist Andrew Carnegie. Carnegie, a self-described "working boy," emigrated from Scotland with his family in 1848, settling near Pittsburgh. He was self-educated, yet nonetheless became the entrepreneur who founded what became US Steel, the world's largest producer of steel by the end of the nineteenth century. Perhaps because of his modest roots, Carnegie was not interested in supporting the nation's most esteemed universities, which he felt were already "large enough" and too purely academic in focus. The need, as he saw it, was to create technical institutes to provide a more practical education to local workers in the "crafts and scientific vocations so as to produce skilled workmen, such as machinists, mechanics, decorators, and so on."[1]

In 1908 Carnegie increased his endowment of Carnegie Tech to $8 million and in 1912 the renamed Carnegie Institute of Technology granted its first 4-year degree. The Institute merged with the Mellon Institute of Industrial Research in 1967 to become Carnegie Mellon University. CMU is made up of seven colleges and schools: Carnegie Institute of Technology, College of Fine Arts, Dietrich College of Humanities and Social Sciences, Tepper School of Business, H. John Heinz III College, Mellon College of Science, and the School of Computer Science. Interestingly, in addition to the Pittsburgh campus, CMU has offered since 2002 graduate programs in computer engineering and software systems in Silicon Valley, enrolling about 200 MS and PhD students. Many of the enrollees are from the ranks of CMU alumni working in the area. A similar program is being launched in Rwanda, starting in 2014.

A variety of national rankings attest to the quality of CMU's programs. *Times Higher Education of London* ranked CMU 22nd in the world and 15th in the US in 2012. In 2010, according to a Wall Street poll of job recruiters, CMU was ranked 1st in computer science, 4th in finance, 7th in business and 10th overall. Reflecting its excellence in the arts, the *Hollywood Reporter* rated the CMU School of Drama 4th in the world. CMU was one of 25 universities in the world invited by the World Economic Forum to join its Global University Leaders Forum. It has consistently placed highly in the *U.S. News & World Report* university rankings. Computer science, computer engineering, and business programs are considered among national leaders, as are its programs in art, design, and associated disciplines. CMU is also

** This case was written by Elaine Rideout and Louis Tornatzky.*

known for its strengths in interdisciplinary and multidisciplinary education and scholarship.

CMU's ratings are also matched by more objective indicators of its science and technology accomplishments. Per National Science Foundation FY2011 data,[2] CMU's total research expenditures were $242.8 million, ranking 84th. Not surprising, 82.7% was from Federal government sources, but a respectable 7.3% came from Business. In terms of R&D fields, the strengths of CMU are apparent, with the total of Math and Computer Sciences ($98.9 million), and Engineering ($93.5 million) accounting for 79.2% of all R&D. Life Sciences accounted for another 6.3% and Physical Sciences 4.9%. Interestingly, Psychology was a shade below the Physical Sciences at 4.0%, likely reflecting the role of cognitive science in software development and expert systems.

CMU is located in the Oakland section of Pittsburgh. Pittsburgh itself had a population of 305,704 per the 2010 census, while the Metropolitan Statistical Area (MSA) that includes several contiguous Pennsylvania counties, plus two West Virginia counties and one Ohio county, had a 2012 population of 2,360,733. The industrial heyday of Pittsburgh proper was most prominent in the mid-20th century when it was still a major durable goods producer, particularly in steel. Since then the economy has significantly transitioned to healthcare, financial services, education, technology, robotics, and allied businesses. The major institutions of higher education in the metropolitan area, including CMU and the University of Pittsburgh, have played significant roles in these transitions.

While CMU does not have great size, its commitment to excellence in a variety of technical and scientific areas, supportive culture, and enhanced commitment to local economic development, have allowed it to become a major regional asset. According to the Carnegie Mellon University website, in the past 15 years, CMU has helped to create more than 300 new companies, adding approximately 9,000 new jobs to the US economy. In Pennsylvania alone, CMU spin-offs represent 34 percent of the total companies created based on university technologies over the past five years.

CMU's pragmatic education approach has produced educational innovations over the years. Today cross-disciplinary study is the norm rather than the exception. CMU offers nine interdisciplinary Bachelor's degrees and 19 advanced interdisciplinary degrees. These include, for example, combined degrees in design and communications, arts and technology, and science and informational technology. But despite these and other changes, the Carnegie Mellon University of today has much in common with the Carnegie Technical Schools of 1900. The school still encourages great thinkers with diverse backgrounds to collaborate toward practical goals. It preaches collaboration and innovation across traditional barriers of knowledge, and is dedicated to enhancing undergraduate education so that students can explore other disciplines while maintaining a core focus on their primary subject. Realizing that today's graduates must understand international issues, Carnegie Mellon is now a global university with an ever-expanding presence across international borders.

University Culture: *Goals and Aspirations*

While some private universities have a tradition of remaining aloof from outside interests and the local community, CMU's historic roots, both as a technical institution and as an institution established to meet the educational needs of a local, working population, have fostered a tradition of engagement. CMU's unique spin on what it means to be engaged can be seen in its current vision and historic mission and values statements. Two important documents speak to these issues. One is the Carnegie Mellon Strategic Plan for 1998; the second is the Carnegie Mellon Strategic Plan for 2008. Since the meetings, processes and interactions that led to these documents usually preceded the unveiling of the final product by at least many months, these two documents are useful for understanding the goals and aspirations of CMU over much of the last two decades.

Let's first look at the CMU Vision as expressed in these planning documents. The 1998 statement was:

> *Carnegie Mellon will be a leader among educational institutions by building on its traditions of innovation, problem solving and interdisciplinary collaboration to meet the changing needs of society.*

In clarifying paragraphs, the 1998 Vision proclaims "we can continue to lead advances in educational and technological innovation, scientific discovery, creative expression and artistic production by fostering an atmosphere of intellectual excitement, innovation and entrepreneurship."

The 2008 Vision statement is similar and consistent:

> *Carnegie Mellon will meet the changing needs of society by building on its traditions of innovation, problem solving, and interdisciplinarity.*

In a more elaborate section of prose in an Overview section of the 2008 document, the above Vision is broadened by noting, "we collaborate across disciplines, and the initiative to do so comes from the ground up, not the top down. We are nimble and entrepreneurial, moving quickly and prudently when we see an opportunity."

The Mission statements are relatively consistent over the two time periods. The 1998 statement included the following:

> *To create and disseminate knowledge and art through research and artistic expression, teaching and learning; and to transfer intellectual products to society.*
>
> *To serve our students by teaching them problem-solving, leadership and teamwork skills, and the value of a commitment to quality, ethical behavior, society and respect for one another.*
>
> *To pursue the advantages provided by a diverse and relatively small university community, open to the exchange of ideas, where discovery, creativity, and personal and professional development can flourish.*

There was also some interesting prose that followed the 1998 Mission statement and added some operational clarity such as "we are interested not only in theory and practice, but also in production, or making, for example, making devices and processes, art, hardware and software, new management tools and literary works…[but] also nurture a concern for the welfare of others and a commitment to improve the world." This is ambitious stuff. The 2008 Mission statement is very similar to the 1998 version, except that sustainability is added as a benefit of knowledge transfer.

The evolution and consistency over time of the Mission, Vision and associated action strategies assumed a certain kind of university capable of their execution. For much of its history CMU was not a research-intensive institution. In fact its transformation in this direction was enabled by two influences. One was the merger of the mostly undergraduate-focused Carnegie Institute of Technology with the Mellon Institute. In 1913 Andrew and Richard Mellon established the Mellon Institute of Industrial Research as an independent contract research organization. It flourished for many years and worked with companies nationwide. The merger in 1967 had the effect of accelerating the transition of CMU into a much more research-intensive university because of the infusion of people and facilities. The second influence was the role played by several key leaders during the next two decades. Between 1972 and 1990 CMU's research expenditures leaped from $12 million to $110 million. Thus by the time of the 1998 Strategic Plan, CMU was well along as a research-intensive, graduate training university.

Over the course of the maturation of the CMU mission, the strategy and goals around innovation implemented by several institutional leaders during the post WWII period included a number of faculty inducements. While traditional academic expectations and standards remained very high, norms and policies (leaves-of-absence, for example) have traditionally been supportive of faculty entrepreneurship. As a consequence, the typical technical, scientific, and business department can lay claim to its fair share of successful entrepreneurs. There is substantial evidence that faculty have embraced and internalized organizational norms and values of innovation, problem solving, interdisciplinary focus, entrepreneurship, and engagement. As one informant reported, "When your current department chairperson spent several years as a principal in a start-up, you figure out that asking for a leave isn't going to be a big deal." A practice that requires new faculty appointments to be endorsed by other academic departments is a good example of the CMU culture of interdisciplinarity.

Since this section is about issues of organizational values and culture, it is probably appropriate to insert here some lighter themes that are integral to what CMU is all about. CMU is a university that honors the cultural traditions of its founders. Andrew Carnegie's Scottish heritage and Andrew Mellon's Scots-Irish ancestry are celebrated with vigor to this day. For example: The CMU Kiltie Marching Band dresses in full Scottish regalia; Scotty, the Scottish Terrier, is the school's mascot; the annual Ceilidh celebration takes place at the CMU Tartans homecoming football game; the Tartan is also the name of the student newspaper; The Thistle is the school's yearbook; and finally, Skibo Gymnasium bears the moniker of Carnegie's Scottish Highland estate. CMU is the only US college offering a Master's degree in bagpiping, and the University's Scottish Pipes and Drums Band, one of the nation's best, actively competes in Grade III Highland Games competitions across the eastern US and Canada. It is not clear whether or how these activities relate to innovation; however they are illustrative of a playfully creative culture and a school that has stayed true to, and continues to celebrate, its roots, a surprising commonality of a number of the successful Innovation U's in this volume.

Leadership

In his letter to the mayor of Pittsburgh establishing the Carnegie Technical Schools, the early 20th century precursor to CMU, Andrew Carnegie wrote, "My heart is in the work." The influence of Carnegie's leadership continues, as this hands-on creed is the official University motto that students, faculty and staff of Carnegie Mellon University live and work by.

CMU's technical, problem-solving tradition began with its first president, Arthur A. Hamerschlag, who led the founding and uneven growth of Carnegie Technical Schools from 1903 until 1912, and then Carnegie Institute of Technology until 1922. He was chosen because of his extensive background in trade schools in New York. He supervised the building of the original campus, started the original schools: School of Science and Technology, School of Fine and Applied Arts, the School for Apprentices and Journeymen, and the Margaret Morrison School for Women. Nonetheless it quickly became clear that the three-year very hands-on program did not create the career opportunities for graduates that were anticipated. Hamerschlag then led the development of bachelor's and master's degree programs, and the renaming of the school as Carnegie Institute of Technology in 1912. Enrollment grew, as did the physical size of the campus. A Division of Applied Psychology was formed which began a research tradition that was to grow significantly later on. Hammerschlag served until 1922, and was followed by the fairly placid 13-year administration of Thomas S. Baker, who improved the physical appearance of the campus. He also established research laboratories for metals, coal, chemistry and physics, and was an advocate for applied science. Baker resigned in 1935, during the depths of the Great Depression.

Robert Doherty, the third president, served from 1936 to 1950, out of the depression and through World War II and into the post-war period. As part of the national defense effort, the university established a number of government-funded research programs including the Nuclear Research Center. Doherty's long-term impacts on curriculum and community engagement were also significant. The Carnegie Plan, which he championed, linked fundamental technical knowledge to practical problem-solving and mandated that students take courses outside their core discipline. Thus, for science and engineering majors a quarter of their courses had to be in the social sciences and humanities. This "liberal/ professional" curriculum was a major contributor to the current interdisciplinary orientation of CMU.

John C. Warner served as president from 1950 to 1965, topping off a long and distinguished career at CMU as a productive professor and then department head of Chemistry, dean of graduate studies, and vice president at the Institute. Important for this discussion, during World War II he played a key role on the Manhattan project, leading the research on the purification and metallurgy of plutonium. He understood the processes of well-funded industry-scale research and its implications for the Institute. Working with Herbert Simon and Allen Newell, he enabled the growth of computer science research and coursework throughout the university. Warner helped raise the funds to establish the Computation Center, and encouraged the partnership between the Graduate School of Industrial Administration, and the departments of psychology, electrical engineering and mathematics to make a robust growing initiative. CMU's leadership in this area started here.

And it continued during the presidency of H. Guyford Stever, from 1965 to 1972. A Department of Computer Science was established in 1965 and began offering a PhD program. The College of Humanities and Social Sciences was formed, as was the Mellon College of Science and the School for Urban and Public Affairs. The most significant organizational change under the Stever administration was the merger in 1967 of the Mellon Institute and the Carnegie Institute of Technology, to form Carnegie Mellon University. The College of Engineering morphed into the Carnegie Institute of Technology (engineering) and the Mellon College of Science. A biographical note on Stever is also important: during World War II he was a member of the staff of the famous radiation laboratory ("RadLab") at MIT, and then scientific liaison officer for the National Research Council, based in London. So, like John Warner (above), he was part of the network of individuals linked to the big-dollar big-mission R&D of the war years, and by extension to people like Vannevar Bush, who left MIT to be the federal science czar for Franklin Roosevelt. President Stever left CMU to become Director of the National Science Foundation and then Presidential Science Advisor.

The six-year Stever presidency transitioned to the eighteen-year presidency (1972-1990) of Richard M. Cyert. This was a period of rapid growth in research and programs for CMU. In 1972 CMU was performing $12 million in research, but at the close of the Cyert presidency it was doing $110 million. He was one of the first university CEOs to embrace a business model for running a university. He was a pioneer in the use of strategic planning and, because of CMU's small size, stressed the importance of achieving a comparative advantage, a focus on excellence in certain fields so that CMU could outdistance its competitors. Although CMU's historical strengths as a pragmatically oriented technical institution helped dictate some of its foci, the specific choices made by Cyert and his colleagues and successors were nonetheless visionary. Early and significant entry into emerging fields like robotics and software engineering, encouragement of entrepreneurial activities and, later on, development of "Andrew," one of the nation's first campus-wide computer networks, were by-products of this approach. The Computer Science department in the College of Science became the School of Computer Science in 1988 and the Robotics Institute was established in 1988 as well. The payoffs from these investments are easy to see: CMU's robotics and computer/software programs are ranked among the best in the world and are vehicles for intensive interaction with industry. At the close of the Cyert administration CMU had reached the status of a nationally prominent research university.

While not a President, Dr. Herbert Simon also had a profound and lasting impact on CMU's culture. Simon was an intellectual giant whose interests and curiosity about human decision-making and problem-solving processes could not be confined to a single field or discipline. A political scientist by training, Simon received the Nobel Prize for economics and major national awards for his work in cognitive psychology, automation, computer science, political science, management, and operations research. Simon is also considered one of the founders of the field of artificial intelligence. Simon influenced CMU in several ways. First, he played a major role in the formation of the Graduate School of Administrative

Science, the School of Computer Science, and the College of Humanities and Social Science's Psychology Department. In addition, he was a supporter of the university's commitment to entrepreneurship. At least as important, he became a role model for the CMU scholar: a problem solver of unbounded curiosity who works at the intersection of various disciplines yet simultaneously achieves the pinnacle of scholarly recognition.

During the Presidency of Robert Mehrabian (1990-1997) a number of undergraduate academic programs were enhanced and several building projects were undertaken. In terms of innovation-focused activities, a technology-transfer program was started and the President and the University became involved in regional development through the Pittsburgh Technology Center and the Regional Economic Revitalization Initiative.

Subsequently, during the presidency of Jared L. Cohon (1997-2013), research expenditures grew to $242.8 million in FY2011 and the performance of the Center for Technology Transfer and Enterprise Creation (CTTEC) reached national prominence for its performance in launching startups as well as implementing novel policies to enable faculty entrepreneurship. He also played a leadership role in two Strategic Plans (1998 and 2008) that were participative, inclusive and set new directions for the University, particularly in innovation-related activities. In June 2013, the University completed "Inspire Innovation: The Campaign for Carnegie Mellon University," exceeding its $1 billion goal to build its endowment, support faculty, students and innovative research, and enhance the physical campus with equipment and facility improvements. CMU's commitment to innovation, problem solving, multidisciplinary focus, and community engagement were reinforced and reaffirmed by successive incoming Presidents. Struggling to emerge from the past decade's economic downturn appears to have reaffirmed University leaders' convictions about how closely intertwined CMU's future is with the health of local industry and community. To date, this recognition has resulted in an expanded, more deliberate, more focused commitment to impacting local and regional economic development outcomes through entrepreneurship and other kinds of town-gown-industry partnerships.

In July 2013, Subra Suresh became the ninth president of CMU. He took the helm at a time when Pennsylvania and Pittsburgh are faced with particularly intransigent economic challenges. Before coming to CMU, Dr. Suresh previously served as director of the National Science Foundation, and Dean of the School of Engineering at MIT where he helped create two new state-of-the-art laboratories, the MIT Transportation Initiative, and the Center for Computational Engineering. He also led MIT's efforts in establishing the Singapore-MIT Alliance for Research and Technology (SMART) Center; and oversaw the recruitment of a record number of women faculty members in engineering. At NSF, he established several new initiatives, in particular the NSF Innovation Corps. Most of these programs seem to emphasize substance or goals that are very consistent with what CMU is all about.

Boundary Spanning: *Entrepreneurship*

Because of CMU's pragmatic approach to education and its focus on what students do with their education, entrepreneurship is a natural priority university-wide, not just in the business school. For example, entrepreneurial startups are mentioned in the second sentence of the first statement about the University that visitors see on the CMU main webpage:

> *CMU has been a birthplace of innovation throughout its 113-year history. Today, we are a global leader bringing groundbreaking ideas to market and creating successful startup businesses. Our award-winning faculty members are renowned for working closely with students to solve major scientific, technological and societal challenges. We put a strong emphasis on creating things—from art to robots. Our students are recruited by some of the world's most innovative companies.*

As in other areas, entrepreneurship instruction has reaped the benefit of being an educational innovation "first mover." Formal courses in entrepreneurship have been offered at CMU since 1972. Recognized as one of the first business schools to focus on entrepreneurship as a distinct arena of management study, the entrepreneurship program has consistently been ranked as one of the best in the country.

Entrepreneurship instruction is also more easily integrated into the disciplines at CMU than at other universities, perhaps because of a longstanding tradition of interdisciplinary studies and the historically pragmatic, applied research and education culture. Many universities have struggled and often failed to overcome bureaucratic inertia and turf obstacles in order to establish entrepreneurship initiatives outside of business schools. CMU has successfully integrated entrepreneurship education across the disciplines through the establishment of programs and centers that can "boundary-span" across departments or colleges. Some involve course credits and are organized into majors, minors or concentrations. Others may have nothing to do with courses or degrees, but are delivered by a University function or organization. CMU has also developed collaborative relationships with entrepreneurial programs that have limited or no formal linkage with the University, but which students may nonetheless affiliate with and use.

In sum, entrepreneurship learning opportunities at CMU involve a mix of three approaches:

- *Curricular.* Course-based learning related to getting a credit, completing a major or a minor, or meeting a degree requirement;
- *Co-Curricular.* Activities that are offered or enabled by CMU organizations but which are generally separate from courses and degrees (e.g., a club, a business plan competition);
- *Extra-Curricular.* This includes activities that may be "outside the walls" in location and governance and are likely to be "real business" in terms of intent and desired outcomes, but which nonetheless have linkages to CMU.

Curricular Programs

The curricular programs in entrepreneurship at CMU, described below, tend to be scattered around the University and reach both undergraduate and graduate students.

- *Undergraduate Entrepreneurship Curricula.* CMU's undergraduate courses in entrepreneurship teach students to think like an entrepreneur, solve problems, and create solutions. Students write business plans, work on field projects, meet entrepreneurs and business leaders, and test theories, models, and strategies learned in the classroom in the real world. The early Carnegie tradition of requiring engineers to take liberal arts classes to ensure a well-rounded education has spread to the other disciplines as well. Today Tepper business students must also choose a minor from another college on campus and take a variety of supplemental breadth courses outside of the business programs. Likewise, the entrepreneurship courses taught at Tepper's Don Jones Center (both undergraduate and graduate) are open to all students, not just business school students. Undergraduate students who wish to graduate with an entrepreneurship "track" in their discipline take six courses, beginning with the introductory Entrepreneurship for Engineers, or Scientists, or Computer Scientists. They take a market research and finance course, as well as "Funding Entrepreneurial Ventures," and "New Ventures Creation." Then they take two of nine electives which include International Management, Open Innovation, Entrepreneurship Practicum, Negotiation and Conflict Resolution, and Web Business Engineering.

On the social enterprise side, the Heinz School offers six undergraduate (and two graduate) courses in Social Innovation that are open to any student campus wide. The courses cover topics including Microfinance and Development, Entrepreneurship, Technology for Developing Countries, and Social Enterprise Incubator. The Technology Consulting in the Community course (TCinC) is a special university-community learning partnership jointly taught by instructors at Heinz and the Computer Science School. Non-profit organizations, schools, and government agencies improve their technology use, management, planning and integration by working with Carnegie Mellon students. Students develop technical consulting and management skills while collaborating on-site with a leader of a local organization. Student Consultants are on-site weekly to work with community leaders to identify, plan, and implement ways in which technology can help the organization better fulfill its mission. There is no fee to participate, but organizations must invest significant time and effort during the semester-long partnership so as to achieve sustainable technology improvements.

- *Graduate Entrepreneurship Curricula.* At the graduate level, the MBA program has three tracks focused on innovation commercialization, including the Entrepreneurship Track, the Management of Innovation Track, and the Technology Leadership Track. Non-MBA graduate students are also encouraged to enroll. Science, engineering, computer science, robotics, fine-arts and design school students, as well as MBAs, learn about technology commercialization, marketing, finance, organization development, and business planning, and they work in teams on capstone projects. Required courses include: Commercialization and Innovation Strategy, Business Planning and Management, Contracts, and the Swartz Entrepreneurial Leadership Speaker Series. The curriculum combines theory with practice through a mix of coursework, hands-on venture capital exposure, corporate consulting, and the close interaction with a world-class faculty, all having successful VC or entrepreneurial backgrounds.

An excellent example of a structured, interdisciplinary collaboration approach to teaching innovation creation and commercialization is CMU's Master of Integrated Innovation for Products and Services(MII-PS), formerly known as the Master of Product Development program (MPD). The MII-PS is supported by the Integrated Innovation Institute, a joint initiative of the Carnegie Institute of Technology, the College of Fine Arts, and the Tepper School of Business. The Institute also houses the MS in Software Management at the Silicon Valley campus. The program connects CMU Innovation MBAs with other creative and innovative Master's Degree students from across the disciplinary spectrum. The curricular focus is at the intersection of three disciplines—Design, Engineering, and Business—and Institute Directors and faculty come from these areas. The program's directors include a Professor in the School of Design in the College of Fine Arts, a Professor in the Department of Mechanical Engineering who also has appointments in the School of Design and Computer Science, and a Professor who has appointments in both the Tepper School of Business and the Department of Mechanical Engineering.

MII-PS is a one-year professional degree program that focuses on the creation of products, services, and interactive experiences that define new product opportunities that exceed user expectations. The program immerses students in an interdisciplinary environment at both the program and university level. Students complete a series of required courses in design, engineering, and business, and then select key electives that tailor the degree to their personal interests, background and professional goals.

Each entering student already has an undergraduate degree, skills and experience in one of the three areas, which allows them to build skills and knowledge in each of the other two critical innovation fields. Courses include Industrial and Engineering design fundamentals (Design students take the engineering course and Engineers take the design course), New Product Planning and Management, Innovation and Entrepreneurship, and Market Research/Ergonomics. MII-PS students also take two electives from a wide array of options.

In the spring they also take the capstone Integrated Product/Service Development (IPD) course with 2nd-year MBA students. Working in interdisciplinary teams on industry-sponsored projects, the emphasis of the course is on the early, "fuzzy front end" stage of product development. Each team focuses on identifying, understanding, conceptualizing, and realizing new product opportunities for their industry sponsor. Teams develop a form model, function model, marketing plan, and manufacturing plan for the product. Each year, student inventions lead to patent applications. This combination of structure and flexibility, combined with interdisciplinary teamwork and interaction with industry professionals on real-world product development, gives students a distinctive experience and competitive advantage.

The Integrated Innovation Institute and its MII-PS transdisciplinary approach encompassing three core product-innovation disciplines is an innovation in itself, emerging from the

CMU tradition of innovative and pragmatic design and engineering. The MII-PS has become a pioneer in the field of integrated product development, and has become so popular that in 2013 it evolved into its own Institute with programs in executive education, and applied research including industry consortia, in the works. The Institute will be housed in its own building at the main campus entrance, to provide a "gateway highlighting CMU's interdisciplinary innovative culture." In 2014 its enrollment will double. As other universities replicate or build on this three-discipline teaching/learning commercialization approach, it may well prove itself to be one of the more effective educational approaches to innovation and entrepreneurship production. The MII-PS /MPD program has consistently been ranked in the top three Best Graduate Programs in Industrial Design by *U.S. News & World Report,* and is one of the Top 30 World's Best Design Programs as reported by Bloomberg Businessweek magazine for its integration of design, business, and engineering.

Co-Curricular Programs

The most significant co-curricular programs supporting entrepreneurship include the following, although this is a fluid and changing support environment.

- *The Center for Innovation and Entrepreneurship (CIE).* A major campus hub for co-curricular support of entrepreneurship education is the CIE, a program that operates under the co-leadership of the Tepper School of Business and the School of Computer Science. The CIE was created in 2013 with the support of a $7 million "Big Ideas" grant from the McCune Foundation to provide financial aid for undergraduate and graduate students who are entrepreneurs and seed money (up to $50,000) for the most promising companies they and faculty establish. Another goal of the grant is to make the region a launching pad for companies and to keep these businesses and jobs in Western Pennsylvania. All too often in the past, CMU spinout companies and their employees have left the state for Silicon Valley or other greener pastures.

  The new center enables the sharing of resources, bringing together a broad spectrum of educational and experiential activities focused on innovation and entrepreneurship. It is a "one-stop shop" for CMU faculty, students, staff, and alumni. CIE connects students to real-world entrepreneurial opportunities including: starting a venture, joining an emerging company, bringing an entrepreneurial perspective to corporations, or starting a business right after graduation. Other opportunities are found in the venture capital/private equity industry, consulting sector, and through social entrepreneurship.

  The CIE serves the entire University, allowing both students (undergrad and grad) and faculty members a central place to pursue commercialization of research and entrepreneurial projects. The objective is to "speed advances from the lab to the marketplace" and all University resources and schools are collaborators in this effort. CIE's Oakland-based incubator is a converted horse barn, set up for CMU entrepreneurs. The incubator provides technological and business know-how, and makes available mentors, a network of resources, and seed money. Oakland is Pennsylvania's third largest economic center behind center-city Philadelphia and downtown Pittsburgh. Oakland is an easy walk west of the CMU campus; it's a trendy, urban neighborhood, home to the University of Pittsburgh and its medical center (UPMC), the Carnegie Museums and a cultural complex offering theaters, festivals and arts activities. It is also home for the huge amount of innovation coming out of the neighborhood's universities (including the University of Pittsburgh) and other institutions, such as the *Revv Oakland* and *Idea Foundry* incubators that support Pittsburgh's entrepreneur community.

- *Project Olympus.* This program was created by the School of Computer Science in 2007 to augment and accelerate the process of moving basic research into development and business stages. The core of the program is a "proof-of-concept" Innovation Lab where the commercial potential of university innovations are explored by students, graduates, faculty members, board members, and a network of off-campus partners. Olympus provides start-up advice, micro "Spark" grants, incubator space, and connections for faculty and student entrepreneurs with alumni and local, national, and global business communities.

  The most important way that Project Olympus goes about accomplishing this goal is by teaming up faculty and students together into PROBEs (Problem-Oriented Business Explorations) that assess the commercial viability of their inventions. Faculty and student PROBE teams from across campus explore the commercial potential of their research and ideas under the guidance of in-house Entrepreneurs-in-Residence, alumni mentors, and a network of economic development partners. Out of the 121 PROBE projects since Project Olympus started in 2007, more than 70 turned into startups, drawing in over $60 million of funding.

- *The Donald H. Jones Center for Entrepreneurship (DJCE).* This center is a program of the Tepper School of Business at CMU that was endowed by Mr. Jones, a successful local entrepreneur. It brings entrepreneurship students together with faculty and practitioners doing groundbreaking research, and offers graduate, undergraduate, and continuing education programs in entrepreneurship. The Center also conducts research on entrepreneurship. The Center's interdisciplinary academic approach, coupled with experiential learning, is geared towards students leading innovation, change, and growth in start-ups, emerging companies, and mature organizations. Students graduate equipped with the tools necessary to start a business and the ability to become leaders and innovators in whatever field they choose. The DJCE was led in the 1990s by John Thorne, a pioneer professor of entrepreneurship at CMU. At the time the Tepper School was one of the first business colleges to offer formal entrepreneurship education.

  Perhaps the one thing that sets DJCE apart from other entrepreneurial programs is the amount of entrepreneurial experience possessed by its faculty. Virtually all of its associated faculty are founders, co-founders, CEOs, presidents, and/or board chairs of a long list of successful high-technology start-up firms. DJCE courses have a significant experiential component to complement the in-class part, including the Project Olympus accelerator program. The most impressive testament to the Center's success, however, is the growing list of successful start-up ventures it has spawned. For example, CMU's professors and student body together produce 10 to 20 new companies each year, a number that has risen consistently over the last decade. Of the 300 companies spun out of CMU over the past 15 years, 10 have been acquired by companies, including Cisco, Google, IBM, LinkedIn and Boeing, and CMU startups have attracted over $500 million in funding over the past decade, according to the winter 2013 issue of the DJCE E-Newsletter.

The DJCE also hosts seasonal Show & Tell events in which students and faculty present their ideas directly to regional investment and business leaders. Other student events include combined activities with the University of Pittsburgh's Institute for Entrepreneurial Excellence, Pittsburgh Startup Weekend, and Pittsburgh Web Design Day.

- *Business Plan Competitions—The Tepper Venture Challenge (TVC).* CMU's largest business plan competition brings together students from all fields to pitch their best ideas to a panel of judges for cash prizes and an opportunity to attend larger business plan competitions. These undergraduate competitors range from freshmen to fifth-year seniors, in majors ranging from business to computer science, political science, mechanical engineering, and English. The TVC is also open to those who attend other Pittsburgh universities such as the University of Pittsburgh, Duquesne University, and Carlow University.

- *The Social Innovation Solutions Challenge.* This is a competition for graduate students at Carnegie Mellon University who are interested in applying social innovations to some of the world's biggest problems relating to basic human needs. Sponsored by the Idea Foundry incubator and organized by CMU's Institute for Social Innovation and Project Olympus, the competition features teams of students from across the University competing for cash prizes. The 2011 competition attracted 8 teams of Master's and PhD students from across campus. The teams were organized by geography (Africa, India, Latin America, US inner city, and China) and pitched ideas for new products that addressed basic human needs such as food, education, healthcare, water, and shelter.

- *McGinnis Venture Competition.* Organized by the School of Computer Science, this competition has been an annual program since 2004. It involves a three-round, five-month long format focused exclusively on CMU students. The program includes an entrepreneurial boot camp and targeted workshops that connect students with top entrepreneurs, venture capitalists, business leaders, and university experts to explore idea generation, opportunity identification, venture pitching, strategy, and team formation. In 2013 nine teams were selected from 30 entries to compete for $60,000 in cash prizes.

- *The Undergraduate Entrepreneurship Association.* UEA is a student run organization dedicated to fostering the entrepreneurial spirit at Carnegie Mellon University through competitions, business development, and networking opportunities. The UEA hosts the annual Tepper Venture Challenge (TVC), CMU's largest business plan competition, as well as an elevator pitch competition, a lecture series, a book club, and movie night.

- *Enactus.* Entrepreneurs in Action for the Greater Good (Us) is CMU's local Students In Free Enterprise (SIFE) chapter. The national organization focuses on empowering local and international communities through applied business strategies and enterprise creation. Each year at CMU Enactus initiates outreach projects around the world, and also participates in regional and national competitions for recognition and prize money. Carnegie Mellon's team recently placed within the top 15 nationally.

- *Idea Lab.* This program is located in the H. John Heinz III College, but serves students campus-wide in a semester-long structured program. Its mission is to create a cluster of social entrepreneurs at CMU by providing a forum for graduate students to bring their concept-level ideas for a social venture to the next level. Idea Lab student-facilitators guide entrepreneurs through the business development pipeline with practical tools and exercises to help them conduct market research, develop business models and plans, and build their entrepreneurial networks.

- *The CREATE Lab.* Officially known as the Community Robotics, Education and Technology Empowerment Lab (thus CREATE Lab), this program of the CMU Robotics Institute has forged long-term working relationships with communities in the Pittsburgh area. The model is to work with residents in the design and implementation of various data gathering tools around issues of concern in their community. Members of the CREATE team encompass many disciplines and fields. External partners include school districts, teachers, communities, early childhood care facilities, local mechanics, and many others. The deliverables of these relationships include modes of inquiry, evidence gathering, and communication. These may be embodied into computerized tools that can be used in a community. For example, the *Message from Me* sends a five-year old's voice home to her parents daily, enhancing her ability to engage her parents about the school day. The CREATE Lab is both a technology developer and a community partner.

Extracurricular Programs

CMU has been organizationally engaged with the greater Pittsburgh region for many years. Partnerships run the gamut from industrial-sponsored research relationships to classroom guest speakers from Pittsburgh companies. Many organizations that are not formally part of CMU are nonetheless engaged in the general area of entrepreneurship and complement the University's initiatives.

- *Idea Foundry.* This is a not-for-profit 501(c)(3) funded by the Pittsburgh Urban Redevelopment Authority, the University of Pittsburgh, and various foundations. It provides infrastructure support, mentoring and modest financial support for early stage companies. It also operates several accelerators focused on Life Science, Entertainment and Ed Tech, and Intelligent Systems respectively. It has invested in more than 85 companies since its founding in 2002.

- *Pittsburgh Venture Capital Association (PVCA).* The PVCA has been active in the metro area since the early 1980s, with a mission to energize and enable VC investing and entrepreneurship. Its membership consists of regional and national venture-investment firms and, for purposes of this case, that network is a significant asset for early-stage companies emerging from CMU. Western Pennsylvania activities include a venture fair, networking events, a membership directory, and award ceremonies for successful entrepreneurs.

- *Open Field Entrepreneurs Fund.* The Open Field Entrepreneurs Fund (OFEF) is part of CMU's Greenlighting Startups initiative, and was endowed by CMU alumni entrepreneurs who hope it will make CMU a destination of choice for young entrepreneurs. The fund provides early-stage business financing to alumni who have graduated from CMU within the past five years, through a new early-stage business financing model. The OFEF provides $50,000 in matching funds, and recipients also gain access to other funding sources, receive personalized mentoring, and attend an annual OFEF business workshop. CMU provides legal and accounting support for OFEF recipients. Since June, 2012, the program has awarded $500,000 in support to 21 startup companies from across the country and in a variety of industries. While awardee locations range from New York to Silicon Valley, seven are from Pittsburgh. The startups represent a diverse range of industries, including medical, technology, consumer, and educational fields.

- *Enterprise Forum Pittsburgh.* This is the local manifestation of the MIT Enterprise Forum that has in effect been franchised to a number of metropolitan areas across the US and around the world. Forum events typically involve a panel presentation, give-and-take discussion, networking, and often food and other refreshment. In Pittsburgh regional entrepreneurs often present their strategies to a live audience of peers and experts.

- *Innovation Works (IW).* This is a seed-stage investment fund and assistance provider that is part of the Ben Franklin Technology Partners in Pennsylvania, a program largely funded by the Pennsylvania Department of Community and Economic Development. Funding is also received from regional non-profit foundations. AlphaLab is also part of Innovation Works and provides business assistance, advisors, space, and a supportive community to increase the chances that the IW investments will take hold. IW has been in operation for over 13 years and has invested over $52 million in 168 companies.

Boundary Spanning: *University, Industry and Community*

University outreach at CMU goes well beyond MBA courses involving a consulting arrangement with local entrepreneurial companies, and faculty involvement in local and community service. Innovation outreach also involves university technology-transfer activities, industrial research partnerships, and formal economic-development partnerships with state and local government partners.

A number of factors appear to have contributed to CMU's strong performance in industrial research. First, CMU has historically emphasized programs that appeal to industry. It has maintained that focus to the present with its three largest colleges (engineering, computer science, and business) all having direct relevance to industry. In addition, the quality of CMU's engineering, science, and business curricular programs serves as a magnet for industrial involvement, sponsorship and hiring of CMU graduates. A long list of programs in engineering, science, computer science, and business are ranked among the best in the nation. One of the reasons behind the high ranking of CMU degree programs is the fact that there is a major emphasis on students' acquiring breadth across substantive disciplines.

This multidisciplinary/interdisciplinary tradition is also a major strength of CMU research. There are now approximately 120 research centers and institutes at CMU. Their attractiveness to industry and community stakeholders lies in the fact that the center/institute model enables researchers and graduate students from various fields to bundle theory, concepts and research methods in ways that permit tackling bigger problems. Big problems, whether they are the theory-driven "grand challenges" of various fields of scientific inquiry or the major industrial problems of a more practical nature, are more likely to yield to interdisciplinary and multidisciplinary approaches. It is also often more challenging and interesting for the faculty members and graduate students involved.

Centers and Institutes. In this section we will describe a small number of centers and institutes to illustrate how this works at CMU, particularly in terms of enabling interdisciplinary and multidisciplinary involvement, engaging business and industry stakeholders, addressing big needs and problems, and producing graduates who will make bigger and sooner contributions after they leave. These are some of the activities that Carnegie Mellon believes are "Inspiring innovations that change the world."[3]

- *The Robotics Institute.* Perhaps the crown jewel among CMU centers is the Robotics Institute (RI). Started in 1979, RI is among the world's largest and most productive robotics research labs. It encompasses 187,000 square feet of space at three sites. Its current annual budget is over $65 million, with research support coming from DOD, DARPA, NASA, NIH and NSF. The Robotics Institute is the only entity in the US that awards the PhD in Robotics. The National Robotics Engineering Center (NREC) is a technology-transfer organization that develops and tests robotic systems for a wide range of users. To date, the Robotics Institute has been involved in creating more than 30 startup companies in robotics-related fields, employing over 1000 people. The operations structure is complex. Thus, within the Institute there are currently eight centers ranging, for example, from the Field Robotics Center to the Medical Robotics Technology Center. Each center conducts a number of projects; for example, the Field Robotics Center (FRC) lists over 30 projects, ranging from Assistive Educational Technology to Lunar Regolith Excavation and Transport. And each project has a number of clients, partners, participants, and diverse outcomes.

- *The Software Engineering Institute (SEI).* The Institute was established in 1984 as a federally-funded research and development center (FFRDC) sponsored by the U.S. Department of Defense and operated by Carnegie Mellon University, with offices in Pittsburgh, Arlington, VA, and Frankfurt, Germany. The mission of SEI is "to improve the state of the practice of software engineering." The DOD's primary interest is in enhancing software engineering within the DOD supplier chain. This yields two foci: improvement of software engineering *management* practices; and improvement of software engineering *technical* practices. Shortcomings in software engineering manifest themselves in functional defects ("bugs") and needs for rework (60-80% of development costs). SEI's

Coordination Center documents thousands of software vulnerabilities, many of which are a function of poor software engineering practice. SEI has over 500 employees, the majority at CMU. It received a five-year contract extension of $584 million in 2010.

- *Institute for Complex Engineered Systems (ICES).* The Institute is organizationally a department in the Carnegie Institute of Technology (the engineering college at CMU) but has 100 affiliated faculty members from several departments and all seven colleges. The Institute occupies 12,074 sq. ft. of contiguous space. The origins of ICES date to 1974 when an informal group of faculty members launched the Design Research Center (DRC), with the goal of exploring cross-disciplinary design research using computational techniques. The DRC evolved into a successful NSF Engineering Research Center (ERC) proposal which was funded in 1986 as the Engineering Design Research Center (EDRC). Accomplishments of the Center were significant and exciting, leading to "ubiquitous networking" of design, prototyping, and manufacturing functions via information technology. After 11 years of NSF support, the EDRC was "graduated," and then was transformed into and renamed the ICES. In 1999-2000 the research structure was also reorganized into several focus laboratories or centers, an approach that has continued. The Institute's vision is "an academic organization which effectively stimulates and fosters multidisciplinary engineering research and collaboration between students, faculty, staff, industry and government agencies."[3] The mix of constituent centers and clusters changes periodically, but currently includes nearly twenty research units. Each of these centers or labs is typically led and staffed by faculty members from across the campus. Research support has come from a number of Federal (NIST, DARPA, NSF, Office of Naval Research) and state government agencies, as well as via many industry affiliate companies.

- *Quality of Life Technology Center (QoLT).* This is a National Science Foundation Engineering Research Center (ERC) founded in 2008. It aspires to transform lives in a large and growing segment of the population (people with reduced functional capabilities due to aging or disability) through the development of assistive technologies that draw expertise from across the University. It focuses on a range of human functionalities (vision, mobility, dexterity, memory) and multidisciplinary inputs including engineering, design, marketing, and service delivery. It involves social and clinical professionals from a number of member companies and non-profit organizations in terms of agenda-setting, feedback, and field-testing. Membership enables participation on several levels, with a wide range of fees for participant organizations. Commercialization of research results has been an important goal for QoLT, and one that has been realized. There are currently nine spin-off companies in the market with a range of products and services.

- *CyLab.* This center was founded in 2003 and it has been a leader in cybersecurity R&D ever since. CyLab is a National Science Foundation Cyber Trust Center, a National Security Agency (NSA) Center of Excellence, and an affiliate of the Software Engineering Institute (above). Advances in computer technology unfortunately come along with security vulnerabilities that can harm everyone from the home computer user to small businesses, large corporations, federal agencies, and anyone dependent on the cyber infrastructure. The CyLab research program is organized around seven Research Areas and leverages CMU multidisciplinary expertise in several cross-cutting thrusts. CyLab involves more than 50 faculty members and 100 graduate students from across the University. Carnegie Mellon's College of Engineering, School of Computer Science, H. John Heinz III College, and the CERT Coordination Center are participants. The research agenda is organized into the five Centers and Programs. Corporate and public-sector stakeholders can more fully access the work of CyLab via 3-year Memberships (with fees ranging from $35,000 to $350,000 per year). Membership includes various combinations of the following: access to seminars, reports/tools, meeting participation, access to restricted portions of the CyLab website, internal-use license of project results, executive education participation, sponsorship of PhD students, input to Master's or doctoral level project topics, and reduced tuition for member-company employees enrolled in graduate study at Carnegie Mellon.

- *The Bruce and Astrid McWilliams Center for Cosmology.* The McWilliams Center was founded in 2008 via a major gift from Mr. and Mrs. McWilliams. Bruce Williams, a CMU alum, member of the CMU Board of Trustees, and a very successful Silicon Valley entrepreneur opined the following at the founding, which says much about the purpose of this case entry:

  Ingrained into the basic DNA of Carnegie Mellon is its ability to work across the boundaries of its departments and schools to form cohesive teams toward a common goal. For this reason the Cosmology Center will thrive at Carnegie Mellon because like few universities research that will be needed to understand the Cosmos can work better here than at any other institution I know of.

  And that is pretty much what has happened over the last 5 years. The Center research program is a mixture of particle physics, astrophysics, computer science, and statistics. It draws faculty and graduate students from all those areas. Local partners at the University of Pittsburgh include the Department of Physics and Astronomy as well as the Pittsburgh Supercomputing Center.

- *Center for the Neural Basis of Cognition (CNBC).* The Center is a joint initiative of CMU and the University of Pittsburgh. Departments involved at CMU include: Biomedical Engineering; Biological Sciences; Computer Science; Electrical Engineering and Computer Engineering; Machine Learning; Psychology; Robotics; and Statistics. Departments from the University of Pittsburgh include: Bioengineering; the Center for Neuroscience; Mathematics and Psychology. The CNBC is also programmatically linked to twelve research centers, institutes or lab facilities at either Carnegie Mellon or the University of Pittsburgh. Allied with CNBC activities, a PhD program in Neural Computation is offered jointly by the two schools, and targets students with strong quantitative backgrounds pursuing a career in experimental neuroscience. Over 200 faculty members and trainees at CMU and the University of Pittsburgh are involved in the CNBC research program.

- *Wilton E. Scott Institute for Energy Innovation.* The Wilton E. Scott Institute for Energy Innovation is a university-wide research initiative at CMU that was established in 2012 and is focused on improving energy efficiency and developing new, clean, affordable and sustainable energy sources. Its initial Co-Directors are two engineering department heads, from Chemical Engineering, and Engineering and Public Policy, respectively. The initial founding endowment from Sherman Scott and Joyce Bowie Scott was established in 2013 and supplemented with a $30 million gift from the Richard King Mellon Foundation. Building on Carnegie Mellon's expertise in integrated systems, problem-solving rigor, and an understanding of the intersection of energy and public policy, the work of the Institute will concentrate on four problem domains: efficient use of energy; sources of energy; delivering energy; and innovation for energy. The new Institute will capitalize on the more than 100 faculty members in the 34 energy-related research centers that span the campus. This is a great example of how CMU organizes around a big problem, in a collaborative multidisciplinary manner, and with an eye to moving solutions out to the world.

Community Partnerships. Regional impact is one of the areas highlighted by the University's latest strategic plan. The plan acknowledges the symbiotic relationship that exists between CMU and the region and asserts the University's intention to address local and regional issues, particularly economic growth, and improved quality of life.

Strategies proposed to address these goals include: (1) "continue to encourage technology driven regional economic growth;" (2) "continue to support improvement of K-12 education in the region through both research and community service;" (3) "enhance the region's quality of life, by working in our areas of strength, such as visual and performing arts, environmental issues, and public policy initiatives;" and (4) "pursue those activities in which the region becomes both a laboratory for research and a site for collaborative inquiry and education innovation." Many CMU officials focus on engagement as an integral part of CMU's culture.

The H. John Heinz III School of Public Policy and Management serves as a critical resource and linking mechanism for regional economic-development activity. This school and its faculty have a great deal of expertise in technology-based economic development. For instance, one of CMU's two Sloan industry centers, the Software Industry Center, is actually housed in the Heinz School. More importantly, the Regional Technology Policy Group within the Heinz School's Center for Economic Development is also heavily involved in the study, development, and dissemination of policies and practices that promote technology-based economic development.

The technology-based state and local economic-development agencies that have linkages with Carnegie Mellon are many. In addition to some of the organizations described in the Extracurricular Programs in Entrepreneurship section above, here are a few other illustrations:

- *Pittsburgh Technology Council.* This is a regional trade association that focuses primarily on technology-based member companies located in the contiguous 14-county region. It has been in existence for 29 years and has 1400 member companies.

- *TiE-Pittsburgh.* This is a relatively new (founded in 2000) not-for-profit network of entrepreneurs, corporate executives, investors and senior professionals who are involved in fostering the tech-based startup community in the Pittsburgh area.

- *Keystone Innovation Zones.* Pittsburgh's Urban Innovation 21 links innovation economy clusters with the needs and assets of underserved communities, by designing programs, building strategic bridges, and teaming up with existing organizations.

- *The Allegheny Conference on Community Development.* The Conference's affiliates include the Greater Pittsburgh Chamber of Commerce, the Pennsylvania Economy League of Greater Pittsburgh, and the Pittsburgh Regional Alliance. All these organizations work together to stimulate economic growth and improve the quality of life in southwestern Pennsylvania.

- *Carnegie Mellon Silicon Valley.* While not located in greater Pittsburgh, CMU's Silicon Valley campus enrolled 133 students in 2013 and offered degree programs in software engineering, software management, information technology, and electrical and computer engineering. Both part-time and full-time programs reflect the University's ongoing focus on creating and implementing solutions for real problems. CMU SV research centers include the Cylab Mobility Research Center and the Disaster Management Initiative, as well as work on context-aware mobile systems, statistical methods, natural-language translation, mobile health, security, hardware-optimization, and open-source software environments. The campus' location at the NASA Ames Research Center has led to significant collaboration in developing projects.

Boundary Spanning: *Technology Transfer*

The Center for Technology Transfer and Enterprise Creation (CTTEC) facilitates the licensing of CMU intellectual property. To help ensure that CMU inventions will have the greatest chance of commercial success, the Center provides a set of guidelines in five steps: Disclosure, Evaluation, Marketing Strategy, License Negotiation, and Enterprise creation. It has also decided to focus on technologies in five broad strategic research areas, which reflect CMU's areas of expertise as well as expanding opportunities for commercialization: (1) computation; (2) sustainability; (3) health and quality of life; (4) social and behavioral sciences; and (5) global and cultural issues.

Carnegie Mellon's technology transfer program started in 1992, with a focus on licensing technology to existing companies and forging partnerships with corporations. Since then, the concept of commercialization in technology transfer has shifted to include a much greater emphasis on learning how to launch new companies to transfer university research into the marketplace. This is consistent with the entrepreneurial culture and scope of entrepreneurial curricular and co-curricular activities described above.

This is especially true at CMU where the traditional approach to tech transfer, which emphasized licensing to existing companies, was literally 'junked' in favor of an approach that was more attuned to enabling startup companies and thereby contributing to the regional economy. CMU used to take as much as a 20 percent stake in new companies plus, in some cases, a board seat. But in order to cut red tape and ease relations with faculty members who wanted to start companies, the university decided to create a policy where there was no negotiation. The new policy calls for a flat five-percent equity participation ("Five Percent, Go in Peace") capped at a $2 million dilution event for the University along with no company interference.[3]

While most university TTOs focus on licensing deals with established companies, CMU's relatively recent policy promoting commercialization via startups has caused the rate of spinoffs to soar since the University revamped its licensing policy in 2004. Start-ups emerging from university research have jumped from one in 1995 to approximately 10 annually from FY2006 onward, according to historical Association of University Technology Managers (AUTM) data. The "Five Percent, Go in Peace" model not only attracts top inventor talent, but also helps solidify CMU's position as a US leader in turning federal and state funding into sustainable economic growth. Per FY2012[4] AUTM statistics this policy, as well as the culture of the CTTEC office, continues to buttress CMU's technology-transfer performance. For example, during that fiscal year CMU realized 172 invention disclosures, which in terms of "batting average" means one disclosure for every $1.6 million of research expenditures. With 10 startups its ratio of startups to invention disclosures was one for every 17 disclosures, and one startup for every $27 million of research. CTTEC also executed 37 licenses and options, and 99 new patent applications.

These are all very good numbers. It is tempting to speculate on what the national harvest of disclosures and startups would be if all of the top 100 universities had AUTM "batting average" statistics that approximated those of CMU. However, that is really the purpose of this book. If more universities adopted the policies, practices and culture of the institutions described in this volume, we might be closer to a more robust and innovative economy. As the founder of Carnegie Mellon's Center for Technology Transfer and Enterprise Creation opined in 1993:

> *In the end, the inventor is still*
> *the hero and always will be.*

Distinctions between "faculty" entrepreneurship and "student" entrepreneurship, created when technology-transfer offices serve primarily faculty inventors, don't seem to exist at CMU. For faculty members and students alike, the CTTEC gets out of the way when it comes to intellectual property, thus allowing it to concentrate its resources on supporting university startups and spinouts. Using a standard (or "express") deal approach to spin-off licensing, CTTEC offers a fair deal, a transparent process, and years of data and experience through multiple rounds of follow-on funding and company acquisitions.

Summary and Parting Comments

Carnegie Mellon University, a relatively young institution for a university located in the eastern part of the US, has gone through many abrupt changes in mission course and program development. It was nearly 10 years into its existence before it evolved from being mostly a trade school, and well into the 1970s before it began to hit its stride as a research university on the move. There are many parts of the CMU story that are attractive and worthy of emulation. One is the strong commitment to a multidisciplinary and interdisciplinary perspective that characterizes its approach to both undergraduate and graduate education.

Students and faculty have easy access to all things entrepreneurial on campus. Undergraduates have few barriers to adding entrepreneurship to their course programs. Of the nine interdisciplinary majors offered to undergraduates, all are conducive to boundary-spanning entrepreneurial creation.

Boundary spanning has served to strengthen this research-intensive university. Carnegie Mellon knows how to do this very well, particularly with its connections to where it lives. Andrew Carnegie was very much involved in creating the industrial and technological strengths of greater Pittsburgh, and CMU has likewise maintained, improved, and built on that heritage. Carnegie Mellon is especially strong in fostering entrepreneurship, in both curricular innovation and related approaches. Among those are its ongoing successes in building the entrepreneurial and tech-based economy of the region.

Because of the limitations of time, resources and necessary restraint, this chapter could not describe all the success stories of how Carnegie Mellon University does what it does. We urge the reader to pick up some of the threads of this narrative and discover more of the "inspiring innovations" of CMU.

Endnotes

[1] Nasaw, D. (2006). Andrew Carnegie (p. 600). New York: The Penguin Press.

[2] National Science Foundation, National Center for Science and Engineering Statistics, FY2011. Table 14. Higher education R&D expenditures, ranked by all R&D expenditures, by source of funds: FY2011. Table 15. Higher education R&D expenditures, ranked by all R&D expenditures, by R&D field: FY2011.

[3] Mark Kamlet, Provost and Executive Vice President, Carnegie Mellon University. *Supporting Innovation in the 21st Century Economy: Perspectives on the Carnegie Mellon Experience.* Testimony to the Subcommittee on Technology and Innovation, Committee on Science and Technology, U.S. House of Representatives, March 24, 2010.

[4] Association of University Technology Managers. (2013). *AUTM U.S. Licensing Activity Survey: FY2012.* Deerfield, IL: Association of University Technology Managers.

Clemson University*

Clemson was established via a grant after the Civil War from Thomas Green Clemson, a wealthy planter in the "up country" region of western South Carolina. Mr. Clemson wanted to both foster higher education in the state and have an impact on the economic prospects for its citizens. In his will, Clemson set aside monetary assets, as well as the land encompassing his plantation, for the purposes of teaching "scientific agriculture and the mechanical arts" to South Carolina's young people.

Upon his death in 1888 the South Carolina legislature and the governor took up the matter, and in 1889 a bill was passed and signed accepting the gift, which established what came to be known as Clemson Agricultural College. The current designation as Clemson University did not come to pass until well into the 20th century.

The new college started business in 1893 with an initial enrollment of 493 students. The student body was composed entirely of males, and the college was launched as a military school with a corps of cadets. In the late 19th century, Clemson also became a Land Grant institution encompassing an experimental farm and the typical extension activities that go along with this type of institution elsewhere.

Clemson students' connection to the University has always been fervent. For example, reflecting both the institution's military tradition and high patriotism, in 1917 the entire graduating class enlisted for the World War. Similarly over 6000 students and alumni served in World War II. In 1955 the military tradition and the cadet corps were dropped and shortly thereafter Clemson became a co-educational institution. In 1964 it was renamed Clemson University and henceforth has built a growing reputation as an academic center of research and service to the state and region.

Clemson has achieved a growing number of positive national ratings regarding its academic programs, its research competencies, and particularly relevant for this book, its engagement with the local community and regional economy. For example, there are several plaudits from *U.S. News & World Report*, such as a 4th place ranking in *U.S. News & World Report's* 2012 "up and comers" category for institutions that made the most promising and innovative changes in areas such as academics, faculty, student life, and campus facilities. Clemson was ranked 4th by the Huffington Post for students' "approachable, supportive, and charitable nature along with their deep love for other students." Similarly, the school received a fourth-place rating of "happiest students" from the 2013 Princeton Review. In another ranking by the 2013 Princeton Review, Clemson

* *This case was written by Louis Tornatzky and Elaine Rideout.*

was described as a school that "runs like butter," presumably administratively. Clemson's recent aspiration to be a "top 20" institution underlies many of the changes described in this chapter.

Clemson enrolled 19,914 students in 2011, an increase from 17,101 in 2001. Three colleges dominate student enrollment. The College of Engineering and Science enrolled 30.5% of all students in 2011, up slightly from 2001 when it enrolled 27.1%. Second in size is the College of Business and Behavioral Science which enrolled 23.8% of students in 2011 versus 26.7% in 2001. The third-largest college is the College of Agriculture, Forestry and Life Sciences, which in 2011 enrolled 18.1% of students up from 13.7 % of students in 2001. Two other colleges enroll somewhat smaller fractions of students—the College of Health Education and Human Development, and the College of Architecture Arts and Humanities.

Somewhat more germane for our purpose of understanding technological innovation at Clemson is the distribution and growth of research and development over the recent history of the University. Per National Science Foundation statistics for FY2011[1] Clemson reported $166.3 million in total R&D expenditures with 36.8% of that in engineering and 28.9% of it in the life sciences. This was close to a doubling from FY1999 when Clemson reported $99.3 million in total research expenditures. During that era 54.3% of total research expenditures were in the life sciences compared to 30.7% in engineering. Clemson does not have a medical school and thus the life science totals primarily reflect its strengths in agriculture and related biological sciences, and not necessarily research that is more closely aligned with clinical medicine.

Two other R&D data points are worth noting as they pertain to the growing role that Clemson is playing in technological innovation, regional economic development, and entrepreneurship. One is the extent to which R&D expenditures come from different categories of funding sources. Clemson in many ways differs from its peers. For example as per FY2011 NSF data, across all institutions 4.8% of research expenditures came from business and industry. These national figures of funding sources have hovered around that level for several years, although the longitudinal trend has been a slight decline. Looking at the same FY2011 NSF data, 6.8% of Clemson's research expenditures came from industry, which is above the national average. Clemson, and other universities in this volume, have also argued that some corporate research funds are coming from private industry foundations, which then gets tallied in the non-profit total. In any case, Clemson is above the national average in terms of research partnering with business and has processes in place to attract more corporate funding.

University Culture: *Goals and Aspirations*

As discussed in the introductory chapter, the development of a university into something that we have labeled an Innovation U, requires an organizational *culture* that energizes its aspirations and behaviors. In other words, it should be very clear when the University talks and thinks about itself that it articulates certain key mutual understandings, such as the following:

- What is its mission?
- What are the goals it aspires to?
- What are the short and long term strategies for getting there?

- What are the enabling structures, systems and processes?
- What are the shared language and concepts?
- What are the processes and procedures by which groups engage?

In contrast to many universities, Clemson has been very deliberate and organized about terms and understandings such as these. It is now in its second decade of a very significant change process during which the university experienced massive core funding disruptions and at the same time was trying in many ways to transform itself from a good university to a great one, as well as becoming an institution focused on innovation and economic development.

Most importantly, Clemson has utilized a "roadmap" approach to articulating and engaging institutional goals, and these are replete with words, phrases and concepts that are quite instructive for understanding the culture of change that has unfolded. For example, the Clemson 2020 Roadmap was approved on April 15, 2011 and will be cited herein extensively. It should also be noted that the 2020 Roadmap was preceded by a 2010 Roadmap with similar language and impact, which was rolled out in 2001. At that point Clemson announced its aspirations to become "one of America's top public universities" and also its goal to be involved in "research-driven economic development."

In the 2020 Road Map Clemson is very straightforward in its *vision* about what it aspires to be:

> *Clemson will be one of the nation's top 20 public universities.*

The subsidiary goals in the Roadmap that will need to be realized in order to achieve that top 20 ranking are noteworthy. Clemson's goals are much more oriented towards making a difference in the world, via technological innovation and economic growth, to create a better place to live for the citizens of South Carolina. The 2020 Roadmap goals also champion addressing the "great challenges" of science and research.

So the goals are as follows, with emphases added by the authors of this chapter:

> *Fulfill Clemson's responsibility to students and the state of South Carolina;*
>
> *To provide talent for the* ***new economy*** *by recruiting and retaining outstanding students and faculty and providing an exceptional educational experience grounded in engagement;*
>
> *To drive* ***innovation****, through research and service, that* ***stimulates economic growth****, creates* ***jobs*** *and solves problems;*
>
> *To serve the public good by focusing on emphasis areas that address some of the* ***great challenges*** *of the 21st century–national priorities such as health, energy, transportation and sustainable environment.*

The reader will note that the economy and economic growth are mentioned twice, innovation is mentioned, and terms such as public good and national priorities suggest that this future vision is more oriented to the world beyond the walls of the university than the more typical university strategic planning document. The document goes on to identify substantive specifics, as follows:

Objectives

Invest in four strategic priorities:

- *Enhance student quality and performance;*
- *Provide engagement and leadership opportunities for all students;*
- *Attract and retain and reward top people;*
- *Build to compete–facilities, infrastructure and technology.*

In a cover letter for the Clemson 2020 Road Map, President James F. Barker reviewed the hardships that accompanied major state budget cuts necessitated by the national recession, but in closing reiterated goals and tactics to implement the 2020 Roadmap, as follows:

We will make investments to:

Provide talent for the new economy;

Drive innovation that stimulates economic growth;

Serve the public good by addressing some of the great challenges of our time.

And:

We will make divestments and generate new revenue to pay for those investments.

In parallel with the goals and aspirations expressed at an institutional level, such as in the 2020 Road Map, there are comparable statements at other levels. For example, the College of Engineering and Science, with the largest student head count and the largest fraction of sponsored research expenditures, had the following Vision:

*Connecting intellectual **and economic development** through **innovative** research and education."* [Emphasis added]

So too, in an R&D-intensive and graduate education-oriented institution such as Clemson, there are even more explicit expressions of innovation aspirations in the R&D Centers and Institutes where external partners in business and industry are engaged on a routine basis.
For example:

- At its launch the Advanced Fiber-based Materials Center of Excellence staked out its vision and goals: "*The center will be a focal point for existing and emerging research activities examining new fibrous materials systems and manufacturing technologies, including **discovery** and **initial commercialization** of technical innovative materials and processes... creating superior industries that will support the retooling and retraining of skilled workers, leading to **business growth, job retention** and further job creation."* [Emphasis added.]
- The more mature CU-ICAR captures itself as follows: *"CU-ICAR is as much an idea as it is a place. It is a unique blend of four things: **education, research, economic development and a magnet venue** for the automotive industry. Each of these elements interacts in such a way that the whole is much greater than the sum of the parts."* [Emphasis added.]

Virtually every one of the industry-oriented centers and institutes at Clemson has comparable vision, mission or goal statements.

As these meta-goals of the university are phrased in terms of innovation and economic impact, they have implications for other goals and investments. The general financial downturn in the 2007-2008 period hit South Carolina particularly hard, which in turn yielded a precipitous decline in state appropriations, which adjusted for inflation were much less than what they were a few decades prior. This funding environment demanded a new and more aggressive approach to fundraising and the launch of *The Will to Lead – A Campaign for Clemson*. Accomplishing the fundraising goal of $600 million to be realized by 2012 was not only highly desirable but essential for realizing the goals embedded in the Clemson 2020 Road Map. Assuming that the goals of impacting its environment by research and innovation still held, Clemson required new investments in faculty and facilities, supported by new financial vehicles such as endowed chairs, increased federal and private research funding, enhanced revenue from summer and online courses, and creative partnerships with industry. Nonetheless, during the dark days of 2007-2008, positions were eliminated, functions were outsourced, construction projects were put on hold, and restrictions on travel and hiring were imposed.

The good news is that the initial fundraising goal for *The Will to Lead: A Campaign for Clemson* of $600 million was reached and exceeded by $9 million by spring 2012. Moreover, the fundraising goal was raised to $1 billion. Funds from the campaign are already being used to permanently change the fiscal situation and associated goal accomplishment in several areas. Thus 357 new scholarships and fellowships were created, 95 faculty positions (endowed chairs and professorships) were funded, and several capital projects were launched or are in planning. The point of this is that many of these investments permanently relieve and enhance the financial situation of the university, and enable the institution to better accomplish its goals for quality education, innovation, and economic impact. For example, a fully endowed professorship removes much of that budget line out of the state-funded side of the ledger. Moreover, if wise choices are made in recruitment, a nationally prominent professor in certain fields can bring in annually significant grant or contract revenues, which can support graduate students, equipment, and defray costs of research administration.

Moreover, if campaign funds result in securing talented people in mission-focused R&D, then the other goals of the university will be realized, such as to "address some of the great challenges of the 21st century."

Leadership

The president of Clemson is into his second decade of leadership, having assumed the position in 1999. However, James F. Barker is not new to campus. He received a Bachelors degree in Architecture in 1970 from Clemson and then a Master of Architecture and Urban Design from Washington University, St. Louis in 1973. From 1973-1974 he was an Assistant Professor at the University of Tennessee; then from 1974 through 1986 he moved through the professorial ranks and became Dean of the School of Architecture at Mississippi State University. In 1986 he became Dean of the College of Architecture at Clemson, and then of the consolidated College of Architecture, Arts, and Humanities. He still teaches in the College.

It would be fair to conclude that without the vision, leadership, and agenda-setting that President Barker has articulated during his tenure, things would be different. However, this has not been a one-person show. Clemson seems to have enjoyed an effective and talented senior leadership cohort. There are four areas in which the leadership cadre of Clemson—president and key appointed administrators—has moved an agenda.

Management of the budgeting and reorganizing process. While precipitated by a national and state economic collapse, the process of deciding what to do ended up with a university laser-focused on innovation, technology, and knowledge-based economic revitalization. Over a period of a few years a cohort of senior leaders, including the president, deans, and senior administrators held frequent face-to-face meetings down to the level of departments. The latter were particularly intense SWOT analyses, and usually involved the VP for Research, the Provost, the Vice President for Economic Development, and the Chair of the Faculty Senate. The discussion topics included departmental strengths and weaknesses, national stature, opportunities to be significantly better, and change strategies. Upwards of 100 meetings like these were held and hard choices were made that would determine the direction of Clemson for years to come.

Continuity of Innovation Leadership. During the last 10-12 years of significant change Clemson has been blessed by a leadership group that has had years of innovation-relevant experience. In addition to the President's background, the former Vice President of Research and Innovation (notice title), who retired two years ago, had been at Clemson for 29 years. He was nationally prominent as an advocate for innovation (chairing the American Society of Mechanical Engineers Innovation Committee), and he participated in various regional and national boards concerned with invention and innovation including the Governors Science and Technology Advisory Council. His recent successor has over a decade of experience at the chief research officer level, and the two patents he holds demonstrate his innovation orientation. The Provost is ten years in her current position, although 39 years at the University. She played a major role in crafting the Emphasis Areas that have enabled substantive clustering of disciplines in ways that track with economic clusters in the state. The outgoing Dean of Business and Behavioral Science held the position for a decade, and recently moved to a college president job. His interim replacement was founder and chairman of four technology companies, has several awards for technological accomplishments, and has served in technology management positions at Georgia Tech and the Office of the Secretary of Defense. The outgoing (on medical leave) Dean of Engineering and Science (since 2006) has served on the National Science Board and while on the faculty of Wayne State University started a technology-based company. She has been at Clemson since 1985. Her interim replacement serves on the Board of Oak Ridge Associated Universities (ORAU), is Chairman of the Bioengineering Alliance of South Carolina, and coordinates the College's research centers, alliances, and institutes. He has been at Clemson for over 25 years and has served as President of Clinical Microsystems, Inc, a technology company.

Creation of New Positions and/or Program Descriptors. While this may be a minor footnote to the Clemson story, often when universities create or re-engineer themselves, they also typically create a leadership position that has a relevant name. That name can also send a message internally and externally. So a Vice President of Research *and* Innovation means something different than a more typical position description. Creating a Vice President for Economic Development perhaps sends a different message than a vice president for community partners. Creating a *Watt Family Innovation Center for Academic Collaboration and Student Engagement* (actually recently launched) is a different message than a mere center for academic collaboration and student involvement. So too when the family spokesman (and distinguished Clemson professor) Charles Watt describes the center's purpose as follows, it says something about Clemson:

> *We want to create an intellectual center that will prepare a new generation of scholars who will take ideas from concept to the marketplace. This will be a place to demonstrate and enable education, discovery and innovation.*

Boundary Spanning: *Entrepreneurship*

Entrepreneurship programs at Clemson are nominally centered in the College of Business and Behavioral Science but in fact the scope and reach of their activities is campus-wide and closely linked to other innovation activities on campus and in the community. The Arthur M. Spiro Institute for Entrepreneurial Leadership, in operation for 15 years, is in many ways the entrepreneurship center of gravity at Clemson. Internal members of the Leadership Board include an Academic Director, an Associate Dean of the college, an entrepreneur-in-residence, a visiting scholar, a Program Director, and the Executive Director of the Board. The Leadership Board also includes a dozen seasoned entrepreneurs from various industries and companies, most with a South Carolina presence.

Curricular Programs

The Spiro Institute also seems to be the entity whose "brand" is on the different course packages that are offered through the College of Business and Behavioral Science. Particularly notable is the fact that most entrepreneurship classes are open to students from across the campus and not just in Business, a program strategy that is likely to have significant "culture-changing" impact on the Clemson community at large as opposed to one that is focused primarily on business students. While there does not appear to be an Entrepreneurship major, an Entrepreneurship Minor is offered for nonbusiness majors, consisting of 15 credit hours. A Technology Entrepreneurship Certificate is offered to graduate students in engineering and science programs, consisting of nine credit hours of graduate level coursework.

A recent program innovation involving the Spiro Institute and the College of Business is the establishment of a 1-year MBA in Entrepreneurship and Innovation, which has several novel features. One, it is located in Greenville at the new off-site campus facility known as Clemson at the Falls, which also houses a Small Business Development Center. Two, it is conceived as a full-time experiential program personalized to a small cohort of applicants (25 students) who have a business idea in mind or in the planning stage. Three, in addition to class-based experiences, a key feature of the program is the expectation that over the year enrollees will work closely with a mentor network of established entrepreneurs to nurture and develop the business idea. Students also receive hands-on real-world skills development in areas that include legal and regulatory aspects of business development, web design, fundraising, rapid prototyping, and a summer internship experience. The initial class started June, 2012.

Another program innovation launched at Clemson at the Falls is a "Mini MBA," essentially a certificate program for fully employed students. It consists of five all-day Saturday instructional sessions around business fundamentals, as well as networking activities with local entrepreneurs. It is being offered through Clemson's Professional Advancement and Continuing Education program.

Co-Curricular Programs

While not formally linked, Clemson's entrepreneurship activities in Greenville are also enabled by NEXT which is an initiative of the Greenville chamber in partnership with a large number of local entrepreneurs as well as major technology-based companies with facilities in the area (3M, Lockheed, GE). The NEXT Innovation Center is an incubation facility as well as a network of mentoring relationships and programs. Greenville has become a robust center of job growth and investment in the upstate region, and a significant partner for Clemson.

The Spiro Institute also recently introduced a pilot class in social entrepreneurship and established a MAD (Make a Difference) video competition where student and community teams each create a 3-minute video showing the impact of their new social venture on the community.

In addition to its involvement in educational programs and research the Spiro Institute is engaged in a number of activities that foster entrepreneurship at Clemson and in the larger community. It has published an online newsletter, *Entrepreneurial Leader,* which informs the community about events, people, program opportunities, research and entrepreneurial insights. It sponsors a Launch Pad competition, now in its second year, that features prizes of over $20,000. Participants include students and state residents. Other events include Network Mondays, Venture Fridays, Lunch Studios with Practitioners, and a guest lecture series.

The Spiro Institute works with the Clemson University Research Foundation (CURF), the Clemson technology transfer program, by serving on the CURF board and as an occasional resource in cases where the commercialization route for a student invention is likely to be a startup. It selects Student Entrepreneur of the Year awards for both undergraduate and graduate students. It recognizes notable Clemson Alumni Entrepreneurs. It spotlights various award and scholarship programs. It holds speaker and panel events to inform the Clemson community about entrepreneurship issues and thinking. It informs and helps organize various contests that are open to students and the community.

Clemson benefits from a well-organized and veteran set of entrepreneurship activities and programs that mesh with a range of other programs and activities to build an innovation culture in the university and in the larger community.

Boundary Spanning: *University, Industry and Community*

One of the better indicators of academia's inclination to be technologically innovative is the extent to which its core activities—teaching and research—are engaged with inputs from the outside world, particularly business and industry. Consider research and the extent to which university research involves industry funds. For several years Clemson has exceeded the national average, which we would argue favors real world innovation. Industry sponsored research conducted by faculty tends to come in several modes: contract research arrangements that involve one company and one university research team; research conducted in the context of a university center or institute, sometimes involving several companies and several faculty members; or consulting relationships between a faculty member and a company (or companies) where the work may be performed during the summer or on the generally accepted "consulting days" that all universities permit. The fees transacted in this last category are rarely counted in a university's research totals.

Centers and Institutes. The center/institute model of faculty research with companies has been important for Clemson and is nationally very important for fostering university-industry innovation outcomes. One reason for the greater impact is that R&D problems in business and industry tend to span academic disciplines and concepts, and centers or institutes often have more conceptual or methodological bandwidth to accommodate them. Illustratively, when an industrial problem gets solved in a novel way and the solution leads to a patent, very often the list of inventors is multidisciplinary. Clemson's approach to Emphasis Areas (described above) may enable them to be more nimble in developing these partnerships.

Clemson, like many research intensive universities, has a multitude of centers and institutes "on the books." Per a Clemson roster dated 8-13-2012 there are 88 centers or institutes. Not all of these are strongly related to R&D and fostering technological innovation (e.g., Clemson Institute for the Study of Capitalism); some seem to have a stronger linkage to teaching or academic matters (e.g., Rutland Institute for Ethics); and some are relatively inactive either because they are in the formative stage or have not been successful in connecting with partners. Nonetheless the fact that Clemson has a large number of centers and institutes indicates that the culture and administration encourage cross-disciplinary cooperation.

There are also a small number of Centers that have higher profiles and more financial support. For example the Clemson University Centers of Economic Excellence are participants in a State of South Carolina initiative, the Smart State SC Centers of Economic Excellence program. Smart State receives state lottery funds that are dispensed on a matching basis. For example, it has supported 16 endowed professorial chairs in 13 key areas and centers. These include:

- The International Center for Automotive Research (CU-ICAR)
- Advanced Fiber-based Materials Center of Economic Excellence
- Advanced Tissue Fabrication Center (in collaboration with the Medical University of South Carolina [MUSC] and the University of South Carolina)
- Cyber Institute
- Health Facilities Design and Testing (also in collaboration with USC and MUSC)
- Optical Materials and Photonics, which is part of the Center for Optical Materials Science and Engineering Technologies (COMSET)
- Optoelectronics (COMSET)
- Regenerative Medicine

- SeniorSMART (with University of South Carolina)
- Sustainable Development
- Supply Chain Optimization and Logistics
- Tissue Systems Characterization
- Urban Ecology and Restoration

Inter-Disciplinary Clustering and Center Linkages. Generally universities organize their operating structures around discrete academic disciplines, sometimes thought of as "silos." Thus traditional engineering disciplines will be bundled into a college of engineering; likewise traditional business disciplines will be grouped into a college of business and so on. The problem for business and industry is that knotty problems tend to involve a wider range of academic disciplines. For example, to design, manufacture and effectively reach markets for a new biomedical device may require innovation in materials, sensors, computer software, logistics, market research and sales. All things equal, universities need to do better at this creative bundling.

As noted above, the research administration function of Clemson has approached its work in terms of broader *Emphasis Areas* rather than the discipline and sub-disciplinary structure that typically drives relationships in a more traditional academic setting. This is not to say that colleges and academic departments should not exist; they do work together to achieve teaching, research, and public service goals. But many R&D activities demand a more inclusive structure that crosses boundaries within the academic setting. From the perspective of the office of the Vice President for Research office the Emphasis Areas:

> *...are notable for their direct economic development potential because of the combination of the University's strength in the field and a related industry presence in the state.*

In a parallel manner, the office of the Provost at Clemson, which traditionally has responsibilities for instruction, professional development, and the curricular structure of the University, has adopted the *same* Emphasis Areas that define the work activities of the office of research. Since another responsibility of the Provost is to oversee graduate education, there has been an effort to identify centers and programs related to each of the emphasis areas. For example, a dissertation project being developed by a graduate student in department X might benefit from committee members who are affiliated with centers or institutes A, B, and C. The articulation of these Emphasis Areas, listed below, involved dialogue among the VP for Research, Provost, college deans, department chairs, and key faculty researchers:

- Advanced Materials
- Automotive and Transportation Technology
- Biotechnology and Biomedical Sciences
- Information and Communication Technology
- Sustainable Environment
- Leadership and Entrepreneurship
- Family and Community Living
- General Education

And for each of these Emphasis Areas a small number of Centers, Institutes or programs that work in that area have been identified. For example, the Advanced Materials Emphasis Area has identified the following related Centers and Programs:

- Advanced Materials Center
- Center for Advanced Engineering Fibers and Firms
- Center for Optical Materials Science and Engineering Technologies
- Clemson Institute for Advanced Materials and Manufacturing
- Clemson University Restoration Institute
- Electron Microscope Facility
- Laboratory for Advanced Plastic Materials and Technology
- Sonoco Institute of Packaging Design and Graphics

In a like manner each of the other Emphasis Areas has been linked to a small number of centers, institutes and programs. This approach is not only neat and tidy, but it seems to make sense to industry partners—and potential funders, as per the *Will to Lead* campaign.

Expanding and Re-Inventing Extension. Clemson has been a center for Extension activities for much of its history. In addition to campus-based research in the agriculture-related sciences, it has led statewide extension services that serve thousands of individuals and enterprises across South Carolina as well as operating six Research and Education Centers (REC). Each REC tends to be a hub for a different agricultural and climatological zone. They house resident faculty and coordinate with extension agents in the field. One REC, located in the West Indies, was established via a donor gift and is operated with regional collaborators. In addition to publications, information-sharing, and instructional programs about agriculture *per se*, the extension activities extend to helping clients succeed in new companies related to the sector. Reflecting its statewide economic-development mission, a study was recently completed looking at the ingredients of prosperity across 46 South Carolina counties.[2] Reflecting the changing vision of extension, a program growing out of the Sandhill REC, the Gussie Greene Technology Center, is expanding technology-related skills in the community of Chicora/Cherokee in North Charleston. The city and some technology companies are partners.

Since 2006 Dr. John Kelly has led Clemson's research, extension, and community engagement in agriculture. Recently Kelly has acquired new duties that leverage his years of experience in ag-related outreach but extend his responsibilities—and an enlarged Clemson vision—into new territory. This includes the establishment of large R&D facilities, away from the campus and often at the other end of the state, that have both technological and economic implications. Appropriately, Kelly's revised title is Vice President for Economic Development (formerly Vice President for Public Services and Agriculture), with a reporting relationship primarily to the President. In addition to the agriculture-related activities described above, he has assumed additional responsibilities pertaining to R&D facilities and programs that are not on campus, some of which are urban-located and most of which are not closely linked to agriculture.

One way to think about these programs is akin to chunking content together for greater scope and impact, and physically locating the programs in venues where they might reach more people and companies. These activities can be large and facilities-based; others can be more distributed and utilize media and the Internet. An example of the latter is the *Technology Village* concept that is being brought to bear in rural and small-town areas and is focused on new technology companies. Using a hybrid mix of Internet-mediated consultant services and "storefront" incubation assistance, the program is reaching a wide range of clients. Service topics include intellectual property, technology evaluation, seed financing and human resources.

There are also larger, more technology intensive activities:

- *The Clemson Restoration Institute* is an interdisciplinary program that aspires to *"drive economic growth in the natural, built and restoration economy"* by developing and fostering restoration industries and environmentally sustainable technologies in South Carolina. Vice President Kelly was involved in the development of the Institute and is the Executive Director. The Institute recently received a $5 million gift from the Zucker family to contribute to a graduate education center, as well as a $700K planning grant from NSF for curriculum development. Two R&D launch activities will include a wind turbine drivetrain testing facility, which is being built with $45 million in Department of Energy funds supplemented by $53 million in private and public funds, and another $3M project to use Intelligent River technology—a battery-powered MoteStack to monitor 312 miles of the Savannah River for water quality. The MoteStacks are anchored to the stream bed, take sensor readings, and then transmit data to the Clemson computing system.
- *The Clemson University International Center for Automotive Research (CU-ICAR)* is also located away from campus, in this case Greenville, which is 50 miles from Clemson near the intersection of two Interstate highways, 90 miles from Charlotte, and 150 miles from Atlanta. CU-ICAR has received "best practice" plaudits from the National Academy of Sciences, and encompasses research, development, graduate education, and a venue ("magnet") for auto industry meetings and conferences. It sits on a green-field 250-acre site that includes laboratories, conference facilities, and instructional settings. The research program is organized into "clusters" that include manufacturing and materials, advanced powertrain, vehicular electronics, human factors, and component testing. CU-ICAR has accelerated the development of an automobile economic development cluster in the upstate region that includes OEMs, suppliers, and industry research organizations. About half of the students receiving graduate degrees through ICAR end up working in the region. There are several buildings and facilities on the site. Most recently, in May 2012, ICAR opened a 60,000 square foot multi-tenant building, which will ease participation for its 17 resident partners and 24 research partners. Vice President Kelly played an important role in launching ICAR and building the facilities and the clientele, and has ongoing strategic responsibilities.
- *The Advanced Materials Center* is located in Anderson, SC, less than 10 miles from campus, and is an external outpost for Clemson's significant strengths in this R&D area. It houses the Center for Optical Materials Science and Engineering Technologies (COMSET),

the South Carolina Research Authority, the Applied Research and Development Institute, the National Brick Research Center, the Tile Council of America and in a new facility the Duke Energy Innovation Center. The facility has over 100,000 square feet of lab and office space. All programs are structured for significant industry involvement. In particular, COMSET (with Rutgers) is a National Science Foundation Industry/University Coperative Research Center, which is structured with paying industry members who play a strong role in defining the Center research agenda and reviewing results. The Center is also under the purview and benefits from the strategic guidance of Dr. Kelly.

State and Local Programs. Clemson has a variety of program and policy links to public and non-profit organizations that enable its mission of innovation and economic development, as per the Clemson 2020 Road Map. For example, the University Center for Economic Development (UCED) is a joint program of the Clemson Regional Economic Development Research Laboratory (CREDRL) and the Clemson Institute for Economic and Community Development (CIECD). It is supported with funds from the university as well as support from the U.S. Department of Commerce Economic Development Administration (EDA).

UCED conducts research and provides technical assistance to local economic entities—urban and rural—in the form of workshops, training, evaluation, and strategy building. UCED also maintains links and information-sharing with other centers and institutes on campus that are working in the general area of economic development, for example the Clemson Center for Workforce Development. It also links to regional and national organizations that pursue economic development via studies, funding and advocacy. These included the Southern Growth Policies Board, the Southern Technology Council, South Carolina Council on Competitiveness, South Carolina Department of Commerce, and Southern Rural Development Center.

Clemson also maintains connections with a wide variety of industry associations, national and regional, that map well against the R&D emphases of the university. One interesting example is a "quango"[3] based in Charleston, the South Carolina Research Authority (SCRA). SCRA was birthed by the South Carolina legislature with a grant of $500K plus a grant of 1,400 acres. While a 501(c)(3), SCRA has a distinctly private sector, technology-oriented set of mission goals. It assists early stage and startup companies in conducting applied R&D that typically involves federal or private sector clients and it builds and manages R&D facilities, via a range of partnership arrangements. For example, it has dozens of contracts with federal agencies as well as with over 200 corporations. Much of the work is performed in South Carolina where SCRA is located. For example SCRA is working with Clemson's Advanced Materials Center in Anderson to significantly enhance R&D space and programs.

The most significant partnerships between Clemson and state government have been embodied in the Smart State program noted briefly above. The history of that large and diversified program goes back over 10 years. Some of the analytic rationale was reportedly provided by a cluster study performed with Michael Porter, which led to the identification of a small number of industry clusters as well as some greater attention to how the R&D assets of the South Carolina university community—Clemson, University of South Carolina, and Medical University of South

Carolina—could be brought to bear. The clusters are: advanced materials and nanotechnology; automotive and transportation; biomedical; future fuels; information science; and pharmaceutical. The Smart State Program was created in 2002 with funds from the South Carolina Education Lottery.

In addition, four other programs were established via the following legislation, as follows:

- *The Research University Infrastructure Act (2004).* This created a pool of funds for the three research universities, awarded on a matching basis for facilities and other investments in areas where the institutions already have some established credentials;
- *The Life Science Act (2004).* This program created a pool of funds available to life science companies, for capital investment, that meet certain criteria of economic impact;
- *The Venture Capital Investment Act (2004).* It created a pool of funds for equity investment in SC-based firms, ranging from seed investments to larger equity levels. It also provided small grants for incubator facilities and services in state universities;
- *The Innovation and Research Centers Act (2005).* While administered by SCRA (above) it supported research, product development and commercialization with links to the three research universities.

Boundary Spanning: *Technology Transfer*

A central enabling function in fostering and enabling innovation and economic impact in a university is the technology transfer function. Faculty research in universities is typically focused on theoretical and empirical questions in a discipline or area of study. Sometimes findings emerge that also seem to have implications for the world of business and industry. The technology transfer function in a university is the entity that works with faculty (and student) inventors and potential users of that invention in the external world.

The Organization. The technology transfer function and associated activities at Clemson are organizationally located in the Clemson University Research Foundation (CURF), which is a 501 (c)(3) not-for-profit corporation. CURF has a reporting and coordinating relationship with the senior leadership of Clemson. It is governed by a Board of Directors (currently 18 members), half of whom are from external organizations (primarily technology-based companies) and the balance are mostly Clemson senior leaders (President, Chief Financial Officer, Comptroller, Vice President for Research, Vice President for Economic Development, two deans, and one professor/department chair). In effect, CURF is able to conduct its mission for Clemson, without being hampered by the departmental and college level politics and processes. This is a common format for technology transfer operations among leading universities.

CURF is physically located off-campus, approximately eight miles away, contiguous with the Advanced Materials Research Center. This kind of physical location tends to facilitate interaction with potential technology transfer partners from the private sector.

Over the last decade the scope and capacities of the CURF organization have grown. Depending on how one counts, there are currently five professional staff (counting the Director) plus two support staff. The newly hired Director has significant experience at Carnegie-Mellon (one of the cases in this volume), Oak Ridge National Laboratory, and Case Western Reserve. These capacities and people represent a significant institutional investment by Clemson, which is paying off. A decade ago the staff was not as deep and even as recently as the FY2010 AUTM statistics Clemson was reporting only three FTE professional staff members.

Performance. Clemson's technology transfer performance has improved markedly over the past decade so as to be clearly among the most effective offices. Looking at FY2012 data from the Association of University Technology Transfer Managers,[4] it is clear that Clemson does well on several normalized[5] metrics of performance. For example, its rate of invention disclosing is better than the majority of the top-100 research-intensive universities. An invention disclosure seems to emerge for about $1.1 million of reported research expenditures. So too its normalized rates of securing patents and option agreements compares favorably to the majority of top-100 schools and also holds up against the distinguished company of this case sample of *Innovation U* institutions.

It should also be noted that the academic members of the CURF Board are primarily drawn from those colleges and areas that are most likely to be sources of invention and intellectual property. As such, they often function as informal early links ("scouts") to research activities and people who are potential sources of invention with commercial potential. Similarly, the business and industry members of the CURF board have the technical backgrounds that map well with what Clemson does in research and development, and can thus broker connections in the larger community—potential investors, commercialization partners, entrepreneurs and so on.

Disclosing, patenting and licensing activities have increased significantly over the years. On the Technology Search page of the CURF website there are[6] over 160 inventions listed as available for licensing. Of these 74 were in the area of advanced materials, 43 in biomedical sciences and 31 in biotechnology. Not surprisingly, these also reflect the core R&D strengths of the institution.

So too do the increasing number of technology-based early stage companies that are populating the area and the state and have some linkage to Clemson. Thumbnail descriptions of several early stage companies are found on the CURF website under Cluster Companies. As above, the technological business opportunities that these companies are chasing tend to reflect the core R&D strengths of Clemson.

CURF is moving toward a somewhat more aggressive and externally engaged approach to its technology transfer work. That is, rather than waiting for faculty disclosures to come in the door or over the transom, CURF staff will be engaging researchers in the centers and institutes where many of them perform their research, and trying to identify invention ideas as they are still emerging. They will then work with the faculty member to move the commercialization process along. In parallel, there will be efforts to reduce "false positives" in the innovation process. For example, if a faculty member discloses an invention that CURF sees as having marginal commercial potential, it may choose to not pursue patenting and in effect give it back to the inventor, although it will retain some modest share in royalties or other returns realized by the faculty member.

Another locus of activity in which the office of the VP for Research and CURF are coordinating is when Clemson is on the brink of signing a contract research agreement with a company and where the company is pushing very hard for advance agreements and special treatments regarding IP. Sometimes the VP will convene an informal "task force" to review the contract terms and decide whether the agreement involves too much "give" to accept—or to come up with a creative solution that will enable the project to go forward.

Technology Transfer Adjunct Facilities. In order to enhance the entrepreneurial side of its activities, CURF also operates or participates in facilities and programs that supplement what the office does.

For Example, the *Center for Applied Technology (CAT)* is an incubation facility that is located in Pendleton, South Carolina. It includes roughly 30,000 square feet of space, including 8800 square feet of wet lab facilities, and 10,500 square feet of office space. Its clientele includes early-stage companies, mostly with a direct link to Clemson, but also "soft-landing" companies that simply need time, space and support to grow. There is a receptionist and the typical office features (internet, FAX, audio conferencing, etc). A regional Small Business Development Center (SBDC) also works with tenants and clients of the CAT.

Another parallel facility also is located in Pendleton, albeit this is a "mixed use" program with a wider variety of tenants and disciplines. It encompasses 18,100 square feet, with 4,100 square feet for offices, 6,100 square feet of lab space, and 8,000 square feet of common areas. The range of services is comparable to those in CAT. The conference space also includes smartboard, polyboard and overhead services.

In summary, technology transfer at Clemson is a robust and growing activity. It also benefits considerably from the larger culture of the institution and the many cross-functional linkages between the university and the community. It benefits from imaginative leadership within the office and across the university.

Summary and Parting Comments

The Clemson case is an enlightening example of a university that over a relatively short period of time—less than 15 years—has expanded the scope and quality of its R&D, enhanced its instructional programs, adopted a daring and novel mission that is much more oriented to technological innovation and economic outcomes and—at the same time—managed an unprecedented decline in state funding in the midst of a national recession. For those universities that are confronting similar goals and challenges, there is much to learn from the Clemson story.

Endnotes

[1] National Science Foundation, National Center for Science and Engineering Statistics, FY2011. *Table 14. Higher education R&D expenditures, ranked by all R&D expenditures, by source of funds: FY2011. Table 15. Higher education R&D expenditures, ranked by all R&D expenditures, by R&D field: FY2011.*

[2] Lipford, J. W., Watkins, T. and Yandle, B. (2011). *Prosperity in South Carolina: An Analysis of 46 Counties for 2000 and 2008.* Clemson University, Office of Economic Development. Retrieved from http://www.clemson.edu/economic-development/files/2011_prosperity_report.pdf

[3] Also known as a quasi-autonomous-non-government-organization.

[4] Association of University Technology Managers. (August, 2013). *AUTM U.S. Licensing Activity Survey: FY2012.* Deerfield, IL: Association of University Technology Managers.

[5] Normalized metrics are equivalent to batting averages in baseball. For example, the total number of invention disclosures is a poor way to compare university A and university B, particularly if B performs 10 times the research that A does. The better comparison is the rate or incidence of disclosing. For example, if university A produces a disclosure (or license or whatever) for every $2 million of research expenditures, it is doing better than B which has one disclosure for every $4 million of research expenditures.

[6] This was as of mid-September 2012.

University of Florida*

The University of Florida's (UF hereafter) rise from a meager, men-only, and poorly supported college to a nationally significant institution parallels in many ways the burgeoning growth of the state that it serves. After a fruitless search for gold and silver by Juan Ponce de Leon and Hernando de Soto during the 16th century, the area that was to become the state of Florida settled into a long Spanish occupation,[1] marked mostly by the establishment of Catholic missions. That lasted until 1821 when Florida became a US territory. Andrew Jackson figured significantly in the territorial period, which was notable for immigration from the rest of the south as well as attempts to evict Seminoles from the region, which met with mixed success. In 1845 Florida was admitted to the union and by 1850 the resident population was 87,445 including 39,000 African American slaves. This gave the new state one seat in the House of Representatives.

The institutional precursors to UF emerged during the mid-19th century. In 1853 the governor signed a bill that provided public support to college education. Concurrently the East Florida Seminary (EFS) was opened in Ocala as a males-only institution of higher education. That college was closed during the Civil War period of 1861-1865 and reopened in 1866 at a new site in Gainesville. Florida Agricultural College opened in 1884. Eventually in 1906 these various educational ventures were consolidated into the University of Florida. UF was still a males-only, whites-only institution, and was eventually designated the Land Grant campus for the State. It welcomed 102 students in September of 1906.

The University of Florida continued for much of the twentieth century as primarily a modest enrollment, mostly teaching institution—as did many public universities across the US Between 1906 and 1945 the student head count never exceeded 3,300 students. In 1946 it jumped to 6,634, nearly doubled by 1956 and jumped to 18,309 in 2006. The GI Bill was part of this, but so too was the rapid population growth in the state—from 1.8 million residents in 1940, to 4.9 million in 1960, 9.7 million in 1980 and 19 million in 2011, as the 4th most populous state in the country. The 2012 fall term enrollment at the University of Florida was 50,086.

The composition of the state economy was also evolving throughout the post-World War II decades, from an early reliance on agriculture, construction, and later on the space industry, to a much more diversified mix of knowledge-based services, technology, and health systems. As these economic changes took hold, so too did the university structure in the state. By 2011 the state of Florida had become the home for four top-100

** This case was written by Louis Tornatzky, Elaine Rideout, and Olena Leonchuk.*

universities (in terms of research expenditures) with the University of Florida leading the pack in 18th place nationally (from 40th in 1992). Between 2002 and 2009 UF increased its research expenditures by 53.3%, exceeding the national growth rate. In FY2011[2] the University had research expenditures of $739.9 million, with the lion's share (81%) in either the life sciences ($506.8 million) or engineering ($92.8 million), reflecting its historic Land Grant history, its emphases in biomedical research, as well as a growing concentration on sustainability issues and problems

Currently the University is structured into 16 colleges supplemented by upwards of 150 research centers and institutes, all of which is enabled by a distinguished faculty of roughly 4200. So too has the University garnered a growing number of accolades and awards. *U.S. News & World Report* ranked it #19 among Top Public Universities in 2011, #7 by *Princeton Review* as Best Value Public College 2012, and #2 in *Kiplinger's Best Values in Public Colleges* 2012. Among its faculty 40 are classified as Eminent Scholars, 27 are members of either the National Academy of Sciences, National Academy of Engineering, Institute of Medicine, or the American Academy of Arts and Sciences, plus two are Pulitzer Prize winners. Faculty excellence is matched by student excellence, with the Fall 2011 entering class havingaverages of a 4.23 high school GPA and a SAT score of 1920.

While all of the above depicts a distinguished university, it does not necessarily describe a university that is deeply involved in innovation and economic impact. In the following sections we will elaborate on the energy and talent that the University of Florida has deployed toward those goals.

University Culture: *Goals and Aspirations*

The "culture" of a university, or any large organization, is an amalgam of what it values, what it aspires to in terms of its goals and strategies, what it does and intends to do more of, and what it talks about. The University of Florida has historically, up until the last decade or so, been mostly concerned about the quality of its educational experience, the scope and excellence of its research and scholarship, and its service to the public good via an educated citizenry and workforce. Like nearly every US University, UF's goals are articulated around pretty much the same themes of teaching, research, and service. In fact, in virtually every professor's evaluation for promotion and/or tenure across the country, those same domains are the key dimensions.

So, the University of Florida Mission Statement for 2010-2011 closes as follows:

> *These three interlocking elements—teaching, research and scholarship, and service—span all the university's academic disciplines and represent the university's commitment to lead and serve the State of Florida, the nation and the world by pursuing and disseminating new knowledge while building upon the experiences of the past. The university aspires to advance by strengthening the human condition and improving the quality of life.*

The three "elements" noted above are pretty much standard fare for US universities everywhere. However, the case analysis that went into this chapter uncovered many stunning examples in which the UF is delving deeply and effectively into innovation, the active commercialization of invention and the encouragement of faculty and student entrepreneurial behavior. So we dug deeper for how other goals and aspirations entered in.

After the current UF president, Bernie Machen, came to the university in 2004 he executed a highly participative strategic planning process that resulted by 2007 in a University of Florida Mission Statement (the above) and an accompanying set of 48 Goals that constituted the Strategic Work Plan for the University going forward. Few had anything to do with the focus of this book, and most had to do with the normal business of a large energetic institution. Digging into the details, only Goal #38 mentioned *innovation* as follows:

> *Increase extramural funding and scholarly productivity for agricultural research, extension and academic programs that span basic discovery,* ***innovation*** *and application. [Emphasis added.]*

Since this is a book about *Innovation U*, what else was going on in 2007 at the University of Florida and since then to assume that UF had evolved into an "innovation culture" as sketched in above? We will argue the following:

- First of all, it is safe to assume that President Machen, who came to the University of Florida in January of 2004, was already very supportive of and experienced in fostering an "innovation agenda" at UF. He was previously President of the University of Utah, an institution that was very active and successful in many of the elements of innovation discussed in this volume. Notably, the University of Utah was one of the 12 cases presented in the 2002 edition of *Innovation U: New University Roles in a Knowledge Economy* (while Machen was President) and continues in this edition.

- By 2008 or so, the University of Florida had become a "top-20" university or thereabouts, and was in some fairly distinguished company. Most members of that cohort of institutions have a broader and more expansive notion of the research, education and service functions of a university. They have found, for example, that if they want to lure and retain a growing fraction of outstanding (and well-funded) faculty members, they will have to be good at innovation, particularly in activities like technology transfer, enabling faculty startups, and private sector relationships. Otherwise people may leave. It should be noted that two of the more interesting and strategic steps taken by UF in the past decade relevant to our topic is a major enhancement in the leadership and staffing of the Technology Licensing office[3] which shortly followed the appointment of a Vice President for Research who was very knowledgeable[4] about university technology transfer and "best practices" therein.

- Sometimes the world changes. Historically, most university senior administrators could opt to be weakly interested, effective or supportive regarding innovation, entrepreneurship or technology transfer and still be OK with their constituencies in state legislatures and governors' offices. But that state of affairs changed quite a bit in the last several years. As the national economy has weakened and nearly collapsed, along with declining state support of universities, more people became interested in how to leverage the university's intellectual assets into the private sector. Thus visions and programs that mentioned innovation, commercialization, and entrepreneurship entered the university and public policy lexicon more frequently.

- Not only have universities changed but so too have contiguous communities and political bodies. In many town and gown settings, the extent of serious collaboration between the two worlds has been minimal or sometimes prickly. That has changed significantly across the country, including at the University of Florida and metro Gainesville. In effect, the culture of university-community interaction has changed.

The argument here is that because of internal and external events over the past several years the *culture* of UF has shifted in a more positive direction regarding innovation, technology commercialization, and business and social entrepreneurship, and that these activities are a growing fraction of the institutional culture. Moreover, President Machen has led that process of culture change, in concert with a cohort of internal and external advocates.

One interesting way to track this at UF is to scan Presidential speeches and attributions over the last few years. Let's start with something from C. David Brown, II, Chairman of the University of Florida Board of Trustees, in a July 17, 2012 press release announcing the formation of a search committee to identify President Machen's replacement:

> *President Machen's tenure has been extraordinarily successful. Under his leadership we have built new state-of-the-art sustainable educational and research facilities, significantly increased research funding and embraced innovation and entrepreneurship.*

And in fact if we go back over the years to speeches by President Machen, there has been a slow but increasingly prominent theme centering around innovation, technology transfer, and entrepreneurship, as he became a significant advocate for these activities:

- In a 2007 eulogy for Gatorade Inventor Robert Cade, the President lauded his many invention triumphs, as well as how "From our experience with Gatorade, we learned a lot about the right ways to support our faculty in nurturing their inventions."

- In a 2008 eulogy Celebrating the Life of S. Clark Butler, he remarked on his many accomplishments as an entrepreneur and praised his role in supporting the UF Center for Entrepreneurship and Innovation.

- In a 2008 speech for Dedication of the Cellulosic Ethanol Pilot Plant, he mentioned, "Lonnie Ingram, a distinguished professor of microbiology, [who] came up with the invention to make this possible."

- In March of 2009, as the recession kicked in with a vengeance, the President made a presentation to the Heart of Florida Economic Summit, about the need to be "willing to innovate to meet new consumer demand for products that are smaller, more efficient and cleaner." He went on to talk about the technology incubators available for these tasks at the University of Florida, and then handed off the UF message to David Day, of the Office of Technology Licensing, "to give you a more detailed look at our innovative technologies."

- A month later, President Machen presented at the UF Technology Showcase and talked about various UF emerging technologies, UF spinoff companies, the extent of venture capital funding achieved by UF startups, the incubation facilities and services that are available and a range of related topics.

- In June 2010, President Machen presented at the Innovation Hub Groundbreaking, a partnership between UF and Gainesville, that would encompass the redevelopment of downtown and will include UF facilities and programs focused on the development of UF spinoffs, via Innovation Square, Innovation Hub, and the growth of a contiguous "creative community."

- In October 2010, President Machen presented at a Lake Nona Groundbreaking (in Orlando), which involved a programmatic collaboration with Sanford-Burnham Institute for Medical Research, UF and the University of Central Florida, that will foster "research and innovation that elevates our ambitions, magnifies our strengths, accelerates our achievements…"

- In November 2010 the President spoke to the Clay County Chamber of Commerce Economic Development Luncheon. His talk was a free-ranging overview about UF accomplishments and aspirations in research, development and entrepreneurship, and how they will "create jobs, economic opportunities, and a unique identity and brand for Gainesville and Florida."

- In August 2011 the President made a presentation to the Southern Governors' Association Annual Meeting that reviewed the UF experience in technology commercialization with a particular emphasis on the cost benefits of startup companies, incubators, and other support services.

- In August 2012, welcoming everyone back to campus for the fall term, President Machen made a presentation on *The State of the University: The Morrill Act and the Path Ahead*, which argued that the innovation activities that are now underway—incubators, startup companies, advancements in instructional delivery—are the logical successors to what was launched by the Morrill Act in 1862.

In terms of what UF is talking about and doing, it is relatively clear that while the core traditional mission goals of instruction, research, and community services go on and dominate the attention of the institution, new mission elements are emerging.

Moreover the president is being an effective advocate for the University's innovation goals, that are being helped by an ambitious fundraising effort. Only three years after its launch in 2010, the "Florida Tomorrow" campaign had, as of early 2013, already reached and exceeded its five-year goal, raising $1.6 billion for research and education. These funds have helped to endow 292 professorships, up from 170 in 2004.[5]

UF excels at quantifying the economic results that fundraising and public investments yield. The Florida Tomorrow campaign, for instance, notes that for each state dollar appropriated, the university generates $8.80 for Florida's economy. Other measures of success include the 140—and growing—start-up companies that have been created using UF technology, and the $100 million in venture capital investments that the university's spinoff companies attracted.[6] Further, an economic impact study notes that of the $8.76 billion that university-related activities generated in fiscal year 2009-10, 16 percent (or $1.43 billion) was contributed by UF technology spin-off companies located in Florida.

The University is also experimenting with other ways to maximize revenue and increase efficiency—most notably by experimenting with a 12-month calendar. Beginning in 2013, a section of the freshman class will take on-campus courses in the spring and summer semesters, but not in the fall. This program, known as Innovation Academy, enables the institution to enroll 2,000 additional students by maximizing space that until now has been underutilized during the summer. The cohort will minor in entrepreneurship, innovation, and creativity, and receive encouragement to launch their own ventures (more on this later). This is an interesting way to marry the economies of better facility utilization with a novel curricular direction that expands the innovation agenda of the campus.

It is also likely that the innovation culture of the University of Florida was enhanced by important external relationships and friendships. Two are particularly noteworthy: Manny Fernandez and Jeremy Ring. Mr. Fernandez was a member of the UF Board of Trustees from 2001-2007 and its Chairman from 2003. Mr. Fernandez was the son of a Cuban immigrant and the family's rise to business success is inspiring. Mr. Fernandez received a BS in computer engineering in 1967 and had a meteoric career as a technology entrepreneur and CEO of Dataquest, Gavilan Computer, and Zilog. He played a strong personal role in recruiting Dr. Machen to the University and has been a strong voice for the changes at UF described here.

Jeremy Ring has been a Florida state Senator since 2006, and has also been an advocate for a more ambitious role for technology-based economic development in Florida, as well as a major role for UF therein. Mr. Ring was an early member of the founding team of Yahoo, during which it grew to over $1 billion in annual sales. Mr. Ring eventually relocated to Florida, became active in politics and a champion of a larger role for universities in the growth of a knowledge-based economy. He was instrumental in creating the Florida Institute for Commercialization and the Florida Growth Fund. Especially pertinent to the development of an innovation culture at UF, Mr. Ring, as a first term state Senator, also took it upon himself to organize a small study team, including President Machen, to visit the Sand Hill Road investment community in Palo Alto, CA, and later on to their counterparts in greater Boston. Arguably the road trips had lasting impacts on what was happening at the University of Florida and elsewhere in the state.

Leadership

What kinds of leadership enable a university to broaden its goals and aspirations to extend to innovation and engagement with regional economic challenges and industry? The "kinds" as plural is intentional. For one, there are several *levels* of university leadership that can influence these issues, from president, provost, vice presidents and other comparable perspectives at a senior level, plus leaders at the college or department level, who can be very influential. For example, in the Stanford case in this volume there were historically important deans many years ago who helped to make Stanford what it is today.

There are also different domains of leadership. For example, university officials as well as community leaders can teach or advocate around the processes of technological innovation. If this is done frequently, it can start to change the *culture* of the institution—as well as the contiguous community—in terms of what is important and valuable.

Then there is *operational* leadership, which involves actually doing innovation—whether in terms of creating a science-based innovation, commercializing it via licensure, or building a new enterprise around an innovation and getting directly involved in its success or failure. This kind of leadership from a system change perspective is very powerful in that it involves one of the more effective modes of learning, whereby others can model the constituent behaviors.

Historically UF leadership had not focused on technological innovation as a mission priority. The University of Florida traditionally has had presidents of similar background, with strengths in academic fields such as philosophy, math, medicine, or economics, who eventually moved up the academic career path to become a president. These experiences shaped the main goals of their leadership: reaching the highest academic standards in instruction and scholarship, leading the university to a higher emphasis on R&D, and being of service to the state and region.

UF has realized significant gains in technological innovation knowledge, attitudes, and behavior across the university. For example, as described in the previous section, President Machen has been extraordinarily effective, and increasingly visible via his speeches and addresses to various audiences, in raising the consciousness of the campus and the community about technological innovation. Dr. Machen's leadership in this area has been both cultural, and operational, being both a design advocate in the development of campus initiatives that will lead to innovation outcomes and playing a role in their implementation.

UF's most significant leadership accomplishments in becoming a university more oriented toward innovation and industry engagement have occurred over the past dozen years. One "double play" combination was exceedingly important: Phillips to Day. Dr. Win Phillips became Vice President in 1999, and during the subsequent years UF research expenditures more than doubled, while the institution moved into the cohort of elite research institutions. Dr. Phillips is not only an outstanding research administrator, but he is also a knowledgeable advocate for an expanded role for the university in regional economic development through innovation and technology, promoting his views both on campus and around the state. He has been very active in state policy discussions about making Florida a more knowledge-intensive economy and has participated actively in regional and national organizations focused on these issues. Notably, he participated extensively in the Southern Growth Policies Board and the Southern Technology Council, two regional policy organizations that have been active for over 40 years in understanding policies and practices to foster innovation-based economic development.

Dr. Phillips and President Machen have effectively teamed up in fostering a more interdisciplinary approach to research and development, which has brought faculty members of disparate epistemological points of view together to pursue much larger research problems—the "grand challenges." These efforts have also enriched the breadth of graduate and undergraduate education. For example, the Digital World Institute has joined together faculty and graduate students from engineering, computer science and fine arts to use interactive tools and technologies for "creative collaborations (using visualization) and creation of digital products." The facilities include the Polymodal Immersive Classroom Theater, the Virtual Production Studio and the Digital Media Suite of production and post-production systems. This center, along with others that are similarly organized, has proved to be a magnet for fund-raising efforts that result in major gifts and position endowments.

When he was the VP for research Dr. Phillips[7] implemented or facilitated a variety of program enhancements that had university-wide impacts, including the expansion of industry-linked research centers, the crafting of technology-focused endowed chairs, the promotion of research partnerships with other institutions, and partnering in several technology initiatives with the State of Florida.

Aside from the above, one of Dr. Phillips' more significant accomplishment was to hire David Day as Director of the Office of Technology Licensing (OTL). Day re-organized the office, expanded services and activities and led UF into a position of national leadership in technology transfer performance. His role goes beyond running OTL, and extends to pulling people together to accomplish larger initiatives. Illustrative is the Florida Institute for the Commercialization of Public Research, which is a non-profit organization that has responsibilities for fostering technology transfer between industry and the 11 state universities in Florida, as well as administering the Florida Research Commercialization Matching Grant Program and the Seed Capital Accelerator Program. Their website has been likened to an invention catalog for investors and commercialization partners.

One of the more interesting aspects of UF leadership has been their joint initiatives with their counterparts in the city of Gainesville. Several town-gown projects have been cooperatively designed and implemented that foster technological innovation for UF participants and concurrently enable community economic development. These community relationships contribute to shifting the culture of the University and vice versa. Perhaps most notable has been *Innovation Gainesville* or IG. The organization operates and facilitates business incubation services, connects early stage companies to potential investors via the Innovation Gainesville Angel Network (IGAN), and thus fosters a "collaboratory" of R&D, networking, and commercialization in Health Sciences and in Green Technology. In the sense of getting things done, the innovation leadership and culture of the University of Florida has merged with its counterparts in the Gainsville community.

In addition to leadership that is exercised by individuals who hold official positions of prominence in the University, there has also been a growing cadre of peer leadership within the UF community, particularly on the part of successful technology innovators/entrepreneurs among faculty and students. The late Professor Robert Cade (Gatorade) was an early pioneer of success, whose experiences ultimately conveyed lessons of why and how the University of Florida should do all this stuff.

Boundary Spanning: *Entrepreneurship*

Entrepreneurship at the UF originated in and is anchored by the Center for Entrepreneurship and Innovation (CEI) within the Warrington College of Business Administration. As program offerings have grown and increasing numbers of students have sought out entrepreneurial experiences, student demand and receptive university leadership have begun the process of getting entrepreneurship out of disciplinary silos so that it may be accessible to all university students and faculty, regardless of department or position.

Within the past few years, this has resulted in a plethora of programs and partnerships, including the refurbishment of the CEI, the launch of a new Engineering Innovation Institute at the UF College of Engineering, and the new Innovation Academy (IA). The multi-disciplinary IA is one of the most interesting examples of the University of Florida's commitment to innovation, leadership, and entrepreneurship. The cross-campus program, which is open to all undergraduate students, was designed with the objective of making the university's diverse innovation resources more accessible to catalyze innovation and entrepreneurship. The first freshmen class of 320 (admitted last year) received a pre-enrollment small-college experience focused on innovation, creativity, and entrepreneurship on a unique spring-summer semester schedule.

The ongoing partnership between the UF and the Gainesville community includes plans to build an Entrepreneur's Residence Hall, for students, faculty, and business professionals in Innovation Square, co-located in the city with the Hub community incubator. While most of this expansion is still in the works, when it is completed UF will have produced an entrepreneurial ecosystem that will be worth watching.

Curricular Programs

Historically the focal point for entrepreneurship at UF, the CEI was established to teach, coach and inspire students pursuing entrepreneurial careers. Partnering with other colleges at the University, CEI delivers introductory and specialized courses, degree programs and complementary activities such as speakers and workshops, in the start-up, social, and corporate venture/entrepreneurship arenas. The CEI currently serves more than 2,000 undergraduate and graduate students per year and offers every graduate student at the University of Florida the option to earn a certificate in new venture creation.

The Engineering Innovation Institute, a second CEI-like center, was recently established on campus (with some parts rolled out in spring, 2012) in the UF College of Engineering. Institute curricula and activities focus on engineering innovation and entrepreneurship, with an objective to produce innovation, engineering, and entrepreneurial leaders. All engineering majors are required to take a 1-credit course as freshmen on leadership and innovation. Engineers may also earn a certificate in engineering entrepreneurship. Experiential student offerings include an internship at a local company or venture firm and the Integrated Technology Venture Program (ITV), a year-long program bringing together business, law, and engineering students onto a multi-disciplinary project team to develop a technology commercialization plan and prototype for a sponsoring company. Program partners include the Office of Technology Licensing, the College of Engineering, and the Levin College of Law.

The Engineering Entrepreneurship Certificate is quickly being followed, beginning in 2013, with a Certificate in New Venture Creation open to all university graduate students. This certificate will require two courses, and three electives. Another certification option available to graduate students is a business concentration/minor in entrepreneurship (4 courses including: business planning, social entrepreneurship, venture analysis, and venture finance). The objective is to provide graduate students the opportunity to pursue careers in the new entrepreneurial economy or to pursue their own venture either upon graduation or at some point later in their careers.

UF students also have access to numerous social entrepreneurship course offerings. Academic courses available in social entrepreneurship include an introductory course and a course in Business Ethics and Corporate Social Responsibility that explores ethical and moral problems in business. Other social entrepreneurship course options include independent studies, applied field studies, and internships. The CEI's Innovative Sustainability and Social Impact Initiative is the experiential learning component of the social entrepreneurship program. The Initiative teaches students to use the skills and strategies of business leaders to solve social, environmental, and economic problems, locally and around the world. Activities include webinars, a speaker series, a film series, and "Dinner with a Social Entrepreneur." The MSE Ethics Fellows Sustainable Lunch seminar series, for example, brings MSE students together with guest speakers for 8 discussions annually on topics including sustainability, ethics, and corporate social responsibility in an entrepreneurial setting. Beginning in 2013 the CEI plans to offer a summer Social Entrepreneurship Study Abroad in India, via a partnership with the Ashoka Youth Venture.

One of the most comprehensive graduate-level entrepreneurship offering is the Thomas S. Johnson Entrepreneurship Master's Program (MSE), a one-year experiential curriculum, with a focus on ethics and international entrepreneurship. The MSE requirements include: core business courses in accounting, economics, finance, marketing, and entrepreneurship; a selection of entrepreneurship courses (Creativity, Entrepreneurship, Entrepreneurial Selling, The Live Entrepreneurship Case Lecture Series, Writing, Communications, Product Development and Management, Venture Finance, Business Plan Formation, the Integrated Technology Venture (ITV) Program, Law for Entrepreneurs, Strategic Management for Entrepreneurs); as well as electives (Global Entrepreneurship, Social Entrepreneurship, High Tech Entrepreneurship, Small and Family Business, Venture Analysis, Cases in Competitive Sustainability, and The Technion Exchange Program in Israel).

In addition, all MSE students must complete two terms of participation in the Lean Entrepreneurship Accelerator Program (LEAP), a live interactive team-based experience focusing on the identification and launch of an actual business venture. As part of this program, student teams can receive startup grants and have the opportunity to access incubation facilities. In parallel with these student-centered activities, the College of Engineering has recently included inventorship and entrepreneurship into tenure consideration.

Students also have the opportunity to take a Global Connections course that covers the intersection of entrepreneurship, international business, and global strategy. It is taught utilizing the case method where students complete a market-entry report. The course is also linked to the opportunity of a week-long international immersive study tour. The Global Entrepreneurship Study Program has sent students to Chile, Ireland, and elsewhere in the EU. Students interested in social entrepreneurship may instead participate in the Sustainability Study Program offered in Costa Rica, which has a deliberate national strategy of balancing business competitiveness and considerations of humane labor practices and protecting the biologically diverse natural environment. The trips are designed to introduce students to global entrepreneurial perspectives, cultural differences, and to special issues, such as doing business in a sustainable manner and in an international context.

Co-Curricular Programs

The focal point for many of the CEI's experiential learning offerings is the Jeff Gold Experiential Learning Laboratory located inside the Center, next to the offices of faculty and staff as well as the student Innovation Café. The Lab is home to a number of entrepreneurial support services and activities including:

- *The Case Lecture Series* includes a luncheon series and a Thursday "Startup Hour," both of which bring prominent practitioners, government support organizations, and service providers to campus to network with students about real-world entrepreneurship topics. Other networking events include off-campus visits and tours of entrepreneurial corporations, business incubators, venture firms, startups, small businesses, and investment firms. One of the more successful networking events has been an informal meet-and-greet hosted by the UF Office of Technology Licensing (OTL) that introduces UF students seeking internships to local tech entrepreneurs in need of student interns.

- *The Venture Analysis, MSE Mentoring Program* is a 16-week program that connects new MSE students with mentors in respective areas such as small businesses, high-growth enterprises, socially-responsible companies, and the investment community. Mentors support students via one-on-one advisement, networking activities, and organized panel discussions (for example on ethical challenges and the mentoring experience).

- *The Entrepreneur-In-Residence Program* brings seasoned entrepreneurs to campus for a week to work one-on-one with students in the CEI Learning Laboratory. Entrepreneurs-In-Residence also conduct classroom lectures, advise student teams, and facilitate networking with UF faculty involved in entrepreneurship education.

- *The JumpstART Workshop in Creative Entrepreneurship* is a one day arts event that attracts more than 70 students and community artists to a campus venue. The program of presentations, networking, and mingling is a collaborative effort involving the CEI, the College of Fine Arts' School of Art/Art History, the School of Music, the School of Theater and Dance, the Harn Museum, and the Gainesville Fine Arts Association. Topics have included creativity and the brain, design and commerce, and panel discussions hosted by successful local visual and performing artists.

In addition to hosting entrepreneurial teams, the CEI's Learning Lab serves as a focal point for student groups on campus, including United World Social Entrepreneurs, the UF NetImpact Chapter (graduate students), and Change the World UF: Student Social Entrepreneurs (undergraduate students). Another student group, the CEI Ambassadors student organization, is charged with promoting CEI activities, entrepreneurship, and innovation beyond the business school to students and faculty campus-wide. The ambassadors participate in and organize speaking events, peer-to-peer mentoring and learning workshops, and social activities (BBQ, bowling, dinners, etc.). They also conduct a semester project, including the annual Technology Entertainment and Design

(TEDx) program, which is a one day event to showcase the "best of Gainesville" startup scene, from engineering and science to music and art. Particularly noteworthy, for our purposes here, is the Ambassadors' stated mission to "transcend the silos of UF, synergizing the entrepreneurial efforts of students from different areas of campus while exponentially increasing their network."

UF Students also are invited to participate in the CEI-sponsored and campus-based Young Entrepreneurs for Leadership and Sustainability Summer Program. Now in its sixth year, the summer program offers full and partial scholarships to 40 college-bound high school students who would otherwise be unable to afford an on-campus leadership development experience. For five weeks each summer, the students learn about entrepreneurship and social entrepreneurship, become inspired to solve social problems, and practice sustainability. In the summer of 2012, the program was expanded to other Gainesville area high school students, who were placed as volunteers in local nonprofits and service organizations, where they learned about leadership and sustainability while working 100 community service hours. The program is co-sponsored by two local nonprofits and private donations.

Boundary Spanning: *University, Industry and Community*

There are many ways in which universities engage business, industry and the community. Outside of the rich linkages involved in the educational mission, there are also opportunities for boundary spanning in terms of research and service. Often these activities are conducted via centers and institutes. Centers and institutes are organizational entities that typically do not match perfectly with the department and college structure of the university, and thus enable interdisciplinary research, service and engagement.

Centers and Institutes. As per data from UF there are 183 "officially recognized" centers and 31 institutes. UF also has well-established rules and procedures on what a center or institute can or cannot do, and how one attains and maintains that status. In order to help internal and external potential partners sort through this large menu, the UF Office of Research provides information about the scope and mission of the larger or more important centers and institutes.

For example, the following have campus-wide missions and a reporting relationship to the VP for Research:

- Center for Smell and Taste
- Center of Excellence for Regenerative Health Biotechnology (CERHB)
- Clinical and Translational Science Institute (CTSI)
- Emerging Pathogens Institute (EPI)
- Florida Climate Institute
- Florida Energy Systems Consortium
- Interdisciplinary Center for Biotechnology Research (ICBR)
- Nanoscience Institute for Medical and Engineering Technology (NIMET)
- UF Genetics Institute (UFGI)

As can be seen this short list reflects the life sciences strengths of UF in terms of instructional programs and research emphases. In addition, not all of the short-listed centers or institutes are equally active in terms of sponsored research or in terms of industry connectivity. In fact, looking at the FY2011 NSF research expenditures for UF, industry sponsored research accounts for 3.1% of the total which is below the national average,

Another list from the VP for Research identifies major research centers with active faculty/industry research collaboration, although not necessarily industry financial support. That seems to vary widely, with several of these centers working with but not funded by companies.

- Center of Excellence for Regenerative Health Biotechnology (CERHB)
- Center for International Business Education and Research
- Center for Particulate and Surfactant Systems (CPaSS)
- Clinical and Translational Science Institute (CTSI)
- Florida Center for Renewable Chemicals and Fuels
- Florida Energy Systems Consortium (FESC)
- Interdisciplinary Center for Biotechnology Research (ICBR)
- Hinkley Center for Solid and Hazardous Waste Management
- NSF Center for High-Performance Reconfigurable Computing (CHREC)
- NSF Cloud and Autonomic Computing Center (CAC)
- Particle Engineering Research Center (PERC)
- Powell Center for Construction and Environment
- Public Utility Research Center

From the perspective of *Innovation U* it is useful to look at the different centers and institutes from the perspective of funding and stakeholders, such as the mix of private sector versus public agency funding and possible implications for commercialization of products/processes.

For example, UF has several centers that are participants in the National Science Foundation (NSF) Industry-University Cooperative Research Centers (IUCRC) program, or the NSF Engineering Research Center (ERC) program. Both programs demand extensive industry involvement; in the IUCRC program companies (in a consortium arrangement) also supply the majority of project funding. Consider the following UF NSF-related centers:

- *The Advanced Space Technologies Research and Engineering Center (ASTREC)* has been an IUCRC program since 2008 with nine partner companies.
- *The Cloud and Autonomic Computing Center (CAC)* has been an IUCRC program since 2008, in collaboration with 6 major companies as well as researchers from Mississippi State University, University of Arizona, and Rutgers University.
- *The Center for High-Performance Reconfigurable Computing Center (CHREC)* has been an IUCRC since 2006, in collaboration with Brigham Young University, George Washington University, and Virginia Tech University,

plus 30 industry and government partners.

- *The Center for Advanced Forestry Systems (CAFS)* has 9 university partners and several industry participants.
- *The Center for Particulate and Surfactant Systems (CPASS)* was launched in 2008 in collaboration with Columbia University with over 25 member companies.
- *The Particle Engineering Research Center (PERC)* was launched as an Engineering Research Center in 1994, "graduated" from the program in 2005, but has continued as a very viable research center with 40 participating (financially and substantively) company members.
- *The Center for Nanostructured Electronic Materials (CNEN)* was launched in 2011 as an NSF Center for Chemical Innovation.

There are other notable examples on the VP for Research list that utilize third party, primarily public sector, funds to enable technology innovation, development and commercialization:

- *The Center of Excellence for Regenerative Health Biotechnology* is mostly supported by federal and state funds, as well as the University, and plays an important role in translational research, drug development services, training, and the improvement of biopharmaceutical manufacturing practices. Its impacts are regional and national.
- *The Clinical and Translational Science Institute* is supported significantly by NIH grant monies and is focused primarily on enhancing the development of new therapies, including field-testing and field trials.
- *The Florida Center for Renewable Chemicals and Fuels* is supported primarily by grants and contracts from several federal agencies (NIH, DOE, DOD, NSF, USDA, NASA) as well as private sector entities in the alternative fuels area.
- *The Florida Energy Consortium* enables cooperative R&D among state-based universities and other entities in the area of energy systems.
- *The Interdisciplinary Center for Biotechnology Research (ICBR)* is in effect an internal contract lab that provides over 250 types of services for UF faculty and staff in DNA sequencing, genomics, proteomics, mass spectrometry, and several other areas. It also works with other research partners across the state and nation.
- *The Hinkley Center for Solid and Hazardous Waste Management* is funded by the Florida Department of Environmental Protections, and explores new practices and technologies in this area.
- *The Powell Center for Construction and Environment* is primarily focused on sustainable policies, principles and practices in the built environment.
- *The Public Utility Research Center* conducts research, training and policy analysis in the area of public utilities and services.

Community Partnerships. An important community asset has been the Innovation Hub, located in Gainesville, and developed as a partnership between the city and the University (http://floridainnovationhub.ufl.edu/). One way to capture the mission and services of the Innovation Hub is to think of it as a supercharged business incubator. The $13.2 million facility had its grand opening in January 2012, and is home to the UF Office of Technology Licensing (OTL) and UF Tech Connect, dozens of startup companies, laboratories, and a variety of ancillary services. Rent for offices started at $230, lab space at $575. This will be a space where companies grow, deals are brokered, and UF students and faculty can have a larger venue to practice entrepreneurship. This is a great example of the mission and cultural merging of the community and the university.

The development of the Innovation Hub also has been conducted in concert with a much larger UF/Gainesville initiative: Innovation Square. This is a novel urban redevelopment effort focused on 12 underutilized square blocks in the city of Gainesville that includes the Innovation Hub. The project received the 2012 Donald E. Hunter American Planning Association award for Excellence in Economic Development Planning. The vision is an urban research and development district that addresses the issue of "where do the graduates of the Innovation Hub incubator go after they get technically and business viable?" Answer: they move across the street or down the block into more business-appropriate space. In 2013 an event billed as *A Celebration of Innovation 2013 Technology Showcase* was held to spotlight the progress and accomplishments of OTL and startup companies associated with UF and Gainesville.

It should be noted that the Innovation Hub is not the only or first UF-related incubator. In 1995 the Sid Martin Biotechnology Incubator was opened for business in the Progress Corporate Park in Alachua, twenty miles from the UF campus. It has specialized facilities that include 40,000 square feet of lab/office space, a fermentation facility, a small animal facility, a large animal facility, and a climate-controlled greenhouse. Resident companies span the life science disciplines and at various stages of business development. It has launched a number of companies, many of which are now part of the expanding life science cluster in the region. As the pace of regional growth in housing and office space continues, the distance between the Sid Martin facility and greater Gainesville diminishes.

The OTL also participates in BioFlorida which is a not-for-profit organization that is predominately a bioscience industry association that has grown in prominence over the last decade, as Florida has become a national leader in that domain. Its activities focus on workshops, conferences, and fostering connectivity among companies, investors and the university research community. David Day is now Vice-Chair of the Board of Directors, as well as serving on the Florida Research Consortium board, the Innovation Gainesville board as well as working closely with the Florida Chamber of Commerce on the 2030 plan. These are examples of "lateral" connections that strengthen the university's activities in both culture building and leadership.

Boundary Spanning: *Technology Transfer*

In a little over 10 years the University of Florida has dramatically increased the scope and success of its Office of Technology Licensing (OTL). As per FY2012 and earlier data from the Association of University Technology Managers[8] the picture is one of increasing excellence. For example, the number of technology licenses and options in FY2000 was 23, in FY2010 it had climbed to 92 and in FY2012 it was 101. Moreover, the rate of innovation, which seeds the whole licensing process, and for which the pace of invention disclosures by faculty members is a good proxy, had climbed to one for every $2.1 million of

NSF-reported research expenditures in FY2012. Most university "batting averages" on this metric are much poorer. The UF technology transfer operation has a high rate of patent applications, enviable levels of overall license income, plus 15 startup companies realized in FY2012.

There are several factors that account for these successes. For one, UF has been smart about staffing its office. The UF Office of Technology Licensing (OTL) had a ratio of research expenditures (in millions) to professional staff of $37 million to one. That relatively rich staffing level compares favorably to the majority of institutions, including all of the schools in this study sample save one. OTL also benefits from a very amiable and supportive relationship with the office of the Vice President for Research. As OTL Director David Day comments: "Win Phillips is equivalent to the RAF in World War II for me; provides air cover."

However, UF excellence in this area is only partly a simple function of staffing ratio and administrative support. The OTL is imaginatively led, and involved in a wide range of campus and community activities that seed the flow of inventions as well as ease the process of getting deals done.

The OTL website (www.research.ufl.edu/otl/) is informative, easy to navigate and is organized into "stakeholder" groups: UF Inventors; Investors and Entrepreneurs; Industry. Each stakeholder group has sub-menus, although all benefit from a very professional background video featuring the Office Director, David Day. The sub-menu for faculty inventors, has information on: Working with OTL; Reporting a New Discovery: IP Policies; Patents, Copyrights and Trademarks; Faculty/Student Entrepreneurs; plus a link to UF Tech Connect. The other sub-menus have some overlap with the faculty one, plus additional choices. For example, the Industry and Investors/Entrepreneurs sub-menu enables the user to do a search of available inventions, using very customer-friendly tools. In addition, there are links to a wide range of organizations and services, local and national that have positive relevance to the technology transfer process. Much of this is "culture-building," such as clips about thriving startup companies that derive from UF innovations.

For example, working in tandem with the OTL is an EDA University Center—*UF Tech Connect*—that operates out of the Office of Technology Licensing and features news squibs and links about business events that concern the technology transfer outcomes of OTL. Looking at the invention disclosures and deals enabled by OTL there has been a growing dominance in the life sciences, particularly biomedical. A recent perusal of the Available Technologies pages yielded over 150 inventions in the human biomedical area, far and away the largest category.

Many universities would relish telling a story comparable to the one sketched in thus far about technology transfer at UF. However, UF through OTL, has significantly extended itself into a much wider array of services, facilities and partnerships that are community based. Perhaps most important for OTL's success has been the culture and practices of the office. Getting out of the office and into the labs and community are an expectation of staff and a perquisite of success. Moreover, as ancillary community programs expand so also do the activities of OTL staff.

The OTL has become much more aggressive at using startups as the preferred approach to commercializing UF inventions. Part of this involves connecting (or reconnecting) successful technology entrepreneurs in the community with emerging opportunities. For example, Jamie Grooms had founded Regeneration Technologies based on UF technology, and realized a very lucrative public offering return, as did the university based on stock that they held via Grooms. The returns enabled UF to build a new orthopedic building and support new lab facilities. David Day was able to convince Grooms to invest in the creation of another new university related company, Axo Gen Inc.

With its database of successful entrepreneurs and venture investors, the OTL has been at the center of efforts to match scientists with community partners. Grooms eventually became CEO in 2012 of the Institute for Commercialization of Public Research, a non-profit organization with a statewide mandate to connect university technology and inventors with investors and successful entrepreneurs to orchestrate these partnerships.

Summary and Parting Comments

Over the last decade the University of Florida has established a remarkable record of not only being a great university in terms of traditional metrics, but also a great university that is doing very well in fostering technological innovation. Moreover it has commendable programs that span the traditional university functions of instruction, research, and community service, but also has become a place that is involved in doing technological innovation in novel and impactful ways. As a very large university in terms of student head count and the scope of its research, there are many parts of the university that seem relatively untouched by the initiatives and culture of innovation and entrepreneurship. That is to be expected given that UF has not been involved in these activities to the extent and duration as some other cases in this volume. The next few years will be an important period for UF to build on its accomplishments to date and become even more a national exemplar.

Endnotes

[1] Britain gained control of Florida in 1763, in a trade for Cuba after the Seven Years war, but Spain regained control in 1784 as an aftermath of their support of the American Revolution and the peace treaty.

[2] National Science Foundation, National Center for Science and Engineering Statistics, FY2011. *Table 14. Higher education R&D expenditures, ranked by all R&D expenditures, by source of funds: FY2011. Table 15. Higher education R&D expenditures, ranked by all R&D expenditures, by R&D field: FY2011.*

[3] David Day was hired in 2001 to head the technology transfer function at UF. By 2006 the University of Florida was ranked 5th in a national empirical study of the effective of university technology offices: DeVol, R, and Bedroussian, A. (2006). *Mind to Market: A Global Analysis of University Biotechnology Transfer and Commercialization.* Milken Institute.

[4] Dr. Phillips had participated in Southern Growth Policies Board and Southern Technology Council during the 1990s and was aware of the NSF-funded research that led to *Innovation U.* in 2002.

[5] Machen, B. (2007, May 18). *Florida Tomorrow and the Value of Volunteering.* Retrieved from http://president.ufl.edu/initiatives/florida-tomorrow/

[6] University of Florida Foundation. *Numbers.* Retrieved from http://www.floridatomorrow.ufl.edu/numbers.html

[7] Phillips is now Senior Vice President and Chief Operating Officer.

[8] Association of University Technology Managers. (2013). *AUTM U.S. Licensing Activity Survey: FY2012.* Deerfield, IL: Association of University Technology Managers.

Georgia Institute of Technology*

The precursor to what is now known as the Georgia Institute of Technology (Georgia Tech) was legislatively authorized in 1885 although it did not open its doors until 1888 as the Georgia School of Technology, with 129 students originally enrolled. Two former officers in the Confederate army—John Fletcher Hanson and Nathaniel Edwin Harris—were the champions of the idea to create a school that would enable the growth of a "New South" replacing the agrarian, slavery-enabled economy that had been the social and economic model for generations. Harris was elected to the state legislature in 1882 and ended up leading a committee to develop an approach to technical-based higher education. Interestingly, the committee visited several institutions in the North—the early MIT, Worcester Free School, Stevens Institute, and Cooper Union. The dilemma that the committee was addressing was whether a new school in Georgia would emphasize a practical/hands-on approach to education ("shop school") or a more academic, classroom-based approach. They ended up opting for both, and this historical tidbit has in many ways defined the culture and development of what has become Georgia Tech—a place that is both theory and science-driven but also a place that has become very good at fostering technological innovation, applications, and knowledge-based enterprise.

Although Harris and his committee had the model pretty much nailed by 1883, it took until 1885 to pass a bill that authorized its founding, plus a $65,000 appropriation from the state legislature to build the original facilities as well as provide ongoing operating funds. After some political wrangling the location was set in Atlanta, and the Georgia School of Technology was open for business in the fall of 1888, with a "shop building" and an academic building side-by-side.

Over the next 50-75 years what was to become today's Georgia Tech sorted out its curricular options and mission, but continued to struggle to balance the practical issues of technology and classroom knowledge delivery. Thus in the 1890s and early 20th Century the Schools of Mechanical Engineering, Civil Engineering, Electrical Engineering, Chemical Engineering, Chemistry, and Textiles were established. But enrollment was very low, with 500 students enrolled in 1905. A School of Commerce was established in 1913, and notably for this chapter, in 1919 the state legislature authorized (but did not fund) an Engineering Experiment Station (more on the EES later on). Post WW I student enrollment reached 2,579 in 1921 (including night and summer school students). In 1924 a School of Ceramics was established, and a year later the first Master of Science degrees were awarded.

** This case was written by Louis Tornatzky.*

By the 1930s the university had begun to branch out from its initial trade school orientation, expanding in a number of substantive and programmatic directions. A School of Aeronautics was formed, and the Engineering Experiment Station (EES) opened for business in 1934, providing engineering assistance on a contract basis to the Federal government and Georgia industry, a mission that continues to this day in a new organizational form. While enrollment growth was relatively stagnant during the depression years, and mostly focused on military-related educational programs during World War II, such as Army and Navy ROTC and the Navy V-12 program, the school was poised for a much larger future.

During the mid to late 1940s a few other schools were added to the campus including Architecture, Industrial Management, and Social Sciences. As peace was breaking out in 1945-1948, the newly renamed Georgia Institute of Technology was ready to embark on an amazing 60-year sprint. This resulted in a steady growth in quantity and quality of undergraduate and graduate students, national and international prominence as a center of science and engineering education, and more germane to this chapter, a locus of technological innovation that was enabled by inspired leadership, a supportive culture, and many novel programs and initiatives. Georgia Tech went through an expansion from a primarily engineering institution to one that embraced the physical and behavioral sciences, computing, and much more.

Before we detail those ingredients in subsequent sections of this chapter, it would be timely to summarize some of the rankings and ratings currently enjoyed by Georgia Tech. For example, *U.S. News & World Report*[1] recently rated Georgia Tech the #7 public university in the country, the #4 graduate engineering college, the #5 undergraduate engineering college, the #1 industrial engineering program, #1 in bachelor's engineering degrees to all minority students, #2 in bachelor's engineering degrees to African Americans, and #1 in doctoral engineering degrees to African Americans, Asian Americans, and all minority students. Georgia Tech also has 27 faculty who are members of the National Academy of Engineering, and is among the top ten universities in the country in terms of faculty receipt of Presidential Early Career Awards in Science and Engineering.

Georgia Tech is in the top ranks of universities in the scope of its R&D activities. Thus in the FY2011 National Science Foundation[2] survey of academic research and development, Georgia Tech reported research expenditures of $655.4 million, which ranks 26th among all US universities and 17th among public universities. Georgia Tech ranks in the top 3 among universities without a medical school. Reflecting its acumen in industry partnering and engineering R&D, of that total an above-average 6.4% reflected business funding and 68.9% of all R&D funding was in the engineering sciences. In 2010 Georgia Tech was invited to join the Association of American Universities (AAU), a significant institutional honor.

University Culture: *Goals and Aspirations*

Technological innovation and economic impact are integral and critical components of the mission of the Georgia Institute of Technology, and this has been true from its very inception, along with its commitment to exemplary academics. As was summarized in the Georgia Tech entry in the 2002 *Innovation U* book of cases:[3]

> *Virtually every combination of industry relationships or economic development activity can be found at Georgia Tech, and in a very real sense the school is an operating partner with Georgia state government in the implementation and management of a variety of technology-focused activities.*

We think this is still true, and even more so. Twelve years ago those goals and aspirations were articulated by then President Wayne Clough; more recently they have been extended and championed by the current leadership. President G. P. "Bud" Peterson has been very aggressive and articulate in developing a new Strategic Vision and Plan[4] that has been an early centerpiece of his administration. The goals and aspirations of that plan are consistent with the Georgia Tech history. From President Peterson's introductory comments:

> *Invoking Georgia Tech's motto of Progress and Service, we embrace the task of guiding the way the world changes for all our constituents. As leaders, designers, and innovators, our role is not only to solve problems, but also to shape our world.*

Later on in the body of the plan, the plea is made about the stance that Georgia Tech should take vis-à-vis the changing world:

> *As we look to our future, it is imperative that we recognize that a great university should not merely respond to changes after the fact, but in reality must anticipate change and shape the future.*

In a section subtitled Economic Impact the document goes on:

> *As envisioned by our founders, Georgia Tech will continue to be an economic driver for Atlanta, the state of Georgia, and the nation...we will create a culture where students and faculty are both scholars and entrepreneurs.*

In a section subtitled *Vision* the following:

> *Georgia Tech will define the technological research university of the 21st century. As a result, we will be leaders in influencing major technological, social and policy decisions that address critical global challenges. 'What does Georgia Tech think?' will be a common question in research, business, the media and government.*

From these introductory sections, the document goes on to articulate five major Goals and Strategies to accomplish each. Goal 3, "Ensure That Innovation, Entrepreneurship, and Public Service are Fundamental Characteristics of our Graduates," is particularly pertinent to this chapter, and three strategies are articulated. In the introductory prose, the section makes some important distinctions:

> *Invention transforms the world of ideas, but innovation transforms society by fundamentally changing established norms. ....Our campus culture needs to be one that supports innovation, entrepreneurship, and public service just as it does teaching and research. In doing so, Georgia Tech becomes a leader among universities in innovation.*

Under Strategy 1 of Goal 3, "establish world-class initiatives to serve Georgia Tech, the state, and other strategic national and international partners," the document calls for a bold change approach:

> *In addition to classroom experiences, Georgia Tech will enable faculty and student interaction in venues such as competitions, short courses, co-curricular activities, and workshops aimed at fostering a culture of innovation and encouraging student creativity and entrepreneurship.*

Under Strategy 2 of Goal 3, "innovate in how we incentivize and support commercialization," the document advances some future steps:

> *Activities that advance Georgia Tech's reputation in innovation and entrepreneurial leadership will play a role in the review, promotion, and tenure process. ..Including flexible work status, leaves of absence to pursue entrepreneurial interests, and sabbaticals with companies that are partnering with Georgia Tech on intellectual property development.*

The above citations from the presidential-led 2010 Strategic Vision and Plan are illustrative of the campus-wide culture and goals. However, it is also useful to look at a follow-on strategic planning[5] document that has emerged from the Georgia Tech College of Engineering (COE). As the largest and arguably most influential college on campus, it has much to say. The structure generally follows that of the 2010 university-wide plan, and there are several elements that comment and expand upon the issues of innovation, entrepreneurship and external engagement.

Under a Vision section, the COE document opines that it will be globally recognized as the preferred institution:

> *For solutions to the grand challenges facing the human community today and for innovations to meet the needs of tomorrow.*

The most pertinent section of the COE plan for this chapter is under Objective 3, "ensure that innovation, entrepreneurship, and public service are fundamental characteristics of our graduates." It goes on to identify pertinent Goals that the COE must accomplish, including:

- *Incorporate aspects of innovation, entrepreneurship, and public service into the COE's core academic mission.*
- *Emphasize research that leads to commercialization.*

Moreover, what Strategies might be deployed, including:

- *Establish core intellectual activities for innovation, entrepreneurship, and public service in grand challenge application areas.*
- *Form a COE committee to vet invention disclosures for Office of Technology Licensing.*
- *Ensure that incentives for innovation, entrepreneurship, and public service are properly aligned with the promotion and tenure process.*
- *Support student design competitions that promote entrepreneurship, innovation, and public service.*
- *Increase the number of internal awards focused on innovation, entrepreneurship, and public service.*
- *Establish venues to connect faculty/students with venture capital firms and angel investors.*

A long list of other actions was suggested, reflecting the fact that at the unit level things get pretty specific and detailed. Nonetheless, the point of this section is to illustrate that Georgia Tech takes its innovation mission seriously, and has done so for a long time.

Leadership

As suggested above, the die was cast for Georgia Tech evolving into a center of technological innovation during World War II, when the Engineering Experiment Station had developed a fairly robust body of contract research to support the war effort. However, the university was blessed in recent decades by two visionary long-term leaders that ensuredd that the promise would become reality. They included: Joseph Pettit (1972-1986) and Wayne Clough (1994-2008). Together their leadership encompassed 28 years out of the last four decades. During that period Georgia Tech became the innovation colossus that it is now. Current President Peterson, who is also expanding the scope of Georgia Tech innovation activities, followed them.

Joseph Pettit. President Pettit came to Georgia Tech with as ideal a learning experience one could have if the objective was to lead the institution to a new plateau in research, innovation, and culture change. He was at Stanford for 25 years, from 1947 to 1972, and Dean of Engineering from 1958 on. This was during the period in which Wallace Sterling and Frederick Terman were inventing a new model of that institution, and Pettit was a significant participant. What they accomplished is described in detail in the Stanford case in this volume. However, it is safe to assume that the leadership initiatives undertaken by Dr. Pettit at Georgia Tech were influenced by the experiences and lessons learned at Palo Alto. Under his leadership Georgia Tech dramatically increased research funding (exceeding $100M for the first time), saw a significant growth in the founding and success of research centers and institutes, became much more involved in technology initiatives that involved an entrepreneurship approach, and saw growing expertise and results in technology transfer activities. Thus in 1981, the Engineering Extension Service expanded to include one of the first technology business incubators, the Advanced Technology Development Center (ATDC). In 1984, the Engineering Experiment Station was renamed the Georgia Tech Research Institute (GTRI), reflecting its growth and expansion. The ATDC and other elements were moved out of GTRI to form what is now the Enterprise Innovation Institute in 1995.

Wayne Clough. Dr. Clough was the first Georgia Tech graduate to become President of the university. Growing up in Georgia, he went on to earn a bachelors and masters degree in Civil Engineering, and a doctorate at UC Berkeley. Interestingly, Dr. Clough was also steeped in the entrepreneurial/innovation culture of Stanford, as was Joe Pettit. After a five-year stint as an Assistant Professor at Duke, he returned to the Bay area as an Associate Professor at Stanford, getting promoted to a Full Professor and staying eight years (1974-1982). This was during the early blossoming of Silicon Valley and the many roles played by Stanford therein. And the evidence is strong that his leadership at Georgia Tech embraced many of the similar goals and practices.

During his tenure, Georgia Tech research expenditures doubled and the university became a model of technology transfer success. The Millken Institute ranked Georgia Tech 11th nationally for technology transfer performance. It was a strong participant in the Georgia Research Alliance, along with its sister institutions in greater Atlanta. Student enrollment increased by 30% and there were strong efforts to increase the quality of undergraduate instruction as well as student involvement in research. Major physical enhancements to the campus were implemented, as were novel programs to increase student financial support. Georgia Tech became even more of a model of a locally, nationally, and internationally engaged institution.

"Bud" Peterson. Two relatively recent initiatives undertaken by Dr. Peterson in his three years as President are particularly relevant for this chapter. One is the new leadership and integrating role of the Enterprise Innovation Institute (discussed in the next section). Second is the speed and scope of the new Strategic Plan that reinforces the progress of the recent past and sets new goals and directions. President Peterson has also been very forthcoming in crediting the long line of previous Georgia Tech leaders who have added to the success of the institution. Upon joining the AAU in 2010 he noted:

> *It is truly a credit to those who have worked so hard to make Georgia Tech the institution it is today. In particular, President Emeritus Wayne Clough and former Georgia Tech Provost Jean-Lou Chameau[6] played a vital role in Georgia Tech achieving this wonderful accomplishment.*

Boundary Spanning: *Entrepreneurship*

In the last few years Georgia Tech has evolved a much more inclusive approach to programs oriented toward entrepreneurship. In most universities these activities are mostly focused on the enterprise startup experience, as addressed by curricular and co-curricular programs operating mostly within the university or closely linked thereto. Nonetheless, Georgia Tech has a long history of partnering with the private sector including companies large and small, and among the "small" enterprises some are truly new companies while others are decades old but nonetheless engaged with the university in very creative ways.

Curricular Programs.

There are various mixes of courses focusing more or less on entrepreneurship along with parallel foci on technological innovation. Given the history and substantive orientation of Georgia Tech that should not be a surprise. The following is a good sampling of what currently exists in this domain:

- *Institute for Leadership and Entrepreneurship (ILE).* The ILE is located in the Scheller College of Business and was founded in 2006, and in many ways represents the vision of Terry C. Blum who was Dean of the Scheller College until 2006. The mission is to "enhance leadership and entrepreneurship for socially responsible value creation." In addition to an ambitious menu of course offerings, it operates the IMPACT Speaker Series and the Leadership Roundtable. Its courses are a resource not only within the Scheller College but also across the campus. A Leadership Minor is offered as well as Certificates (Graduate, MBA and Undergraduate) in Entrepreneurship. The courses tend to cluster into three areas: Leadership with two courses (Impact Forum; Servant Leadership, Values and Systems); Entrepreneurship with six courses (Social Entrepreneurship; Entrepreneurship Forum; Entrepreneurship; Principles of

Management for Engineers; Principles of Management; Technology Ventures); and Sustainability with two courses (Business Sustainability Ethics; Special Topics-Business and the Environment). There is also a Study Abroad opportunity in Budapest.

In order to get the Graduate Certificate in Entrepreneurship, a graduate student in engineering would be required to take Principles of Management for Engineers, and Technology Ventures, plus two courses from a long list of advanced courses in the Management Area.

- *Denning Technology and Management Program.* This is a 22 credit undergraduate minor program within the Scheller College of Business that is offered to business majors as well as students from the college of engineering and the college of computing. The structure of the curriculum includes required courses that are limited to either business, engineering or computing students, as well as required courses where business students, engineering, and computing students work together. One of the major goals of the Denning program is to create cross-functional leaders via the mixing process.

- *Georgia Tech Master of Biomedical Innovation and Development (BiolD).* This is a one-year program that is offered via the Wallace H. Coulter Department of Biomedical Engineering, a novel joint department of Georgia Tech's College of Engineering and the Emory University School of Medicine. Between the two partnering organizations, over 100 academic and research faculty, plus post-docs, bring extensive expertise to the program. The focus of the yearlong masters experience is the "bench-to-bedside" progression that transforms research into better and more practical techniques and products. Students study with clinical practitioners, device designers, engineers, device manufacturers, and technology commercialization experts. The program provides a bridge between the traditional disciplines of medical research and practice, and the commercialization of biomedical products. Clinical team projects are conducted in a wide variety of Atlanta-based settings.

- *TI:GER (Technological Innovation: Generating Economic Results).* TI:GER teaches students that the main hurdles to commercializing research are seldom technology-related. More often they involve legal issues and problems interfacing with the public and market. TI:GER takes an interdisciplinary approach to surmounting those obstacles, assembling students who win acceptance into the program into five-person teams. These teams include two Georgia Tech MBA students and two Emory Law students who focus over a two-year period on the commercialization of a Georgia Tech PhD student's research. TI:GER teams work together in the classroom and the research lab to learn how to:

    - Advance early-stage research into real business opportunities;
    - Comprehend the economic, regulatory and legal mechanisms affecting the venture-creation process;
    - Maximize the commercial potential of emergent research by considering market goals at an early stage of innovation;
    - Understand how the potential market application of technology can influence research directions and priorities.

  TI:GER students benefit from assigned business and legal mentors as well as meeting with industry representatives at biannual advisory board meetings. The program has received funding from a variety of sources, including the National Science Foundation, the Alan and Mildred Peterson Foundation, the Hal and John Smith Chair in Entrepreneurship, and others. They also engage in consulting projects for startup companies associated with ATDC, a business incubator located at Georgia Tech.

Co-Curricular Programs and Extra-Curricular Programs

The Enterprise Innovation Institute, or EI2, is headed by a Vice President with deep experience in technology commercialization and venture investing. It has ten Directors and two other senior staff personnel carrying out the significant management responsibilities of the fourteen programs that come under the Institute purview. The programs are quite diverse in terms of clients or participants, physical and organizational location, and collectively they encompass a continuum that extends from early technology and venture development to established firms with significant history. These programs leverage a mix of state, Federal and private sector funding to enhance economic development in the state of Georgia. Conceptually, the programs and clients are all united by the emphases on innovation and entrepreneurship, and the structure enables program leadership to share best practices and policies across the heterogeneous mix. Among the cases in this volume this is probably the most novel organizational solution to the inherent diversity of activities that fall under the labels of innovation and entrepreneurship, and one that seems to have enough authority to give it a fair trial. As structured, EI2 has responsibilities that encompass both co-curricular and extra-curricular programs, and are intermingled in the following several pages. So the programs include the following with interconnections noted:

- *Advanced Technology Development Center (ATDC).* This program was founded in 1980 and is one of the oldest and one of the most acclaimed business incubators in the country, and *Forbes* magazine has argued that it is one of the best in the world. The ATDC now has three facilities serving somewhat different constituencies. Its headquarters facility is located in Atlanta's Technology Square and serves as a hub for incubation activities more generally across the Atlanta metro area and across the state, with also strong linkages to later stage ventures emerging from the Georgia Tech campus. The ATDC Biosciences Services facility is located in the Ford Environmental Science and Technology building on campus and caters to ventures in the biomedical and biological sciences. A third facility, ATDC Savannah, provides a physical location for startups in coastal Georgia, and assists with statewide outreach and services to entrepreneurs in art and design. ATDC programs in each location typically include a mix of the following: educational programs; mentorship via entrepreneurs-in-residence; linkages to angel investors and large partner companies; facility rentals, office space, and wet lab space; startup circles, composed of smaller groups of client companies organized around focus areas or geography; SBIR grant assistance; co-working relationships; and brokering expertise in the University and across the community. ATDC works with over 300 companies annually and has been instrumental in launching over 150 ventures that have attracted $2.5 billion in investment and created over 5,500 jobs.

- *Innovation Corps (I-Corps).* Georgia Tech was one of the two original I-Corps "nodes" established by the National Science Foundation, and the total at Georgia Tech is now five. The I-Corps more generally is focused on identifying product opportunities deriving from academic science, along with entrepreneurship training to students, and thereby fostering the commercialization of NSF-supported science. Activities focus on input from experienced entrepreneurs and investors. The I-Corps national program has also been supported by the Ewing Marion Kauffman Foundation and the Deshpande Foundation.

- *VentureLab.* This is a campus-based program that primarily focuses on emerging technological innovation that derives from Georgia Tech sponsored research. As such, the participants are typically faculty members, graduate students, or research staff who are very early in the process of developing a business concept. Thus NSF Innovation Corps (I-Corps) funds and program services are administered primarily through Venture Lab. So too is a 6-week activity called Startup Gauntlet which involves field-testing of business models/customer problems by actually talking with real people. VentureLab also has links to Georgia Research Alliance Venture Fund support for emerging enterprises. Finally, GT:IPS (described above) is a key component of VentureLab that is also joined to the technology transfer function of Georgia Tech. Recently, VentureLab was ranked 2nd in the world in a benchmarking comparison conducted by UBI Index, a Stockholm-based organization that works with incubation programs. In addition to the overall 2nd place recognition, VentureLab was ranked 1st among early-phase university-linked programs.

- *Georgia Tech Integrated Programs for Startups (GT:IPS).* Housed in the Georgia Tech Research Corporation, this jointly supported program offers training to Georgia Tech inventors interested in commercializing or licensing university intellectual property for a startup. While offering some traditional guidance, like formulating a business plan or pitching an opportunity, this program largely focuses on navigating unique challenges an academic entrepreneur faces in establishing a new company. Courses such as how to appropriately access campus resources, and effective management of conflict of interest, are taught by experts in the field. Upon completion of the program, participants may enter into a well-vetted facilitated license with the Office of Industry Engagement that has been developed to streamline the negotiation process.

- *AMAC* (Accessibility Solutions). The University System of Georgia established this organization in 2006 with a mission to develop technologies, technical systems, and training programs to enable organizations to accommodate the special needs of disabled workers. To accomplish this goal AMAC develops new approaches to materials such as textbooks and manuals, real-time captioning, assistive technologies, and worker accessibility. AMAC works with universities, educators, corporations, and government entities. It is in effect doing innovation that serves larger social goals.

- *The Contracting Education Academy.* This organization was launched in 2011 to provide professional education on the how and why of contracting and subcontracting, particularly with state and federal agencies. The Academy delivers best practices in government acquisition and strategic sourcing. As a Defense Acquisition equivalency provider, the Academy's course work satisfies both the FAC-C and DAWIA certification programs. The Academy helps private entities of all sizes that are engaged in government contracting.

- *Energy Management and Technology.* This program is engaged in projects that are staffed by faculty and staff from across the Georgia Tech community. The goal is to enhance efficiencies in energy production and use, across the economy. Thus activities range widely in kind (e.g., developing and implementing standards for new energy technologies), and target large corporations to startups. Current initiatives include: smart grid; bioenergy/biofuels; solar, wind and water alternatives; and various strategic analyses. A major objective of Energy Management and Technology is to provide focused expertise on energy-related issues as they pertain to other programs of the Institute.

- *Flashpoint.* Launched in 2010, Flashpoint is an intense, 4 months long accelerator experience for a competitively selected group of 12 startups. Participants get access to and advice from mentors, subject matter experts, and experienced investors. This includes a weekly cohort dinner with startup founders from around the country, as well as ad hoc engagements. Participant startups are drawn from across the state, with a strong preference for technology-focused endeavors. Each Flashpoint cohort concludes with "investor demo days" in Atlanta, New York City and the San Francisco Bay area. Thus far, over 90% of the initial 30 participants are still in business, and participants in the first cohort have landed jointly more than $8 million in investor funding.

- *Georgia Manufacturing Extension Partnership (GaMEP).* The Manufacturing Extension Partnership has been a program of the National Institute of Standards and Technology (NIST) for 16 years, and the Georgia program has been in operation for over five decades, with nine offices around the state. Services include coaching and training that focus on process improvement, ISO standards, sustainable manufacturing processes, and energy efficiencies in manufacturing and innovation management. In the last year GaMEP worked with 1,770 small and medium-sized manufacturers, with significant impacts on cost savings, increased sales, and jobs created or retained. Most MEP program activities are not extensively linked to that part of the Institute mandate that focuses on start-up ventures, but there have been some novel exceptions. For example, the GaMEP staff provides direct assistance to startups in SBIR proposal development and manufacturing startup plans. The GaMEP also funds a start-up mentor within the ATDC incubator for product-based firms.

- *Georgia Tech Procurement Assistance Center (GTPAC).* This program component is focused on enabling Georgia-based companies—large or small—to win government contract competitions at federal, state, and local levels. In a recent program year GTPAC worked with 2,900 companies, conducted 150 training seminars, and helped participants win $559 million in contracts.

- *Health IT Outreach Partnership.* The mission of this organization within EI2 is to develop, disseminate, and implement healthcare-focused information technologies. It works with practitioners, hospitals, healthcare providers, and health-related IT companies. It is supported by federal programs and initiatives, Georgia-based government, and private entities including startups and early stage companies.

- *Minority Business Development Agency (MBDA) Business Center-Atlanta.* As noted elsewhere in this chapter, Georgia Tech has had significant success in recruiting and graduating minority students as well as engaging the minority communities of greater Atlanta. This program works with existing minority business enterprises (MBEs) in metro Atlanta, via a training/technical assistance model, to increase their likelihood of success. The activities cover issues such as access to capital and finance management, access to markets, business strategy, business process improvement (e.g., ISO-9000), and business model assessment. The MBDA-Business Center Atlanta has helped create over 3,700 jobs and contributed to obtaining finance, contracts and sales of $600 million.

- *Southeastern Trade Adjustment Assistance Center (SETAAC).* This center is part of a national network of 11 centers that provides financial assistance of up to $75,000 to companies within a nine state region that have experienced economic decline in sales and employment as a result of import competition.

- *Startup Ecosystems.* This program assists communities, governments, universities, entrepreneurs, and small business—most outside of the Atlanta metro area, including clients overseas—in fostering technology-based economic growth and entrepreneurship. Top emphases include incubation practices, faculty startup programs, commercialization research, feasibility studies, strategic planning, policy research, and organizational development.

- *InVenture Prize.* The InVenture Prize at Georgia Tech is a faculty-led innovation competition for undergraduate students. Students can work independently or in teams to develop and present inventions that will be judged by experts. The students introduce their inventions in preliminary rounds and eventually the competition is whittled down to approximately eight. They advance to a final round which is televised live by Georgia Public Broadcasting. Final round prizes include:

    - A cash prize of $20,000 for 1st place or $10,000 for second place;
    - A free US patent filing by Georgia Tech's Office of Technology Licensing;
    - A People's Choice Award of $5,000 selected by text voting during the event;
    - The winner(s) of the InVenture Prize will automatically be accepted to the Summer Class of Flashpoint, a Georgia Tech startup accelerator program.

Looking across the various programs managed and led through the Enterprise Innovation Institute the outcome accomplishments have been notable. During Fiscal Year 2012 the Institute:

- Evaluated 199 research-based innovations and helped form 30 new companies that in turn attracted $21 million in investment;

- Helped 261 companies interested in collaboration with Georgia, yielding over $1 billion in investment and saving 3,342 jobs;

- Helped 322 startup companies develop Small Business Innovation Research proposals, leading to $7 million in awards;
- Assisted 85 minority entrepreneurs, who realized over $77 million in new contracts, increased sales, new bonding or new financing;
- Served 1,370 manufacturing companies in Georgia reduce operating costs by $38 million, increase sales by $451 million, and create or save 978 jobs;
- Assisted 3,056 students via technology accessibility services, and saved the University System of Georgia $1.4 million by reusing textbooks converted for students with disabilities.

Boundary Spanning: *University, Industry and Community*

In addition to EI2 there are several organizations and programs that enable what has been for Georgia Tech an ongoing and robust presence in the world outside the gates. This section will highlight several of those enabling organizations, programs, and services. While the discussion of the Enterprise Innovation Institute in the previous section was likewise all about externally focused activities, most of those were "entrepreneurial" in focus, and the ones below for the most part are administrative-enabling.

Georgia Tech Research Corporation (GTRC). Originally chartered in 1937 as the Industrial Development council, a not-for-profit organization, the GTRC serves as a supporting organization for Georgia Tech. In addition to handling research contracting in a timely and efficient manner, GTRC also assists the University in start-up costs for new faculty hires, appropriates funds for purchase or lease of research facilities and equipment, handles travel advances and reimbursement for faculty expenses, addresses compliance issues with State or Federal agencies, and more germane for this chapter, obtains patents on Georgia Tech inventions and serves as the entity for licensing of intellectual property.

Within the Georgia Tech Research Corporation, the Office of Industry Engagement is responsible for negotiating sponsored research agreements with industry. In addition to more traditional contract vehicles, GTRC offers a suite of agreements (referred to as the Contract Continuum) that allows researchers to engage with industry across a spectrum of research opportunities. By providing potential sponsors with appropriate intellectual property access for the contemplated research, the negotiation process has been streamlined and the transfer of technology has been facilitated.

Georgia Research Alliance. A major contributing factor to Georgia Tech's excellence in industry research partnerships has been the presence of the Georgia Research Alliance (GRA). While not an organization of the University, it is a very important partner of Georgia Tech, as well as other research universities in the state. Founded in 1990, the GRA is a 501c3 that makes strategic investments—in people and facilities—in order to build centers of research excellence in Georgia universities. GRA also fosters research partnerships among the participating institutions. Research foci have tended to be concentrated in a small number of strategic areas, that also reflect key areas of expertise among the participating universities (Georgia Tech, University of Georgia, Emory, Georgia State

University, Georgia Health Sciences University, and Clark Atlanta University). The primary program strategy has been to support senior faculty hires and outfit them with state-of-the-art laboratory facilities and equipment. Over the years, 60 Georgia Research Alliance Eminent Scholar Chairs have been endowed across the six member universities of the Alliance, and over 150 companies have been launched. Since 1990 the GRA has raised $525 million in state funds, and leveraged it into $2.6 billion of federal funding and private investment. The Georgia Research Alliance also funds a commercialization grants and loans program to assist university researchers in translational research for turning inventions into startup companies. An affiliated venture capital fund, the GRA Venture Fund, can make follow-on equity investments, either solo or in syndication with other venture firms.

Georgia Tech Research Institute. Continuing the historical narrative that started on the first page of this case, the Engineering Experiment Station (EES) that was established in 1934 slowly gained momentum during the WW II years as a problem-solving practical-oriented R&D facility. While much of its work in the 1930s was agriculture-related, the wartime growth of projects moved into helicopter research, radar, and defense-related electronics, with the majority of its projects funded by government and industry. In a way, the rise of the Engineering Experiment Station (EES) was an instantiation of the shop skills plus academics vision that characterized the original conceptualization of the university in the 19th century.

After World War II, Georgia government wanted to protect itself from being the contract-liable organization for research at Georgia Tech, and two important changes occurred during the 1946-1947 time frame. The Georgia Tech Research Corporation (GTRC) became the contracting entity for Georgia Tech, and the EES became the Georgia Tech Research Institute (GTRI), the applied research entity to serve industry and government clients, particularly in the defense area.

As GTRI grew and evolved it became the "part-of-but-separate-from" Georgia Tech. It has a full time staff of scientists and engineers who are not members of academic departments or units of Georgia Tech. The total head count as of June 2012 was 1,642 staff, of which 799 were full time scientists and engineers. Of the latter, 72 percent hold advanced degrees, and many have joint appointments with Georgia Tech academic departments. In addition, Georgia Tech faculty members and students (over 350 annually) are often deployed on projects on a part-time basis. So the links between GTRI and the academic units of Georgia Tech are indeed strong. GTRI had $248 million of research revenue in FY2011, with Federal agencies accounting for over 90% of that total. The U.S. Air Force accounted for 31% of grants and contract income in FY2011.

GTRI's applied research program complements the main foci of the campus academic research and instruction program, as well as the needs of its major clients, and is organized into eight laboratories: Advanced Concepts Laboratory; Aerospace, Transportation and Advanced Systems; Applied System Laboratory; Cyber Technology and Information Security Laboratory; Electronics Systems Laboratory; Electro-Optical Systems Laboratory; Information and Communications Laboratory; and the Sensors and Electromagnetic Applications Laboratory. In addition to the Atlanta-based facilities and organizations, GTRI has over a dozen smaller business and research service facilities scattered around the country, mostly contiguous with military operational or technical centers around the US. GTRI also operates an applied research facility in Ireland, as part of Georgia Tech partnerships with the University of Limerick and the National University of Ireland, Galway.

Supplementing the organizational structure of the Laboratories are 25 physical facilities and capacities that are very interdisciplinary in nature. They range widely in what they do, as per the following illustrations: the Accessibility Evaluation Facility; the Environmental Radiation Center; the Food Processing Techology Division; the Interoperability & Integration Innovation Lab; the OSHA Training Institute; the Unmanned and Autonomous Systems Group; and many others.

Interdisciplinary Centers and Institutes. One of the assumptions and themes of this book of cases is that innovation, entrepreneurship, and private sector interest is enhanced when universities do more research and problem-solving in the context of interdisciplinary centers and institutes. Georgia Tech has wholeheartedly embraced that assumption. There are over 200 centers and institutes that cut across intellectual boundaries of methodology, conceptual frameworks, as well as the scope and affiliation of those participating. Some on the list are primarily facilities, as opposed to more organizationally complex centers and institutes.

Most centers are still within a college in terms of a reporting relationship, and the range of interdisciplinary mixing therein is somewhat less. Of the 200 centers at Georgia Tech, the vast majority have a reporting relationship with the College of Engineering, with the College of Computing and the College of Sciences distant seconds.

Many of the most visible and more broadly interdisciplinary centers have a reporting relationship directly to the Executive Vice President of Research and are designated as Interdisciplinary Research Institutes. There are ten in this category, and they tend to have many more faculty, graduate students, and industry partners involved, as well as links to external agencies and other universities. Thus the Institute for People and Technology involves several dozen faculty members and researchers, with approximately the same number of companies and other organizations involved. Likewise, the Parker H. Petit Institute for Bioengineering and Bioscience involves over one hundred researchers from 10 departments across six universities, as well as a large and changing mix of corporate and institutional involvement. Many of the other multidisciplinary centers and institutes at Georgia Tech have comparable breadth of involvement. For example, one of the indicators of external and internal breadth of involvement that we have watched among the cases in this book is the extent of direct financial and substantive involvement (e.g., project agenda-setting) on the part of private-sector participants.

In universities with rich engineering traditions the extent to which there are National Science Foundation Industry-University Cooperative Research Centers (IUCRCs) or Engineering Research Centers is an interesting indicator of private sector participation. At Georgia Tech the following IUCRCs are in place: the Center for Pharmaceutical Development (CPD); the Power Systems Engineering Research Center (with other collaborating schools); the Center on Optical Wireless Applications (with Penn State); and the Hybrid Multicore Productivity Research Center (with several collaborating schools). Among

NSF Engineering Research Centers, the ERC for Compact and Efficient Fluid Power (with two other schools) is at Georgia Tech. Among NSF Science and Technology Centers, Georgia Tech is a participant in the following: the Center for Emergent Behaviors of Integrated Cellular Systems (with several other schools); and the Center for Materials and Devices for Information Technology Research (with several schools). These involvements put Georgia Tech in fairly exclusive company among institutions that are able to launch and maintain these fairly complex partnership relations with other institutions as well as corporate technology leaders.

Taking Innovation to the Community: Technology Square. Many universities located in urban areas become space-constrained as they expand student head count, as well as greater involvement in research and technology development. One design choice becomes whether the new space is to be a functional extension of the existing campus, primarily dedicated to classrooms, labs, and student housing. Alternatively, the new space can be more physically separated from the campus and also include "civilian" activities, such as private sector offices, housing, restaurants, bars, etc. One potential benefit of the latter course is that the new space becomes more genial for inter-sector interaction, "connecting," and doing deals. For example, El Camino Real adjacent to Stanford, and the Oakland neighborhood by Carnegie Mellon, have witnessed many deals cooked.

Technology Square can be seen as an intentional design effort by Georgia Tech to foster inter-sector engagement by creating a mixed-use district. The plan was announced in 2000 and much of the site was built out by 2003, although additional buildings are still being constructed. Much of the site was originally vacant surface parking lots. Tech Square can access the main campus via a pedestrian plaza bridge. Georgia Tech buildings located there include: the College of Management, notably the Ferris-Goldsmith Trading Floor; the Advanced Technology Development Center; Venture Lab; the Technology Square Research Building, that is home to five research centers with 500 faculty members and students; and the Georgia Tech Hotel and Conference Center. Technology Square also houses extensive retailing, restaurants, condominiums, and office buildings. Technology Square is still only 10 years old. It is early and the aspiration is that this area will evolve into a high tech bazaar with a large variety and number of entities involved.

Boundary Spanning: *Technology Transfer*

There are two organizational paths within Georgia Tech when it comes to moving novel solutions into the marketplace that emerge from research conducted by faculty as well as students. One is embodied in those programs and services of the Enterprise Innovation Institute, which are described in great detail above. Before that however, emergent faculty inventions are evaluated in terms of their true novelty and their potential for intellectual property protection via patenting and other mechanisms. Assuming that an invention can be protected, there is also an evaluation of whether it is worth protecting in terms of potential impact. And finally, assuming a viable and protectable invention, what is the best path for commercialization.

A second organization that comes to the fore in making these decisions is located in the Office of Industry Engagement, within the Georgia Tech Research Corporation (briefly described above). Here the Innovation Commercialization and Translational Research group functions as Georgia

Tech's technology transfer unit in the usual sense of the term. This team, with a combination of legal and technical backgrounds, annually evaluates hundreds of potentially patentable Georgia Tech inventions. To execute that process the group works closely with the Enterprise Innovation Institute. In FY2012[7] the Office received 408 invention disclosures, was awarded 79 patents, successfully negotiated 130 licenses or options, and was involved in 13 startup companies. Users can search via Techfinder an online cumulative data base of inventions that are still available for exclusive or nonexclusive licensing arrangements. Of note, roughly 50% of licenses executed by Georgia Tech in 2012 were granted to Georgia companies.

As is the case with most university technology transfer offices, most of the inventions managed by the Office of Industry Engagement end up being licensed by established corporations, in either exclusive or nonexclusive licensing arrangements. However, as noted above, the Office also claims several startups that resulted from their work. And it is in this domain that the programs of the Enterprise Innovation Institute, especially VentureLab and I-Corps, play a key partnering role in fostering the entrepreneurial agenda at Georgia Tech.

All unencumbered inventions disclosed to the Office of Industry Engagement are passed along to VentureLab for assessment. This assessment includes not only the traditional technological evaluation, but, borrowing from the I-Corps process, an assessment as to the viability of a startup within the intended field of use of the technology. By working closely on mitigating the market and technological risk, VentureLab and the Office of Industry Engagement reach the decision as to whether to initiate company formation or regard the technology as a licensing opportunity. Should a company be formed around the technology, then the nascent company is coached by VentureLab, and will seek to license the technology from the Office of Industry Engagement, using the GT:IPS program and standard license.

Summary and Parting Comments

One of the more heartening aspects of the Georgia Tech story is that the institution has largely stayed true to the aspirations of the founders back in the 19th century. Those aspirations were to develop a first class technological university, one that combines excellence in academic education with a hand "in the shop," and one that will enable Georgia to create a modern economy. All those things have been achieved and the bar continues to be raised as its impact is felt throughout the world. Georgia Tech is one of the great American stories of sustained inspired leadership, diligence in execution, and an ever-expanding vision and culture can accomplish amazing things.

Endnotes

[1] Georgia Institute of Technology. *Facts and Figures*. Retrieved from http://www.gatech.edu/about/factsandfigures.html

[2] National Science Foundation, National Center for Science and Engineering Statistics, FY2011. *Table 14. Higher education R&D expenditures, ranked by all R&D expenditures, by source of funds: FY2011. Table 15. Higher education R&D expenditures, ranked by all R&D expenditures, by R&D field: FY2011.*

[3] Tornatzky, L., Waugaman, P. and Gray, D. (2002). *Innovation U: New University Roles in a Knowledge Economy*. Research Triangle Park, NC: Southern Growth Policies Board.

[4] Georgia Institute of Technology, Office of the President. (August, 2010). *Designing the Future. A Strategic Vision and Plan.* Retrieved from http://www.strategicvision.gatech.edu/

[5] Georgia Institute of Technology, College of Engineering. (2012). *Defining Tomorrow. A Strategic Plan.* Retrieved from http://coe.gatech.edu/content/defining-tomorrow-strategic-plan

[6] Since a redundant theme of this book is the importance of visionary leadership, it should be noted that after playing an important role at Georgia Tech, Jean-Lou Chameau went on to do the same at Cal Tech. See the Cal Tech chapter in this book for further discussion.

[7] Association of University Technology Managers. *AUTM U.S. (2013). Licensing Activity Survey: FY2012.* Deerfield, IL: Association of University Technology Managers.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY*

After several years of relentless campaigning by William Barton Rogers, an academic scientist and educator, the Commonwealth of Massachusetts passed a bill that was signed by the Governor on April 10, 1861, chartering the "Massachusetts Institute of Technology and Boston Society of Natural History." However, since the Civil War started within the week, the new school didn't get underway until four years later. Nonetheless, the institution was to be a contrast to the prevailing norm of higher education in the late 19th century. It would be:

> *A school of industrial science [aiding] the advancement, development and practical application of science in connection with arts, agriculture, manufactures, and commerce.*

In other words, as a polytechnic institution, it would be distinctly different from Harvard and other private institutions of the times. One of the little-known and novel strategies that President Rogers and the other founders pulled off was to use the Morrill Act, passed in 1862, as a financial and organizational vehicle for starting the university. The basic purpose of the Act was to enable, via the sale of federal land for cash, the establishment of Land Grant campuses all over the country. But the MIT situation was different:

> *MIT's exploitation of the Morrill Act was unique. Firstly, because it was the only federal land grant extended to a private university, and secondly, because MIT was the only land grant school founded by industrialists for industrialists. In other words, the Institute would develop technology and train engineers to serve the needs of established industry. MIT's technology was not initially developed for engineers to start their own companies. Neither were industrialists funding MIT labs to give science away to farmers, like most of the agricultural land grant schools in the Midwestern states. To MIT corporation members, technology was a means to improve the fortunes of privately held industrial enterprises, just like the enterprises they founded themselves.*[1]

The entering class of 1865 numbered 15, and the school struggled during its early years. But "learning by doing" (*Mens et Manus*—"mind and hand") became a path for a new kind of university. MIT was an early innovator in the use of laboratory-based instruction and project emphases, as well as warm working relations with private industry. However, economic conditions during the 1870s hampered the growth of both funding support and enrollment, with the latter inching up to

** This case was written by Louis Tornatzky and Elaine Rideout.*

only 253 by 1880. Finally, beginning in 1887, the Commonwealth of Massachusetts started a series of grants to MIT that lasted until 1920, and enabled MIT to begin to grow and achieve some financial stability. Total enrollment was 1277 in 1900, 3,436 in 1920, and maintained that approximate level on through the 1930s. Through this period there were major investments in laboratory facilities and program development, all of which was accelerated when MIT moved in 1916 to a mile-long tract of land along the Charles River in Cambridge that was gifted to the university by George Eastman.

Over the latter half of the 20th century the MIT enrollment mix between graduate students and undergraduates shifted significantly. By the 1960-61 academic year, the student breakdown was 55.5% undergraduates to 44.5% graduate students. By 2010 the fractions had flipped with 59.3% graduate students to 40.7% undergraduates. Most recently, there have been extensive efforts to enrich the undergraduate laboratory and project experience as well, along with a growing Institute-wide focus on technological innovation and entrepreneurship.

In terms of student breakdown across MIT's separate colleges, the 2012-2013 total enrollment of 11,189 included 6,686 graduate students, with 3,166 in the School of Engineering, at either doctoral (2,093) or Master's (1,070) levels. This was followed by Master's (1,241) or doctoral (138) students in the Sloan School of Management, and doctoral students (1,086) in the School of Science. The School of Architecture & Planning, and the School of Humanities, Arts & Sciences, accounted for the balance of graduate enrollment. Among the 4,503 undergraduates, the dominant major was Engineering, followed by Science.

Per National Science Foundation (NSF) statistics[2] MIT ranked 20th in terms of total R&D expenditures for FY2011, with a total of $723.6 million. Interestingly, in terms of funding sources, like all research-intensive universities, most research funding comes from the Federal government. However, MIT currently ranks the second highest among the top-100 schools in terms of the fraction of research funds from industry sponsors (15.2%). In addition, reflecting rankings by R&D field, MIT's research expenditures are mostly in engineering (42.2%), followed by life sciences (16.4%) and physical sciences (15.9%). Over the recent past, research involvement in the life sciences has accelerated, a trend that is likely to continue.

Significant financial sponsorship of university research in the US, by either government or industry, was limited until the 1950s. This was not the case for MIT. Early in the buildup to and onset of World War II, as a function of campus research leadership, the institution got a very large head start in government-funded military research contracts. As postwar Federal research became a more regular process, executed by established and new Federal R&D agencies, the mix of science funding sources for MIT shifted. Thus in the 1970s the largest sponsors of MIT research were the Department of Defense and NASA, while in the last few decades the importance of HHS sponsorship has grown. Nonetheless, MIT maintains its national standing in total research funding and has become very adept at expanding the fraction sponsored by industry. MIT also continues to increase its research volume per faculty member. MIT has very entrepreneurial faculty members and research staff, as we shall describe below.

University Culture: *Goals and Aspirations*

The MIT motto, *Mens et Manus*, is an excellent shorthand descriptor of the key elements of the MIT culture and history. The current expression of that culture applauds daring research that pushes the envelope of science, but also focuses on moving that work into applications in the real world. Those cultural values also support technology entrepreneurship across the campus.

Some additional history is useful here. During the time MIT was going through its founding struggles in the late 19th century, when it was receiving repeated offers from Harvard for consolidation, the cultural values of *Mens et Manus* that have been depicted in the MIT seal since 1864 (the tradesman leaning a hammer on the anvil; the scholar deeply into the book) were revisited again and again. After fending off Harvard, and launching the new Cambridge campus, the years between the early 1910s and the late 1930s involved an intense period of further discussion around how *Mens et Manus* would be operationalized. Christophe Lecuyer describes[3] this as three visions in competition. It should be pointed out that at the onset of this period, MIT was basically an undergraduate teaching institution, preparing engineers with practical skills who could move directly into industry.

The culture that got established in the 1920s and 1930s and during the World War II years, as these sub-cultures competed and consolidated, was instrumental in making MIT what it is now. Early in this period MIT was a very practical hands-on undergraduate teaching institution that covered the science and engineering basics, and mixed in a lot of practice-oriented instruction and interactions with industry. One competing intellectual movement that emerged was a demand for greater student exposure to the basic sciences and the scientific method, coupled with an expanded emphasis on graduate education. A second group wanted to increase MIT's engagement with industry, including both small and large companies, in what amounted to a service relationship. A third group of faculty wanted to modernize and enhance the scientific and technological position of the university, but also develop a service relationship with companies, particularly smaller ones. The emphasis on service relationships evolved into the Tech Plan and a centrally managed Division of Industrial Cooperation and Research (DICR), which grew to working with over 200 companies. The companies involved were very diverse in size and the sophistication of their interests. This approach was at odds with those who wanted to increase the science and methodological sophistication of what MIT was all about. The Tech Plan and DICR grew and by the late 1920s exceeded $700K in volume (equivalent to several millions in current dollars). It also became, in the eyes of many faculty members, intrusive and controlling. Central administration could prevent publication and academic freedom of action, and the role of companies in the University was becoming intrusive.

Beginning in the late 1920s and on into the 1930s, the terms and goals of these external engagements with industry changed significantly, particularly during the presidential administration of Karl Compton starting in 1930. This process was influenced by advisory roles played by the senior leadership of General Electric, Bell Telephone Laboratories, and other well-established science and technology-focused companies. They, and others, advocated a more science-based curriculum (particularly physics), in a research-oriented university.

MIT was to be a university deeply involved in scientific research that addressed very complex and little understood phenomena, but where novel results could be applied to big problems in the real world. MIT would lead in both the science and the engineering of solutions. MIT would become more involved in graduate education, but science-linked engineering would be part of both the undergraduate and graduate educational experiences. While solving complex problems in the real world required innovative thinking, teaching, and cross-disciplinary collaboration within the University, it also required working directly with industry partners. A culture unique to MIT arose that rewarded out-of-the-box thinking and taking action to turn research into novel real-world solutions. Leadership committed to these things, implemented policies and procedures to help make them happen and these, in turn, soon became traditions and part of the MIT culture.

For example, in the MIT of today, faculty can use a fraction of their time to engage in work outside of the University itself, to consult, or to work at their own startups.[4] Faculty members have continued to work at MIT while also serving as co-founder and CTO of a successful startup built around a technology they invented. Rodney Brooks, for example, was Director of the Computer Science and Artificial Intelligence Lab at MIT while he launched iRobot, which, among other things, produces the popular Roomba vacuum cleaner. Furthermore, tenure at MIT is not necessarily based on teaching skills as much as it might be elsewhere, but by virtue of a person's being at the top of their field. In general, teaching loads may be lower at MIT, and the administrative duties of professors are much lower as well. These policies enable faculty to spend more time in a research productive manner.[5] Leave policies, performance reviews, and salary structure are all also supportive of a more venturous approach to a research career, as are policies encouraging cross-disciplinary collaborations and lab sharing. Karl Compton was the champion who enabled all of these things to blossom, and put forth a more substantive and forward-looking interpretation of *Mens et Manus*.

Leadership

In all the cases in this volume we have tried to describe the roles that key leaders have played in enabling their universities to become focused and effective in fostering innovation and entrepreneurship. The MIT history is long and colorful and, for the most part, we will concentrate on those leaders who have been most important during the last few decades. Nonetheless much of the current culture of MIT starts with Karl Compton, who from 1930-1954 was the dominant voice and guide of the Institute. But first a little background.

Karl Taylor Compton was born in Ohio in 1887, trained as a physicist, and had a nationally prominent career—National Academy of Science member—at Princeton before he became MIT's President in 1930. He held that position until 1948, which was followed by being Chairman of the MIT Corporation until his death in 1954. In those years MIT became the MIT that we now know: a full-fledged research university that joined science and engineering into a national exemplar of research and graduate education. MIT joined the Association of American Universities in 1934 and restructured its undergraduate and graduate curricula to make fundamental science a more central component of what students learned. Relationships with industry continued and grew, but were less premised on a practice-oriented service relationship.

During this period Compton enjoyed a strong partnership with his Vice President and Dean of Engineering, Vannevar Bush, another key leader in the MIT story (as well as other cases in this volume). Beginning in the late 1930s and accelerating at an extraordinary pace during the 1940s and thereafter, MIT become a university leader in research and development focused on national defense. Bush left MIT in 1938 to be President of the Carnegie Institution for Science in Washington and, as preparations for war increased, was made Chair of the National Defense Research Committee (NDRC) working closely with President Roosevelt. President Compton was an NDRC member and chair of a committee concerned with instrument and controls.

At a top-secret meeting held on September 19, 1940, Compton and other participants from MIT and industry were introduced to work pioneered in Britain that had resulted in a prototype cavity magnetron, which would eventually be the key technology in radar systems that, in turn, would be instrumental in winning the forthcoming Battle of Britain and the worldwide air war later on. The question was where and how could a development laboratory be established by NDRC to quickly move the technology beyond the prototype stage into production-readiness. At a follow-on meeting on October 17, (attended by Compton and Bush, MIT Electrical Engineering professor Edward Bowles, and Frank Jewitt, President of the National Academy of Sciences and Chairman of Bell Laboratories, and others), a key question discussed was where 10,000 square feet of lab space could be made immediately available and what organization could manage a rapid build-up of R&D leadership and capacities. Bowles offered up his lab space and within a week a contract to MIT was signed for $455,000. This would be equivalent to about $7.5 million today.

MIT, Bush, and Ernest Lawrence (an NDRC member from the University of California) immediately moved to hire Lee DuBridge from Rochester as lab director. Other key individuals were hired from across the country and from MIT, and the lab was operational within weeks. Named the Radiation Laboratory, or "Rad Lab," the facility not only accomplished its focal mission but also established an organizational model for how MIT would work with Federal contractors within the defense system. Within a year of its founding the Rad Lab had:

> *...employed 466 staff members, including 320 scientific personnel. Seventy of the scientific staff members....were MIT employees who now split their time between teaching and research activities at the Rad Lab."* [6]

The Rad Lab went on to extraordinary accomplishments during the World War II years. It transitioned to a huge operation, employing a large percentage of the country's physicists. So too did what became known as the Draper lab (led by MIT professor, Stark Draper), which rose to national prominence in the area of instrumentation. The scope of war work at MIT was phenomenal, and as noted by President Compton:[7]

> *The Institute spent on its war contracts as much money as it had spent on its normal activities during its previous 80 years of existence.*

While defense contracts dipped significantly immediately after the end of World War II, they rose again during and after the Korean conflict, and continued at a relatively high level. During the politically tumultuous 1960s and 1970s, MIT went through a tortuous self-examination process, fueled by the times and growing disenchanment with the scope of DOD-related research and development on campus. That eventually led to the divestiture of the Instrument Lab, which had been officially renamed the Charles Stark Draper Laboratory. The DOD-funded Lincoln Laboratory, which was established in 1951 and was more physically separated from the MIT campus, was nonetheless retained as a part of the MIT family (See Industry and Community, below).

In discussing what happened after the 1970s, and what leadership came to the fore, it is instructive to review how the MIT R&D portfolio and priorities changed over time. An analysis conducted a few years ago is useful.[8] Starting in FY 1957, federal support accounted for 89% of research expenditures, and has stayed pretty much in the 70-80% range since. In FY 1970, the largest sponsor of MIT research was the Department of Defense, at 28% while the total of agencies that are the current equivalent to HHS was 16%. In contrast, by FY 2006 the DOD share had dropped to 15% and HHS was at 33%. In the 1970s the fraction of MIT research funded by industry stood at 3%; more recently, the fraction in FY2011 was 15.2%. Also, per NSF data, the fraction of research expenditures categorized as life science increased from 11.7% in FY1992 to 16.4% in FY2011. So, to some degree, major sources and substantive foci of sponsored research have shifted over the years, and despite occasional periods of retrospective controversy, MIT has been very adept at rolling with the punches while retaining its basic orientation—*Mens et Manus*—intact.

Different institutional leaders have played significant roles. Susan Hockfield, MIT's recent 14th President, played a special role in bridging the life sciences and engineering. A particular accomplishment, for instance, is the thriving David H. Koch Institute for Integrative Cancer Research, where life scientists and engineers are working to develop new solutions to diagnosis, treatment, and prevention. Dr. Hockfield was also an effective advocate and enabler for the flourishing of the Kendall Square locus of life science and biotech companies. Her presence speaks to the larger role of life sciences at MIT, as well as a dramatically increased number of women students. Before her departure in 2012 she was also instrumental, in a time of major economic dislocation, to see an ambitious advancement campaign—the Campaign for Students—achieve its $500 million goal. In parallel, in a carefully orchestrated management effort, she balanced the General Institute Budget (for the first time in 10 years).

Her predecessor, Charles M. Vest, served a 14-year term as President. Dr. Vest came from the University of Michigan, where he had been provost and a professor of engineering. His MS and PhD in engineering were earned at Michigan, and he had a long and deep involvement with the manufacturing sector, particularly during its transition to advanced computer-based technologies. It is not coincidental that industry financial support of MIT research reached its current level of national leadership during his presidency. He also was an effective advocate and advisor on the national science policy in roles such as vice chair of the Council on Competitiveness for eight years and member of the President's Committee of Advisors on Science and Technology. He also served as president of the National Academy of Engineering.

Paul Gray must also be mentioned as a key leader in the flourishing of MIT, particularly among the cohort of undergraduate students. Not only did he serve as President for 10 years, and Chairman of the Corporation for seven years, but he had been at MIT since the 1950s as an undergraduate and graduate student, an instructor, through the faculty ranks, an Associate Dean, an Associate Provost, and Dean of Engineering. After retiring from the Corporation, he returned to classroom teaching and graduate student advising, with a particular love for expanding the quality of the undergraduate experience. This included establishing the Undergraduate Research Opportunities Program (UROP) as well as efforts to enhance the undergraduate curriculum in the social sciences, humanities, and biology. Dr. Gray's academic field is in electrical engineering, and he served as a co-chair of the Council on Competitiveness. He also apparently knows everything and everybody that pertained to MIT, which came out of his 40-year connection.

Gray's career, from its humble roots within the University to the Presidency to his current position illustrates the incorrectness of the assumption that the only important leaders in the story of MIT are those in high office. For example, in a recent issue of MIT Technology Review,[9] the editor highlighted some MIT faculty members who have been extraordinarily productive innovators far into their senior years. Carver Mead (79 years old), electrical engineer, has cofounded over 20 companies, developed the first software compilation of a silicon chip, and is now working on how animal brains work. He is also trying to figure out a better way to teach freshman physics. Barbara Liskov won the Turing Award for work on programming languages, and the IEEE John von Neumann Medal for work on distributed computing. She is 73. Mildred Dresselhaus works on the physics and properties of nanomaterials, and was the "first scientist to exploit the thermoelectric effect at the nanoscale." She is 82 and is usually in her office by 6:30 AM.

Robert Langer[10] is only 64, but is known for his extensive patent portfolio (over 800 and counting), his role in starting 25 companies, and the 250 companies that have licensed or sublicensed Langer Lab patents. Graduate students, post-docs, and faculty members populate his lab. He works actively and regularly with lab members who come to him with an idea or a proposal, and is famous for returning his feedback within 24 hours. The Langer Lab has a research budget of over $10 million, primarily from Federal agencies, and is housed in the David H. Koch Institute. Dr. Langer also has extensive relations with the venture capital community in greater Boston and elsewhere. The Langer Lab approach, and its close links between cutting-edge science, invention, commercialization, and startups, provides a good transition to the next sections.

Boundary Spanning: *Entrepreneurship*

As noted above, MIT is, by headcount and mission, predominately involved in graduate education, with a heavy concentration in engineering. The culture also supports and encourages technology entrepreneurship among faculty, graduate students, undergraduates, and throughout the MIT community. While a thousand pages could be written about the MIT entrepreneurial ecosystem, some of the curricular and co-curricular highlights, that are most illustrative of the MIT approach, are described below.

Curricular Programs

The Martin Trust Center for Entrepreneur-ship, located in the Sloan School of Management, is the primary enabling organization for Entrepreneurship courses and programs. One of the more interesting things about MIT is the relative dearth of formal entrepreneurship degrees, majors, minors, and certificates in comparison with some of the other schools featured in this volume. For example, the only formal entrepreneurship degree offered is the major in entrepreneurship offered as part of the Sloan MBA, Entrepreneurship & Innovation (E & I) Track. Apparently, no degree programs, minors, or even certificates in entrepreneurship are offered at the undergraduate level, even to undergraduate business students.

Entrepreneurship learning opportunities abound at MIT but in nontraditional ways. For example, while there may be a shortage of degrees and certificates, there does not appear to be a shortage of courses in entrepreneurship available to undergraduates; nor is there a shortage of extra and co-curricular opportunities. Outside of the business school, several entrepreneurship courses are offered within the disciplines—for example, the Founders Journey course for undergraduates in the school of engineering, as is a product development/design course that includes prototype development. Undergraduate engineers can also take advantage of the Gordon Engineering Leadership program, which promotes innovation and leadership, including innovation in the established firm.

But intentionally or unintentionally the approach that appears to be working at MIT, in view of the relative lack of structured curricula, is the willingness to blur the traditional boundaries between graduates and undergraduates. In some courses—Medical Device Design, for example—undergrad and graduate students work together to apply mechanical and electrical engineering fundamentals to the design of medical devices that address clinical needs. However, graduate students do complete additional assignments. Learning labs are widely utilized at MIT as curricular mechanisms to provide instruction and entrepreneurial experiences customized to student interests, regardless of their level.

The office of undergraduate education's D-Lab program offers courses to any student interested in the design, development and dissemination of technologies that meaningfully improve the lives of people living in poverty in South America, Africa, India, and Southeast Asia. Classes in technology development in areas including health, energy, waste management, education, agricultural, and assistive technologies are cross-listed across a number of academic departments. In addition students can take courses in design, creativity, business venture development, supply-chain management, cross-cultural dialogue, and can study abroad, working with social entrepreneurs to support youth entrepreneurship and help scale up other social innovations.

Other curricular innovations that offer entrepreneurship education to any MIT student, and any student anywhere for that matter, include the MIT OpenCourseWare (OCW) initiative. OCW has posted all of the materials used in the teaching of over 2,000 courses on static course websites. The curricula are free and available to teachers and students anywhere with an internet connection. In entrepreneurship and related subjects 66 courses are offered, including product development and design, invention creation and development, patents, business planning, managing innovation, entrepreneurial finance and marketing, supply chains, pricing, etc. According to their website, OCW remains one of the most widely used digital resources on campus, accessed regularly by 92% of students and 84% of faculty.

Building on the success of OCW, in 2012 MIT and Harvard University launched edX, a Massively Open Online Course (MOOC) platform that offers 75 interactive online classes in subjects that include law, history, science, engineering, business, social sciences, computer science, public health, and artificial intelligence (AI). The courses are free and anyone anywhere in the world with an internet connection can enroll. The nonprofit enterprise has already attracted 18 additional education providers, including UC Berkeley, Caltech, and universities in China, the UK, France, Australia, Germany, and others.

While we are interested here in the approach MIT takes in teaching entrepreneurship, the school, more than any of the other cases described herein, epitomizes what happens to institutions of higher education that operationalize their entrepreneurialism internally into university operations and teaching practice. For example there is an applications course in entrepreneurship where students can consider projects that may lead to a solution that significantly enhances the MIT environment for entrepreneurial activity among students. MIT instructional delivery and pedagogy has clearly evolved into new approaches and modalities.

As noted above, the core of curricular entrepreneurship at MIT is the Martin Trust Center for Entrepreneurship at the Sloan School of Management, which launched its first class in entrepreneurship in 1990. Since then, the Center's practice of entrepreneurship education has evolved considerably. The Trust Center prides itself on inventing a "disciplined approach" to entrepreneurship education. The Center's flagship program is the Entrepreneurship & Innovation (E & I) Track of the Sloan MBA program. One feature of the curriculum is the use of "dual-track faculty" for courses and course activities. One track is populated by tenure-track faculty; the other track involves adjunct instructors and lecturers who are experienced entrepreneurs, investors, and inventors. Many of the Sloan entrepreneurship courses are open to all MIT students, undergraduate and graduate, from all disciplines. To illustrate how this works out in practice, the Martin Trust Center posted the 27 courses offered during fall semester of 2013, of which a third (9 courses) had no prerequisites. The courses were offered in the following four categories:

- Foundation subjects (practice and theory)
- Entrepreneurial skill sets (e.g., finance, law, leadership, marketing)
- Industry focus (e.g., construction, energy, medical device, drug development, materials, data analytics etc.)
- Other entrepreneurship electives

One likely advantage of this situation is that it mixes up students from different methodological and substantive backgrounds, which arguably enables creative solutions.

One particularly important asset of the Martin Trust Center is its ample entrepreneurship incubation space where students can meet 24/7 to scheme, design, prototype, and move their entrepreneurial visions forward. The Center also offers grants, mentors, a speaker series, a newsletter, and networking events, with an emphasis on team activities that, again, result in mixing of students from different disciplines and interests.

Sloan MBA students also have access to the MIT Global Entrepreneurship Lab courses to engage in experiential learning in international settings, particularly in less-developed countries. These include innovation development and consulting with companies and other institutions in China, India, Africa, and Southeast Asia. One such lab, the GlobalHealth Lab, pairs faculty-mentored student teams with enterprises on the front lines of health care delivery in sub-Saharan Africa and South Asia. Or, students can join an E-Lab team working closer to home with high-tech startup companies on targeted projects. The goal of the Labs is to have students interact directly and deeply with actual companies to experience what a startup is really like, and to be able to work effectively in ambiguous and dynamic situations.

Other courses and programs allow MIT graduate students to team with other technical and scientific graduate students (from MIT and elsewhere) on a number of lab-style courses and programs. For example, the School of Architecture and Planning has a Media Lab entrepreneurship program that offers courses to graduate students from Harvard and MIT in media arts and sciences, in an effort to develop novel technologies that span disciplinary boundaries. The program's courses include Development Ventures, Imaging Ventures, and Neurotech Ventures, together with the flagship Media Lab Enterprise course. Since its inception in 1985 the Media Lab has become famous as a "factory" of innovation, (See University and Industry, below), spawning over 120 startups around ideas that include wearable wireless biosensors, digital holographic printing, smart airbags, glucose-powered prosthetic limbs, fabric-based computers, etc.

Similarly, the Biomedical Enterprise Program (BEP) is jointly administered by the Harvard-MIT Division of Health Sciences and Technology (HST) and the MIT Sloan School of Management. The program exposes graduate students to an integrated curriculum focused on the complex process of product development and commercialization in the health care industry. Graduates are trained to identify and pursue new ideas, manage scientific and clinical research, procure resources, and build successful biomedical businesses.

Co-Curricular Programs

Much of the student-based entrepreneurial experience at MIT (especially at the undergraduate level), comes via co-curricular programs rather than formal courses. Some include programs focused on faculty inventors, with graduate students along as a team member. The most significant programs include:

- *MIT Deshpande Center for Technological Innovation.* This program provides seed grants to faculty-led teams, that can include students as well as faculty, trying to develop novel technologies with the potential to solve very big problems. The grants are at two levels: $50K Ignition Grants, to demonstrate proof-of-concept and/or a working prototype; and $250K Innovation Grants, to refine and develop the innovation, explore markets and develop a business model over the course of one year. The Center also offers mentors, corporate sponsorship, and hosts various events and presentations of interest to the MIT entrepreneurship community.

- *MIT $100K Entrepreneurship Competition.* This program has been around for 23 years and counting, and is primarily focused on working with and mentoring student teams developing technology-based entrepreneurial ventures. Mentoring and advice is provided by a large network of "world-class entrepreneurs, investors and potential partners" over a year's time, which then leads to a competition of team presentations and pitches. The program has enabled the birth of "over 160 companies with aggregate exit values of $2.5 billion captured and a market cap of over $15 billion." The success of the Competition has spawned several other similar programs including its social entrepreneurship counterpart, the MIT Global Challenge, as well as the MIT Clean Energy Prize, and the Creative Arts Competition.

- *Founders Skills Accelerator.* MIT offers a summer program sponsored by all five MIT schools for any team of student entrepreneurs. And students need not worry about giving up their summer jobs as $1,000/month fellowships are available to help cover living expenses. Furthermore, teams that meet summer milestones on their startup ideas can secure significant additional financial support from external partners. Student teams receive instruction, mentors, and an advisory board (a simulated board of directors) to keep them on track.

- *Lemuelson-MIT Program.* This program was endowed by Jerome Lemuelson and his wife in the 1990s and is administered through MIT's College of Engineering. The $30,000 Lemuelson-MIT Student Prize is awarded annually to a "full-time MIT senior or graduate student" who has been involved in creating a "key invention within a team environment." The Lemuelson Foundation also supports a number of much larger and more visible awards, which are implemented on a national basis.

- *Martin Trust Center's Entrepreneurs in Residence (EIR) Network.* This program is administered through the Martin Trust Center in the School of Management, but its services are available to all current MIT students. An initial meeting is held with a "student evangelist" during which the scope or level of needs are assessed. The student is then referred to an EIR, with a level of experience appropriate to the student's situation. These include: highly experienced entrepreneurs with significant success in entrepreneurship (Gurus); entrepreneurs whose companies are a few years old but experiencing some success (Coaches); current students or recent grads who have just completed some early stages in launching a company (Peer-to-Peer). Meetings take place either on campus or in the EIR workplace.

- *MIT Venture Mentoring Service (VMS).* Since 2000, the VMS has been offered to faculty, students, local alumni, staff, and local licensees of MIT inventions. A cadre of volunteer mentors works with teams to address business and technological problems of a startup, (product development, IP, finance, human resources, management, leadership, etc.). Volunteers are obligated to subscribe in writing to a Statement of Principles that defines the responsibilities and obligations of all involved. VMS has been generous in passing on its methods and approach to other academic institutions. Often those engagements may begin with an intensive Immersion Training experience and then follow-up advising. No fees or equity participation is required for VMS services to

MIT-linked would-be entrepreneurs. Virtually all of the mentors have MIT lineage.

- *Enterprise Forum; Enterprise Forum of Cambridge.* The original Enterprise Forum event and format was founded at MIT in 1978, but has now in effect been franchised around the US and internationally. Attendees are not restricted to people with MIT ties, and community participation is widely encouraged from anyone interested in entrepreneurship. The format is generally the same. It is a late afternoon/early evening event, some modest meal is served cafeteria style often accompanied by beer or wine, there is a panel of speakers who hold forth on some issues pertaining to technology entrepreneurship (and with each other), and then discussion is opened up for Q & A, audience comment, etc.

- *Independent Activities Period (IAP).* This is an established tradition and program, going back nearly four decades, not focused primarily on entrepreneurship per se, that provides a novel platform for co-curricular activities. The January-February break between fall and spring semesters constitutes a special "term" in which literally hundreds of how-to sessions, forums, seminars, films, tours, etc. are offered either credit or non-credit (http://web.mit.edu/iap/about/index.html). Faculty, staff, students, and MIT alumni develop offerings in a kind of a free-market bazaar. Posted standards and procedures provide some guidance on appropriateness. During a recent IAP, a number of activities were proposed that were relevant to entrepreneurship, including: Management and Entrepreneurship, with over 30 offerings; Sales Boot Camp; Patents & Pizza: Careers in Intellectual Property Law; Design Thinking for Scientists; Entrepreneurial Strategy for Engineers; 3 Day Startup Entrepreneurship Program; Beating the Corporate System: An Engineers Guide; Coolhunting and Coolfarming through Swarm Creativity.

- *Student Clubs.* Several entrepreneurship-oriented clubs exist at MIT and cater to different cohorts of students interested in entrepreneurship, with each club having somewhat different program activities and participants. Some current examples, large and small, include:

    - The Entrepreneurs Club (EClub), in operation for 25 years, is based in the Sloan School and many of its activities happen in the Martin Trust Center. It holds weekly meetings, enables undergraduate seminars, convenes networking events, provides practice sessions for presenters, and participates in the Independent Activities Period (IAP).
    - The Sloan Business Club (SBC), formerly Science and Engineering Business Club (SEBC), encompasses both undergraduate and graduate students from the Sloan School as well as the science and engineering community within MIT. Its activities include focus groups, an occasional newsletter, a Fall Networking BBQ, student workshops, and speaker events. It has secured industry sponsorship for larger and more ambitious events. The SEBC claims to have over 1650 members.
    - The MIT Venture Capital & Private Equity Club (VCPE) is one of the larger clubs and has extensive financial and substantive involvement on the part of the venture capital community,

local and national. The VCPE Club's major activities include: an annual MIT Venture Capital Conference, a day-long widely attended gathering that includes prominent speakers, panels, and a "pitch-off" event; a Private Equity Symposium, involving over 400 investment professionals and students, with panels, individual speakers and networking events; the annual MIT Sloan Venture Capital Investment Competition, in which dozens of student MBA teams from across the country compete while pretending to be VCs and making investment decisions about actual companies.

- The MIT VentureShips Club enables teams to focus on business issues of existing entrepreneurial companies in various stages of development. Students work with company personnel and entrepreneurs from the MIT Venture Mentoring Service to solve real-life problems, usually during a semester time frame. Over its history VentureShips has worked with dozens of companies, and involved hundreds of students.

The Roberts-Eesley Impact Report. While the courses, experiences and co-curricular opportunities described in this Entrepreneurship section arguably have impacts on the propensity and odds for MIT students to become successful entrepreneurs, so too does the Leadership and Culture of the MIT have complementary impacts. And arguably, the MIT organization as a whole has impacts on faculty and staff that last after students graduate and go on with their lives. Those suppositions, in fact, find supportive evidence in a large empirical study[11] reported in 2009 by an MIT professor, Edward B. Roberts, and a then-doctoral candidate, Charles Eesley. Two tranches of data collection were reported on. One was a survey sent in 2001 to 105,928 living MIT alumni, which yielded 43,668 responses, 34,846 of which had answered a question on whether or not they had become entrepreneurs. Of those, 8,176 responded in the affirmative. In 2003 these individuals were followed up with a more detailed survey about their entrepreneurial experiences, yielding 2,111 responses from alleged founders. Based on their analyses, the investigators concluded that companies founded by MIT graduates would constitute the 11th largest economy in the world, and when the sample findings were extrapolated to the total population of alumni, the group likely founded 25,800 active companies and those that survived likely employed upwards of 3.3 million people with revenues approaching $2 trillion. Other analyses suggested that the fraction of MIT graduates who go on to start companies seems to be accelerating, and that those new entrepreneurs seem to start companies at an earlier age. Moreover, while students who come to MIT are from everywhere in the US and the world, the entrepreneurial activities after they graduate seem to be heavily concentrated in Massachusetts (just under 1 million jobs) and a few other places domestically, principally California (526,000 jobs), New York (231,000), Texas (184,000) and Virginia (136,000). The reader is encouraged to peruse the entire report. It comments extensively on the cultural influences within MIT that enable these trends.

Boundary Spanning: *University, Industry and Community*

There are several boundary spanning organizations through which the university engages business and industry, the larger research community, and the contiguous business and political community. It will be recalled that MIT gets special plaudits for the fraction of its research expenditures that are supported by industry, which places it highest among the research-intensive institutions that do not have a medical school. Industry-funded research was 3rd, just behind the Departments of Defense and Health and Human Services sponsors of MIT research, and ahead of NSF. These working relationships with the private sector are a key relative advantage. So how do the 1,022 MIT faculty members, 3,077 research staff and research scientists (including post-docs), and 2,490 graduate student research assistants (as enumerated in the 2013 MIT Briefing Book[12]) work with industry? Cutting through the complexity, there are essentially two organizational formats in which industry-sponsored research happens. One is the one-time project, in which a team is assembled to perform a project that is contracted or otherwise supported by a company. Often a project leads to follow-up work, but there is less likely to be an ongoing organization set up to serve that company. The other approach for industry-sponsored research is in the context of a center, institute, laboratory, or program. In this case, the organizational relationship may continue on for years, with different MIT investigators and private sector clients passing through, and a changing menu of projects going on at any given time. Some centers last a long time, and become part of an ongoing portfolio of a funding agency, with industry involvement built in.

For example among center programs operated by the National Science Foundation (NSF), MIT has a Science and Technology Center in Emergent Behaviors of Integrated Cellular Systems, in collaboration with Georgia Tech and the University of Illinois. It also is a partner institution on an NSF Science and Technology Center focused on the Science of Information, as well as being a partner member of a Science and Technology Center on Microbial Oceanography, led by the University of Hawaii. MIT partners on a third Science and Technology Center for Biophonics, led by the University of California, Davis. MIT also operates an NSF Materials Center on Materials Science and Engineering. Among NSF Engineering Research Centers (ERCs), MIT is well represented: it is a partner on the Synthetic Biology ERC, led by UC Berkeley; a partner on the ERC for Sensorimotor Neural Engineering, led by the University of Washington; and a core partner on the ERC for Quantum Energy and Sustainable Solar Technologies, led by Arizona State University. Other federal funding agencies also have portfolios of centers and project-funding initiatives that involve MIT, many with opportunities for companies to be part of the mix.

The above is just a sample of one Federal science agency's investments in MIT-based centers or programs. A perusal of the results that emerge from typing in "MIT labs, centers and programs" on one's search engine produces several hundred listings, each of which necessitates a deep dive into the particular center, lab or program. The interesting question from an industry perspective is how to navigate this diversity of richness. MIT has one great answer: the Office of Corporate Relations (OCR), which has several component programs and activities.

Office of Corporate Relations (OCR). In addition to the MIT culture, which tends to reinforce a mindset among faculty, staff and students that industry partnering is a mutually beneficial activity, the Office of Corporate Relations operates or brokers a number of programs and services to help companies get engaged. They include the following:

- *MIT Industrial Liaison.* These personalized services enable companies to get engaged with centers, departments and faculty (discussed in more detail below).

- *MIT Industry Briefs.* These mini reports provide a potential corporate partner with several pages of thumbnail descriptions of centers, departments, groups, and labs conducting research and education relevant to a particular industry. They are concise and readable, and enable MIT-industry connections.

- *Industrial and Other Non-Federal Collaborations and Agreements.* Produced by the Office of Sponsored Programs, this is a thumbnail guide to over a dozen types of agreements that cover most all activities in which a company might be interested, including cooperative research contracts, but also gifts, student placements, etc.

- *Recruiting MIT Students.* The OCR also tries to guide industry partners to several programs that are operated mostly out of the schools and colleges, and enable student placement, either pre-graduation or post-graduation. The Sloan Career Development Office and the Bernard M. Gordon-MIT Engineering Leadership Program are examples.

- *Interdisciplinary Research at MIT.* The OCR posts lists and thumbnail descriptions of those units that are heavily involved in interdisciplinary work and are also significantly involved in working with companies.

- *Disseminating Best Practices.* MIT also aspires to raise our understanding of corporate partnering. To that end it has posted on the OCR website a recent *Sloan Management Review* article[13] on Best Practices for Industry-University Collaboration.

MIT Industrial Liaison: Brokering University-Industry Partnerships. Over 200 companies are now paying and participating members of the Industrial Liaison Program (ILP). The ILP serves as a facilitated gateway to a wide range of services and connections. Each member company is assigned to an Industrial Liaison Officer (ILO) who is a full time facilitator of company engagements with faculty members and center expertise. Members are free to search the ILP Knowledge Base to become familiar with centers and individuals who might be a good fit with their needs for particular areas of expertise. In addition, the ILO can set up face-to-face meetings involving member-company personnel and members of the research community of MIT. The latter are guided in these interactions by the ILO, and MIT researchers involved in these interactions can accumulate Revenue Sharing Points, which amount to a fixed percentage of gross revenues realized via ILP membership fees. A wide range of events, conferences, and briefings is also available to ILP member companies. This system is designed to replace the informal, often *ad hoc,* way in which industry technologists get connected with faculty, staff, and students at many universities.

The ILP seems to be having an impact that is likely to grow. In FY2013, ILP member companies accounted for "approximately 54% of all corporate gifts and single-sponsored research expenditures at MIT." In many universities the facilitation of industry partnerships is managed at the unit (college or department) level and with widely varying effectiveness. The centralized, seemingly very professional approach of the ILP could be adopted elsewhere. The other thing to re-emphasize is that, generally-speaking, relationships enabled by competent human beings are likely to be more effective than those enabled by Web sites.

Departments, Laboratories and Centers with Major Industry Funding. Listed below are the departments, laboratories and centers that in FY2013 were the ten highest at MIT in receiving industry financial support for their research. These programs are significant not only by dint of their demonstrated industry partnering behavior but also in terms of the scope of their support by Federal agencies and non-profit organizations.

- MIT Energy Initiative
- Chemical Engineering department
- MIT Computer Science and Artificial Intelligence Laboratory
- MIT Media Laboratory
- Koch Institute for Integrative Cancer Research
- School of Management
- Mechanical Engineering department
- Aeronautics and Astronautics department
- Research Laboratory of Electronics
- Materials Science and Engineering department

Why are they so effective? Below is more detail on the research programs of several of these organizations and how they operate *vis-à-vis* business, industry and government.

- *MIT Energy Initiative (MITEI).* This program was launched in 2006, as a major campus initiative with significant involvement on the part of then-President Susan Hockfield. The Report of the Energy Research Council, convened to develop a preliminary plan, cited MIT's "capacity to work across disciplinary boundaries, our long-standing focus on innovation and 'technology transfer', and our demonstrated willingness to work with industry and government…" as a major part of the rationale of what has happened in the last seven years. MITEI has developed 16 research focus areas, and is implementing an ambitious program involving 20 departments and 37 laboratories, centers and programs as well as dozens of faculty and students on campus. Three main thrust areas are: science and technology for a clean energy future; improving today's energy systems; and energy utilization in a rapidly evolving world. Resources to support the activities of the Initiative have been garnered from several federal agencies, foundations, and the private sector, and a growing number of reports and studies have been completed. A Membership Program provides a vehicle to support graduate students and post-doctoral Energy Fellows, as well as funding of research projects. Support as a Founding Member involves a commitment of $5 million per year for five years; a Sustaining Member commits to $1 million per year for 5 years; an Associate Member provides $100,000 per year; and an Affiliate Commitment is $5,000 per year.

- *Department of Chemical Engineering.* A good argument could be made that the field of chemical engineering was largely invented at MIT in the 1920s, and it has been a national exemplar ever since. About 20% of chemical engineers in the National

Academy of Engineering are either MIT alumni or faculty, and 10% of alumni are senior executives in industry. In 2012 the department performed $53 million of research, with industry as a significant sponsor. Working across fields and disciplines, as well as with research and commercial organizations outside the university, are important values in ChemE at MIT. The research activity of MIT Chemical Engineering covers these problem domains: thermodynamics and molecular computation; catalysis and reaction engineering; systems design and engineering; transport processes; biological engineering; materials; polymers; surfaces and structures; and energy and environmental engineering. There are many research partnerships between ChemE and other units on campus.

- *Computer Science and Artificial Intelligence Lab (CSAIL).* This organization has a long and rich history at MIT, originally founded in 1963 as Project MAC, which contributed to the development of UNIX. The AI Lab was founded separately in 1959. With the funding and erection of a building to house the information sciences in 2003, a merger led to the formation of CSAIL. The lab has over 100 Principal Investigators who, in turn, work together via 50 research groups organized into three broad focus areas: AI, Systems, and Theory. Cross-area research initiatives are also focused on issues of BigData, Robotics, and Wireless. CSAIL has spun off over 100 companies, including: 3Com, Lotus Development Corporation, iRobot, and many others. CSAIL continues to be financially supported via a wide range of collaborative research partnerships, including both government agencies and information companies. These working relationships enables some joint intellectual property to emerge from the funded projects, many of which involve collaborative work. In addition to contract and grant-funded activities, an Industry Affiliates Program enables companies and other organizations to preview emerging research findings and technologies, to connect with CSAIL students, to convene and discuss future technology trends, and to explore potential project collaborations or sponsorships. More than 20 organizations are involved.

- *MIT Media Lab.* For nearly 30 years the $45M Media Lab has gone beyond interdisciplinary or multidisciplinary approaches to implement an "antidisciplinary" problem-solving and design culture. Over 100 Master's and PhD students work with a few dozen faculty in 25 work groups, and 100 members and partners, which at any given time are deployed on several dozen projects. The core of students, faculty and permanent staff, is supplemented by dozens of research affiliates, postdoctoral researchers, visiting scientists, plus graduate students from a variety of MIT departments. The research program is coupled to a graduate degree program in Media Arts and Sciences. An important theme of the Lab is how people experience their environment and how that can be enhanced with technology and design. The projects typically play out at the intersection of disciplines such as computer science, design thinking, ergonomics, urban anthropology, psychology, or whatever seems most relevant to the problem at hand. Some research foci include: the City Science Initiative, trying to develop a data-driven approach to urban design and planning; the Autism and Communications

Technology Initiative, focused on technologies to impact autism therapy; and the Center for Civic Media, creating technical tools to address the information needs of communities.

- *David H. Koch Institute for Integrative Cancer Research.* Launched by a $100 million gift in 2007 from David H. Koch, an MIT graduate in Chemical Engineering, the Institute brings together research faculty from a wide range of disciplines including: electrical engineering and computer science; mechanical, chemical and biological engineering; and materials science and engineering. The core cancer research team at MIT includes five current and former Nobel Prize winners, 17 current faculty who are National Academy of Science members, five current faculty members elected to the National Academy of Engineering, and nine Howard Hughes Medical Institute Investigators. The five strategic research foci of the Koch Institute include: nanotechnology-based cancer therapeutics; novel devices for cancer detection and monitoring; the molecular and cellular bases of metastasis; personalized medicine through analysis of cancer pathways and drug resistance; and engineering the immune system to fight cancer. The Koch Institute has 180,000 square feet of lab and workspace, and also houses the Swanson Biotechnology Center; the MIT-Harvard Center of Cancer Nanotechnology Excellence; the Integrative Cancer Biology Program; and the Ludwig Center for Molecular Oncology.

- *Research Lab of Electronics (RLE).* This lab has perhaps the most remarkable history of any at MIT, being the successor of the RadLab that employed 4,000 people during World War II. The RadLab developed microwave radar, created over 100 radar systems, and constructed $1.5 billion of radar equipment. The RadLab closed at the end of 1945, and a small basic-science division continued. That division became RLE on July 1, 1946. The $30M RLE is focused on seven research themes: atomic physics; circuit, systems, signals and communications; quantum computation and communication; energy, power and electromagnetics; photonic materials, devices and systems; nanoscale science and engineering; and multiscale bioengineering and biophysics. There are 72 principal investigators (64 MIT faculty members) who primarily come from nine academic departments and divisions. The $30 million in annual funding for RLE research comes primarily from three Federal agencies: DOD (33%), NIH (20%), and NSF (15%), and private companies (10%). About 20% of RLE projects involve collaboration with other universities, private companies, or government in their execution.

- *Department of Materials Science and Engineering (DMSE).* This academic department executes approximately $40 million of research annually, with a third of its support coming from industry. Its Graduate Program has been consistently ranked 1st nationally by *U.S. News & World Report*. The program views materials science and engineering from a life-cycle approach encompassing mining and processing, production and utilization, and recycling and disposal. It also looks at materials science and engineering from different disciplinary perspectives, including history, design, and entrepreneurship. Each DMSE graduate receives a bronze medallion of the MIT seal, which is made in the department foundry.

Contiguous Science Partner Organizations. Outside the doors of MIT other science-performing organizations leverage MIT's assets and vice versa. They are mostly physically near, independent organizations that nonetheless have evolved dense and mutually advantageous relationships with MIT.

- *Lincoln Laboratory.* The MIT Lincoln Laboratory is a large (3,700 total personnel) DOD-funded research and development center (FFRDC) located in Lexington, MA. Since 1951 the Lincoln Lab has been a venue for MIT faculty, staff and students to get involved in DOD research projects. In addition, the MIT Technology Licensing Office (TLO) has worked collaboratively with the Lab in patenting and licensing for many years. The Lincoln Lab also partners with MIT on professional education short-courses, student capstone projects, and a variety of joint efforts.

- *The Whitehead Institute.* Founded in 1982, and handsomely endowed ever since, the Whitehead Institute is a numerically small but scientifically prominent research institution focused on basic biomedical research. It is staffed by a small cadre of sixteen world-class principal investigators, supported by state-of-the-art research facilities and a generous support staff. It was founded as a free-standing self-governing MIT affiliate. Despite its modest size, the Whitehead Institute has world-class standing in its current focal research areas: cancer research; Parkinson's disease; stem cells; obesity and diabetes; and autism.

- *The Eli and Edythe L. Broad Institute of Harvard and MIT.* The Broad Institute is a creative partnership of Harvard and MIT researchers in the biological and medical sciences with extensive connections to investigators and institutions around the world. Its scientific focus is primarily at the cellular and molecular level, seeking to discover causes of inherited diseases and various types of cancers and infectious diseases. The Broad Institute's core scientific and administrative leadership is drawn from Harvard and MIT, although its corporation is separate from MIT.

Boundary Spanning: *University and Community.*

To one degree or another, all of the universities profiled in this volume make a concerted effort to conduct themselves in ways that help support the social and economic advancement of their surrounding communities. Some universities have adopted elaborate projects and partnerships going beyond their immediate locales to benefit surrounding regions and even their home states (Carnegie Mellon and Purdue are good examples). On the other hand MIT is unique among its peers, (perhaps with the exception of Stanford and Caltech), in that its impact on seeding the Route 128 Tech Corridor, spawning the Massachusetts Economic "Miracle" and advancing the fortunes of Boston and even Western Massachusetts, is widely known and even considered a fait-accompli. What is less known is how this impact continues to grow and spread beyond the state of Massachusetts into New England, to California, and beyond, as will be described next.

- *Kendall Square.* MIT is involved in one of the most robust technology-cluster communities in North America. Kendall Square has been a locus of commerce and technology for over 200 years, starting as a wagon route, and then a canal network in the early 19th century, and then home to distilleries, brewers, and the Kendall Boiler and Tank Company. When MIT moved to its Cambridge campus in 1916 it became a neighbor. Today, Kendall Square is visible confirmation that MIT is as much about the life sciences and biomedical innovation as it has traditionally been in other areas of science and engineering. Moreover, the MIT Investment Management Company (MITIMCo), which has responsibility for managing MIT's endowment and associated capital investment, is an active partner, with the Kendall Square Association (KSA) in planning the future of the area. MIT has built and staffed several research facilities in the complex, including the David H. Koch Institute for Integrative Cancer Research, as have several major biomedical, life-science, and information technology companies. The count of resident companies is over 150. Current planning efforts, with MIT playing an active role, are focused on making the Square richer in amenities, public spaces, cultural settings, food, retail and a more interactive hub of street-level activity.

- *Route 128.* One of the principal technology corridors in the US, Route 128 is named for the partial beltway around Boston where many of the innovative companies spun out from the Cambridge-based Universities settled. In 1957, there were 99 companies employing 17,000 workers along Rt. 128; in 1965, 574; in 1973, 1,212.[14] In the 1980s, the Reagan-era military buildup pumped hundreds of millions of DOD, DOE, and NASA expenditures into MIT and the area's defense contractors (Raytheon, Rockwell International, McDonnell Douglas, Digital Equipment Corporation, etc.) creating the so-called "Massachusetts Miracle." Whole new industries sprung from these efforts, including computers, biotechnology, and artificial intelligence, among others. And while the largest Route 128 corporations may have produced a disproportionate share of the region's wealth generation at the time, the plethora of small firms that emerged to service the giants over the years grew to be substantial employers in their own right. The development of electronics-related companies on the 65-mile highway surrounding Boston and Cambridge made the area comparable only to Silicon Valley in technology startups. But in fact, many of the California-based technology firms, also have roots in MIT research.

- *And the World Beyond.* Like many of the other universities profiled here, MIT has established a number of "beachhead" campuses, institutes, and education programs outside of Massachusetts and around the world. In consort with its *Mens et Manus* philosophy, MIT has focused beyond education in their global activities to action by providing venues and assistance for research and entrepreneurial engagement. MIT's Global Education & Career Development organization thus has a more global footprint with job placements, internships, and study-abroad experiences than many. But even beyond this are MIT's International Science and Technology (MISTI) and Regional Entrepreneurship Acceleration Program (REAP) Initiatives.

MISTI is an applied international studies program (in Mexico, South and Central America, Russia, China, India, Southeast Asia, a number of African countries, Israel, Japan, and several European countries) that connects MIT students and faculty with research and innovation around the world. In each country, MIT brings together a network of corporations, universities, and research institutes, and then matches faculty and students to develop and implement R&D ventures, international economic development, human capacity building, and network building. REAP enrolls participants from countries including Spain, China, Finland, Turkey, and Mexico who learn how to mobilize key players, collaborate cross-regionally, and leverage best practice to catalyze regional action. MIT faculty experts in engineering and technology work with teams made up of government, economic-development officials, entrepreneurs, universities, risk capital, and large corporate stakeholders, and conduct training in cultivating entrepreneurial and innovative capacities.

Boundary Spanning: *Technology Transfer*

MIT was one of the handful of universities that established technology-licensing operations way in advance of the Bayh-Dole legislation in 1980 that launched university technology transfer on a national basis, and the origins of its patent policy go back to the early 1930s. Apparently, a group of entrepreneurially inclined professors and administrators engaged in a running debate to define what the patent policy would be and how it would be executed. A 1996 study[15] of the period concluded the following:

> *Committee debates centered on the distribution of equity in patents, on the terms of licenses, and on public relations concerns. Over time, the Patent Committee began discussing potential revenues and the financial risks of litigation. Research Corporation, a non-profit patent agent with close ties to MIT, further influenced MIT's patent policy....The premise of this dissertation is that a fundamental transmogrification occurred: In 1931, MIT's interest in patents was essentially passive. After a period of about 15 years, those passive interests were transformed into an enthusiastic culture of technology transfer. Administrative practices for technology transfer in 1946 conceptually resemble those of today.*

While this 15-year period of discussion and wrangling may seem inordinate, it needs to be put into context. In fact, before the passage of Bayh-Dole in 1980 only a handful of universities were ahead of the curve in terms of establishing patent offices or technology offices (U. Wisconsin/WARF, Iowa State, Washington State, Kansas State, University of Minnesota, University of Utah, Stanford). MIT was clearly an innovator in terms of its supportive culture and early establishment of policies and procedures. It is not widely known, but Karl Compton, the President who was instrumental in making MIT the MIT we now know, was involved after leaving the Presidency in creating an early venture-capital firm—American Research and Development (ARD)—that went on to be an important investor in Digital Equipment. Compton[16] was also significantly involved in overseeing the development of policies and procedures that became MIT technology transfer. The initial planning effort resulted in the Patent, Copyright and Licensing Office, which apparently had somewhat of a legal staffing and mindset, and was located in the MIT Division of Sponsored Research. In 1985 the function was renamed the Technology Licensing Office (TLO), along with new leadership and staffing.

Currently, the MIT Technology Licensing Office is an esteemed and very productive operation. Illustratively, per FY2012 statistics from the Association of University Technology Managers[17] MIT had the largest number of startups (16) among institutions listed, the highest number of invention disclosures (690),[18] and the highest number of patents issued (219). It also had 426 patent applications, 107 licenses and options executed, and $137 million in 2012 license income. These are all excellent process and outcome metrics.

The office is very well led, staffed and organized, with 21 licensing FTEs reported to AUTM, and a total staff complement that is much larger, but which includes a number of non-technical support staff. There is a strong emphasis in the MIT TLO on supporting and enabling entrepreneurial outcomes as well as the more traditional focus on licenses to established companies.

There are two documents that are available from the MIT Technology Licensing Office web site (http://web.mit.edu/tlo/www/) that pretty much summarize everything that they do plus the "why" of their doing. These are: *An Inventor's Guide to Technology Transfer at the Massachusetts Institute of Technology,*[19] and *An Inventor's Guide to Startups: for Faculty and Students.*

The Inventors Guide to Technology Transfer was, as described in the endnote, based on the original version that was developed at the University of Michigan. Several leading universities have adopted the booklet and made minor changes that reflect local policies and approaches. In 32 succinct pages—starting with stirring mission language from the MIT President—the guide covers the tech-transfer process, disclosures, patent issues, marketing the invention, license agreements, commercialization, conflict of interest, revenue distribution and reinvestments of revenues.

The 27-page Inventors Guide to Startups was developed and written at MIT, and now is being modified and its content used at other universities (with MIT permission). In addition to providing information and guidelines on intellectual property issues, the guide digs deeply into organizational issues pertaining to the startup path to commercializing an invention, including a delayed schedule of financial payments to the university until the venture raises sufficient capital. It goes on to address knotty problems that might confront a startup, such as whether a license can be granted if the venture is not incorporated (no, but maybe an option would be better) and so on. There is a very useful section on ownership of the invention, particularly if the inventor is a student (Answers: MIT might own it if the student works for MIT, if MIT resources were used in developing the inventions, or if the invention was created under a contract or grant to MIT). Conflicts of Interest or Commitment may pertain to any technology-transfer situation, but are often more prominent in a startup situation, so the Guide addresses this area as well.

The Guide to Startups also provides members of the MIT community with information on the MIT Entrepreneurial Ecosystem and many of the organizations described above, as well as MIT's most prominent and long-lived co-curricular organizations that provide information, networking, competitions, and various experiential learning opportunities. This is a useful document and one that other universities should consider emulating.

Summary and Parting Comments

These few pages cannot do justice to the story of MIT as it pertains to technological innovation and its links to entrepreneurship. We urge the reader to do a deep dive into the history and current operations of the Institute. Few other universities have been quite as explicit at the outset of their founding to embrace something as simple and eloquent as *Mens et Manus*, and all that it implied regarding higher education, approaches to understanding science and technology, and connections to the world outside the walls of academe. Moreover, MIT's story is also a tale of how the institution stayed true to the basic rationale of its founding.

A university founded to work with industry has, by definition, been interested in innovation and entrepreneurship for decades. In this regard, MIT could be considered the earliest innovator among the other cases in this volume, and in some respects it may illustrate the direction that other schools are evolving toward. At MIT the institution of higher education itself has changed in ways that include novel organizations, boundary-spanning functions, and policies and procedures for faculty that not only support but help to catalyze invention and subsequent entrepreneurial execution. The institution has also had a major impact beyond the campus itself. This includes the transformation of Kendall Square from wagon route to smokestack to a thriving biotechnology city-center, and outward to Route 128, America's other Silicon Valley, and its thriving suburban communities. MIT continues to do what it has always done, but on a larger canvas. It has made a huge commitment to sharing its experience and involving students and faculty in *Mens et Manus* efforts in many countries interested in learning how.

As a function of the World War II Rad Lab experience, MIT was early out of the starting gate to transform itself into a modern, research-intensive university—and one that was dedicated to innovation in most things. There were many talented and prescient leaders throughout the MIT history, and this narrative has only quickly described a few. There is a lot of useful homework that the interested reader should pursue. For one, the MIT organizational infrastructure is particularly dense. As noted above, the institution is home to dozens of centers, institutes, labs and programs, each with a vision, structure and set of operations to conquer its part of knowledge, understanding, technology, and innovation. The interested reader should spend time exploring each organization in their area of interest, and reach out to the talented people there, to learn more about how they work and what they do.

Endnotes

[1] Fishman, E., Allen, T. J. and O'Shea, R.P. (2013). The historical development of an entrepreneurial university: a study of MIT. In Allen, T. J. & O'Shea, R. P. (Eds). *Building Technology Transfer within the Research University: An Entrepreneurial Approach*. UK: Cambridge University Press.

[2] National Science Foundation, National Center for Science and Engineering Statistics, FY2011. *Table 14. Higher education R&D expenditures, ranked by all R&D expenditures, by source of funds: FY2011. Table 15. Higher education R&D expenditures, ranked by all R&D expenditures, by R&D field: FY2011.*

[3] Lecuyer, C. (2010). Patrons and a plan. In Kaiser, D. (Ed.). *Becoming MIT. Moments of Decision*. Cambridge, MA: The MIT Press.

[4] Etzkowitz, H. (2002). MIT and the rise of entrepreneurial science. NY: Routledge, p. 38.

[5] Sieh, K. A. (2007, October 2). *The Entrepreneurial University: What the University of Colorado Has to Learn from MIT and Stanford. Silicon Flatirons Center.* Retrieved from SSRN: http://ssrn.com/abstract=2298739 or http://dx.doi.org/10.2139/ssrn.2298739

[6] Douglas, D. (2010). MIT and war. In Kaiser, D. (Ed.). *Becoming MIT. Moments of Decision.* Cambridge, MA: The MIT Press, p. 88.

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[11] Roberts, E. B. and Eesley, C. (2009). *Entrepreneurial Impact: The Role of MIT.* The Ewing Marion Kauffman Foundation. Copyright, Edward B. Roberts. In addition to describing the survey results this 74-page report is an excellent history and current status summary of the entrepreneurship infrastructure at MIT as of a few years ago.

[12] Massachusetts Institute of Technology. (2013, September edition). *MIT Briefing Book 2013.*

[13] Pertuze, J.A., Calder, E.S., Greitzer, E. M. and Lucas, W.A. (2010, Summer). Best practices for industry-university collaboration. *MIT Sloan Management Review.* Vol. 51, No.4, 83-90.

[14] Rosegrant S., and Lampe, D. (1992). *Route 128.* NY: Basic Books.

[15] Fishman, E. A. (1996). *MIT Patent Policy, 1932-1946: Historical Precedents in University-industry Technology Transfer.* Dissertation, University of Pennsylvania.

[16] Fishman, E., Allen, T. J. and O'Shea, R.P. (2013). *Building Technology Transfer within the Research University: An Entrepreneurial Approach.* op. cit.

[17] Association of University Technology Managers. (2013). *AUTM U.S. Licensing Activity Survey: FY2012.* Deerfield, IL: Association of University Technology Managers.

[18] One metric that can be computed is the "batting average" of disclosures relative to millions of research expenditures. Thus MIT reported 690 invention disclosures in FY2012 and its level of research expenditures for the university was $723.6 million (NSF FY2011 data), which is almost one disclosure per million of research spending—a phenomenonal rate. However, the Technology Licensing Office at MIT also has IP responsibilities for the Lincoln Laboratory FFRDC, which adds several hundred million of expenditures to this computation, despite the fact that FFRDC scientists tend to make fewer disclosures, because of the nature of their work and the prevailing DOD culture. So, MIT's record here is either phenomenal or just very good.

[19] Massachusetts Institute of Technology. Technology Licensing Office. *An Inventor's Guide to Technology Transfer at the Massachusetts*

Institute of Technology. Undated. The booklet is based on the University of Michigan's publication "Inventor's Guide to Technology Transfer," whose development was led by Ken Nisbet and Robin Rasor of the University of Michigan Office of Technology Transfer.

North Carolina State University*

Like many of the nation's major land grant universities, North Carolina State University began as a small, primarily agricultural and technical college. Founded in 1887 as North Carolina College of Agriculture and Mechanic Arts, the school was conceived as a "people's college" and as a vehicle for promoting the economic and cultural transformation of the state during the post-Civil War period. It was also established as a Land Grant institution under the Morrill Act, which included donated land and a mandate for education in "agriculture and mechanic arts." Its first class of 72 students was admitted in 1889, served by 6 faculty members in one building in Raleigh.

The university experienced gradual growth for much of its early years, and did not exceed a thousand students until after World War I, when it became known as State College. It also began involvement in the USDA Cooperative Extension Service established by the Smith-Lever Act of 1914. Like many state schools of its type NC State participated in the post-World War II enrollment surge fueled by the GI Bill and its student head count grew significantly. Beginning in the 1950s there was a concomitant growth in sponsored research fueled by new federal research agencies. This helped accelerate its transformation from a small, primarily technical college into a comprehensive research university. After a back-and-forth discussion with state government during the 1960s, North Carolina State College officially became North Carolina State University at Raleigh in 1965. NC State continues to emphasize its scientific and technical strengths and its focus on outreach-based economic impact.

NC State is part of the 16-campus University of North Carolina system. It is the system's largest university, enrolling 34,767 students in fall of 2011. It is the system's flagship science and engineering university. While it does not have a medical school, it contains 12 colleges, offers doctoral degrees in 61 programs and houses four different extension programs. Total enrollment in 2011 was heavily concentrated in the College of Engineering (8,765), College of Agriculture and Life Sciences (5,583), the College of Humanities and Social Sciences (5,047) and the College of Management (3,205). Reflecting its heavy technological emphasis, of a 2011 graduate student enrollment of 9,591 most was concentrated in the College of Engineering (2,804) and the College of Agriculture and Life Sciences (1,039).

Unlike many land-grant universities, North Carolina State is located in an urban and industrialized setting. The campus is in the state's capital, Raleigh, and constitutes one defining point of the research triangle area along with Duke University (in Durham) and the University of North Carolina

** This case was written by Louis Tornatzky and Elaine Rideout.*

(at Chapel Hill). Research Triangle Park is now home to 170 global companies primarily in the information, and technology fields, and Federal Government research laboratories, including IBM, GSK, RTI International, Cisco, the National Institute of Environmental Health Sciences of the NIH, and EPA. Nearly 40,000 people are employed full-time in the 7,000-acre Research Triangle Park campus, many with connections to NCSU.

In the FY2011 National Science Foundation survey[1] of academic research and development NC State reported research expenditures of $378.2 million, which placed it 57th among all US universities. Of that total, 48.1% of expenditures were in the life sciences, and 30.1% in engineering. Interestingly 10.8% of research expenditures came from business, a high fraction among the top-100 research universities and an accomplishment that reflects a long history of external research partnering.

NC State does fairly well in national rankings and ratings. *U.S. News & World Report* ranked it 5th in terms of "best value" (2013), 1st in graduate textiles (2007), 3rd in graduate veterinary medicine (2013), and 10th in undergraduate biological and agricultural engineering (2013). The university has 20 faculty members who are members of the National Academies. The University's College of Design is internationally recognized, and the engineering program draws the largest fraction of undergraduate students and is one of the largest in the United States. There are 57 multidisciplinary institutes or centers on the campus.

In some respects, NC State can be seen as a hybrid of the major types of institutions found in this volume. For example, its service-oriented vision and mission and diverse suite of industry-oriented outreach services clearly mark it as a "knowledge-economy Land Grant" institution, one that has moved from a primary focus on agriculture to one that is oriented to industry. Illustratively, the school was involved in agricultural extension early in its history, and later on was a pioneer in providing industrial extension services. In addition, its location in an urban setting and its proximity to high-technology industry, has caused it to respond to the more intense demands for interaction that have helped to shape an engaged institution. While the technology-intensive research triangle area has been a major focus for NC State, it has nonetheless stayed true to its statewide mission. Early in its history, the University played a role in the founding and growth of the tobacco, textile and furniture industries; later on in the post-World War II period, particularly in the 1980s, NC State played a significant role in launching a technological revolution, concentrating on electronics, chip design, materials, and more recently biotechnology. NC State University has had a decades-long involvement in innovation-related activities and programs.

University Culture: *Goals and Aspirations*

The NC State Mission[2] is consistent with these themes:

> *As a research-extensive land-grant university, North Carolina State University is dedicated to excellent teaching, the creation and application of knowledge, and engagement with public and private partners. By uniting our strength in science and technology with a commitment to excellence in a comprehensive range of disciplines, NC State promotes an integrated approach to problem solving that transforms lives and*

provides leadership for social, economic and technological development across North Carolina and around the world.

So too is the associated NC State Vision from the same planning document:

NC State University will emerge as a preeminent technological research university recognized around the globe for its innovative education and research addressing the grand challenges of society.

Those two statements came out of a strategic planning effort led by a new Chancellor two years ago. They are echoed by recent comments[3] from Terri Lomax, the Vice Chancellor of the Office of Research, Innovation & Economic Development:

As a land grant university, NC State has an important mission: to support research; translate research into products and services that benefit the public; and support entrepreneurs and aid in job creation.

And in a Dean's mission statement for the College of Engineering:

Creating a better future through discovery, learning and innovation is the core of our mission in the College of Engineering at North Carolina State University.

Which in turn is elaborated in an Envisioned Future document written by a faculty committee in Engineering:

We will be a global leader in facilitating intellectual property and technology transfer, involving faculty, staff, students, industry and government to assist existing companies and encourage the success of start-up companies in North Carolina and beyond. Located on Centennial Campus we will be a leader in developing innovative ways of partnering with industry and government to enhance economic well-being.

Another example is a Mission statement from the North Carolina Industrial Extension Service:

We engineer success for North Carolina business one solution at a time by understanding our partners, building long-term relationships, crafting meaningful sustainable solutions, and inspiring continuous learning.

From a skeptical standpoint one might argue that all the above mission and vision statements are fairly recent—which would be correct—and wonder what has been the long-term record of NCSU, since chancellors, VPs, deans and department chairs come and go. In fact, the longitudinal success of NC State as an innovation-oriented university has been consistent and getting better in many areas and for many years, as will be seen below.

Leadership

The NC State innovation story is somewhat different than other cases in this volume in the extent to which its growing success in innovation has been linked to major ventures in infrastructure and what might be thought of as "technology real estate" championed by far-sighted and persistent leadership that went beyond the university and started over fifty years ago. NC State would not be achieving extraordinary innovation successes today without the blossoming of Research Triangle Park in the 1960s and beyond, nor without the successful launch and growth of its Centennial Campus 20 years later.

The deep background of Research Triangle Park[4] goes back to the post-World War II era of the 1950s. North Carolina was a low-wage low-tech state, with an economy anchored by tobacco, furniture, and textiles, and which ranked near the bottom nationally on most important social and economic indicators. In addition, there was growing concern about the brain-drain of university graduates leaving for jobs elsewhere. In 1954 an enterprising State Treasurer, Brandon Hodges, met with Romeo Guest, a major contractor, and Robert Hanes, the president of Wachovia Bank, and puzzled over ideas to promote economic growth. Some sort of a research park idea emerged from those meetings. Hodges and Guest went on to confer with deans and faculty at North Carolina State College, and persuaded Chancellor Bostian to take that message to Governor Luther Hodges (no relation). A 10-page concept paper was written by the Director of the Textile Research Center at NC State and delivered to the Governor in early 1955. While initially skeptical, Governor Hodges eventually became a champion of the idea, after getting endorsements from the presidents of Duke and the University of North Carolina.

Over the next two years a Research Triangle Development Council was formed, transformed into the Research Triangle Committee, and an effort was made to implement the park idea as a private real estate development that was premised on companies moving their operations into the triangle area, connecting to the expertise of the three major universities and making investments in the area. An extensive campaign of mailings and corporate visits was conducted, led by a Sociology professor at UNC.

This morphed into an implementation effort led by Mr. Guest that began by acquiring options on land through a private development group named Pinelands Inc. Eventually it was concluded that private investors, many out-of-state, could not carry forward the vision. In 1958 Governor Hodges[5] turned to Archie Davis, a senior banking executive (also with Wachovia), to pursue a different course that ultimately involved state-based donations, the buyout of Pinelands, and the transfer of development into a nonprofit organization named the Research Triangle Foundation.[6] In addition to raising money to acquire the targeted land, the Foundation also established the Research Triangle Institute (RTI) and constructed a building to house both RTI and the Foundation, all this by 1959.

Luring additional tenants was slow-going for the first few years, but in 1965 the Federal Department of Health, Education and Welfare announced plans for a major facility in the Park, and in the same year IBM decided to build a major R&D facility. Terry Sanford, Governor Hodges' successor, played a major leadership role in these catches, and in inducing other companies and organizations to settle in the park. From the beginning, the organizations that were recruited were to be R&D-oriented, not involved in mass production on-site, but able to do product development and prototype manufacturing. Companies bought park land for their facilities, but in order to retain the campus and park atmosphere, there were land limitations and other architectural rules.

After the important arrivals to Research Triangle Park in 1965 the next few decades witnessed slow and then accelerating growth. By 2006 there were 134 companies and 37,485 employees engaged in information technology, health sciences, pharmaceuticals, and environmental science. These areas matched well with the strengths of the three research universities that, in effect, serve as the points of the research "triangle." Archie Davis led another university-bridging innovation in 1974 in his role as President of the Research Triangle Foundation. He set aside 120 acres in the Park for dedicated use as the Triangle Universities Center for Advanced Studies, Inc. (TUCASI). This eventually became the home base in the Park for Duke, the University of North Carolina, and NC State, as well as for the National Humanities Center, the National Institute of Statistical Sciences, the North Carolina Biotechnology Center, and MCNC (the non-profit organization that provides broadband communication technology services and support to K-12 school districts, higher education campuses, and academic research institutions across North Carolina).

Currently RTP encompasses 7,000 acres and is home to over 170 companies and 39,000 full time employees. Most pertinent to this chapter, it also became a national model for the research park movement, a locus for untold R&D partnerships with NC State faculty and students, and a place for its graduates to secure rewarding jobs. It was also an organizational-design learning experience for what North Carolina State was to eventually try closer to home, and that would involve many of the same campus and community leaders. In the chapter sections that follow there will be many examples of instances where leadership and an innovation culture came together to perform remarkable feats.

Boundary Spanning: *University, Industry and Community*[7]

On October 23, 2009 a groundbreaking ceremony was held at North Carolina State University for a new library to be named after former North Carolina Governor Jim Hunt. Hunt talked about how earlier in his political career he had been a champion, tilting against real-estate developers, for the setting in which he was speaking:[8]

> *The easy thing to do was to give them the land, take the money, put it in the state treasury, and cut taxes. But that's not how you build a great state. The right thing to do was to think about the public purpose; how does this serve the public, the vision, and what we can be?*

That vision, which came to pass, was the Centennial Campus at North Carolina State University, an exemplar of university, industry and community boundary spanning.

The Centennial Campus. As described above, Research Triangle Park has, since the mid-1970s, become a major venue for NC State research, student instruction, and industry partnering. However, by the 1980s, the main campus of the University was expanding and pushing against the boundaries of its historic footprint in urban Raleigh. In 1980 Jim Hunt had won his second term as North Carolina governor, and his administration was very focused on building what would later be called a knowledge economy, requiring increased educational attainment across the state, more research, and expanded university-industry partnering. Since 1856, in an area called the Lake Raleigh basin, only a few miles from the main NCSU campus, the Dorothea Dix Hospital had operated as a large treatment facility for the mentally ill. Through various land acquisitions the Dorothea Dix property had grown to several hundred acres, located in the middle of a dense urban area. Eventually the treatment program was attenuated and in 1974 most of the parcel was transferred to the Department of Agriculture of the State of North Carolina. This was followed by a variety of informal uses (jogging, walking, picnicking) by people living in the area, as well a number of suggestions for more structured applications: a state-run farmers market, a vocational training school, real-estate development, etc.

On December 18, 1984, in the last few weeks of his 2nd term, Governor Hunt allotted[9] a 355-acre parcel of the site to North Carolina State University. Bruce Poulton, then NC State Chancellor, had actively campaigned for the transfer. In early 1985, in the new administration of Governor James Martin, a second transfer of 450 acres was made, subject to certain contingencies articulated by Bill Friday, the head of the University of North Carolina system. Eventually the plot was expanded to over 1000 acres. There were some knotty legal and policy issues raised about the transfer, but eventually the State Attorney General's office ruled the exchange legal.

NC State moved carefully and deliberately to develop a program model and plans for building out the site. Bruce Poulton, Chancellor from 1982 to 1989, led the planning process. However, early on, the creation of the master plan and its implementation was fraught with some controversy. Claude McKinney, Dean of the School of Design who eventually became Director of Centennial Campus, saw the challenge in the following terms:

> *We are clearly doing something different from any other university in the nation; that is, seeking to create an environment in which scientists from university, industry, and government can work together in close proximity: multi-disciplinary research, workforce partnership, and service are benefits of such interaction.*

The Centennial Campus project became a very large and lengthy architectural planning effort to apply high standards of physical design, optimal usage patterns, and environmental stewardship, for the R&D stakeholders that were to use it—graduate students, faculty members, and their counterparts from the private sector. It also had to be economically viable. The model for achieving the latter was for the university to lease buildings and land to private industry and other organizations, similar to the Stanford Research Park model. New state legislation ended up being necessary for that revenue model to be possible.

As the Campus has been built out and developed, the R&D objectives have been achieved via mixed-use clusters, including university and corporate tenants, laboratories, offices, classrooms, and space for informal interactions among the various tenants. As the campus evolved, some important milestones were achieved to accelerate the goals of the project. The College of Textiles moved from the main campus to Centennial in the 1990s. The National Weather Service became a tenant. More space and programming became dedicated to entrepreneurial activities and startup tenants including a technology incubator.

All the NC State Chancellors since Bruce Poulton contributed to the further growth and refinement of the Centennial Campus. During Larry Monteith's administration there was "explosive growth," and during Marye Anne Fox's tenure there was a doubling of buildings on Centennial. Across town, the College of Veterinary Medicine became the Biomedical Centennial Campus. As we describe other partnership relationships in this section, many are tied to the assets of the Centennial Campus.

Today over 11,000 employees and students work at the Centennial Campus, and the site now includes over 1200 acres, 1013 on the main campus, and 214 on the biomedical campus. Sixty partner organizations have a presence on the campus, including corporations such as ABB, Red Hat, WebAssign, and Eastman Chemical. The College of Engineering has moved its operations from main campus to Centennial. Centennial is also home to a number of centers and institutes, including two major NSF-funded Engineering Research Centers and the Nonwovens Institute, one of the largest centers in the country operating in a consortia model. The newly opened Hunt Library supports teaching and research at Centennial, and student dormitory housing and apartments have been built to meet the needs of students who call Centennial Campus home, in terms of their program and interests. Two Innovation Hall dormitories making up the Entrepreneurship Live and Learn Center, one for undergraduates and the other for graduate entrepreneurs of all majors, are under construction. Adjacent will be a hub for student entrepreneurs on campus in the form of the freestanding *Entrepreneurs' Garage* design-build center. Construction is also underway on a "town center" retail district, which will be rounded out with a hotel (under construction). Already completed are a townhome residential community, two campus-based K-12 schools, and a full 18-hole golf course.

Industry-University Research Partnerships. As noted above, NC State has been very successful with the scope of industry funding of campus research, ranking consistently in the top ten among research universities in the US. The existence and growth of the Centennial Campus and RTP have undoubtedly been a major factor in this accomplishment. Given the rich regional connectivity between adjacent technology companies and NCSU faculty, graduate students, and post docs, ongoing project-based support is very robust.

NC State has also carved out a niche in developing cooperative research relationships in the form of centers, institutes and the like that involve financial and substantive relationships with companies. In addition to the large number of such organizational relationships, there has been notable success in maintaining center-based programs that may last for years—even decades. The university boasts of 60+ interdisciplinary research centers across a a number of disciplines.

Of these, 14 have a home base in the College of Engineering, nine are in the College of Agriculture and Life Sciences, and nine have a reporting/coordinating relationship with the Office of Research, Innovation and Economic Development (ORIED). Others are scattered across the campus.

The ORIED is itself worth commenting on in more detail, since it represents a more elaborate way of structuring the functions that typically are associated with the chief research officer. One way of thinking of this office is as the head, hand, and voice of innovation at NC State. It positions itself as a one-stop shopping site for industry, government agencies, non-profit organizations, and the faculty and research staff of NC State. It encompasses not only the centers and institutes, but also technology transfer, the Centennial Campus, and the Small Business and Technology Development Center. Too often, on many campuses, doing business with these disparate functional areas is very difficult, but at NC State interested persons can engage the Office of Research, Innovation and Economic Development (ORIED) via an email (consierge@ncsu.edu), a call to its Partnership Concierge, or through the Springboard portal (see Entrepreneurship and Innovation, below). The Office also has an active program of disseminating information about campus accomplishments in the form of a periodic journal aptly named *Results* that is disseminated digitally (www.ncsu.edu/results/) and in more traditional forms.

One interesting example of how well NC State does in fostering and maintaining industry research partnerships is its success in the National Science Foundation (NSF) Industry-University Cooperative Research Center (IUCRC) program. These centers, as mentioned in other case chapters, consist of a consortium of member companies working with (and financially supporting) faculty-based researchers to execute an agenda of projects which both decide are particularly important to an industry or problem. The IUCRCs in which NC State participates are:

- The Center for the Integration of Composites into Infrastructure (with Rutgers, West Virginia University, and University of Miami);
- Advanced Processing and Packaging Studies (with Ohio State and UC-Davis);
- Silicon Solar Consortium (with Georgia Tech);
- Center for Advanced Forestry Systems (with eight other schools).

Another NSF program that emphasizes industry-university cooperation is its Engineering Research Centers (ERC) program. A recently established ERC at NC State, with 30 industry partners involved, is the Nanosystems Center for Advanced Self-Powered Systems of Integrated Sensors and Technologies (ASSIST). While led by NC State, other partner schools include Penn State, the University of Virginia, and Florida International.

NCSU's Future Renewable Electric Energy Delivery and Management (FREEDM) Systems Center is also an NSF Engineering Research Center. It has support from 46 participating companies as well as the NSF, and program funds will approximate $10 million annually. The Center's goals encompass fundamental research in energy storage, and power semiconductor devices, as well as partnerships to accelerate the commercialization of intellectual property and foster start-up companies. Partner organizations range from energy companies to technology incubators and venture capital firms, and the initiative has contributed to the development of a green technology cluster in the Research Triangle Park area.

Among other center programs with a strong industry component, NCSU also operates (with Duke University and the University of North Carolina) the National Evolutionary Synthesis Center, and the Nonwovens Institute. The Nonwovens Institute works in collaboration with over 40 companies and executes a $3 million budget of research and development.

In addition to the multi-company center or institute model, NC State is also experimenting with expanded one-on-one longitudinal research partnerships with large technology-based companies. Particularly notable is the Eastman Chemical Innovation Center launched in 2013. Eastman will provide $10 million in research funding for NC State researchers over a six-year period that will link to the Eastman Chemical Company Center of Excellence. The overarching goal is to "solve the grand challenges of society" in its R&D domain. Projects will be selected by a joint steering team from the University and Eastman, with participating scientists from at least six colleges at NC State. The interactions will be guided by cost formulas and intellectual property agreements already in place.

Another initiative launched concurrently, was the Laboratory for Analytic Sciences, primarily funded by the National Security Agency (NSA). The award was for $60.75 million, and the program is expected to involve a range of government agencies as well as companies in the information industry.

The North Carolina Research Campus at Kannapolis is another major initiative that involves NC State in a unique university-industry R&D partnership. This one is located in Kannapolis, close to Charlotte, and involves researchers and graduate students from across the UNC system, including NC State, UNC Chapel Hill, UNC Charlotte, UNC Greensboro, North Carolina Central, North Carolina A&T, and Appalachian State. The research program focuses on the fields of biotechnology, nutrition, and health. The Campus offers over a million square feet of lab and office space, including the David H. Murdock Research Institute, that encompasses state-of-the-art facilities that enable research in proteomics, genomics, and metabolomics. Graduate students (Kannapolis Scholars) are supported in on-site research funded by a major USDA grant, and work closely with faculty from across the involved institutions, as well as private sector scientists.

One unique advantage that NCSU has in the area of industry research partnerships is a 20-year applied behavioral science program, in the College of Humanities and Social Sciences, focusing on best practices, policies and organizational configurations to foster technology transfer and university-industry research. This has resulted in informal on-campus sharing of how-to-do-it wisdom, management guides[10] and ongoing research on the topic. Most recently the latter has resulted in a series of case studies of NSF industry-university centers that have lasted 20-30 years, a commendable accomplishment that seems to be a function of the way that the centers are managed and led, with the report[11] being circulated widely by the National Science Foundation.

Similarly, the Center for Innovation Management Studies (CIMS) is a distinguished research center that is focused on better understanding corporate innovation. CIMS is a 29-year old industry-university research center (originally launched at Lehigh University) that has focused on processes of product and process innovation in corporate settings. Launch funding came from the National Science Foundation and there are continuing collaborative ties. It has a small number of company members and a core of NCSU-affiliated faculty researchers and has developed a portfolio of evidence-based best-practice strategies, tools, and assessments to enable industry and corporate managers to better understand, organize, manage, and ultimately improve their innovation processes and outcomes.

Industrial Extension. The fact that NC State is a Land Grant campus, and thus has more than a century of experience providing technical assistance to agriculture, has also enabled the university to extend that mode of outreach to technology-based business and industry outside of agriculture. Industrial extension is the vehicle by which this happens, and this activity has been ongoing at NC State for over 50 years.

The Office of Research, Innovation and Economic Development is the entity that oversees the industrially oriented extension activity at NC State, consistent with its mission to enable a coordinated set of activities pertaining to innovation. NC State pioneered extension beyond the farm with the establishment of the Industrial Extension Service in 1955. The North Carolina State Industrial Extension Service (IES)[12] was the first extension program in the nation to offer technical and management services to industry, particularly manufacturing. It has a strong working relationship with the College of Engineering and its research and expertise. Reflecting the needs of the North Carolina industry base, IES services address issues of manufacturing cost, product development, process efficiencies, and the growing concerns regarding environmental impact. For nearly 18 years the IES has been the state's agency for the National Institute of Standards and Technology (NIST) program in Manufacturing Extension Partnership (MEP) activities.

IES administers the Technology Incubator located on NC State's Centennial Campus and the Minerals Research Lab in Asheville. The many partners of the North Carolina MEP include the Business and Industry Development Division of the NC Department of Commerce, the Polymers Center of Excellence in Charlotte, NC, and the Manufacturing Solution Center in Conover, NC.

In 2011-12, IES served a total of 2,295 organizations. Of those, 1,236 were manufacturing companies. In 2011, 159 companies responded to the MEP surveys and reported $313 million in economic impact from IES activities and the creation of 1,146 jobs. While much of the IES program is focused on small to medium-sized manufacturers, IES also serves non-manufacturing businesses and government agencies across the state. IES operating revenue comes from state appropriations, federal agency funds (primarily via the contract with NIST to operate the North Carolina MEP), state and industry contracts, direct sales of services, and other supplemental funds. Its engagements with clients cover the gamut from on-site problem diagnosis and implementation to a wide range of courses and events.

As an advocate for the state's manufacturers, IES created the *Manufacturing Makes It Real Network* in 2011 to promote the image of manufacturing. The Network hosts events at manufacturing facilities across the state about six times a year that attract more than 100 manufacturers to benchmark and share best practices.

While the IES has long been a bulwark of direct assistance to North Carolina companies, it has been joined within the last decade by a partner extension program that operates out of the College of Textiles, a prominent curricular and research entity at NC State for many years. The Zeis Textile Extension Education for Economic Development department was formed in 2006, although the College's extension work with the industry goes back over 50 years. TexEd fulfills its external extension role to the textile industry in North Carolina and beyond primarily through a professional education program, providing topical industry courses covering the entire gamut of textile processing. These courses, typically held on campus, are integrated with the TexLabs facilities. The facilities, comprised of yarn spinning, knitting, weaving, dyeing, and finishing, plus physical testing laboratories, not only provide support to the academic and professional education courses, but are also available to industry for research, analysis, and product and process development. In addition to these textile-oriented programs, TexEd offers Lean Six Sigma training to manufacturing, healthcare, and transactional industries, as well as government and service organizations. TexEd also offers companies the ability to tailor any program in its catalog and provides staff to deliver it on-site. Finally, TexEd offers a range of eLearning, featuring detailed videos and animations of textile machinery and processes and provides learning opportunities for organizations across the country and internationally, reaching hundreds of participants each year through its programs.

Community Partnerships. Given the incredible richness of technological organizations in the RTP region plus the fact that the NC State campus is less than 15 minutes away from the state capital on a busy traffic day, the extent of boundary-spanning between the University and the levers of political activity are extensive. Moreover, as illustrated in the previous few pages, town-gown linkages and connections go back to 1955 and the administrations of Governor Hodges and Chancellor Bostian, and for the most part have continued to this day. Most recently, the University has partnered with Raleigh's Economic Development Office, Wake County, and the Downtown Alliance to help support a new Innovate Raleigh initiative. Innovate Raleigh is built around a capital-intensive investment strategy, leveraging the innovative architecture and design of Centennial Campus to attract innovators to the city, and begin to build an entrepreneurial ecosystem that potentially connects innovations born in the University to new products, new companies, and jobs based in the community.

However, while North Carolina State is a major innovation presence in Raleigh and the larger Triangle community, it is also an asset for communities across North Carolina. There are research and outreach activities throughout North Carolina that have been in place for decades, many built from the historic role of NCSU in agricultural extension that are now strengthened by NC State's parallel work in industrial extension. The boundary-spanning of North Carolina State University, locally and across the state, is likely to remain a strong asset for the foreseeable future.

Boundary Spanning: *Entrepreneurship*

Boundary-spanning across this broad area is achieved at NCSU via the Vice Chancellor of Research, Innovation, and Economic Development office's Springboard group, which is charged with more readily connecting the University's disparate technology innovation and entrepreneurship activities. The Springboard to Job Creation effort created one-stop-shop access to the University's New Venture Services of university resources designed to facilitate and support business partnerships and speed up flow through the pipeline via which research becomes reality. The hub of the effort is physically co-located with the University's Office of Technology Transfer on Centennial Campus. The New Venture Services include:

- A sounding board for faculty and students evaluating a startup opportunity;
- Workshops on spin-outs, company formation, NSF Innovation Corps, and SBIR/STTR grant programs;
- Mentoring and supporting the launch of NC State Fast Fifteen Venture Teams;
- Linking NC State entrepreneurs with subject matter experts and plugging them into University programs campus-wide.

- Marketing NC State Technologies to the world.

Springboard also includes a virtual counterpart, the Springboard portal, where local community members, regional/RTP partners, other US universities, and even interested persons and institutions from around the world can get a window into the university through which they can learn how to access and take advantage of university research, training opportunities, courses, labs, engineering, prototyping and business support, just as university members and partners are able to do.

Fast Fifteen awardees receive business support, incubation, mentoring from a regional pool of veteran entrepreneurs, sector expertise and alumni coaching, and even acceleration with help from the $1.2 million Chancellor's Innovation Fund.

Curricular Programs

The cross-campus Entrepreneurship Initiative (EI) currently offers two open enrollment General Education Program entrepreneurship survey courses, which count toward a Certificate in Entrepreneurship. NC State's curricular programs in entrepreneurship primarily reside in the College of Engineering and the Poole College of Management, although design, veterinary, textile, and music students all have access to courses on entrepreneurship within their disciplines. For undergraduates, the business school offers both a Concentration and a Minor in entrepreneurship. For graduate students, the Technology Education Commercialization (TEC) Graduate Certificate is offered "especially for graduate students with backgrounds in management, engineering, science or other technology related fields that are interested in developing entrepreneurial ventures based on intellectual property." Teaching is project-based and centered on actual IP that is in some stage of commercialization. Teaching faculty come from the College of Management (Department of Management, Innovation and Entrepreneurship), the College of Engineering (Department of Materials Science and Engineering), and there is curriculum sharing with the College of Management MBA program. The basic approach of the TEC Curriculum was developed nearly 20 years ago with backing from the National Science Foundation. It has been taught on four continents.

The undergraduate Engineering Entrepreneurs Program (EEP) in the College of Engineering takes a different experiential learning approach. Undergraduate engineers (all majors with the exception of Civil and Aerospace engineers) may take two capstone courses as an alternative to Senior Design, the more typical curricular path. They consist of Entrepreneurship and New Product Development, I & II, three credits each. While not a requirement, most of these Seniors also take a one-credit course, An Introduction to Entrepreneurship and New Product Development, as underclassmen. The entrepreneurial version of Senior Design requires students to form teams around student innovation ideas, many of which are tied to "grand challenge" themes to which they have been exposed to in various courses in their program. The core of the educational experience in the entrepreneurial course, however, is the fact that students work on their own IP (unlike TEC, where students work on existing unexploited IP) and produce technology prototypes and a credible business plan.

EEP, unlike TEC, does not use multidisciplinary teams, and intentionally so. Instead the objective of EEP is to provide all engineers with exposure to the multifaceted skills they will need to become successful entrepreneurs. These include market research, leadership, management, pitching and presenting, business plan writing, as well as engineering design and build. Conversely, TEC's graduate student teams divide up the work of product development and enterprise creation along team-member skill sets.

The EEP underclassmen get a taste of the program by developing their own product (e.g., a toy for local Kindergarten students) based on customer-development curricula, while working as "employees" for the higher level senior design students. This is one of the few pedagogical models we've found that explicitly emphasizes team-building, leadership, and employee management skills development, as well as business instruction and engineering design-and-build in a single technology entrepreneurship course.

EEP students have access to a multifaceted Engineering Entrepreneurship Lab, as well as the Entrepreneurs Garage where they can use 3-D printers and scanners, SolidWorks and similar software, ShopBot Desktop, PCB milling software, laser cutters, electronic components, ultrasonic bath, vinyl cutter, drill presses, routers, lathes, machining equipment, hand tools, workbenches and other equipment.

In the spring semester the EEP students have an opportunity to take the annual Silicon Valley Trip, which has helped a number of them establish network relations. One successful EEP entrepreneur, upon achieving a lucrative company exit, has returned from Silicon Valley to the Triangle as an angel investor and supporter of NC State's current crop of EEP students. The EEP enrolls nearly 100 students annually, frequently several continue their venture beyond graduation, some with help from the Fast Fifteen, the Chancellor's Fund, alumni mentoring, and RTP and Silicon Valley support systems.

While the business and engineering programs are arguably the most robust on campus, given their success in producing new companies and new jobs, and their highly regarded pedagogy, a course in entrepreneurship is also a requirement for students in Fashion and Textile Management, Textile Design, and Fashion Design. Teams of students develop novel textile products and write a business plan.

Co-Curricular Programs

The Entrepreneurship Initiative (EI) provides the entire student body with a variety of co-curricular events and activities that cut across the University so that entrepreneurially inclined individuals—students or faculty— can be plugged into what others are doing. For example, the EI sponsors the Entrepreneurship Lecture Series, which features prominent leaders in innovation and entrepreneurship and showcases them among University alumni, students, and partners. The EI has operated the "Entrepreneur's Garage," a meeting, design, and prototyping center for student venture development and creation. Currently the Garage is located in temporary space on Centennial Campus, but it will soon be located in a new Innovation Residence Hall, which is currently under construction. Many of the Garage activities are in turn sponsored by students, in particular the EI Ambassadors student group. Student ambassadors take it upon themselves to catalyze student entrepreneurship on campus and to inform the student body about all things entrepreneurial. Among the activities they help to organize and champion are fireside chats in the Garage with Research Triangle entrepreneurs, angels, and supporters, and the Local Tours program, which involves a day-long tour of entrepreneurial companies in the Research Triangle, lunch, and one-on-one chats with company founders and funders.

A number of co-curricular activities and events in the entrepreneurship area support all of the above curricular offerings, including the following:

- The Poole College of Management holds an annual Leadership and Innovation Showcase and Venture Pitch Competitions, which involve student pitches and poster presentations that compete for scholarship awards and cash prizes. The University also hosts regional competitions including Startup Madness, Triangle Startup Weekend, and the ACC Clean Energy Challenge competition.

- The University is experimenting with a Global Health Case Competition in which interdisciplinary teams of undergraduate and graduate students present their proposals to address a global health challenge.

- University students campus-wide have their own entrepreneurship competition program complete with $50,000 in prizes. The Lulu eGames Competition, jointly sponsored by the Entrepreneurship Initiative, the College of Management, and a local e-publishing company begins with students elevator-pitching their way into the finals in three events. Finalists compete on the basis of their business plan, arts venture feasibility plan, and/or the quality of a design-prototype.

Boundary Spanning: *Technology Transfer*

Like other activities described in this case, the Office of Technology Transfer (OTT) benefits from being a program component of the Office of Research, Innovation and Economic Development by virtue of spatial location and lateral working relationships within Springboard and the University's other "way stations" in the processes of technological innovation.

OTT is a well-staffed, energetic operation that has had a good record of success in enabling technology transfer at NC State. The staffing of the office is reasonably rich in terms of the number of senior staff (e.g., Directors, Licensing Associates) and most came to NCSU with significant experience in technology transfer with other top-tier research universities and/or the private sector. In terms of the usual ratios of professional staff to scope of research portfolio, NCSU compares favorably to the other institutions discussed in this volume. Notably, given the relative emphasis on entrepreneurial ventures at every level at NCSU (and in the larger RTP area for that matter) the OTT also has an experienced Director of New Venture Services. The office emulates other nationally prominent technology-transfer offices in various best practices. Illustratively, it makes available to the campus community an *Inventors Guide to Technology Transfer* that is very similar to those of Stanford, MIT and Michigan[13] and is an excellent quick-study tool for first-time inventors as well as the campus community more generally.

Periodically the OTT publishes several cumulative statistics (presumably over the history of the office). These are commendable to say the least:

- US patents issued: 820
- US patents pending: 256
- IP disclosures: 3,450+
- Products to market: 400+
- Startups launched: 100+
- Jobs created: 6800+
- Jobs created in NC: 3,250+
- Financing raised: $1.5 billion

The most recent FY2012 statistics[14] from the Association of University Technology Managers (AUTM) provide some additional perspectives. For example, the ratio of invention disclosures to research expenditure is quite commendable, in effect one disclosure per every $1.47 million dollars of research. Similarly, the pace of licenses and options executed is high, with one license or option executed per $6.8 million of research expenditures; or looked at another way, one license or option for every 4.6 invention disclosures. These are all good "batting averages" for a technology-transfer office.

While the above accomplishments are impressive, it is also appropriate to note that OTT also does its work in a setting in which there are many other programs that arguably impact or connect with technology transfer, and where OTT may play an advisory, collaborative, or beneficiary role. Several were mentioned in the previous section dealing with entrepreneurship activities. Here are a few more:

- The Chancellors Innovation Fund (CIF) is an initiative launched in 2010 by the incoming Chancellor. Financial support of up to $75,000 is provided to faculty, staff, or students who have disclosed IP to the OTT, and where commercialization potential has been established via proof-of-concept/product-development work. These awards are for less than one year and are made by a CIF Selection Committee that includes NC State personnel as well as external partners.
- The Daugherty Endowment provides grants of up to $25,000 to emerging companies and early-stage companies at NC State to enable them to mature their innovation and organizational base.
- The NCSU Technology Incubator is located on the Centennial Campus and, as of this writing, has 20 startup client companies involving not just members of the NC State family—faculty, staff, current students, and post-docs—but also companies that are community-based, with minimal NC State staff or students involved. Services include business and financial planning, mentoring, and technical/engineering services via the NC State Industrial Extension Service. The university has no "cut" in the business proceeds of these startups.
- The OTT has been working with a number of IP brokers and service providers. These are organizations external to the University that have ongoing relationships with companies in a technology or business domain and that can function as an entry point for NC State technology transfer. Examples include Southeast TechInventures (STI), the Council for Entrepreneurial Development, UK-based Plant Bioscience Limited, and North Carolina Centers for Innovation (nanobiotechnology, design, marine biotechnol-

ogy, etc.). A strategic partnership with Nagoya University in Japan has the potential for enhancing licensing and technology bundling.

Summary and Parting Comments

On many dimensions North Carolina State University provides a model for an Innovation U campus. Along with its sister institutions, Duke and UNC, it demonstrates how universities can engage with an industrial research park for mutual benefit. It is living proof that the traditional activities and orientation of a Land Grant school can be enhanced so as to serve technology-based industry and build knowledge-based economic growth across a state and a region. NC State provides a model for how industry-university cooperative research relationships can be conducted such that they are long-lived and high-leverage organizational models. Its Centennial campus is a successful model of how physical propinquity and joint tenancy is a great way to develop innovation and cooperative research between academia and industry. While all of these initiatives develop quirks and wrinkles that need to be fixed and ironed, the long term trajectory of NC State as a place for collaboration in innovation with industry and its community has many features that could be emulated elsewhere.

As this book was going through its last pre-publication scan, big and positive news came via a White House release that illustrates all the points of NC State's excellence in being a center of innovation. On January 15, 2014 the White House announced the award of $150 million to support a Manufacturing Innovation Institute that will be led by NC State and involve 6 universities and labs (Arizona State University, Florida State University, University of California at Santa Barbara, Virginia Polytechnic University, National Renewable Energy Laboratory, and U.S. Naval Research Laboratory) and 18 companies including Delphi, Delta Products, John Deere, Monolith Semiconductors, and others. Five federal agencies will provide $70 million in support over five years, with the Department of Energy the major funder. Others involved include: NASA, National Science Foundation, DOD, and the Department of Commerce. The participating companies and university partners will match federal funds. As per the White House press release, the focus is on "enabling the next generation of energy-efficient, high-power electronic chips and devices by making wide bandgap semiconductor technologies cost-competitive with current silicon-based power electronics in the next five years." The State of North Carolina is also a partner in the effort. This is another current and huge example of all the things that NC State does well, and have been discussed in this chapter: Industry partnering, large technology development and commercialization thereof, partnering with public and private R&D organizations, developing industry consortia, and engagement with the manufacturing sector. NC State just keeps on rolling.

Endnotes

[1] National Science Foundation, National Center for Science and Engineering Statistics, FY2011. *Table 14. Higher education R&D expenditures, ranked by all R&D expenditures, by source of funds: FY2011. Table 15. Higher education R&D expenditures, ranked by all R&D expenditures, by R&D field: FY2011.*

[2] North Carolina State University (2011). *The Pathway to the Future. North Carolina State University Strategic Plan 2011 – 2020.* Retrieved

from http://info.ncsu.edu/strategic-planning/overview/pathway-to-the-future/

[3] Lomax, T. (2012, Spring). InnovateRAL: The Start of Something Big. *Results. Research, Innovation, and Economic Development at North Carolina State University.* Retrieved from http://www.ncsu.edu/research/results/vol12n1/index.html. It should be noted that relatively few chief research officers at universities have Innovation and Economic Development in their position title. This says something about NC State.

[4] Much of the material in this section is drawn from three sources: Hardin, J. (2008). North Carolina's Research Triangle Park. In Hulsink, W. & Dons, H. (Eds.). (2008). *Pathways to High-tech Valleys and Research Triangles: Innovative Entrepreneurship, Knowledge Transfer and Cluster Formation in Europe and the United States,* 27-51; Dordrecht, The Netherlands: Springer Publishing. Leyden, D. P. & Link, A. N. (2011, December). *Collective Entrepreneurship: The Strategic Management of Research Triangle Park.* Unpublished paper presented at Strategic Management of Places Conference, La Jolla, CA; Link, A. N. & Scott, J.T. (2003). The growth of Research Triangle Park. *Small Business Economics*, 20, 167-175.

[5] For the RTP story from the political trenches, the reader might consult Governor Hodges' memoir: Hodges, L. (1962). *Businessman in the Statehouse. Six Years as Governor of North Carolina.* Chapel Hill, NC: University of North Carolina Press.

[6] Archie Davis became President of the Research Triangle Foundation and continued in that leadership position for many years.

[7] This section has been put in this place in the NC State narrative for thematic continuity and similarity of the processes that created RTP and those involved in developing the Centennial Campus.

[8] This quote, and the context, is drawn from: Pearce, G. (2010). *Jim Hunt: A Biography.* Winston-Salem, NC: J.F. Blair.

[9] This sub-section draws heavily from: Meszaros, P. (2004). *The History of North Carolina State University's Centennial Campus. Centennial Campus Documentation Project.* North Carolina State University Libraries, Special Collections Research Center.

[10] Gray, D.O. & Walters, G. (Eds.). (1998). *Managing the Cooperative Research Center.* Columbus, OH: Battelle Press.

[11] Gray, D., Tornatzky, L. and McGowan, L. (2013). *Managing the Path to Self-sufficiency: Case Studies in Fidelity and Reinvention of Industry/University Cooperative Research Centers.* Industry-University Cooperative Research Center Program, National Science Foundation. Retrieved from http://www.pse.umass.edu/cumirp/FinalReport-GraduatesCases.pdf

[12] We are thankful to Jane Albright, of the NC State Industrial Extension Service, who provided much of the detail for this section.

[13] The original *Inventors Guide* was written by Ken Nisbet at the University of Michigan, and other institutions have subsequently replicated that effort and used much of the text (with modifications) while acknowledging the fine work of Mr. Nisbet. This is a great example of righteous free transfer of valuable intellectual property.

[14] Association of University Technology

Managers. *(2013). AUTM U.S. Licensing Activity Survey: FY2012.* Deerfield, IL: Association of University Technology Managers.

Purdue University*

Purdue University was founded four years after the end of the Civil War, thus taking advantage of the Morrill Act and becoming a Land Grant university. The Indiana General Assembly passed founding legislation in 1865, but did not formally establish the institution until May 6, 1869. Classes did not begin until September 16, 1874 with 39 students served by six instructors. The university was located in West Lafayette, with initial financial support of $150,000 from John Purdue, a Lafayette businessman, $50,000 from Tippecanoe County, and 100 acres donated by local residents.

Even today, Purdue's location is demographically modest. West Lafayette has a population of roughly 30,000 (topped by the student population of nearly 40,000) and Tippecanoe County's population is approximately 175,000. The university is 60 miles from Indianapolis, the largest Indiana city and 120 miles from Chicago, a major economic center and travel hub. There is no air service but there are bus shuttles to the Chicago and Indianapolis airports, and the semi-isolation of the university, coupled with its grand ambitions and the average January maximum temperature of 31.5 F, have led to novel solutions for enhanced access. Since the 1930s the university has operated Purdue University Airport to support both educational and research pursuits. It currently has a training fleet of 25 aircraft and 8 simulators, and during the 1960s and 1970s operated its own charter business, Purdue Airlines. In addition several regional or national companies use the facility, and it is one of the busiest airports in the state in terms of aircraft operations. Consistent with the rest of the Purdue culture, a certain amount of panache has been a part of the operation. (Amelia Earhart was an adjunct faculty member in the 1930s and prepared for her attempted around-the-world flight there.)

From the onset the vision for Purdue was to fulfill the intent of the Morrill Act and focus on practical education and innovation that emphasized agriculture, science and technology. Engineering was an emphasis from the beginning. Thus a Department of Practical Mechanics was established in 1879, which developed into a mechanical engineering curriculum, and by the turn of the century the university had formed colleges of agriculture, engineering, and pharmacy. A College of Science was established in 1907 and a College of Education in 1908. Not until 1953 was a College of Liberal Arts established (Purdue's first B.A. degree), followed by the College of Veterinary Medicine in 1959, the Krannert School of Management in 1962, the College of Technology in 1964, and the College of Health and Human Sciences in 2010. Some of these colleges, as at most universities, involved consolidation of existing departments as well as adding new departments.

** This case was written by Louis Tornatzky and Elaine Rideout.*

From its founding the university's enrollment did not exceed 5,000 students for the first 70 years. The original complement of campus buildings was constructed in the late 19th and early 20th century, with modest incremental expansion over the next half century. There was a temporary enrollment bump of non-traditional and short-term students during World War II when the campus hosted Army and Navy training programs, whose student headcount accounted for more than 50% of total enrollment in 1943.[1] During this period Purdue also operated a number of short-term technical training programs, scattered around the state, for defense workers. As will be described, this tradition of statewide technical education partner-ships has continued, particularly through the College of Technology.

Like a number of other state Land Grant universities, the post-World War II decades saw massive growth in terms of students, as well as research activities and graduate education. From fewer than 5,000 students in 1944-1945 (and negligible graduate enrollment) total enrollment climbed to 30,000 by the 1979-80 academic year, including 5,000 graduate students. Several colleges were added, or formed via consolidation, during the next few decades.

Today, Purdue University is composed of ten academic colleges or schools, with a headcount enrollment for Fall 2012 of 39,256, of which 30,147 were undergraduates and the balance consisted of graduate or professional students. The 2012-2013 enrollment was heavily concentrated in four colleges: Engineering at 10,173; Health & Human Sciences at 4,862; Science at 4,570 and Liberal Arts at 4,514. The next tranche included Technology at 3,658, Agriculture at 3,289 and Management at 3,137. To better appreciate the historic mission priorities of Purdue, only the College of Liberal Arts awards the Bachelors of Arts degree in any significant number.

Expanding upon its traditional orientation towards the sciences and engineering, Purdue has become a research and development powerhouse. Per FY2011 National Science Foundation statistics[2] Purdue had research expenditures of $578.3 million for the West Lafayette campus, which gives it a national ranking of 32nd. Expenditures in engineering accounted for 37.5% of this total and life sciences another 34.8%. In terms of funding sources indicated on NSF statistics, 44.9% came from Federal sponsored programs and 4.5% from Business funding. It should be noted that at Purdue, as well as other cases in this volume, much of the industry financial support for research comes via nonprofit transactions, such as from corporate foundations, and may be allocated to the Nonprofit column. Under the pre-2010 NSF approach to accounting funding sources the Purdue 2011 percentage of business support of research would have been much larger. In fact, the internal Purdue University Data Digest for 2010-2011 indicates the same total of $578.3 million, but indicates a much larger portion of funding (11.5%) coming from "industrials." The National Science Foundation was the largest Federal funder, followed by Health and Human Services, Department of Defense, Department of Energy and Department of Agriculture. The level of industrial support exceeds all Federal agency expenditures except NSF.

In terms of rankings and ratings Purdue does quite well. In the 2012 *U.S. News & World Report* the institution was commended in several areas. It was ranked 25th among all US public universities, and 11th for "the most promising and innovative changes in the areas of academics, faculty and student life." The College of Engineering was ranked 10th and the Krannert School of Management was 21st. In engineering specialties Purdue was ranked first in biological/agricultural, 4th in aerospace/aeronautical, and 4th in industrial. Also *U.S. News & World Report* placed the Pharmacy doctoral program 7th, and the graduate program in Analytic Chemistry 2nd. According to *Smart Money* the university was ranked 8th nationally as a "best buy" and by *Kiplinger's* as among the top 100 in the country. *Financial Times* ranked the Krannert School MBA program 12th among public universities and the *Wall Street Journal* ranked Purdue among the top four universities favored by corporate recruiters. A large number of other programs also placed highly among national peer institutions.

University Culture: *Goals and Aspirations*

One of the themes that cut across Purdue's early history up through the present day is to be a science and technology asset to the State of Indiana and the world. This is demonstrated by the robust presence of adjunct facilities and curricular programs, as well as many service programs located around the state. These include activities such as technology problem-solving for established companies as offered by the Technical Assistance Program (TAP) now going on 30 years, as well as services focused on startup companies offered by a large, decentralized system of new business incubators located around the state. Both are consistent with Purdue's mission to be a center of technology invention and commercialization. Perhaps the most interesting example of Purdue's ongoing goal to serve the people of Indiana is its important role in enabling the establishment and growth of the IUPUI campus in Indianapolis. In effect, Purdue (and Indiana University) worked cooperatively to create and grow a competitive institution and thereby expand services to a key urban constituency. While Indiana University (IU) is the managing entity for the IUPUI campus, Purdue has responsibility for engineering and science. In another joint agreement for a smaller but significant branch campus, IU-Fort Wayne, Purdue is the operating manager and IU a partner. This campus has strengths in engineering and technology, and good relationships with regional business and industry.

These themes have been articulated by Purdue leadership for years. From the 2005-2010 Strategic Plan for the Purdue Research Foundation (itself created to enable the university to be responsive to the "outside" world), then Purdue President Martin Jischke opined the following:

> *At Purdue, we believe that our university belongs to the people of Indiana and that it exists to make their lives and their futures better. One of the ways Purdue serves its state and community is by having a positive economic impact.*

And:

> *Today we have the opportunity in Indiana to harness the sciences and technologies that are driving changes throughout the world. We can start by coming together as a people and deciding what we want Indiana to be.*

The Purdue Research Foundation Strategic Plan itself staked out the following vision at that time:

> *The Purdue Research Foundation will be recognized as the national leader in university-stimulated entrepreneurship*

and economic development through the commercialization of science and technology.

These goals have been approximately repeated in many similar forms, before and since. After France Cordova became Purdue's 11th President in 2007 within a year she led the development of a "New Synergies" strategic plan. One of the three major goals articulated therein was:

Promoting discovery with delivery by conducting field-defining research with breakthrough outcomes and catalyzing research-based economic development and entrepreneurship.

Just five years later Mitch Daniels, coming from a successful political background, was named university president in 2012. In an Open Letter to the People of Purdue dated January 18, 2013, he articulated many issues and problems facing Purdue and other institutions of higher education, but did note, relevant to this chapter:

An area of much recent success, but requiring continued emphasis and development, lies in the more rapid and continuous transfer of Purdue technology into the marketplace. We must produce and recruit scholars imbued with a passion to see their genius converted into goods and services that improve human life.... As one of Purdue's most renowned faculty leaders said to me, 'It's not an innovation until it's useful to someone.' There is no greater societal contribution we could make to a nation struggling to maintain economic opportunity and upward mobility, and there is no more tangible way to demonstrate to our fellow citizens the high return their investments of tax dollars in us can bring.

Leadership

The University has been blessed throughout its history by consistently able and often brilliant leadership that has enthusiastically embraced Purdue's role as a Land Grant institution focused on engineering and the sciences, along with a very conscious mission to build the human assets and economic prospects of Indiana.

This leadership tradition started with the 19th century administrations of Emerson White and James Smart ("the engineers' president") that firmly launched the university. When a fire destroyed Havilon Hall in 1894, Smart vowed that it would be rebuilt "one brick higher," which has been pointed to as defining the Boilermaker spirit.[3] This was followed by a 21-year period of continuous growth, particularly in agriculture and engineering, led by Winthrop Stone.

During the roaring twenties, and the dismal depression on into the WW II era, Purdue was led by President Edward Elliott for 23 years. The vision and the process of building continued around the themes of technology and external engagement. The School of Aeronautics and Astronautics was established, as was the Purdue Research Foundation, which was an early model of how the modern university would manage its research transactions with funders and industry partners.

The 25-year (1946-1971) post-war period was marked by a much more ambitious flowering of the Purdue vision and mission. It was ably led by Frederick Hovde, and saw enrollment grow from

5,628 to 25, 582, the budget increase tenfold, and the establishment of new schools of Industrial Engineering, Materials Engineering, Technology, and Veterinary Medicine. Research expenditures increased significantly as did the reputation of Purdue throughout the nation and state as the harbinger of science, engineering and technological excellence. One of the most important accomplishments of the Hovde administration was the establishment of the Purdue Research Park in 1961 and its rapid climb to national prominence.

Arthur Hansen, a former Marine pilot in WW II, was an advocate for high performance computing and was president from 1971 to 1982. His founding of the President's Council buttressed Purdue's already strong linkages to private sector research and technology partners, as well as private research funding which is strong to this day.

The Steven Beering administration (President from 1983 to 2000) was significant on several counts. The Purdue Research Park significantly expanded its physical and programmatic assets via a business incubation facility, a multi-tenant building, and a gateway program. Also guidelines and procedures were developed to clarify how faculty-owned businesses were to be treated. Since the early post Bayh-Dole years coincided with Dr. Beering's administration, and Purdue aspired to be active and effective in technology transfer and entrepreneurship, much of Purdue's policy and program foundation in this area was buttressed during his tenure as President.

Martin Jischke, Purdue's 10th president from 2000 to 2007, also accomplished several significant goals relevant to technological innovation and building a supportive organizational and cultural framework. For one he completed a "next level" strategic plan that involved a dramatic increase in faculty positions, an upgrading of campus infrastructure, and growing sponsored research. Part of this vision was to be supported by a Campaign for Purdue, which Jischke launched with a $1.3 billion goal and which raised $1.5 billion. He was also a strong and visible advocate for continuing and expanding Purdue's partnerships with private and public sector leaders around the state. New construction for core labs as well as instructional facilities was significant, with the most notable example being Discovery Park, a $300 million central campus initiative that is described in more detail below.

France Cordova's administration, 2007-2012, succeeded in dramatically increasing the scope of research funding as well as private philanthropy. Dr. Cordova also was a strong advocate of technological innovation and the commercialization of faculty inventions, and those activities grew during her administration. The College of Health and Human Sciences and the Global Policy Research Institute were initiatives that she supported.

The current Purdue President is Mitch Daniels, who was most recently the Governor of Indiana. As this chapter is being written, Mr. Daniels and Purdue are still early in their joint engagement. Nonetheless, given his background, it can be expected that President Daniels will be a strong advocate for programs and activities that enable the state of Indiana to prosper from the intellectual assets of Purdue. Recently, for example, he has engaged university leaders to tackle and tear down any obstacle, bureaucratic or otherwise, in the way of commercializing Purdue innovation. Rules and procedures are being re-written to get the university "out of the way" of inventors, to reward entrepreneurial behaviors, and to raise significant seed funds to help move ideas into commercial reality. There has also been an increasing emphasis to enhance organizational efficiencies to serve both internal and community-based constituencies. The Purdue Innovation & Commercialization Center (ICC) is an example of "one-stop shopping" in the area of technology commercialization and services for start-up companies that come out of Purdue.

Boundary Spanning: *Entrepreneurship*

In 2007, with funding from the Ewing Marion Kauffman Foundation, Purdue became a "Kauffman Campus" charged with creating a culture of entrepreneurship in the business school and beyond to benefit the entire campus, the local community, and citizens statewide. One hub of entrepreneurship education on campus, and of the Kauffman initiative, is the multidisciplinary Burton D. Morgan Center (BDMC), the first building to open in Discovery Park. A second organizational locus of entrepreneurship education is the Krannert School of Management. Perhaps the most pervasive program in student entrepreneurship curricular programs at Purdue is the Certificate in Entrepreneurship, available to all students, and operated out of the Burton D. Morgan Center. Purdue's programs in entrepreneurship are more numerous in co-curricular activities as opposed to curricular ones, although the latter may reach more students.

CURRICULAR PROGRAMS

- *Certificate in Entrepreneurship and Innovation.* This program is organizationally attached to the Burton D. Morgan Center. It provides the opportunity for undergraduate students to take a tightly focused group of courses that is complementary to all majors. Launched in 2005, the program now has involved thousands of students "from every college, school, and department at Purdue," which would arguably make it one of the largest in the country. The Certificate involves 5 classes, two core courses, two option courses, and an experiential capstone. The list of approved options changes regularly, and the student can take an additional capstone course as a substitution for one of the required options. The options can vary widely, such as an internship (e.g., facilitated by either Interns for Entrepreneurship or the Lilly Endowment-funded Purdue Interns for Indiana program), a consultancy, or a study-abroad program. The approved option courses also vary widely, and might be in health, education, languages, and media as well as business, science, engineering, and technology.

- *Krannert School of Management MBA in Technology Innovation and Entrepreneurship.* This program includes topics such as technology planning, new product management, patents, capitalization, venture formation, commercialization, and related issues. Ten hours of coursework are required, including two Foundation Seminars focusing on Technology Realization Topics. The program is linked to various mentoring opportunities, hosts entrepreneurship activities and events, and generally facilitates the transition of campus research findings to real world applications.

- *Krannert School of Management MS in Global Entrepreneurship Program (GEP).* The GEP is a year-long program that begins every August and is delivered in partnership with EMLYON Business School in France and Zhejiang University in China. GEP students begin their studies in the fall at Lyon, and then travel to Hangzhao, China for the spring semester. They complete the program at Purdue University's Krannert School of Management during the summer. Students graduate with a Master of Science degree with a specialization in Global Entrepreneurship.

Co-Curricular Programs

These organizations provide a number of competitions and events that supplement the ongoing programs described above. These include:

- *Purdue Innovation and Commercialization Center.* This is an organizational and information entity that brokers and facilitates innovation and commercialization partnerships across the campus. It provides online links to 37 "resources" which includes every program activity described in this chapter and more. Its Leadership Team is composed of on-campus individuals with significant experience in information systems, innovation, and entrepreneurship. That Team is also linked to an Operating Committee that includes on-campus as well as community experts in comparable domains. The Center has been operational since 2012. In addition to its information systems and connectivity activities, the Center also hosts various face-to-face meetings and consultations.

- *The Purdue Entrepreneurship and Innovation Club,* and the *Krannert Entrepreneurship and Venture Clubs,* are designed to provide students with the knowledge, resources, and first-hand experience in launching a startup company while at Purdue, but in a club context. The clubs provide a campus forum for networking and collaboration, host events featuring guest speakers, enable networking opportunities, organize advice on business plan preparation, and facilitate access to startup capital. Some MBA club members also work at the BDMC where they serve as entrepreneurship consultants and help other entrepreneurial students with their business planning, marketing, and finance information needs.

- *The Purdue Realization and Entrepreneurship Postdoctoral/Doctoral Fellowship Program (PREPP)* is a Kauffman-funded program that offers workshops and seminars to graduate students, and provides financial support for competitively selected postdocs or doctoral candidates for up to a year, while they work on the commercialization of their research-derived invention.

- Purdue University's *Elevator Pitch Competition* was created in 2006 and is hosted by the Certificate in Entrepreneurship and Innovation Program. The competition gives participants two minutes to describe the value of their entrepreneurial business venture to a panel of judges. There are two divisions in this competition: one for Purdue Certificate in Entrepreneurship and Innovation undergraduate students and another for staff/faculty entrepreneurs, graduate students, representatives from Purdue Research Park companies or Certificate Program Alumni. Winners in each category receive prizes of $1,000 for first place, $500 for second, $250 for third, and $500 for most entertaining. The competition has several sponsors including the Otis Elevator Company.

- The *Burton D. Morgan Business Plan Competition* is the third oldest business plan contest in the US. Graduate and undergraduate student teams develop and present business plans to a panel of judges and compete for cash and in-kind awards to further the commercialization of their inventions. "Gold" or open-division teams comprise undergraduate students, graduate students, or a combination of both. Staff and faculty of Purdue University may be included in the team. Off-campus personnel may also be included, but cannot make up more than 50% of the team. Student members of the team must be enrolled at Purdue University at the time of registration. "Black," or undergraduate division teams, must be wholly made up of currently enrolled undergraduate students. All members of the team must be enrolled undergraduate Purdue students at the time of registration. The team must have a faculty advisor.

- *The Purdue Entrepreneurship and Innovation Learning Community (ELC).* This is a residence hall located near the Burton D. Morgan Center for students enrolled in the Certificate program, or for those otherwise interested in entrepreneurship. It serves to enhance networking among would-be student entrepreneurs.

- *The Student Soybean and Corn Product Innovation Competition* offered by the Agricultural and Biological Engineering Program is open to all students with ideas for novel, economically and technically feasible new soybean and corn products. The contest is sponsored by the Indiana Soybean Alliance and Indiana Corn Marketing Council, and offers a $20,000 first prize. The contest has resulted in the commercialization of a number of new products.

- The Burton D. Morgan Center also hosts the *National Idea-to-Product Competition for Social Entrepreneurship.* Sponsors are the Social Entrepreneurship and Education Consortium, National Collegiate Inventors and Innovators Alliance, Kauffman Foundation, and a National Science Foundation grant through the University of Texas, Austin.

- *The Faculty Boot Camp* is conducted during the fall break and attracts over 70 participants. The program educates faculty, staff, and graduate students about sources and processes of seed and venture capital, company formation, company valuation, and various other topics. Assistance is also provided online through Kauffman-funded Purdue portals. The program also supports test marketing, business plan development, and brokering linkages to funding and mentors.

- *The Docking Station.* Established in 2012, with sponsorship by the Burton D. Morgan Center and the Purdue Research Foundation, this off-campus facility is a co-working and networking space for students, faculty members, and community entrepreneurs. It is walking distance from the main Purdue campus, has high-speed broadband Internet, and is open 24/7. It is a place to work and connect.

- *The Entrepreneurship Leadership Academy (ELA),* another project of the Kauffman Foundation Campus Initiative, leverages off the Faculty Boot Camp experience, providing support for up to ten mid-career or senior faculty members annually. Faculty interested in cultivating their own leadership and entrepreneurial skills apply for seed funding for a commercialization project derived from their science. Fellowship awards are $5,000 while Scholars can win $15,000 for continued project work. Fellows and Scholars also participate in discussions and events that enhance their knowledge about available resources, the processes of commercialization, and the development of networks of like-minded faculty members.

- *The Entrepreneurship Bootcamp for Veterans with Disabilities (EBV)* offers free, experiential training in entrepreneurship and small business management to post-9/11 veterans with disabilities from their military service. Participants develop entrepreneurial knowledge, tools, and skillsets in new venture creation and growth, gain university and peer supporters, and make connections with other programs available to veterans with disabilities.

- The *Purdue Research Park* offers a summer academy program to Indiana high school juniors and seniors who demonstrate aptitude in the areas of math, science and technology along with an interest in entrepreneurship. High school students accepted into the Purdue Research Park Entrepreneurship Academy spend five days at the Purdue Research Park, led by Purdue Research Foundation staff with critical assistance from Purdue University faculty, industry leaders and successful high-tech business entrepreneurs.

- *The Young Entrepreneur Program,* established by the State of Indiana in 2011, is an innovative approach to increase student entrepreneurs' ability to continue with their projects after graduation, and actually launch the ventures they worked on in college. A panel of judges reviews student business plans and selects entrepreneurs with the top proposals to participate in a state-wide, tradeshow-style event. Community officials then compete by offering incentives including free rent, grants, loans, and utility support, in exchange for the Young Entrepreneur's agreeing to locate their start-up business within their community. The Indiana Small Business Center, Indiana Economic Development Corporation, and the Office of Community and Rural Affairs help communities prepare bids and compete financially with larger communities to attract a Young Entrepreneur. Qualified participants must be enrolled in an educational institution located in the state of Indiana or have graduated from an educational institution located in the state of Indiana within the last three years.

Boundary Spanning: *University, Industry, and Community*

Throughout its history Purdue has had an extensive record of connecting to external constituencies. Two areas that are among the most active and extensive involve partnerships with industry and significant educational partnerships with Indiana communities outside of the West Lafayette main campus.

Industry Partnering and Centers. In terms of the scope of industry-sponsored research, Purdue does very well in operating R&D programs in which companies are both substantive and financial partners. Some of this activity takes place in the context of one-time research contracts, with a company working with a professor or research staff person. There is a dedicated Assistant Vice President for Industry Research who provides leadership in this area. In addition, Purdue is adept and aggressive in launching multi-year multi-participant research centers and institutes. Within the Office of the Vice President for Research there are *two* Managing Directors for Launching Centers and Institutes. Not surprisingly, the number of centers and institutes, and the aggregate scope of their R&D, has increased significantly over the last decade. Many of these are interdisciplinary or multidisciplinary in foci, and the extent of industry participation, substantive and financial, is high. For several years the Office of Research and Technology programs has published an industry-targeted online newsletter entitled *Purdue/Industry Partnerships* to pique the interest of companies.

Over recent decades the successful development of centers and institutes has accelerated and they now number 116 University-approved initiatives. Of these, several are explicitly organized to maximize industry involvement, including the NSF Industry-University Cooperative Research Center model, where Purdue participates in the Cooling Technologies Research Center and the Center for Advanced Forestry Systems. Purdue also participates in a Quantum Information Center for Quantum Chemistry, another NSF program. The Purdue Center for Cancer Research has been supported for many years by the National Cancer Institute. Research funding from Federal agencies is led by the National Science Foundation, followed by HHS. Reinforcing Purdue's capacities to conduct cutting edge science are the nearly 100 core labs that enable access to instrumentation, equipment, facilities, analysis and expertise.

Purdue Research Foundation and Purdue Research Park. Insightful leadership, coupled with a desire to make Purdue more relevant to industry, led to the launch of the Purdue Research Foundation in 1930, at the low point of the Great Depression. Two enabling gifts of $25,000 each, from J.K. Lilly and David Ross, led to its establishment. The Foundation is organizationally separate but linked in mission to Purdue University. As such it plays a role in managing external relationship, gifts, acquiring and managing property as well as enabling research contracts with the university. It also is the organizational home of the Purdue Office of Technology Commercialization.

Perhaps the largest—clearly the most visible—contribution of the Purdue Research Foundation to Purdue was its role in the establishment in 1961 of the Purdue Research Park system, with the largest component in West Lafayette, and three ancillary facilities elsewhere in the state. The Purdue Research Park system was designed to enable working relationships between mostly technology-based companies and the R&D and human resources of Purdue. To that end it has succeeded in a spectacular manner.

The 725-acre Purdue Research Park in West Lafayette has over 160 resident companies, most of which are technology-oriented. It also hosts one of the largest clusters of business incubation facilities in the country, over 350,000 square feet. More than 3,200 people work in the park's tenant companies.

The Purdue Research Park in West Layayette is arguably, in terms of size and international acclaim, on a par with Research Triangle Park in North Carolina. Unlike the Purdue park, RTP—as has been noted in the NC State chapter—is in the middle of a major technology cluster community. Nonetheless, Purdue Research Park has received the following awards: Association of University Research Parks's *Creating the Culture of Innovation Award, 2011*; International Economic Development Council's *Excellence in Economic Development Award, 2012*. In addition, several of the resident companies in the Park have received various national awards.

The Purdue Research Park Northwest Indiana occupies 393 acres and provides incubation services for 21 early stage companies, plus facilities for four established companies. The Purdue Research Park Indianapolis opened in 2009 on 78 acres and includes a 55,000 square foot incubation facility. The fourth leg of the Purdue Research Park is located in southeast Indiana on 40 donated acres and includes 18,000 square feet of incubation space. This pattern of statewide partnering in programs and facilities repeats itself in other domains, as will be described below.

Discovery Park. The development of Discovery Park over the past dozen years has given Purdue a capacity that has many similarities to the NC State Centennial Campus but without the need to get in your car and drive there. It is also attaining comparable outcomes in terms of research scope, commercial outcomes, and cultural change on campus.

Discovery Park is an on-campus R&D "district" of 40 acres that is anchored by eight centers, each of which is aggressively interdisciplinary, as well as conceived so as to address the "grand challenges" of the planet, and to do that in such a way as to nurture the technology sector of Indiana. The core labs, centers and related facilities are clustered in the central campus, and thereby benefit considerably from the propinquity of talented people pursuing large problems and ambitious business opportunities. The Park encompasses 113,000 square feet of laboratory space and 93,000 square feet of office and meeting space. Over $30 million in equipment has been acquired thus far.

Discovery Park planning was initiated in 2001 via $5 million in state support, initially for a nanotechnology center. Lilly Endowment got things rolling with a $26 million gift, also in 2001, which in turn led to the founding of the original six centers. This gift was supplemented by Lilly in 2005 with another $25 million, which led to the creation of more centers as well as the consolidation of programs across the Park.

After consolidation and reorganization, Discovery Park is now a self-sustaining entity consisting of the following eight core centers, plus their seven subsidiaries: Bindley Bioscience Center; Birck Nanotechnology Center; Burton D. Morgan Center for Entrepreneurship; Discovery Learning Research Center; Global Sustainability Initiative; Advanced Computational Center for Engineering and Sciences; Oncological Sciences Center; and the Regenstrief Center for Healthcare. Each of these centers encompasses human assets as well as facilities and laboratories. There is also reportedly a robust organizational culture among the centers in Discovery Park that encourages and enables interdisciplinary science and problem solving across the 4000+ faculty and students who work there.

As Discovery Park has evolved and grown, so too have the resultant outcomes since 2001: over 40 companies seeded or assisted; over $500 million in externally sponsored research; 174 invention disclosures; and 27 licenses/options from Discovery Park research.

Technical Assistance and Extension. Somewhat of an anomaly in the context of the contemporary research-intensive university, since 1986 Purdue has operated a set of outreach and assistance programs designed to improve the economic performance of Indiana companies and organizations. In terms of operations there are many similarities with the traditional agricultural extension programs that have been in existence for many years in Land Grant universities. The mission of the Technical Assistance Program (TAP) is "to advance economic prosperity, health and quality of life in Indiana and beyond." TAP is financially supported by a changing mix of state, Federal, university and client service fees. Its activities have gone through many reconfigurations over the years, but it nonetheless claims to have:

> *...assisted over 12,000 organizations, trained over 26,000 employees, created or retained $872 million in sales, increased capital investments by $217 million, contributed to cost savings of $107 million, and created or retained over 11,000 jobs in the state...*

The constituent program activities include:

- *Technical Assistance Projects.* These are essentially problem solving consulting efforts that include up to 5 person-days gratis.

- *Manufacturing Extension Partnership.* This is a long-standing Federal program managed and supported by the National Institute of Standards and Technology (NIST) which is very oriented toward process improvement, quality management, and related issues in sub-tier supplier firms.

- *Energy Efficiency & Sustainability.* This program tends to be workshop-oriented and delivered in collaboration with the U.S. Department of Energy, and is mostly focused on energy savings coupled with productivity improvement.

- *Green Enterprise Development.* This program focuses on environmental best practices that also benefit general enterprise productivity.

- *Purdue Healthcare Advisors.* This activity helps healthcare entities to utilize lean and six sigma concepts to streamline, reduce costs, and increase efficiencies in healthcare services.

Consistent with other technology programs at Purdue the TAP activities and offices are scattered around the state, again with the intent to serve the economic geography of Indiana. While TAP is not a major set of activities in the grand scheme of Purdue, its existence and robust program attest to how Purdue defines its mission and culture.

Statewide Community Engagement. More than many public flagship universities in other states, Purdue has taken very seriously the challenge of delivering undergraduate and graduate education around the state, via the Regional Campus System. This is consistent with its geographic dispersion of satellite incubation activities and industrial extension. There are three smaller campuses, and an additional very large partnership with Indiana University.

- *The Calumet campus*, located in Hammond, enrolled 10,054 students in fall 2012-13 and offers programs in six Schools at the Associate, Baccalaureate, and Master's levels.

- *The North Central campus*, located in Westville, enrolled 6,048 students in fall 2012-13 and offers programs in a dozen Schools at the Associate, Baccalaureate, and Master's levels.

- *The Indiana-Purdue Fort Wayne campus* enrolled 13,771 students in fall 2012-13 and offers programs in ten Schools at the Associate, Baccalaureate, and Master's levels.

It should be noted that each of these institutions is located in a mid-size Indiana city with established business, industry, and employment prospects. However, a niche that these campuses are filling is for students who have educational aspirations but constraints of family income or social situation that make enrolling in the residential campus in

West Layayette less attractive. All three of these campuses have majors that have high employment potential in technology-based industry.

Another example of broad regional outreach, coupled with a non-traditional applications-oriented approach to engineering education, is the College of Technology. Since its founding Purdue has struggled and worked with how to address engineering as a scientific discipline as well as a practical skill set. Some research universities leave the field and opt primarily for the scientific path. In the 1960s, influenced by the national Grinter report which advocated a dual path for engineering education, a College of Technology was launched at Purdue that encompassed programs that were more pragmatic than scientific in focus. Currently the College is organized into seven departments, offers programs in nine locations around the state, and enrolls nearly 5,000 students with the majority on the West Lafayette campus. The seven departments and programs therein are very applications-oriented. The 14 majors are structured around specific areas of technology and related issues, such as: Aviation Flight Technology; Computer Graphics Technology; Industrial Distribution; and Organizational Leadership and Supervision. This is a major commitment on the part of a research-oriented institution to address the staffing and problem-solving needs of Indiana business and industry, including a commendable effort to bring courses and curriculum to locations around the state.

IUPUI. The most significant example of Purdue bringing education to where the student market and employment opportunities exist is the Indiana University/Purdue University at Indianapolis (IUPUI). This university was launched in 1968 as a joint partnership between the city (Mayor Richard Lugar), Indiana University (President Joseph Sutton) and Purdue (President Frederick Hovde). A major impetus for this unusual partnership was to more directly serve the population center of the state, and a large live-at-home potential student body in Indianapolis.

IUPUI has now grown to a campus with an enrollment of over 30,000 undergraduate and graduate students, a curriculum that accommodates over 250 degree programs, and a sponsored-research portfolio that is significant and has national recognition. The somewhat novel organizational arrangement for operating "Yooey-Pooey" includes the offering of degrees by both Indiana University and Purdue, with the positive result for students of having access to a very broad curriculum and selection of majors. The college of engineering is the Purdue College of Engineering, as is the Purdue College of Science. Most of the other colleges and units have Indiana University in their nomenclature and linkages. Perhaps reflecting its parentage, IUPUI has become increasingly active in technology transfer, working through the Indiana University Research & Technology Corporation. Curricular, research and innovation partnerships with Purdue (and Indiana University) are a major theme of the IUPUI Strategic Research Roadmap and its vision of how to make a difference. While an entire case history can be written about IUPUI the role that Purdue has played in its success also speaks to its own mission of serving the educational and technology needs of Indiana.

Boundary Spanning: *Technology Transfer*

The Office of Technology Commercialization (OTC) operates out of the Purdue Research Foundation, which as noted above is a separate entity that is linked to the University and assists in management of gifts, contracts, corporate relationships, and business incubation. An advantage of having OTC attached to the Research Foundation is that this kind of structure often helps to keep the tech transfer functions out of college or department politics.

OTC has compiled a commendable record of intellectual property management and transfer, including a growing practice in commercializing inventions via startup companies. In terms of either gross metrics or better yet, normalized measures of "base hits" per unit of research expenditures, Purdue does well. In FY2012 data from the Association of University Technology Managers,[4] the university reported 356 invention disclosures, 77 licenses or options, 54 US patents secured, gross royalty income of $4.85 million and 5 startup companies. These outcome metrics are commendable, and even more so when one looks at normalized "batting averages" such as inventions per unit of research expenditures. OTC engages faculty, staff and student inventors, would-be entrepreneurs and potential external partners and licensees via a very informed and experienced staff, on-line tools and series of outreach events. License revenues (minus OTC costs) are distributed in a formula of 1/3 to inventors, 1/3 to the inventor's department and 1/3 to the Trask Innovation Fund (TIF), which supports Purdue technology commercialization.

The primary tools of the Trask Fund are in the form of grants up to $50,000 to campus inventors to support commercial development such as developing working prototypes, and reducing the invention to practice. If license royalties come to pass, the inventor has agreed to dedicate the initial funds to repay the TIF award. Competition for the TIF award includes a written proposal plus a short "pitch" to a TIF Advisory Council. Inventors can receive up to three awards to a maximum of $150,000. A 10-member Trask Innovation Advisory Council is the primary entity making decisions on the TIF proposals. It is composed of external business leaders, leaders of the Purdue Research Foundation, representatives from the office of the Vice President for Research, and Purdue faculty and staff members with knowledge about technology commercialization.

In addition to the TIF administered through OTC, the Purdue Research Foundation has other programs to foster innovation and commercialization. The Emerging Innovations Fund (EIF) is primarily focused on companies that are based on Purdue inventions and/or early stage companies that are based in the Purdue Research Park. Support can be in the form of seed investments or loans, with funding ranging up to $150,000. Support is often linked to various milestone events and the OTC is the entity that typically works with applicants in the development of proposals. Applications include an approximation of a full business plan, including proposed financial plan, management team, IP description, and proposed capital expenditures. The applicant must also specify the customer problem, the solution being developed, the market opportunity, illustrative customers, business model, and other aspects of the enterprise. Interestingly, a Student-Managed Venture Fund graduate course offered in the Krannert School of Management involves students in conducting the due-diligence, reviewing startup funding applications, and making funding award recommendations to the Purdue Research Foundation.

OTC also works with accredited investors looking for opportunities among businesses located in the Purdue Research Park, as well as emerging companies coming out of OTC activities. This activity includes investment opportunities at the incubator facilities located around the state, but managed by the Purdue Research Foundation. There is also a Technology Roadshow program that is led by the Foundation and involves the OTC as well. These are free events (including lunch) that are open to investors and potential business partners, and which feature presentations by Purdue faculty and staff of emerging technologies with significant business potential. Consistent with Purdue's statewide orientation discussed above, these are located in various venues all over the state and happen several times a year.

The Purdue Technology Centers are incubating high-technology companies throughout Indiana. With locations in West Lafayette, Indianapolis, Merrillville, and New Albany, the centers create dynamic entrepreneurial business environments to attract high-technology companies and to launch new startups. The Purdue Technology Centers offer business coaching, access to capital and talent, meeting space, business equipment, and a variety of offices and laboratories. Other joint efforts between Purdue and other Indiana campuses include: the Nanotechnologies New Ventures Competition, a partnership with the University of Notre Dame, for nanotechnology researchers and innovators from across the State of Indiana; the Life Sciences Business plan Competition, which draws participants from around the country to compete for $100,000 in prizes; and, the Purdue University Calumet Big Sell Entrepreneurship Elevator Pitch Competition with $60,000 in cash prizes.

Summary and Parting Comments

The previous several pages have attempted to document the historical evolution, the long line of forceful visionary leadership, and the many programs and activities that have been launched to enable Purdue to have a positive impact on the lives of Purdue students and Indiana residents. As suggested many times, Purdue is a place that seems to reach farther and try harder than many other institutions. It is not located in a large and rich metro area. West Lafayette, Indiana has more in common with Clemson, South Carolina than with Santa Clara County, CA or Raleigh-Durham-Chapel Hill, NC. But, starting early in its history, Purdue has consistently reached out farther across its state, nurtured more creative partnerships, and succeeded in creating more productive industry-business partnerships involving technology and innovation than most US universities. It is rare to find a university as active as Purdue is in incubating startup companies, offering industrial extension services, operating regional educational delivery programs, and running research parks in several locations around the state. Its efforts to enable the launch and flourishing of IUPUI are particularly noteworthy.

And Purdue continues to push that agenda further with new program ideas, new relationships, and new approaches to doing better at what it already does well. To a significant degree the case histories in volumes like this too often sound like a mishmash of descriptions of worthy activities, with sometimes little understanding of how these things fit together.

One of the more interesting developments in universities "doing technological innovation" is the continuing effort to engineer collaboration and communication across different program components. Purdue's relatively new Innovation and Commercialization Center provides centralized coordination and online access to nearly 40 Resources (programs and activities; most described above) and a fairly slick website to compare, contrast and engage. Purdue continues to be a benchmark campus in terms of fostering and enabling technological innovation, and via that activity, serving the people of Indiana.

Endnotes

[1] Wood, K.M. (2011). *Gridiron Courage: The Navy, Purdue, and World War II.* (Masters of Arts thesis, Department of History, Indiana University).

[2] National Science Foundation, National Center for Science and Engineering Statistics, FY2011. *Table 14. Higher education R&D expenditures, ranked by all R&D expenditures, by source of funds: FY2011. Table 15. Higher education R&D expenditures, ranked by all R&D expenditures, by R&D field: FY2011.*

[3] This was mentioned in Acting President Timothy Sands' commencement speech of December 16, 2012.

[4] Association of University Technology Managers. (2013, August). *AUTM U.S. Licensing Activity Survey: FY2012.* Deerfield, IL: Association of University Technology Managers.

Stanford University*

From its onset, the history of Stanford University is replete with aspirations and visions to join scholarly pursuits and real life outcomes. The university was established in 1891 by Leland and Jane Stanford in honor of their only son, Leland Stanford Jr., who died at a young age of typhoid fever. Leland Stanford Sr. was an entrepreneur who made his fortune supplying goods to gold prospectors and as one of the "Big Four" investors in building the Central Pacific link of the transcontinental railroad. He had also been a Governor of California and a US Senator. Prior to the founding of the university, Leland Stanford acquired extensive acreage in the vicinity of the small community of Palo Alto, with aspirations to develop a world-class stock farm to raise trotting horses. That plan came undone with the death of Leland Jr. in 1884 while the family was traveling in Europe.

The impetus for the university came out of the parents' grief and the idea that "the children of California shall be our children." The parents toured some of the more prominent East Coast institutions to develop their own vision of what the new university should become and how it might be different from the established models of the era. And it was to be different. It was to be co-educational, non-denominational, and emphasize a "practical education to produce cultured and useful citizens."

In 1885 Jane and Leland executed a deed of trust transferring the Stanford land and a financial bequest that mandated the development of a "university of high degree." In addition to money, the bequest included 8,800 acres in Palo Alto, California. The availability and use of this "private land grant" has played a significant role in Stanford's impact on the regional economy to this day.

The bequest launched an intensive six-year period of planning and building. For the latter Stanford brought in Frederick Law Olmstead to design the campus layout and develop the architectural style. FLO, as he was known, was generally considered among the leading lights of planning and design, with New York City's Central Park as one of his projects. David Starr Jordan, a Cornell graduate and then President of Indiana University, was brought in as the initial Stanford President. In his opening day speech Jordan set the goal of developing a unique university with the following challenge to the small group of faculty and students:

> *It is hallowed by no traditions; it is hampered by none. Its finger posts all point forward.*

He was to stay for 22 years and is an icon in the university's history. After the founding class of 555 students in 1891, served by 15 professors, the university slowly grew, although

** This case was written by Louis Tornatzky, Jennifer Fuss, and Elaine Rideout.*

it was resource-constrained. Leland Stanford died in 1893 and the financial uncertainties continued until the estate went through probate in 1898. In 1899 Jane Stanford transferred $11 million in funds to the university. She continued to hold a guiding and loving connection to the university, particularly to see out the initial tranche of construction, until her death in 1905.

Stanford University went on from this start to develop and establish the schools that defined its mission, including engineering, medicine, education, and law. While building out the core campus continues up until the present, much of the land grant has yet to be developed. The university is now the largest private owner of undeveloped land in Santa Clara County. Stanford University land holdings are parts of one other county, two cities, and two towns. As we shall see other portions have been strategically utilized to advance its historic vision of being connected with the real worlds of business and technology.

Enrollment grew slowly well into the 20th century, with 3,460 undergraduates and 1,782 graduate students enrolled as late as 1940. Like all American universities, the post World War II period was marked by rapid growth in enrollment as well as the process of becoming a world-class research university. The latter was of course helped along by the newly available and rapidly increasing opportunities for Federal research funding. Between 1940 and 1970 undergraduate enrollment increased nearly 80%, but in comparison graduate student enrollment increased 192%. Since 1990 graduate student enrollment has exceeded undergraduate student enrollment by a significant margin. Fall 2012 enrollment was 15,871 of which 55.8% were graduate students.

Between the early 1900s and mid 20th century Stanford also defined itself in terms of the colleges and schools that would comprise its intellectual agenda. There are currently seven schools. The largest is the School of Humanities and Sciences, encompassing 50 departments and degree programs and awarding about 75% of all degrees. The broad mandate of the college spans the humanities, languages and literature, and the physical and life sciences, as well as several research centers that are interdisciplinary. The College of Engineering is the second largest academic unit, enrolling over 4,500 students. It is organized into nine departments and 84 centers, institutes, laboratories and programs. The 3rd largest school is the School of Medicine, which encompasses about 450 medical students as well as 700 M.S. and PhD students in allied disciplines. Clinical training is provided through Stanford Hospital and the Lucille Packard Children's Hospital. As with all Stanford schools there are a wide range of interdisciplinary research opportunities that connect medical students and faculty members across the campus. This is likewise true with the Law School which, while enrolling less than a few hundred J.D. candidates, is also involved in 21 joint degree programs that reach every other School across the campus. The Law School is also a partner in research centers and projects that involve students and faculty members elsewhere in the university. In addition to the J.D. degree, the Law School offers Masters programs more oriented toward legal research and policy issues. The Graduate School of Business serves about 1,000 students in an MBA program, an M.S. in Management, a PhD program, and a part-time program focused on entrepreneurship and innovation. The School also offers a wide range of executive education programs that serve Silicon Valley as well as executives from most anywhere. A part-time program, *Stanford Ignite*, is oriented toward entrepreneurship. The School of Earth Sciences enrolls 150 undergraduates and 350 grad students, including a doctoral program. The Graduate School of Education has an enrollment of roughly 400 students at Masters and doctoral level, with a significant orientation toward leadership development in educational settings.

One of the things that characterizes the educational and research programs at Stanford is a very energetic and accepting interdisciplinary and multidisciplinary approach. Current President John Hennessy has opined and advocated that he would like to produce "T-shaped" students, with expertise in a core discipline, but extensive involvement in a broad array of disciplines, and the ability to work with others on significant problems that are not understood or solved from a narrow perspective.[1]

Stanford has been notable from its founding and struggling early years for engaging in creative and practically-oriented partnerships with business and industry. It also should be noted that California was "out there" on the Pacific Coast when Stanford was founded and many relatively adjacent areas were yet to become states. From the beginning faculty members and leadership encouraged engagement with real world issues.

Dr. Fredrick Terman, who joined the faculty in 1925 and later on served as dean of engineering and provost, was possibly the most important leader in the development of the university's role as an engine of economic growth and innovation. Terman received his undergraduate education at Stanford (where his father was a distinguished faculty member) following World War I—and went on to MIT for graduate work. While there he was the first dissertation student of Vannevar Bush, a person who was to play an important role in moving US universities into more active participation in research and technological innovation, particularly during World War II.

After MIT Terman returned to Stanford to teach electrical engineering, becoming a leader in that field. In addition, he tirelessly worked to link the university's research and education efforts to the interests of business and government. He was concerned that there be jobs in the region for Stanford graduates, as the contiguous Santa Clara valley of that era consisted of a sleepy small town in a rural region. In 1939 he encouraged students William Hewlett and David Packard to commercialize their work in audio oscillators, which led to the garage founding of what became Hewlett-Packard and some consider the birthplace of Silicon Valley.

During World War II Terman returned east to head the Radio Research Laboratory (RRL) at Harvard that focused on radar countermeasures and by the end of the war had a budget and staff larger than that of Stanford. The relevance of this to Stanford's history is that it enabled some reconnection between Terman and Bush who was playing a major role in the Manhattan Project and the general ramp-up of US R&D to support the war. It was also an opportunity for Terman to become more familiar with the robust technology partnerships with industry that MIT had been successfully forming. Vannevar Bush had also laid out a blueprint for the growth and development of America's post-war scientific enterprise in his report *Science, the Endless Frontier.*"[2] The report was commissioned by Franklin Roosevelt but implemented by President Truman when the National Science Foundation was established in 1950. It proposed an intensive effort to advance science and technology in the service of the nation's foreign policy and welfare that would include an unprecedented and significant increase in the funding of university research by the Federal government. After NSF was launched, the Federal government went on to found the many academic research funding programs that we see now.

Terman returned to Stanford after the war, and as Dean of the College of Engineering, he was determined to enhance the scope of research and industry partnering. Those aspirations were matched by J. Wallace Sterling who became President in 1948. Terman is credited with such programmatic innovations as the Research Park, the Engineering Honors Cooperative Program, and the concept of building academic "steeples of excellence," composed of clusters of nationally prominent professors and research collaborations. The policy that permitted faculty members to consult one day a week was established. Salary-splitting was introduced that encouraged faculty members to secure external funds to buy out a portion of their salary, which enabled more time spent on research and more potential faculty hiring slots. Similarly, graduate students were encouraged to work with industry partners in the area who could enable or financially sponsor their thesis or dissertation work. Industrial Associates (now Affiliates) programs were established to support faculty research via tax-deductible gifts to the University. Terman served as dean of the School of Engineering until 1955 and as provost until his retirement in 1965. No other person could more legitimately claim the title of father of Silicon Valley, and much of what followed over the next nearly 50 years at Stanford has origins in this period. These will be detailed in this chapter, but some highlights are worth noting.

For one, in the current age of now research-intensive universities, Stanford stands out. For example, as per National Science Foundation FY2011[3] data on higher education research expenditures, Stanford ranks 9th at $907.9 million, with the substantive foci concentrated in the life sciences ($555.9 million), engineering ($121.7 million), physical sciences ($97 million) and math and computer sciences ($30.9 million). However, while some have argued that Stanford is excessively focused on serving Silicon valley and the technology clusters therein, it is worth noting that the social sciences draw $22.7 million in funding, non-science and engineering fields another $39.5 million, and environmental sciences $26.1 million. It sounds like the kind of breadth that was a goal at the founding of the institution. While the bulk of research funding comes from the Federal government (72.2%) a reasonably healthy fraction comes from business (6.4%) which exceeds the national average and which may be underestimated since it is not clear how much of this percentage includes funding through affiliate relationships, corporate foundations, and the like.

Other indicators attest to Stanford's status as a first rank institution. Among its "community of scholars" there are 19 Nobel Laureates, 24 MacArthur Fellows, 3 National Humanities Medal winners, 18 National Medical of Science awardees, 152 members of the National Academy of Sciences, 95 National Academy of Engineering members, 66 members of the Institute of Medicine, 31 National Academy of Education members, 51 members of the American Philosophical Society and 4 Pulitzer Prize winners. The *U.S. News & World Report* ratings and rankings are replete with high placements by Stanford Schools and Programs, too many to list all of them but some illustrations: tied for 1st with Harvard as best Business School; 2nd in undergraduate engineering; 2nd as research-oriented college of medicine; 2nd in graduate level entrepreneurship; 3rd ranked law school; 1st in environmental engineering, and so on.

However, returning to the primary focus of this book—how, via leadership, vision and exemplary programs, universities can influence the pace of innovation—Stanford has done detailed and recent assessment of that question. This is particularly so in terms of trying to document the extent of campus impact on regional and national innovation outcomes. This is found in a 103-page project report[4] available on the Stanford College of Engineering website. The second author is William Miller, a professor emeritus of computer science and a former provost, who was there when Silicon Valley blossomed; the first author, Charles Eesley, is an Assistant Professor and Faculty Fellow in the School of Engineering.

The survey on which the report was based was sent to all living Stanford alumni for whom contact information was available, or 143,482, and the overall response rate was 19%. Surveys were also sent to 1,903 Stanford faculty members, and resulted in returns of 59.6%. Some findings:

- 29% of respondents had founded a for-profit or non-profit organization;
- 32% of alumni "described themselves" as having been at some point an investor, early employee or board member in a startup, and 25% of responding faculty attested to having founded or incorporated a firm;
- Among respondents who had become an entrepreneur in the preceding 10 years, "55 percent reported choosing to study at Stanford because of its entrepreneurial environment."

Propinquity to Stanford also seemed to play a significant role in where respondents started companies, particularly those who graduated since 1990, with 25% of that group forming their companies within 20 miles of the campus. Of all alumni-started firms 39% were within 60 miles. Estimates drawn from the data suggest that 39,900 "active companies can trace their roots to Stanford. If these companies collectively formed an independent nation, its estimated economy would be the world's 10th largest." The report also goes on to note that in addition to for-profit enterprises the Stanford experience also seems to accelerate alumni involvement in social entrepreneurship and innovative non-profit organizations.

The authors took great pains to argue that it is the total "entrepreneurial ecosystem" of Stanford and not just its strengths in engineering and the sciences. Thus students benefit from "a robust liberal arts environment that gives them the broad world view they need to be innovators and leaders of tomorrow..." In effect, it is the culture of the place.

University Culture: *Goals and Aspirations*

To a significant degree the organizational culture of Stanford today is derived from the one that began to evolve during the Sterling-Terman period after World War II and has matured ever since. After boiling down the history, current activities, notable triumphs, and marker events, this is what the chapter authors see as some of the most important elements of the culture at Stanford:

- Stanford's culture is about a *liberal, interdisciplinary and multidisciplinary mindset* approach to everything. From the founding years the expectation has been that faculty and students would be engaging the world from many perspectives, methods and premises, and would endlessly fuss over the differences. For example, the most recent major multi-year fundraising campaign ($6.2 billion), The Stanford Challenge, had as a key priority "to reduce traditional disciplinary and organizational boundaries to bring together experts from all across campus."[5] An example will be a Center on International Security and Cooperation that blends experts from political science, engineering and physics.

- Stanford is and has been for most of its history *a place that welcomed many kinds of people,* in terms of gender, beliefs, backgrounds, and wealth. After all, Stanford had women students from day one while many of its elite brethren on the East Coast would debate that prospect for another 60 or 70 years. While perhaps too much has been made of it, the early Stanford was only a few decades removed from gold-seeking rascals and the nearest city rife with madames, hookers, and hustlers.

- Stanford is *engaged concurrently in the world of scholarship and the world of business and community*. This is reflected in the mindsets of many of its key leaders, as well is in the changes that they have wrought in various academic programs and outreach functions. Illustratively, it was an early adopter of practices and policies that were used to commercialize faculty inventions in Silicon Valley and throughout the world. In effect, Stanford and a few other universities—several in this volume—invented university technology transfer.

- Stanford, because of fate and leadership, has also been *an early leader in fostering entrepreneurship as both a field of instruction and a set of activities* pursued by the entire University community. It is part of the culture; it is also enabled and enhanced by the interdisciplinary mindset of the campus.

Leadership

The university's leadership has built a significant portion of Stanford's unique culture, both past and present. What sets these leaders apart is a tradition of leading by example. Stanford's current president John L. Hennessy, now into his second decade in office, brings to the table a background not only in academics but also in technological innovation and entrepreneurship. Dr. Hennessy received his bachelor's degree in electrical engineering from Villanova University before moving on to earn his master's degree and doctorate in computer science from the State University of New York at Stony Brook. He arrived at Stanford as an assistant professor of electrical engineering in 1977 and reached the rank of full professor in 1986. Dr. Hennessy also rose through the leadership ranks to serve as chair of Stanford's computer science department from 1994 to 1996 and then as dean of the School of Engineering beginning in 1996. From dean he progressed to Provost in 1999 before his appointment as Stanford's tenth president in October 2000.[6]

Much of Hennessy's academic work has been in the area of computer architecture design. In addition to co-authoring two textbooks on the subject, he has performed research on a revolutionary piece of computer technology, reduced instruction set computer (RISC) architecture, designed to increase processor efficiency. Based on this research, President Hennessy co-founded MIPS Computer Systems in 1984, a designer of microprocessors. The company sold for $333 million in 1992 to Silicon Graphics. President Hennessy also co-founded a semiconductor company in 1998, Atheros Communications, which was bought in 2011 by Qualcomm for $3.1 billion.

Keeping with the Stanford tradition of faculty engagement with real problems in both public and private sectors, President Hennessy sits on the board of directors of both Cisco and Google. He argues that companies such as these face a similar challenge to that of a university: "How do they maintain a sense of innovation, of a willingness to do new things?"[7] President Hennessy's experience in the startup world has furthered his ability to lead a university with a culture so rich in innovation. This real world experience has first and foremost led to a greater understanding of organizational change and development: "For large organizations, change is a very hard thing. So you can learn in a smaller company how to deal with that kind of change." Working with Silicon Valley companies has also taught the president how to recruit and retain a talented university faculty as well as budget management.[8]

President Hennessy's leadership has certainly provided him with a significant budget to manage. The president serves on Stanford's endowment board, and from 2000 to 2012, Stanford's endowment grew to nearly seventeen billion dollars. Stanford arguably benefits from Dr. Hennessy's Silicon Valley ties in the form of gifts, donations, and fundraising help from Stanford alumni and local companies.[9] President Hennessy has also demonstrated his own abilities as a gifted fundraiser through The Stanford Challenge, a successful five-year program that raised $6.2 billion for the university from 2006 to 2011. The funds from this program encouraged interdisciplinary and collaborative interactions among students and faculty through fellowships, research grants, scholarships, and campus renovations.[10]

At this point let us turn the calendar back to continue the Terman- Sterling story that we began a few pages back. To stretch a metaphor, the Sterling-Terman era and the Hennessy administration, can be understood as the most visible bookends of a line of leadership that has fostered the Stanford culture and institutional accomplishments. It would be fair to say that Wallace Sterling and Fredrick Terman were significantly responsible for launching the entrepreneurial culture, now so prevalent at Stanford, that President Hennessy and others have expanded to the university's benefit. Inaugurated as Stanford's fifth president in 1949, Sterling went on to serve the university for almost twenty years, until 1968. For many of those years Sterling and Terman overlapped one another with Terman serving as Dean of Engineering from 1946 to 1955, and then as Sterling's Provost and Vice President during a solid decade of major culture-changing and institution-building accomplishments.

Sterling entered into the presidency with the university facing financial difficulties still left over from World War II and before. The university's endowment was struggling and faculty salaries also felt the pain of the university's financial condition.[11] During his time as president, Sterling addressed the issue of money through the fundraising of millions in gifts and bequests. Sterling also significantly improved the graduate program as well as the student-professor ratio and pushed Stanford towards a reputation as a world-renowned university, including the establishment of many branches overseas.[12] Richard Lyman, Stanford's seventh president, credits the university's "phenomenal rise in the later 1950s and 1960s" to the ability of Terman and Sterling to work together. One of the greatest accomplishments resulting from this partnership was the establishment of the Stanford Industrial Park, now known as the Stanford Research Park.

Between 1970 and the onset of the Hennessy administration, Stanford presidential leadership was more visibly preoccupied with issues somewhat distant from technological innovation. The Richard Lyman presidency (1970-1980) was successful in completing a $300 million Campaign for Stanford, then the largest fundraising effort in the university community. However, much of the campus was preoccupied with the national political turmoil over the Vietnam War, which accelerated during his decade as president. Lyman was dedicated to maintaining order while strongly supporting peaceful dialog about the war and civil rights issues. Peter Bing, a Trustee in that period, described Lyman's role as a "hero in an era when very little was heroic." Sensitive to ethnic slights, he banned Stanford's use of the Indian as a team symbolic mascot, earning the scorn of many alumni. Despite these distractions, Stanford was still growing in prominence as a center of research and innovation. As discussed below, it was during the Lyman era that the Stanford Office of Technology Licensing was formed, having increasing successes in patenting and licensing. This included the Cohen-Boyer technology deal late in the decade, which not only resulted in handsome financial returns to the inventors and the universities, but also helped to accelerate the growth of biomedical industry in Silicon Valley. Unfortunately, after these successes the wheels came partly off as a function of an indirect cost controversy with the Federal government during the Donald Kennedy presidency (1980-1990).

After Kennedy stepped down, the less exciting but heartening administration of Gerhard Casper (1992-2000) ensued. Casper was an international legal scholar, and his leadership was characterized by steady growth in Stanford's reputation, innovations in instruction, and the founding of several centers and programs that reached national prominence. Caspar also addressed issues of student financial support, including the creation of a Graduate Fellowship program. A program of small group studies, Stanford Introductory Studies, was launched for students during their first years at Stanford. Part of Caspar's mission, which he clearly accomplished, was to maintain Stanford's burgeoning relationship with the technological colossus of Silicon Valley, but also maintain and enhance Stanford's presence and programs in the humanities and undergraduate teaching. President Caspar was an excellent and popular leader who fixed many problems and continued to build the reputation of Stanford.

Boundary Spanning: *Entrepreneurship*

Given the pervasive culture and practice of entrepreneurship on the Stanford campus and in the contiguous Silicon Valley, it should not be surprising that both curricular and co-curricular programs in entrepreneurship are well represented on campus. Interestingly, Stanford does not have formal undergraduate or graduate degree programs in entrepreneurship. Instead, Stanford excels in an informal ubiquitous approach that offers a number of experiential courses, networking events, and other opportunities around the theme of entrepreneurship. Many of these are also available in executive education programs and via online communication offerings. Most prominent is the Stanford Technology Ventures Program

(STVP), which is located in the department of Management Science & Technology in the School of Engineering. However, STVP is visible and accessible campus wide. Moreover, many of its activities are available to students, faculty and entrepreneurship programs everywhere.

Curricular Programs

STVP offers roughly thirty courses that range from introductory to graduate level, with many being delivered multiple times over the academic year. Engineering faculty provide instructional leadership to most of the courses but there is also extensive involvement of venture founders and investors from the contiguous Silicon Valley community. The courses are also balanced between undergraduate and graduate levels. A few are particularly tailored to PhD-level students. For example, one seminar is built around presentations from entrepreneurial thought leaders, drawing heavily on Silicon Valley connections. The course is sponsored by an internationally prominent venture capital firm, and the connectivity to material and participants is fairly profound. The thought leaders' seminar is also open to the public.

In addition to these more widely available courses, STVP offers on a very competitive basis the Mayfield Fellow Program (MFP). Admission to the program is determined during winter quarter, via application documents as well as in-person interviews with faculty members and industry mentors. Fellows are chosen by March, and start the program during the spring quarter. Summer employment consists of a paid placement at a start-up company pre-screened by the program directors. In fall quarter students take a required "debriefing" course. Mentors consist of individuals with significant operating and/or investment experience in a startup.

One of the more interesting information utilities that is enabled by STVP is ECorner (http://ecorner.stanford.edu), an online compilation of thousands of free videos and podcasts available to anyone. There are thousands of plays per day and millions over the years. All of the materials have to do with entrepreneurship and the topics include: Creativity and Innovation; Opportunity Recognition; Product Development; Marketing and Sales; Finance and Venture Capital; Leadership and Adversity; Team and Culture; Globalization; Social Entrepreneurship; and Careers/Life Balance. Most of the presenters are experienced and active entrepreneurs, and the material is presented in a fairly lively manner. There are relatively fewer presentations by university professors or administrators (unless your President is a successful serial entrepreneur, like John Hennessy).

Co-Curricular Programs

The Stanford Entrepreneurship Network (https://sen.stanford.edu/members) is run by STVP, and is a good place to start in order to link to dozens of entrepreneurship activities elsewhere in the university. For example, the Graduate School of Business has a number of organized activities that include a Center for Entrepreneurial Studies that enables students and faculty to get further networked within the College, as does the Graduate School of Business Entrepreneurship Club, which has been around for decades and boasts a rich menu of talks, presentations and events. So too does the Center for Social Innovation, with a little different substantive tilt. Another high point for the Stanford Entrepreneurship Network is Entrepreneurship Week, held during winter quarter. Dozens of events—lectures, panel discussions, hands-on engagements—draw in hundreds of participants.

Outside of the GSB and School of Engineering there are other entrepreneurship-oriented organizations that have multidisciplinary orientations. The Hasso Plattner Institute of Design at Stanford (d.school), which is discussed in more detail below, is a center which bridges design thinking and entrepreneurship. Of note, Tina Seelig,[13] Executive Director of the STVP, is one of the key instructional leaders in the d.school. She is also Director of the Center for Engineering Pathways to Innovation (Epicenter) an NSF-supported initiative to improve engineering education by inserting more innovation and entrepreneurial content therein. Recently the Stanford Law School announced a new senior faculty appointment to also head the Juelsgaard Intellectual Property and Innovation Clinic, a new component of the Mills Legal Clinic. The Juelsgaard Clinic will work with law students on complex issues in how the law can "promote (or frustrate) the inventiveness, creativity, and entrepreneurship that provide the real engine for economic growth." The Graduate School of Business and the School of Engineering offer a joint two-quarter course entitled Entrepreneurship Design for Extreme Affordability.

Boundary Spanning: *University, Industry and Community*

Given the generally accepted notion that Stanford was a major "inventor of Silicon Valley," along with the many examples of Stanford leadership being deeply involved in the contiguous region, this boundary-spanning section will be somewhat delimited compared to other cases in this volume. The boundary-spanning episodes involving Stanford over the last few decades could fill a multi-volume work. In the following pages we will describe a few illustrative examples, historical and contemporary.

Stanford Research Park. An important benefit of having available land since Stanford's founding was the ability to create facilities-based programs that reinforced and expanded the university's aspirations and culture. One important example was the contiguous research park[14] implemented in the 1950s. The idea of a park setting for industry partners developed when Varian Associates, an early technology spin-off company, approached the university with a proposal to build its facility on leased university land in order to be adjacent to the intellectual resources of the institution. Plans were already afoot to build the Stanford Shopping Center as an income-producing investment. Dr. Fredrick Terman, who was then dean of the School of Engineering and a supporter of the Varian brothers' venture, built on this proposal with a concept that companies with technological interests complementary to Stanford would also be interested in locating near the university. Since the founding charter specified that these lands could not be sold, the concept of long-term leases to partner companies and other entities became the vehicle of choice. The Master Plan of 1953 specified most partnership objectives, expectations and procedures. Industry tenants would be technology-focused, preferably with some link to Stanford programs and curriculum. Land leases were to be signed for a maximum of 99 years, and tenants were restricted by various regulations (limited building heights, facilities would occupy only a fraction of the leased parcel, mandatory setbacks of construction, parking not visible from the street, etc.).

Subsequently, the university planned and developed a 700-acre park, known first as the Stanford Industrial Park, then later as the Stanford

Research Park. Recalling the original vision of the Stanford land grant, companies could not buy building sites but could get long-term leases. Early occupants, in addition to Varian, included Hewlett-Packard (whose world-wide headquarters are still in the park), Eastman Kodak, Beckman Instruments, Syntex Pharmaceuticals, and Xerox Corporation. The original park, although modest by today's standards, served as a prototype for later ventures such as North Carolina's Research Triangle Park and became a *de facto* incubator for science-based technology innovation in Silicon Valley. In addition to being a national model for a research park, it led to a number of Stanford programmatic innovations that had linkages to Park tenants as well as to other companies in Silicon Valley. These include the Industrial Affiliates Programs and the Honors Cooperative Program.

Industrial Affiliates Programs. As the Stanford Research Park blossomed, along with the meteoric growth of Silicon Valley, many companies wanted a closer relationship with Stanford-based research programs and activities. There are currently over 50 Affiliate Programs in operation, with opportunities for companies to link with academic teaching departments, centers, forums or institutes. For an annual fee that ranges considerably, companies support research, attend meetings and events, and receive copies of reports (including preprints yet to be published) and program-related publications. Nonetheless, this access is not privileged, as presentations and reports are routinely made available to other interested parties. One additional and very positive feature of the Affiliates relationship is the opportunity to interact with students who might be potential hires. The financial support that companies provide typically is tied to a multi-project program of research, rather than particular projects. Affiliate program contributions are treated as gifts by Stanford, and are subject to a modest (8%) indirect cost fee. (Stanford also encourages sponsored projects in which a company negotiates a particular project, pays full direct and indirect costs, but has options to license inventions deriving from the work.) Over the years hundreds of companies have participated in Affiliate Programs, with the relationships having positive benefits for company and university alike.

Honors Cooperative Program (HCP). Given the significant degree of substantive commonality between Stanford and the companies that have populated Silicon Valley and the technology industry more generally, it is not surprising that creative vehicles for educational partnerships have blossomed at Stanford. The HCP is the most prominent partnership, with 175 participating companies. Graduate course work is offered primarily via instructional television by the Stanford Center for Professional Development. Each academic quarter approximately 70 graduate courses are offered, with electrical engineering accounting for a plurality. Some courses are offered on campus as well. Individuals study for the MS degree as well as Graduate and Professional Certificates. In any given quarter, enrollment is well into the hundreds. Tuition is typically paid by companies that are members of the HCP, and students can only enroll if they are working for an HCP member company. Annually, several thousand individuals take at least one class through the HCP.

Centers and Institutes. In most research-intensive universities the "center" or its equivalent has become the venue in which interdisciplinary and multidisciplinary research and education takes place. As the other cases in this volume have illustrated the center/institute organization has also often been the place where technological innovation takes place. Not all centers or institutes are focused on technological issues; many are wrestling with important epistemological and substantive issues in the humanities, the arts, and the social and behavioral sciences. Some centers or institutes are heavily facilities-based, where significant investments have been made in state-of-the-art instrumentation made available to a range of users.

There are approximately 100 Research Centers at Stanford. They are not evenly distributed across the colleges and schools, and some centers have participation from departments and schools across the university. This is a good sign from the perspective of interdisciplinary and multidisciplinary richness. In addition there are some centers, labs or institutes that have particular relevance for this project, in that they are tied more directly to innovation, technological or otherwise. One is the Hasso-Plattner Institute of Design. While organizationally located in the School of Engineering, the d.school, as it is fondly known, brings "design thinking" to courses that are available to students from across the University. In their self-description:

> *The d.school does not grant degrees; instead it serves as a university-wide hub for innovation where students from engineering, the arts, medicine, education, law and the social sciences come to take classes together and work on projects.*

The d.school draws heavily from the intellectual tradition of IDEO, a Palo Alto-based, and Stanford-linked, design firm. David Kelley founded IDEO and now heads the d.school. While the intellectual traditions of the d.school are centered on design thinking, the method is distinctly action-oriented. Again, from the self-description:

> *At the d.school, we learn by doing..... Our bias is toward action, followed by reflection on personal discoveries about process. Experience is measured by iteration: students run through as many cycles as they possibly can on any project.*[15]

The most formidable cohort of centers and institutes at Stanford are the provost-approved Independent Laboratories, Centers and Institutes, of which there are now 17. This initiative was launched in 1982, with significant leadership by then-provost Al Hasdorf. The key organizing features of this program are the explicit and strong emphasis on interdisciplinary research and the strong emphasis on "finding solutions" to big problems. As has been noted throughout this volume the nature of technological innovation is often found in work that cuts across substantive and methodological boundaries, a point of view that has been part of the Stanford culture since its founding.

Below are listed a sample of the provost-approved programs that clearly exemplify interdisciplinary problem-solving.

- *The Ginzton Laboratory.* This lab works in three intersections of science and engineering fields: quantum science and engineering, photonic science and engineering, and nanoscience and engineering. It explores applications in areas such as sensing, communication, biology and medicine, energy, and environment. The lab has a 50 year history at Stanford, but recently occupied new laboratory facilities in the Spiker Engineering and Applied Science building, in the Science and Engineering quad.

Faculty members and students associated with the Ginzton Lab are primarily drawn from Electrical Engineering or applied Physics.

- *The Stanford Woods Institute for the Environment.* This is arguably Stanford's primary locus for interdisciplinary research concerning environmental sustainability issues. Affiliated fellows and faculty members are drawn from all of Stanford's seven schools, and comprise roughly 10 percent of faculty and research professionals. The Institute was formed in 2004 and its vision is to "create a healthier environment now and richer possibilities for generations to come." The research program is organized into the following Centers, Programs, or Projects: Center for Ocean Solutions; Center on Food Security and the Environment; Global Freshwater Initiative; Natural Capital Project; OSA and Golfito Initiative; Water, Health and Development; and Water in the West.

- *Stanford Bio-X.* Located primarily in the James H. Clark Center, Stanford Bio-X pursues a broad spectrum of research activities associated with human health and disease. It draws faculty (over 500 to date from 60 departments) and graduate student participation from across the university, although principally in the biosciences, medicine, engineering, and computational sciences. Its Interdisciplinary Initiative Program (IIP) funds collaborative research projects (about $150,000 and 2-3 years in duration) that are so "forward-looking it may not work," but which might yield huge benefits. The Bio-X Stanford Interdisciplinary Graduate Fellowships (SIGF) supports dissertation projects that have the potential for significant benefit and which often also cut across disciplines. The Bio-X Corporate Forum provides a vehicle for companies to participate.

- *Spectrum.* This is a center within Stanford that supports and enables translational research that moves basic science findings into practical solutions to improve human health. Spectrum is significantly supported via a Clinical and Translational Science Award (CTSA) award from NIH. In addition, Stanford researchers also utilize the facilities and staff of the Jill and John Freidenrich Center for Translational Research, which is located adjacent to the Stanford Hospitals. The facility includes patient bays, a sample selection lab, pediatric study rooms, remote observation facilities, and various other data collection capacities. Spectrum is led by a multidisciplinary team of faculty and technical staff.

- *Precourt Institute for Energy.* Since 2009 the Institute has served as a hub and organizing entity for energy-related research and education at Stanford. As an Institute, it coordinates with over 22 academic departments, two dozen centers and institutes, and over 200 faculty and staff. A smaller group of 24 Stanford faculty members serve as Precourt Institute Fellows, who help the organization identify new directions and build connectivity within the University. The Institute also operates a seed grant, proof-of-concept program for faculty researchers, as well as various activities designed to facilitate connections and research partnering across disciplines. These include a weekly Energy Seminar program, a Stanford Energy Newsletter, and an annual one-week Energy Conference. It also supports the Stanford Energy Club that involves upwards of 600 students, researchers, and local energy professionals.

SLAC-Stanford's DOE Partnership. In a manner not unlike Cal Tech's Jet Propulsion Lab, Stanford has benefitted from a 50-year working relationship with a Federal agency through a university-based state of the art facility. The partnership was enabled by Stanford's land holdings as well as the leadership of the university when this all came to pass in 1962. Now known as SLAC National Accelerator Laboratory, the facility occupies 430 acres of Stanford land, west of the main campus. It is one of the U.S Department of Energy's 10 national laboratories and is operated by Stanford, under contract with the DOE. Approximately 1500 full time employees work at SLAC, and the laboratory is structurally a department of Stanford. Annually, a large number of researchers from other universities and other federal facilities spend weeks or months working at the facility. On three occasions individuals associated with SLAC have become Nobel prize-winners in Physics, based on work conducted there. Building and operating the world's longest particle accelerator was the original impetus for the laboratory, but over the years a number of ancillary facilities and capacities have been added. These included its X-ray free-electron laser, the Stanford Positron Electron Asymmetric Ring (SPEAR), the Linac Coherent Light Source (LCLS), and FACET, a test bed for accelerator technologies. Recently, Stanford and DOE have agreed to extend the lease and operating agreement another 33 years. The intellectual foci of the research conducted here will ensure that Stanford will play a significant partnership role in energy solutions that will affect the planet. Moreover, the terms of this recent lease allow that further extensions can be crafted as "mutually beneficial" to Stanford and the Department of Energy.

An Almost Community Partnership: StanfordNYC. Stanford recently engaged in a bold venture to develop a partnership with New York City and establish a presence on the East Coast. In early 2011, the university submitted an expression of interest to the city of New York to compete with other universities for the chance to build a graduate school of applied sciences and engineering. Stanford's final proposal in October of 2011 discussed a $2.5 billion, 1.9 million square-foot campus on Roosevelt Island that would provide an opportunity for over 2,000 graduate students and 200 faculty members. "StanfordNYC" planned to offer graduate degree programs in engineering, applied sciences, technology and business.[16] The New York campus would enjoy significant ties with Palo Alto through videoconferencing for faculty members, as well as online classes for students and connections to Silicon Valley venture capitalists for startup companies. In addition, Stanford would partner with the City University of New York and the City College of New York to create an undergraduate degree program for city students and establish a presence in New York before the completion of the campus on Roosevelt Island.

However, on December 16, 2011, Stanford unexpectedly announced the withdrawal of its bid, soon after which Cornell University and its partner, the Technion-Israel Institute of Technology, were selected to build the NYC campus. President John Hennessy stated in a press release that Stanford and the city of New York "could not find a way to realize [their] mutual goals." Stanford's administration ultimately determined that the risks and costs to build a campus aligned with the demands of the city outweighed the benefits for the university.

Despite the failed negotiations, the university claims that the $3 million it spent throughout the proposal and negotiation process was well worth the investment. The StanfordNYC team declared in a press release that Stanford "received tremendously positive visibility" on the East Coast and maintained its "reputation for exploring bold ideas."[17] Stanford believes it has stayed true to its founding principles through this venture. Alyson Yamada, president of Stanford Women in Engineering, agreed in her statement to the Stanford Daily, "Stanford teaches its students to be entrepreneurial like that...practice what you preach, right?"[18]

Stanford@CCNY. Stanford is persistent. It is still pursuing a "boundary-spanning" presence on the East Coast through community partnerships in NYC despite the fact that StanfordNYC will no longer become reality. In a University press release following Stanford's withdrawal from the competition, Stanford officials announced that the partnership with CUNY and CCNY that was part of the StanfordNYC proposal, "will absolutely continue." The strengths of both universities are aligned, as President Hennessy declared that CUNY and CCNY "share [Stanford's] commitment to innovation and technology commercialization."[19] Although not directly related to the proposal for the Roosevelt Island location, Stanford@CCNY originally would have provided space for faculty and classes prior to building StanfordNYC. In addition, highly qualified CCNY students would have the opportunity to participate in joint CCNY-Stanford B.A./M.A. and B.S./M.S. degree programs.

Without Stanford's physical presence in NYC, this degree program will need to be reworked. Although CCNY students will no longer be able to pursue a Stanford master's degree in New York, Stanford and CCNY intend to move forward with the joint development of undergraduate curriculum in entrepreneurship and technology. In addition, Stanford faculty will be available to advise CCNY students in marketing technological innovations. Juniors, seniors and recent graduates from New York will also have the opportunity to participate in the Stanford Research Experience for Undergraduates Program as well as attend the Summer Institute for General Management through the Stanford Graduate School of Business.

Stanford and CCNY believe students and faculty from both locations will reap the benefits of the partnership through more research opportunities and a chance to bring Silicon Valley to the East Coast.[20] The partnership also provides a chance for both universities to contribute to the New York economy and to cultivate technological innovation and entrepreneurship in New York City.

Boundary Spanning: *Technology Transfer*

Stanford was both an innovator in and an early adopter of the practice[21] of technology transfer in a university setting. Stanford's efforts in this area were initially led by Niels Reimers in the late 1960s, which really anticipated the passage of Public Law 96-517, the Bayh-Dole Act. Reimers was an Associate Director of the Sponsored Projects Office, but had industrial experience in technology areas. Heretofore invention licensing at Stanford had been farmed out to an external contractor, with little visibility, less activity, and not much success. In addition, this was the era in which inventions developed under Federal research funding would nominally be controlled by the involved government agency, and very little was successfully commercialized. In addition, during this period most universities questioned whether it was appropriate to get involved in technology transfer, as it came to be known. Prior to 1969 only a few institutions were involved in technology transfer: Iowa State, MIT, Kansas State, the University of Minnesota and Wisconsin (e.g., WARF).

After surveying university policies and practice around the country, Reimers proposed (and the Stanford administration approved) the creation of an Office of Technology Licensing (OTL). The office was officially launched on January 1, 1970, with Reimers as the sole professional staff person and Director plus one assistant, and a modest budget. This was 10 years before Bayh-Dole, but the office in that year received 70 invention disclosures, licensed 3 inventions, and was beginning to realize royalty income ($50K). It was not until 1975 when a permanent licensing associate was added to the staff. Nonetheless, some early accomplishments paid off handsomely later on. One 1971 invention disclosure concerned computer-based sound synthesis, with a particularly novel application in music. In 1974 a demonstration to Yamaha led to an eventual license and later on to $23 million in royalties.

Things picked up around 1979-1980. One important chapter involved the recombinant DNA research led by Stanley Cohen of Stanford and Herbert Boyer of UC Berkeley; the second was the passage of Bayh-Dole which gave universities the rights to inventions produced from federally sponsored research with the proviso that faculty inventors would receive a share of licensing revenues. Federal funding agencies were also given a royalty-free license and "marching in" rights—both of which did not prove to be a big disincentive. Stanford was already advantaged by 10 years of experience in working with its growing cadre of inventors, and was moving forward on the Cohen-Boyer patent commercialization. The latter commercialization strategy ended up being a non-exclusive licensing offer from the OTL with a 12-15-81 deadline, which resulted in 73 companies signing agreements and two positive outcomes: it contributed to the launching of a major worldwide industry; and it put the OTL on the map both on the campus and nationally.[22]

Since then the Stanford OTL has had over 40 years of growing success. As of 2010 there had been 8,000 inventions and $1.3 billion of royalty income. It has a staffing ratio that is rich when benchmarked nationally (e.g., professionals per unit of research funding). OTL staff typically bring advanced science and technology degrees as well as intellectual property and industry experience. The office had a staff of 40 as of early 2013. Most deals end up as royalty-based license agreements, but the office will participate as an equity partner as appropriate. Google was an example, and Stanford's equity cash return was $335 million, which far exceeded the norm.

Stanford, like most of the cases in this volume, has superior "batting averages" for its technology transfer office. For example technology transfer outcomes in a university are complex indices that are a function of culture at both the institutional and unit level, as well as the quality and promptness of technology transfer practices and reasonable policies. However, one can compute "batting averages" of things such as disclosures. For example if one divides total research expenditures in millions by number of invention disclosures or patents, there are huge differences across universities. The former index for Stanford for FY2012[23] is 1.7, or for every $1.7 million of research an invention disclosure results. For most universities that number is much higher. Another metric is number of licenses, and Stanford reported 137 licenses and options executed in FY2012.

Royalties from licensing deals are designed to maintain and enhance the science assets that led to the invention and to maintain OTL operations. Thus 15% of gross royalties are dedicated to the Office of Technology Licensing and the net is distributed equally to the inventor, the inventor's school, and the inventor's department. The expectation is that this formula will incentivize schools and departments to be strong supporters of technology transfer, which appears to be the case at Stanford.

The university has also successfully developed a number of policy and practice innovations that have extended benefits to the university and to OTL licensees. The *President's Venture Fund* makes equity investments in early stage companies that have licensed Stanford technologies. The ability to do so is stipulated in the license agreement, and these investments are made prior to an acquisition or an IPO. As of early 2011 over $21 million had been invested in 28 companies, with investments ranging from $600,000 to $5 million.

The Stanford OTL has also been effective in the promulgation of very well-written "guides" for members of the university community. One, the 44-page *Inventors Guide*,[24] was adapted from one produced by the University of Michigan and written by Ken Nisbet. A second, *Start-Up Guide*,[25] was recently developed, largely because of the very large interest among members of the Stanford community in starting technology-based companies, as well as the significant curricular and co-curricular activities at Stanford focused on entrepreneurship. Recently available, it draws on information (with permission) that MIT developed into *An MIT Inventor's Guide to Startups: For Faculty and Students.* The OTL has been active for many years in licensing to startups although the financial returns from those deals via equity participation therein has been exceeded by returns from straight licensing royalties. The recent very large exception was of course Google.

The Stanford OTL also operates a separate LLC to work with nonprofit organizations that have developed intellectual property, but have neither the wherewithal nor the assets to license it or otherwise commercialize. Stanford OTL-LLC performs that function on a limited basis.

As one of the more distinguished and long-lived technology transfer offices in the US, the OTL also takes it upon itself to document and opine on policy and practice issues in the field. The leadership and staff of the office has been very active in the Association of University Technology Managers (AUTM) and OTL staff members publish in the practice and research literature on technology transfer. Perhaps the most compelling written product of the office is the series of Annual Reports that are available on the OTL website.[26] While most readers think about annual reports with a big yawn, these are way different. They are written with almost lyrical prose, accompanied by compelling graphics and each tells a different story. While the annual statistics are there, every issue focuses on a theme that illustrates an important goal and accomplishment of OTL but also of Stanford. For example, the 2010-2011 report is titled *Entreprenurture*; the 2008-2009 report addresses *What is value?* and drills down into the dollars and cents, but also the relationships; the 2002-2003 report focuses on *Imagine the World* in terms of "discoveries that will change the world." These reports are commenting on the ebb and flow of Stanford research and innovation, but also contributing more generally to the enabling culture of the institution.

Other writings are available on the OTL website as well as in the larger literature, that discuss issues about the practice of university technology transfer. The late Jon Sandelin, a staff member since 1984 (along with the current OTL Director, Katharine Ku) continued his contributions after retirement as a Senior Associate Emeritus and produced a number of very readable analyses that range from a history of the Stanford Research Park, a history of technology transfer in the US, and a thoughtful piece about the role of technology transfer offices in new business formation. In sum the OTL's influence has been both local and national in scope, and continues to be.

Summary and Parting Comments

The Stanford story is an enlightening narrative of how a mostly regional, good but not yet great, university transformed itself into one of the classic examples of university-linked innovation and entrepreneurship. Of course the "Stanford story" is also the Silicon Valley story, as they are hopelessly intertwined. Furthermore it is a case in which early on the outcomes to be achieved decades later were heavily contingent on certain leaders being in place in the 1950s, and in the critical decades thereafter . Would Stanford today be what it has become if Fred Terman had stayed on the East Coast after peace broke out? But similarly, could Terman have been Terman without Wallace Sterling and Vannevar Bush? And what if the development of the Stanford lands had stopped with a great shopping center, some student housing, and a handful of administrative buildings in 1955?

Nonetheless, those people were in place, smart decisions were made, and the rest is history. Of course, the history keeps reliving and renewing itself. Stanford might not be what it is now without the administration of John Hennessy, or a number of other key events and people.

It will be recalled from the introduction to this volume that a premise of our analysis is that university leaders can learn from the fortunate, lucky, or wise decisions that others in comparable positions have made. In summary, the Stanford story is not about a formal, deliberate approach—buttressed by carefully wrought mission and vision statements. Rather it is a story of timing, leadership, and the triumph of a robust entrepreneurial culture.

Endnotes

[1] Auletta, K. (2012, April 30). Get Rich U. *New Yorker*. It both praises and questions Stanford's role *vis-à-vis* Silicon Valley.

[2] Mazuzan, G. (1994, July 15). *The National Science Foundation: A Brief History*. National Science Foundation. NSF 88-16.

[3] National Science Foundation, National Center for Science and Engineering Statistics, FY2011. *Table 14. Higher education R&D expenditures, ranked by all R&D expenditures, by source of funds: FY2011. Table 15. Higher education R&D expenditures, ranked by all R&D expenditures, by R&D field: FY2011.*

[4] Easley, C. E. and Miller, W. F. (2012). *Impact: Stanford University's Economic Impact via Innovation & Entrepreneurship.* Stanford University School of Engineering. Retrieved from http://engineering.stanford.edu/about

[5] *Stanford Report.* (2012, February 8). Stanford concludes transformative campaign. Retrieved from

http://news.stanford.edu/news/2012/february/stanford-challenge-concludes-020812.html

[6] For Dr. John Hennessy's full biography, visit Stanford's Office of the President page at http://www.stanford.edu/dept/president/biography/

[7] Aulett, K. Get Rich U, op. cit.

[8] For more on how Hennessy's involvement in Silicon Valley has influenced his time as president, see Banerjee, D. (2011, January 10). Atheros Deal Highlights Hennessy's Role in Silicon Valley. *Stanford Daily.*

[9] Hechinger, J. & Buckman, R. (2007, February 24). The golden touch of Stanford's president. *Wall Street Journal.* This article includes detailed information regarding the president's activities and their financial benefits for Stanford.

[10] For more information on the Stanford Challenge, see http://thestanfordchallenge.stanford.edu

[11] Lyman, Richard W. (2009). *Stanford in Turmoil: Campus Unrest, 1966-1972.* Redwood City, CA: Stanford University Press.

[12] For a more detailed account of Dr. Sterling's life, see Malnic, E. (1985, July 3). Stanford's J. Wallace Sterling dies: widely honored educator headed university for 19 Years. *Los Angeles Times.*

[13] Dr. Seelig is also author of two recent very readable books that are targeted for young people and students generally trying to figure out what they might do in school and life: Seelig, T. (2009). *What I Wish I Knew When I Was 20.* New York City: Harper Collins; Seelig, T. (2012). *InGenius: A Crash Course On Creativity.* New York City: Harper Collins.

[14] Sandelin, J. (2004). The Story of the Stanford Industrial/Research Park. Paper presented for International Forum of University Science Parks, China.

[15] Stanford University Institute of Design, (2013). Retrieved from http://dschool.stanford.edu/our-point-of-view/

[16] Galagher, B. (2011, October 27). Stanford Submits Final NYC Proposal. *Stanford Daily.*

[17] *Stanford Report.* (2011, December 27). Stanford Team Answers Questions About NYC Proposal, Process and Withdrawal.

[18] Chen, C. (2012, February 3). NYC bid informs future, admins say. *Stanford Daily.*

[19] *Stanford Report.* (2011, October 11). Stanford Teams Up with The City University of New York and The City College of New York in a New Engineering and Science Collaboration in NYC.

[20] Zaw, C. (2012, January 10). CCNY Partnership will "absolutely continue." *Stanford Daily.*

[21] Many will recognize the voice of the late Everett Rogers whose classic *The Diffusion of Innovations,* 5th Edition, has informed much of what happens in the technology transfer business.

[22] For a brief summary of the historically important roles played by Reimers and OTL in Cohen-Boyer, see Bera, R. K. (2009). The story of the Cohen-Boyer Patents. *Current Science,* Vol. 96, No. 6, 26, 760-763.

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[26] See http://otl.stanford.edu/about/resources/about_res_archives.html

University of Utah*

The precursor to what is now the University of Utah, and the flagship public institution in the state of Utah, was founded in 1850 as the University of Deseret, in the then proposed State of Deseret. What became the state of Utah 50 years later was only a part of the vast, largely unsettled Mormon claim that encompassed parts of what are now several western states. A petition to become a state, under that name and at that time with those territorial aspirations, was rejected by the US Congress, along with many petitions that followed. This led to several decades of political and sometimes military conflict, mostly focused on Mormon religious practices. Utah finally became a state in 1896 with all traces of polygamy and other religious/political obstacles out of the way.

In the meantime, the fortunes of the University of Deseret waxed and waned. Three years after its 1850 founding in what was to become Salt Lake City, the school closed, opened again on an intermittent schedule, and then was reestablished in 1867. It was finally re-named as the University of Utah in 1892, a few years before President Cleveland proclaimed Utah a state. Land was acquired on the east end of Salt Lake Valley, and the university set down roots there in 1900. Enrollment growth was encouraging in the early years of the new century, with some ups and downs. Of these, most notable was a "speakers controversy" in which several faculty members were dismissed after an apparently politically incorrect speech after the 1915 commencement, which in turn led to a third of the faculty resigning in protest. Some attributed this event to the ongoing adjustment issues of a public university in the midst of a very religious state. Operations were also temporarily interrupted during World War I, and later on during the depression. In a pattern similar to many universities in this volume, enrollment reached its nadir during World War II, with 3,418 students in 1945. Also, like most other universities in that period, enrollment climbed rapidly during the decades after the war, reaching 12,000 in the mid sixties. The GI Bill was a major factor in changing the age and experience mix of the student body. As the university expanded into a research-intensive institution, and Utah became a more technology-intensive state, enrollment climbed.

In a pattern similar to a number of public universities the University of Utah ("U of U") transformed itself into an institution that is in the first rank among its peer institutions. Total enrollment in Autumn 2012 was 32,388, which included 7,548 graduate students. Of the total, 83% were Utah residents. The 15 colleges awarded 7,444 degrees in 2011-2012, including 1,342 bachelors in Social and Behavioral Sciences, 925 in the Humanities, 686 bachelors in Business (plus

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482 MBAs), 444 in Health, 442 BS in Engineering (plus 202 MS and 77 PhDs), and 332 BS degrees in Science. The the highest number of doctoral degrees awarded by college were in Medicine (149), Law (130), Engineering (76), Health (76), Pharmacy (62), Science (52), and Nursing (50). Over the years, Utah has become an institution very much oriented to the life sciences. For example, the top three departments in terms of doctoral degrees awarded in 2011-2012 were in Chemistry, Educational Psychology, and Bioengineering. As of 2011 the number of faculty elected to one of the National Academies stood at 36, including present and former U of U faculty members.

Looking at the regular faculty roster for 2012-2013 the life science tilt is again apparent. Of 728 full professors, 262 were in the College of Medicine, and of the 830 Assistant and Associate Professors across the University 283 were in the College of Medicine. The College of Science is a distant second. This degree and disciplinary tilt is also reflected in innovation outcomes such as technology transfer and entrepreneurial activity.

The University of Utah has become nationally visible among the many university ratings and rankings that have been noted for other cases in this volume. Thus for FY2012 as per the Association of University Technology Managers (AUTM) Licensing Survey[1] the University of Utah technology transfer office reported 14 startup companies, which places it tied for 3rd among all universities. However, if one looked at this from the perspective of startups per unit of research, the University of Utah has a superior "batting average," since the other highly productive universities in terms of startups were much larger in terms of their sponsored research portfolio.

The University of Utah is a top-50 university in the scope of its R&D activities. Thus in the FY2011 National Science Foundation[2] survey of academic research and development, it reported research expenditures of $414.3 million, of which 63.9% was in the life sciences, reflecting its increasing work in the biomedical sciences. Next highest was engineering, with 17.4% of total expenditures. Of total research expenditures, 3.1% was from business funding, which is below the national average of 4.8%. This may partially be a function of Utah's relative geographic isolation, as well as the increasing focus of the university on medical science.

The U of U Health Care system was ranked 1st by the University Health System Consortium, a rating which focuses heavily on clinical services but is still notable nonetheless. In the highly cited *U. S. News & World Report* national ratings the university was ranked 2nd in Physician Assistant Training, 8th in Nursing-Midwifery training, 5th in Family Medicine, and 9th in Physical Therapy. It also was rated 3rd by the U.S. Environmental Protection Agency for Green Power on Campus.

Notable among the university's accolades above is the prominence of its biomedical programs, and that is one of the more interesting themes in the history of the University of Utah, given that much of Utah and the Salt Lake area were just this side of unsettled wilderness in the 1890s. Starting early in the 20th century the U of U slowly took several organizational development steps that, along with a sharpened set of goals and aspirations, made it a major biomedical center in the west and then in the nation. A two-year medical course was established in 1905 in the College of Arts and Sciences, and then incorporated freestanding into a two-year Medical School to satisfy accreditation organizations. In 1916 a School of Pharmacy was established, although the program was attenuated during the 1917-1919 war years. The two-year medical program persisted until 1942. However, this arrangement demanded that students needed to do their clerkships out-of-state, and transfer, in order to finish their medical degrees. Clinical training experiences were enabled via an affiliation with the local VA hospital in 1945, and other local hospitals. Residency programs expanded, but there were few on-campus teaching/treatment facilities until 1965 when University Hospital opened.

During the 1960s the first significant medical research grants were awarded in a stream that was to grow into a river over the ensuing decades. The scope of clinical and research training expanded significantly, as did the founding and funding of various centers and institutes, including the following: the Huntsman Cancer Institute; the Utah Diabetes Center; the Eccles Critical Care Pavilion; the Eccles Health Sciences Building; and the Moran Eye Center. In parallel with these facility expansions, the U of U medical complex achieved national status for its wide-ranging programs of clinical and laboratory science. All of these accomplishments were consistent with the increasing focus of the University on becoming a national leader in research, innovation, and entrepreneurship.

University Culture: *Goals and Aspirations*

As the largest university, and the largest employer in a sparsely populated state, the University of Utah could hardly abstain from being engaged with its community. The fact that it is located in the largest Utah city, which is also the State Capital, contributes to that posture. While state financial support is a relatively small fraction of the university budget, nonetheless the U of U has linked its mission to statewide economic improvement via research and development. Thus, and not surprisingly, the current Mission Statement[3] of the University of Utah, as articulated by the new President is:

> *To serve the people of Utah and the world through the discovery, creation, and application of knowledge; through the dissemination of knowledge by teaching, publication, artistic presentation and* ***technology transfer****; and through community engagement. [Emphasis added]*

Furthermore:

> *In its role as a research university, the University of Utah fosters the* ***discovery and humane use of knowledge*** *and artistic creation in all areas of academic, professional, and clinical study....The University also cooperates in research and creative activities with other agencies and institutions of higher education, with* ***the community, and with private enterprise.*** *[Emphasis added]*

And:

> *In its role as contributor to public life, the University of Utah fosters reflection on the values and goals of society. The university augments its own programs and enriches the larger community with its libraries, hospitals, museum, botanical gardens, broadcast stations, public lectures, continuing education programs, alumni programs, athletics, recreational opportunities, music, theater, film, dance, and other cultural events. The University facilitates the* ***application of research findings*** *to*

> *the health and well being of Utah's citizens through programs and services available to the community.[Emphasis added]*

As is normal practice among universities, the University of Utah identifies three broad focus areas: teaching, public life, and research. Each of these foci has innovation or entrepreneurial expressions. During the 1980s, James Brophy, a senior research administrator at the University, used the term "academic capitalism" by way of encouraging faculty to pursue active relationships with business and industry, particularly in areas that would have an impact on state economic development. This long-stated goal has manifested itself in a variety of practices and policies at institutional and unit levels, and still does.

For example, the University confers annually a Distinguished Innovation and Impact award to recognize "faculty innovators for contributions that improved the lives of people." It considers innovation in all disciplines and markets "entrepreneurial activities that resulted in innovations with a measureable societal impact." At an institutional level the Carnegie Foundation for the Advancement of Teaching recognized the University for its Community Engagement.

In summary, the goals, culture, and key values of the University of Utah are significantly aligned with community engagement. This is expressed in how the instructional programs are delivered, as well is in the many cultural and artistic events that enrich the City of Salt Lake and communities across the state. For the purposes of this chapter, it is also true that the U of U is significantly engaged in innovation and technology with a host of community, private, and philanthropic partners. The activities range from the encouragement of university-industry research relationships via centers or project partnerships, cooperative relationships that define and enrich curricula, and the fostering of engagements in support of faculty invention of new products and new companies. Those relationships to a significant degree define what the University is, what it values, and what goals it holds close.

Leadership

Since its inception, but most prominently in the last few decades, the University of Utah has been blessed by a series of leaders, particularly at the presidential level, who have championed the development of the university into a first-rate research institution, and also one that is connected with social and business innovation. Those themes are illustrated in the following presidential vignettes, drawn from the post-World War II era, in which the University achieved its most significant growth. This expansion was not only in student head count, but also in the amazing strides that were achieved in R&D, and in engaging in innovation processes of various types.

Ray Olpin was President from 1946 to 1964, the era in which the modern American research university was being created on campuses across the country. A physicist by training, during the World War II years, he worked on the Manhattan project, and was connected with many of the individuals likewise deployed on large scale war-related research, and who returned to their universities and transformed them into R&D powerhouses. It should also be mentioned that after the war ended in Japan, he spent some time there, contributing to its recovery in rebuilding efforts, before returning to university life. Olpin orchestrated a massive campus building effort, as well as a community education campaign focused on the benefits of hosting a research-intensive university.

Another physicist, James C. Fletcher, who led the university for 7 years, succeeded Olpin. Fletcher went on to serve two terms as NASA Administrator, as well as several years as an executive in the aerospace industry in California and Virginia. Notably, one of the space companies that he led was an entrepreneurial venture that he co-founded and then led to a merger with another company in the industry. There are clearly some themes in Fletcher's career that resonate with what U of U has become: research, technology, private sector partnerships, entrepreneurship, and public service.

The 13-year era of Bernie Machen (1998-2004) through Michael Young (2004-2011) was another period in which the university made great strides in terms of focusing on innovation processes, and achieved national visibility in terms of tangible accomplishments from those initiatives. For example, the U of U was one of the featured cases in the 2002 edition of *Innovation U*. Both of these presidents pointed to their administrations' records in increasing the university's R&D, its contributions to the Utah economy, and in turning out science and engineering graduates who tended to stay in Utah. There were also direct impacts from the University of Utah's national prominence in technology transfer and startup companies. Moreover, the U of U was accomplishing these things with a relatively modest portion of its total budget coming from State of Utah funding. As another indicator of leadership continuities, after Bernie Machen left the University of Utah in 2004, in the years since he has been instrumental in leading the University of Florida in its climb to research and innovation prominence. Michael Young, upon his departure in 2011, was able to point to the number of spin-off companies from U of U research, the growth of the sponsored research portfolio, and significant growth in national rankings.

The University of Utah is now early into the administration of President David Pershing, who took office in 2012. It is not clear how the mission statements he articulated above will specifically play out in the context of innovation, entrepreneurship, and the like. At his inauguration on October 26, 2012 he did state that: "I will continue to champion basic research as well as technology innovation." That is very consistent with the views of his predecessors.

It is also worth mentioning that Pershing is a veteran U of U hand, having spent over 35 years at the University encompassing his appointment as an Assistant Professor in 1977, his rise through the ranks to Dean of the College of Engineering after only 10 years on campus, and then to Vice President of Academic Affairs in 1998. Dr. Pershing's career has included traditional academic accomplishments and honors, as well as winning several patents, and the Governor's Medal for Science and Technology.

Several of his predecessors mentioned above have deep Utah backgrounds and connectivity. Thus Ray Olpin grew up in Pleasant Grove, Utah and secured his undergraduate degree from Brigham Young. David Gardner, although not born in Utah, got his bachelor's degree at BYU and was a lifetime member of the LDS Church. After his stint as U of U president, and after his time as President of University of California, he returned to the University of Utah as a senior professor. Chase Peterson, Gardner's successor as President, also had a Utah background, growing up in Logan, and a lifetime LDS member. Michael Young, President from 2004-2011, had a BA from BYU. It is noteworthy to see the many ties that leaders of the University of Utah have had to the state, what it stands for, and how it contributes to technological innovation tied to economic growth. There is a certain continuity of culture over many years among the leaders of the University of Utah.

Boundary Spanning: *Entrepreneurship*

As discussed in other cases in this volume, there are two strands of entrepreneurship activities that are focused primarily on students. One is the *curricular* activities that include courses, degrees, and minors that are typically found in academic units across a campus. The second is the *co-curricular* activities that tend to be more in the vein of learn-by-doing opportunities for students (and sometimes faculty as well), which include competitions, incubation opportunities, forums, and speaker series. The curricular offerings in entrepreneurship at the U of U are many in number and rich in scope. The University's entrepreneurship curricular programs, in both its graduate and undergraduate colleges, ranked in 2012 among the top 20 by the *Princeton Review*. Key factors leading to the prevalence of entrepreneurship at the University were academic programs, faculty entrepreneurship, and, in particular, the experiences and partnerships available outside of the classroom.

James Brophy's "academic capitalism," which has become institutionalized over the years, may help explain the University of Utah's unusual ability (compared to other schools) to successfully integrate curricular and co-curricular resources for both student and faculty entrepreneurs. The focal point for this effort is the David Eccles School of Business 's Pierre Lassonde Center. The Center recognizes that while classroom education is important, applied experience is critical.

Curricular Programs.

Entrepreneurship courses are offered at both graduate and undergraduate levels. Originally, entrepreneurship courses were designed by, and taught primarily by, adjunct faculty selected from the entrepreneurial, small business, and venture-finance communities in the Salt Lake City region. Today, the University is taking a different approach. While other Universities ramp up their hiring of seasoned entrepreneurs to serve as adjunct instructors, the U of U has concluded that a different strategy works better. As stated by Bill Schulze, Entrepreneurship professor and Director of the Foundry incubator:

> *Adjuncts telling war stories is not the way to go about that. It turns out learning how to teach entrepreneurship is very difficult if the outcome is a business, and not just a business plan.*

The University is increasing the role of tenure track faculty teaching in the discipline. Because there are so few faculty candidates familiar with solid curricular theory and practice in entrepreneurship, they have adopted a strategy of "developing their own" entrepreneurship scholars.

The pedagogy being designed and built by faculty takes a two-pronged action-oriented approach. Students learn that opportunities can be created by direct action, not simply objectively observed; they practice developing opportunities, then plan and implement business strategies to exploit that opportunity. Students work in teams, employ tools to conduct experiments, and validate concepts and markets that they build business models around. Evidence-based research supports the effectiveness of this curricular approach.[4] As part of the validation process, the U of U is notable in that it practices the accountability it teaches by collecting data about actual student entrepreneurial outcomes—businesses created, money raised, employees hired, for example.

- *Graduate Programs.* The MBA degree includes course offerings, and a minor in entrepreneurship at the graduate level is in the works. In addition to classroom work, the Lassonde New Venture Development Center connects graduate students in engineering, business, law, and science, with faculty researchers with breakthrough technologies. They team up to determine the commercialization potential of those ideas while providing students a unique educational experience in new business development. The Center is managed by an accomplished local entrepreneur, with an advisory board made up of venture capitalists, inventors, and entrepreneurs. During a year-long program, students receive weekly mentoring and teaching from both the executive director and local professionals. Students work in teams to evaluate business opportunities, engage in market research, research funding opportunities, and develop business models and plans based on real technologies coming out of the labs at the University of Utah.

- *Undergraduate Programs.* At the undergraduate level the UU offers both a major and minor in Entrepreneurship. The major prepares students to follow trends, identify emerging opportunities, and pursue those possibilities through the creation of new products and services and/or with the creation of one's own company. In addition to three prerequisite classes in economics and management, students take courses in Fundamentals of Entrepreneurship, New Venture Finance, Business Discovery, Entrepreneurial Marketing, along with a Global Perspectives business course. The minor in Entrepreneurship (for business and non-business students) provides base-level content on entrepreneurship and start-up businesses. Students in the program focus on analysis, decision making, and business planning skills that support their academic major.

- *Certificate Program.* Beginning in the fall of 2013 a Certificate program was made available to all students regardless of major as part of a campus-wide Entrepreneurship Initiative. To earn a Certificate, undergraduates take three business/entrepreneurship courses, two "tools" classes, two classes in their home college, and a capstone venture creation course.

- *Innovation Scholar Program.* At the undergraduate level, the Innovation Scholar program allows undergraduate students interested in entrepreneurship and innovation to build their undergraduate experience around big questions and problems that inspire them. The students begin by enrolling in the Innovation Scholar Road Map course where they map out a course of study (major and general education courses) for finding innovative solutions to these questions. In addition, students identify extracurricular activities to engage within the larger university community around innovation. The experience culminates with an Innovation Scholar Portfolio, that summarizes their innovative experiences and the product/service solutions they have created.

- *BlockU Program.* The success of the Innovation

Scholar program in retaining students, making their college experience more relevant to their lives, and improving 4-year graduation rates, led to a brand new approach offered in the fall of 2013 to all entering freshmen. The BlockU program attempts to make required General Education (GE) prerequisite courses more relevant to students' future lives and issues they care about. Interestingly, entrepreneurship (business and social) is a multidisciplinary, integral component of the program. The BlockU Program establishes for each freshman enrollee a 2-year multidisciplinary curriculum organized around a number of specific themes: Entrepreneurship and Society, Global Citizenship, Sustainability, Medical Humanities, Art and Science, and Creativity and Community. BlockU students participate in a core learning community and a set of general education (GE) courses organized around a central theme, and have the support of peer mentors and student success advocates. For example, an incoming student interested in the issue of poverty might take an Entrepreneurship and Society course in the fall, then do a social venture project in the spring. They will take their GE courses organized around poverty as a theme, and will engage in research during the second semester of the core learning community in a problem-based learning research project. BlockU students also take an international trip abroad (a service project in Peru, for example), then complete a capstone course where they document their research on the problem, their analysis, and their enterprising solution into a learning portfolio. Students receive a designation on their transcript upon the completion of two semesters of BlockU.

- *Lassonde Living Learning Center.* Students interested in starting a business will soon be able to live, work and perfect their ideas in one place at the Living Learning Center on-campus dormitory, which is slated to house about 400 students from all campus disciplines when it opens in Fall 2016. The $45 million project will be funded by a $15 million donation from mining magnate Pierre Lassonde and $30 million in bond proceeds to be paid off through housing revenue. The new project will be similar to the Marriott Honors Residential Scholars Community that opened its doors last year, but would instead offer workshops, materials, computers, and business lunch space, as well as venues for competitions and events.

- *Campus-Wide Entrepreneurship Initiative.* The Initiative ties together each of the above programs in an attempt to scale the homegrown U of U curricular approach beyond the business, engineering, and health disciplines into the humanities, social and behavioral sciences, and fine arts. The University has built a culture around the belief that by making entrepreneurship a ubiquitous part of the campus experience, they will create, from the ground-up, a university community that will naturally self-organize itself into an entrepreneurial ecosystem that will attract outside interest and investments. The hoped-for result will be the realization of Brophy's vision of "academic capitalism"—University as institutional economic dynamo—serving Utah's citizens and communities by literally catalyzing state economic development, particularly so via its emphasis on entrepreneurship and technology development.

Co-Curricular Programs.

In addition to entrepreneurship classes, the Pierre Lassonde Center offers a number of co-curricular activities, including TechVentures, the Utah Entrepreneur Series (UES), the Student Entrepreneur Conference, The Foundry Accelerator, and the Lassonde alumni mentor network. The Center also serves as a clearinghouse for information about scholarships, courses, and financial resources. The Technology and Venture Commercialization (tech transfer) office also hosts a variety of faculty and student programs at a separate location.

- *Student Entrepreneur Conference and Business Plan Competitions.* The Entrepreneur Conference and Utah Entrepreneur Series (UES) business plan competitions are the best-known co-curricular programs offered by the Lassonde Center. The Conference showcases local professionals and entrepreneurs who share with students their knowledge in business formation, business plan creation, marketing, and finance. The business plan competitions offer students statewide the chance to compete for cash and in-kind prizes. Students who hope to enter into a competition are first encouraged to attend a spring orientation conference. Round one of the techTITANS (tT) competition is held each fall. Students at this stage of the business process receive mentoring and support to fully develop their ideas, and successfully compete with other teams. Round two, the Opportunity Quest (OQ) competition, occurs in the winter. Students receive coaching on how to prepare their business plans for the final round. They attend forums where they meet industry mentors and investigate local opportunities within the surrounding community in order to make their business plans feasible and realistic.

  The cornerstone competition of the Utah Entrepreneur Series is the Utah Entrepreneur Challenge (UEC), which is one of the larger business plan competitions in the nation. In 2013, the UEC saw 121 submissions competing for a grand prize of $40,000. The competition includes awards for Best Presentation, Best Technology, and Best Bootstrap, among others.

- *Bench to Bedside Competition.* The U of U's Center for Medical Innovations Bench-to-Bedside competition is a medical device innovation competition designed to attract teams of medical, engineering, and business students. The multidisciplinary teams' first task is to identify an unmet clinical need. They are then given six months and $500 to develop medical device concepts that address that need. Teams are given access to over 100 University physicians from a broad area of specialties to serve as their consultants, and stakeholders. The program culminates in a formal presentation of all team projects at an annual awards competition. The event draws participation from faculty physicians, community residents, industry leaders, venture capital firms, and University leaders. The team projects are evaluated and scored for business strategy, design quality, and potential healthcare impact by a panel of judges. The top teams are awarded over $70,000 in prizes intended to support further project development.

- *Foundry Utah.* Foundry Utah is a business accelerator educational program funded and supported by the David Eccles School of Business, Chase Bank, and Ally Bank. The program provides an experience-based educational community where entrepreneurs (either university or community) can start acting on their business ideas and access resources to help them along the way. More than a dozen Utah business leaders have helped launch the program and others participate as coaches, provide targeted training, invest in Foundry startups, provide internships, and hire Foundry participants. Entrepreneur teams enter a 12-week cohort with an idea for a company. Cohorts complete a discovery process in an effort to develop their idea and assess the market. They attempt to validate their customer, their market, and their profitability, before assembling the company, filing articles of incorporation, or soliciting for funding. Since the beginning of the program, the Foundry has served 259 entrepreneurs, 59 companies were incorporated, and nearly $3.2 million in external funding was raised.

- *The Student Entrepreneur Club* and *StaC.* Like the Foundry, the Student Entrepreneur Club at the University of Utah has partnered with a community lender (Zions Bank) to provide seed grants to students who need cash to start a business. To date the Club has funded 30 teams an average $2,000 each to help develop a viable proof-of-concept. The Club partners with the Startup Center for Students (StaC), which is a program offered by the Technology and Venture Commercialization (TVC) office. StaC helps students execute their business ideas and development, and provides seed funding, mentoring programs, business and legal services, and marketing advice. The StaC walks students through the funding process, beginning with an easy application in which they present their idea as a three-slide pitch and brief question and answer. StaC's expertise is building companies around ideas that are scalable and have an intellectual property component.

- *TVC Student Internships and University Venture Fund.* Another TVC program for students includes a TVC Student Internship Program (summer and during the school year) where students assist in the analysis and commercialization planning of University technologies. Legal, MBA, and science interns learn how to perform patent searches, conduct market analyses, work with companies, and assist with licensing agreements. In addition, student internships are available via the University Venture Fund (UVF). The program enables students to perform real-time due diligence and actively participate in direct investment deals, working alongside professionals in the firms they assist. Students work with mentors who bring industry expertise in venture capital and entrepreneurship across a wide array of industries. The experience allows students, who come from several Utah universities, and from various disciplines, to understand how to effectively identify successful companies, as well as the principles upon which successful companies are built. To date, UVF has invested in eighteen companies; three of which experienced successful exits via two initial public offerings, and one acquisition by a financial buyer.

It should be noted that a number of other activities and programs are more closely aligned with TVC, and are described later.

Boundary Spanning: *University, Industry and Community*

In 2011, Utah governor Gary Herbert said of the U of U:

> *Utah has always possessed a unique pioneering and entrepreneurial spirit.*

> *That spirit, along with our state's sustained commitment to fostering economic development, has made Utah a premier destination for business. This is exemplified by the University of Utah's record of technology commercialization. The University of Utah is not only doing innovative and groundbreaking research, they're using that research to form successful start-up companies that generate jobs and boost the economy.*

The U Of U has indeed been involved in a range of initiatives that engage processes of technological innovation and the external community. Many are similar to those operated by other universities, along with many features and wrinkles unique to Utah. They include:

Centers and Institutes. As has been emphasized elsewhere in this volume and in the larger literature on innovation, technological innovation is often interdisciplinary or multidisciplinary in content; new areas of understanding or application often cannot be understood in the context of established departments or colleges. The answer for this need is found in the form of centers, institutes, or other organizational forms where faculty members and graduate students can address research questions from new perspectives.

As of late 2013 the U of U listed 91 Centers and Institutes that were in operation on campus. These ranged across many departments from the humanities to engineering and the physical and life sciences. In fact, if one does a crude sort among categories of research it appears that the life and medical sciences accounts for a plurality of centers and institutes. Not surprisingly, when one digs into the foci of startups and patenting/licensing activities they tend to track major center programs, as do the emphases of doctoral dissertations.

In 2012, three Utah state agencies commissioned the Battelle Technology Partnership Practice (TPP) to conduct a study[5] of the life science industry in Utah, and in particular how it interfaced with state-based universities as well as private sector companies and organizations. Since the life science industry has had healthy growth in Utah, and the U of U has been a significant player therein, the study identified centers and institutes at the University of Utah that are key assets in the life sciences and developed strategies for enhancing their impacts. The University of Utah served as a "convening institution" in the project. The report identified four strengths that were seen as key to life science growth: medical devices; molecular diagnostics and personalized medicine; molecular medicine, drug discovery, development, and delivery; and natural products and dietary supplements.

The following centers, institutes or units at the University of Utah were identified in the Battelle report as key U of U research centers in one or more of those four areas, and several have wider links across the University.

- *The University of Utah Nano Institute.* The Nano Institute is less than four years old, but has grown in size and intellectual stature. Roughly 70 individuals are Members of the Institute, primarily faculty members drawn from across the University in fields such as computing, engineering, medicine, materials science, biology, energy, and other disciplines. The Institute is a State of Utah Science and Technology Advanced Research (USTAR) program, and as such has both scientific and technological goals, including advancing the state of knowledge about nano materials and processes, fostering a Utah-based nanotechnology industry, as well as accelerating the commercialization of U of U nanoscale invention (over 40 disclosures). There is a strong emphasis on industry partnerships and involvement. USTAR funds many of these activities, particularly the recruitment and support of nationally prominent researchers as USTAR Professors at the U of U. The research program of the Nano Institute is organized around the following Centers and research foci: Nanomaterials; Interfacial Science; Nano BioSensors; Nanomedicine; and System Integration. A director and small administrative staff manage the ongoing Institute business, as well as a number of integrating activities which include a newsletter, workshops and conferences, and the planning and implementation of projects, proposals and events.

- *The Huntsman Cancer Institute.* The Institute is designated by the National Cancer Institute as both a both a treatment and a research Cancer Center, and is prominent in the intermountain west. It was founded with a philanthropic gift from John Huntsman, Sr., with continuing gifts totaling $250 million. In addition the NCI Cancer Center Support Grant (CCSG) has enabled a longitudinal research program that involves over 135 faculty and staff associated with the Institute. Major thrusts of the Institute are in human genetics and the understanding of cancer at a molecular level. There are four interdisciplinary areas that constitute the research programs of the Institute: Cancer Control and Population Sciences (e.g., genetic risk factors, genotype-phenotype associations, and gene-environment interactions); Cell Response and Regulation (e.g. cell turnover in cancer, tumor microenvironments); Experimental Therapeutics (e.g., individualized approaches to diagnosis and treatment, bidirectional collaboration between clinic and laboratory); and Nuclear Control of Cell Growth and Differentiation (e.g. fundamental processes in the cell nucleus that go awry in the cancer cell). The HCI also benefits from the availability of 18 core labs associated with the Health Sciences Center, plus other core facilities that are available campus-wide.

- *University of Utah Cardiovascular Research and Training Institute.* The CVRTI is co-located with the University of Utah School of Medicine, and occupies 27,000 of space that houses 19 experimental laboratories, an operating room, a computer core, and associated offices and meeting rooms. Research at CVRTI is focused on problems of cardiac electrophysiology and ion transport, encompassing levels of analyses from whole heart to molecular. Researchers associated with the Institute have published widely on a range of specific research questions. These include computational modeling, tissue and organ level electrophysiology, regulation of intracellular pH and calcium, cardiac chromatin remodeling, mathematical modeling and computational simulation, excitation-contraction coupling, and others. The Institute has been in operation at the U of U for over 40 years, and associated with the research program are faculty members, post docs, graduate students, core personnel and support staff.

- *University of Utah Scientific Computing and Imaging Institute.* The SCI Institute has been in operation for over 15 years, and is one of eight research institutes having permanent status at the University of Utah. It involves over 200 faculty, students, and staff, with 16 tenure tract faculty members drawn from the School of Computing, the Department of Bioengineering, the Department of Mathematics, and the Department of Electrical and Computer Engineering. It has been named by the State of Utah Science and Technology Advanced Research (USTAR) program as a *Cluster Performer* in imaging technology, an honor that comes with resources to expand faculty positions in this area. Its expertise in visualization, scientific computing, and image analysis have been applied to a wide range of problem areas. The Institute has developed a number of software packages for applications in domains such as fluid dynamics, parallel computing, neuroimaging, and electrophysiology. It is associated with many other institutes and centers, both at the U of U and nationally.

- *University of Utah College of Pharmacy.* The College of Pharmacy is nationally ranked (10th of 125 Doctor of Pharmacy programs by *U.S. News & World Report* in 2013) in both its educational programs (PharmD, Master of Science, PhD) as well as its research and development activities (3rd nationally in research awards in this field from the National Institutes of Health). The College is organized into four academic departments, and 8 centers or programs. For example, the Center for Controlled Chemical Delivery (CCCD) has developed a national reputation and a diverse portfolio of funding, in research focusing on the use of different types of polymers for more efficacious drug delivery and release. Other research is developing ways to enable drug delivery to specific organ targets or via long-term release systems. The Center for Human Toxicology (CHT) is an independent non-profit laboratory that is nonetheless administratively part of the College of Pharmacy, and which provides various analytic and research services for a variety of public (NIDA, NIST) and private (Eli Lilly, Hoffman LaRoche) clients. The CHT is developing a Sports Medicine Laboratory, which will focus on the detection of performance-enhancing drugs; various US and international sports organizations are partners.

The University Research Park. As another boundary-spanning strategy in the service of innovation and economic development, the University has operated a research park since 1968 that is open to both university and private sector organizations. The Park is located adjacent to campus on 320 acres close to Lake Bonneville, and the business tenants include established corporations as well as early stage ventures, typically with some link to the University. The University thus provides an environment that fosters entrepreneurial growth, practical research, and business and career opportunities for both graduate and undergraduate students. The mission of the park is to promote connections and foster growth between industry and the University and to provide a space that brings industry and outside companies closer to student entrepreneurs. As of spring 2013 the University Research Park was home to 82 University organizations—including many academic departments—with 3,554 employees, and 53 businesses with another 6,174 employees. Since its establishment in 1968, the park reportedly has aided companies that have added an estimated 6,000 jobs to the economy. A quick scan of the companies in the Park suggests—as above—that the plurality of innovation activities focuses on the life and medical sciences, with engineering and information systems close behind.

In addition to the apparent continuing success of the University of Utah Research Park, one of the things that is remarkable relative to many other universities is how early in the game that the Park was launched. This was 12 years prior to the passage of Bayh-Dole, and the U of U was among the "early adopter" cohort of universities that likewise took the step of a co-located research park, many of which are described in this volume.

Entrepreneurial Faculty Scholars (EFS). The EFS is a self-generated linking organization that works in the community and with faculty and students on campus. It was started by 12 faculty members as a pilot in 2007 and now has grown to a voluntary membership of 100 that includes representatives from across the campus. Each of those individuals is a person who has had some significant experience in some aspect of technological innovation, either via invention, starting a company, or fostering interdisciplinary inquiry around an important problem. The EFS works with and through existing campus organizations (e.g., The Lassonde Center, Technology Commercialization Office) and often at the request of the office of the Vice President for Research. EFS members work as volunteers and without any alteration of their faculty position description. In 2010 the EFS created a Distinguished Innovation and Impact Award (DIIA) to recognize faculty accomplishment beyond the usual measures of academic excellence and which improve the lives of average citizens. EFS members also often serve—as requested by the VP for Research—on the Internal Commercialization Advisory Board, which has the mission of continuous improvement in how the University of Utah does technology innovation and commercialization. Recall that the U of U takes seriously its connection to the state economy and citizen well being, and keeps track (and regularly posts online) its contributions in terms of numbers of faculty inventors, invention disclosures, startup companies, jobs created, personal income, and state tax revenues.

USTAR- The Utah Science Technology and Research Initiative. USTAR has been a novel and moderately successful partnership between Utah state government and research-intensive university programs around the state. The program rationale is based on the observation that Utah has been notably successful in launching and nurturing technology-based companies around the state *and* that the state's universities have played important roles. Program monies tend to be focused on building R&D capacities in conjunction with the universities via investments in state-of-the-art laboratories, as well as in supporting startup packages to enable the hiring of established investigators—in both research and commercialization—from elsewhere around the country. The premises and operations of the program have some similarities to the activities of the Georgia Research Alliance which is discussed in the Georgia Tech case. USTAR claims to have attracted "50 leading researchers from MIT, Harvard University, UCLA, Case Western, University of Arizona, Oak Ridge National Laboratory, and other top research institutions..." to the universities and the state.

Utah Technology Council (UTC). The U of U has no official linkage to the Utah Technology Council, however on a selective and voluntary basis university staff and leadership tend to be plugged in to what the UTC is doing. The Utah Technology Council has a tiny staff, but hundreds of participants, mostly from the technology-oriented community across the state. It has become an essential business resource for high-tech, clean tech, and life science companies. Its emphases tend to cluster around issues of talent shortage and investment funding, and its annual agenda of activities is impressive.

Technology Commercialization and Innovation Program (TCIP). This is a linking and funding program that operates out of the Utah Governor's Office of Economic Development. The TCIP conducts three proposal solicitations a year for grants that will enable the commercialization of technology innovations emerging from Utah universities. While not exclusive to the U of U, it has been a significant source of resources to enable the innovation process. Historically, grants went to universities, but starting in the 2010-2011 fiscal year, proposals were welcomed from Utah-based companies, including startups. Other administrative changes in the program made the proposal process more flexible, and faster.

Boundary Spanning: *Technology Transfer*

Technology transfer at the University of Utah is housed in the Technology and Venture Commercialization (TVC) office, which serves as an interdisciplinary vehicle for connections between research within the University and its commercial development via either license partnerships with existing companies or increasingly via startup ventures. It also places a major emphasis on serving a very technology-savvy entrepreneurial cohort of faculty members and graduate students. Its performance has become noted by the Association of University Technology Managers and others in terms of metrics such as disclosures, licenses, startups, and commercialization revenues. For example, if one quickly divides current research expenditures in millions by the number of invention disclosures, the U of U index number is 1.4, which suggests that for every $1.4 million of research an invention disclosure seems to emerge. This suggests a very robust entrepreneurial culture as well as a very responsive technology transfer office. The TVC also has a rich collaborative relationship with the Pierre Lassonde Entrepreneur Center, which is located within the David Eccles School of Business, but operates university-wide.

Technology and Venture Commercialization (TVC) receives program guidance from both an internal steering committee that is drawn from colleges and academic units across the campus, as well as an external advisory board that includes investors, intellectual property experts, and entrepreneurs drawn from both Utah and around the country.

The TVC staff offers procedural and strategic guidance that includes well-articulated policies, procedures, forms, and staff advice. Reflecting its parallel involvement in commercialization of IP via licensing as well as help in launching innovation-based startups, the office provides two online guides for its customer. One is an *Inventors Guide* that covers general principles of IP, the licensing process, inventorship, technology disclosures, and various approaches to protection and commercialization of an invention. In parallel, TVC offers a *Startup Guide* that covers many of the same issues but focuses more attention to the processes, decision criteria, business development processes, and planning necessary to commercialize an invention via launching a new enterprise. The guides are similar to those available at other universities in this volume, but these are unique to the U of U. These are excellent guides and have links to other TVC tools, procedures, and policies.

In addition, the TVC has a number of events and services open to students, faculty and the larger Utah community. They include:

Boot Camp. One of the most informative workshops put on by the TVC is their Boot Camp program that occurs several times during the year. Boot Camp is targeted at University of Utah faculty, researchers, graduate students, and other interested parties in the U of U community. Throughout this program, faculty members learn more about TVC and the services that it provides. This program also provides informative seminars on patent law, opportunities for funding, and the University's intellectual property and disclosure procedures. The benefits of Boot Camp include evaluating the potential of faculty inventions and University based start-ups, grant and funding analysis, and an introduction to Business and Technology Development (BTD) Teams.

BTD Teams. These units guide faculty and graduate students through the commercialization process. Each team falls under one of three categories: Health Sciences; Science, Business and Humanities; and Engineering. Depending on the type of intellectual property, one of these teams will serve as the point-of-contact between faculty and industry, including the pursuit of funding and the steps from disclosure to commercialization. BTD Teams also work in conjunction with the University's Entrepreneurial Faculty Scholars (EFS) and the Entrepreneur-in-Residence program. Through working with a BTD Team, a faculty or student inventor will be able to formulate an IP strategy, a commercialization strategy, and a funding strategy vital to the technology's success.

Tech Tuesdays. These are networking events held weekly at the end of the workday. The program typically includes a guest speaker, "speed pitches" by TVC staff, technology showcases and exhibits, and opportunities for networking. Generally Tech Tuesdays are by-invitation events and reach out to those most active in developing inventions and pushing their commercialization. Attendance is usually around 100. Each Tech Tuesday is built around a theme, which may be an area of technology or an issue in commercialization. The events are designed to foster connections and deal-making.

Commercialization Interchange. This is a limited participation event, with registration costs in the range of $2,000 per person. Events unfold over 3-4 days, and draw participants from universities and companies across the country. The focus of the event is to spotlight and discuss best practices in the commercialization of university-linked technologies. Participants are "technology managers of all types".

Utah Innovators Showcase. This two-hour event features "speed dating" pitches by university technology representatives, faculty, and student inventors to venture capitalists and angel investors. This program is early in its history but has made a number of successful placements.

The Engine Funding Program. The Engine is a novel approach to accelerate the appraisal, business vetting, and commercialization of early stage inventions that come to the attention of the TVC office. The approach is based on progressive technical and business development milestones, plus developmental funding. A U of U inventor can apply for the program whenever the Engine Committee meets. There are also three key roles and role incumbents that seem to make the program work: One is a private sector Sponsor, who has the assets and experience to potentially be an investor in an innovation; another role is a Champion, who is someone who has the will and business experience to potentially be the startup manager; lastly is the Subject Matter Expert, who could either be a U of U faculty member or researcher or a private sector expert in the technical domain. If the Engine Committee feels that the ingredients are in place to move forward, funding will be allocated to finance an approved set of tasks, deliverables, and milestones that will be monitored by the Engine Committee. An innovation can receive more than one Engine funding round. Engine Fund projects must involve a U of U affiliation and a principal investigator.

Software Development Center (SDC). This Center works separately from, but in collaboration with, the Technology and Venture Commercialization office. Substantively, it is a creature of the Scientific Computing and Imaging Institute (SCI) and is organizationally linked to the many pockets of software development across the U of U campus. The SDC staff of a half-dozen individuals is deep in terms of academic and business perspectives on software development. They have been involved in software development across a wide range of problem domains, and all have deep entrepreneurial experience in the software space. Most have advanced degrees from a Utah-based institution, and one had served former Governor Huntsman as State Science Advisor and Director of the Utah Economic Clusters Initiative. The SDC team works with early stage ideas for application software—and their inventors—with the goal being the development of a working prototype.

The TVC office clearly plays an important role in the technology transfer of University inventions. Listed on the TVC website are the available technologies from student and faculty inventors. The site also extensively details areas of interest for students, faculty, start-ups, and partners. Each of these sections contains material and contact information in order to further pursue areas of commercialization or tech transfer. This is reflective of the overall facilitative culture discussed previously.

The primary aim of TVC is to foster commercialization of University technology through connections between student teams, faculty, and industry partners. TVC also enables students (Innovation Scholars in particular) to participate in various competitions and internships in a wide variety of disciplines. Various technologies are highlighted and featured by TVC each month to foster marketing and partnerships. TVC also sponsors the Student Entrepreneur Conference and programs such as the Startup Center for Students (StaC).

Summary and Parting Comments

While the state of Utah's sustained commitment to fostering economic development has made Utah a premier destination for business, the University of Utah has established a complementary campus-wide culture of "academic capitalism," as championed by James Brophy in the 1980s. This is exemplified by its record of technology commercialization and entrepreneurship education programs. The University of Utah is not only doing innovative and groundbreaking research, they're using that research to form successful start-up companies that generate jobs and boost the economy.

One of the clearest concluding statements about technological innovation at the University of Utah is that there is a lot going on and it changes pretty fast. Among all of the cases in this volume this university is also perhaps the truest reflection of the culture and development of its setting. The state of Utah has been a risk-taking, entrepreneurial place since its founding, which in turn is a reflection of the people who settled there and their struggles to survive, and their ability to establish a culture that reflected their values and outlook. It is no coincidence that our case selection process for this project ended up with two institutions from one relatively low population state characterized by lots of dry country and many rugged mountains. Innovation and struggle have always been part of the deal.

And in fact the struggle continues. However, one of the challenges of being in a place like Utah is that there are limitations on the scope of potential community partnerships in the corporate environment. Salt Like City is not a Chicago, nor a Santa Clara County, nor a greater Dallas. In that context it is interesting to note the relatively modest amount of industry sponsored research at the University of Utah. As the state and the metro area mature, that will likely change, and partnership opportunities will expand in scope and variety. The perspectives, creativity, and out-of-the-box thinking that characterize Utah are needed to tackle global problems. But the U of U seems to understand this; they are bending over backwards to encourage diversity, creative boundary-spanning, and divergent thinking. One of their key challenges will be to ensure that their corporate partners expand in number and will support cutting edge research requiring diverse approaches, unconventional students, and independent faculty. Another key challenge as the U of U continues its path of growth and competitive excellence is to stay entrepreneurial and innovative in research and technology, as well as in organization and management.

On the other hand, a very positive characteristic of the University of Utah case is that while the University has been innovative in developing technologies and business models, it has been likewise innovative in developing the mix of program and service models to accomplish those ends. Several of the cases in this volume describe schools in which the primary organizational and service models for fostering innovation have been in place for several years and undergo as-needed changes in a fairly deliberate manner. The University of Utah setting seems a little different. To stretch a metaphor, the Utah innovation dish is more like a creative *bouillabaisse* that changes spices, protein sources, and vegetables depending on what was snagged in the most recent hunting or fishing expedition.

The culture of the University is amazingly caught up in innovation and change, as is the evolving culture of the metro area and the state for that matter. So, this chapter represents what was happening in and around the U of U in early 2013. It will likely be a different mix next year.

Endnotes

[1] Association of University Technology Managers. (2013). *AUTM U.S. Licensing Activity Survey: FY2012.* Deerfield, IL: Association of University Technology Managers.

[2] National Science Foundation, National Center for Science and Engineering Statistics, FY2011. *Table 14. Higher education R&D expenditures, ranked by all R&D expenditures, by source of funds: FY2011. Table 15. Higher education R&D expenditures, ranked by all R&D expenditures, by R&D field: FY2011.*

[3] University of Utah. Mission Statement. Retrieved from http://admin.utah.edu/office_of_the_president/university-mission-statement

[4] Rideout, E. C. (2012, March 21). *Bounded Rationality and the Supply Side of Entrepreneurship: Evaluating Technology Entrepreneurship Education for Economic Impact* SSRN: http://ssrn.com/abstract=2027023).

[5] Battelle Technology Partnership Practice. (2012). *Accelerating Utah's Life Science Industry*. Columbus, Ohio: Battelle. org

Summary and Recommendations*

As promised in the Introduction, this book showcased twelve case studies of exemplary innovation-producing universities in the United States. Based on the selection and data collection methodologies described earlier, we make no claims that this dozen has cornered the market on innovative universities. Notwithstanding the methodological limitations discussed in Chapter 1, we do believe that the universities are very good indeed at converting discovery and instruction into real inventions, products, services and enterprises, and ultimately impacting economic development.

Our case studies demonstrated the following: (1) that there are universities that are demonstrably more "innovative" than most of their peers (even those that are at about the same level of research spending); (2) that there are policies, practices and behavioral patterns that *may* have a causal relationship to "innovativeness;" (3) that despite the page count, we have probably only dented the range of innovation-related policies, practices and behaviors that are out there; (4) but nonetheless, the practices, policies and behaviors that we did discuss are promising, as well as *fungible* and *adaptable* (other universities can emulate and flat out copy them, and we encourage our readers to do exactly that). That is really the *raison d'etre* of the project.

Our team's goal was really to facilitate *doing* rather than pondering. The case studies were intended to pique the interests of readers who might be motivated to perform their own analyses and plot their own change efforts. As discussed in the Introduction chapter, we hope that the book reaches non-university people, such as legislators, community leaders, corporate R&D managers, and technology entrepreneurs, who appreciate the roles and constraints of academe, but who also want to nudge the change process.

We are pleased that our sample of cases and our data collection yielded great diversity in schools and practices. The schools are public and private, large and small (Arizona State with 73,000 students; Cal Tech with 2,200, graduate and undergraduate). Some schools have a predominant engineering history (Georgia Tech, MIT), Land Grants are well represented, while others have a more humanities and life science orientation (Stanford, University of Utah). Some schools were born out of and retain a religious mission (Brigham Young) and others emerged from an historical desire to foster the ranks of "skilled workmen, such as machinists, mechanics, decorators" (Carnegie Mellon).[1] The cases are geographically diverse and come from all regions in the US.

** This case was written by Elaine Rideout , Louis Tornatzky, and Denis Gray.*

In the next few pages we would like to revisit the themes or domains that structured our information collection and writing, and remind our readers of why each is important. We will point out some compelling anecdotes and findings that emerged during the case study process. We will discuss some of the strategies, policies, and best practices that seemed to be most important in that they involved commonalities across a number of schools. Finally, we will offer some suggestions and action steps within each domain for readers interested in implementing some of the strategies in their own institution.

The Key Role of Culture

The "culture" of a university, or any organization, is an amalgam of what it values, what it aspires to in terms of goals, what it intends to do more of, and what it talks about. In the context of an Innovation U, culture consists of norms, standards, and aspira tions that energize innovation-related planning and actions. It includes, but goes beyond, what comprise the standard goals and aspirations of the "typical" university. Innovation culture is identified not only by poring over innovation outcomes (e.g., invention disclosures), but also by reviewing each university's most cherished institutional declarations including its mission statements, goals and strategies, press releases, shared language, and reward structures *as they pertain to innovation*.

While leadership is about making things happen; organizational culture is the juice that makes people *want* to make things happen. It is manifested in our case universities when professors strongly believe that entrepreneurship competencies are a worthy thing to impart to students. It is revealed when universities decide forthrightly to be a major player in enhancing the economic well being of their region, their state and the nation, and widely proclaim those goals. It is also expressed in historical themes and slogans that can capture a mindset for generations of students and faculty—like *Mens et Manus* at MIT, *My Heart is in the Work* at Carnegie Mellon, or *Think and Do* at NC State.

Sometimes people pooh-pooh the existence or power of organizational culture and associated values. But in addition to university cultures and values that *encourage* innovation and private sector engagement, there have been instances of university cultures that actively *discourage* activities such as technology patenting and licensing, or students starting companies, as being dangerously contrary to the core objectives of fundamental science and education. More recently, that argument is not carrying the day as it once did.

Academic culture goes beyond the articulation of what's right and righteous for faculty members; it also encompasses the goals and practices of undergraduate and graduate education. It is arguably harder to "do innovation" when students (and faculty members) are locked into narrowly construed, discipline-bound programs of study and research. It is encouraging to hear the President of Stanford (who is both a serial entrepreneur and a prominent scholar) advocate making students into "T-shaped people," who have deep competence in a key discipline and also breadth in knowledge across other fields. Culture is illustrated when the vision of a *New American University* at Arizona State calls for academic enterprise *and* societal transformation, or when the Georgia Tech Strategic Plan and Vision states that the "campus culture needs to be one that supports innovation, entrepreneurship, and public service .... [and be] a leader among universities in innovation." Those are all *cultural* value statements that reinforce innovation-related behaviors.

Among our Innovation U 2.0 schools these value statements are constantly being refreshed and expanded, coupled with efforts to align the encouraging words with how things are actually done. For example, in support of faculty entrepreneurs, Georgia Tech enables flexible work status, leave policies, as well as sabbaticals with companies. Purdue's rules and procedures are being re-written to "get the University out of the way" of inventors, and to better reward entrepreneurial behavior and actualizing ideas in the real world. Innovative universities even turn the spotlight on themselves by encouraging new and novel ways of operating. MIT's academic experimentation has resulted in open courseware including Massive Open Online Courses, new education technologies, the creative use of time (Intersession courses), and unorthodox student groupings, to name a few.

To summarize, university culture goes beyond the articulation of what's right and righteous for faculty members and students; it includes aspirations of how the institution wants to impact the surrounding community and the larger world. It is the fuel that drives behavior.

The Importance of Leadership

Although from one perspective it seems that some of our schools have benefitted from having the ingredients for innovation in their organizational DNA, *all* of the universities benefited from having effective leaders at critical periods. These often were most apparent during significant shifts in the direction and growth of the university, and the cases illustrate current and historical examples. These included: RadLab veterans who impacted events when they went back to their home universities at the end of World War II; senior administrators at Clemson reaching across the departments to promote the planning of interdisciplinary curricular and research initiatives during the depths of a recession; mounting the bully pulpit and enabling dozens of curricular and technology program innovations to bloom at Arizona State; or doing the deal to turn Carnegie Institute of Technology into Carnegie Mellon University. While our cases are not rich in detail on leadership behavior at the level of deans, department heads and faculty, ancillary data indicated that there are many; the brief story of Bob Langer at MIT is one. Moreover, when one sees inordinately large chunks of industry-sponsored research in a department, and faculty feeling comfortable asking for leaves of absence to do a start-up, you can surmise that there is an effective and effectual chair involved.

A theme that was very prominent in these case studies, more so than in 2002, was the massive growth of research activity and organized research units that cut across disciplines, departments, and colleges. There were many examples of leaders extolling this way of doing impactful research to both address the "grand challenges" of science, as well as to be more responsive to industry partners who don't usually address R&D opportunities from the perspectives of academic disciplines. An academic discipline or body of fundamental science is typically structured to focus on methods, theoretical frameworks, modes of analysis, and key questions as defined by members of its "invisible college;" it is not necessarily an approach that translates well in understanding innovation that cuts across bodies of knowledge and changing problems, as they unfold in a business or application setting. Innovation leaders recognize this. A look across the exemplary universities identified several key leadership strategies, practices, and results:

Big Transformational and Durable Changes. Each of the institutions experienced several leadership episodes that dramatically and permanently changed the course of the university. Some had to do with leaders successfully and significantly bringing in new resources, such as research funding. The rapid acceleration of DOD-related research during WW II and afterward in the Cold War years is an example; some schools, effectively led, did much better. So too were the significant bumps of research and curricular program development at Georgia Tech during the presidencies of Joseph Petit and Wayne Clough. The transformation of Carnegie Institute of Technology into Carnegie Mellon University during the presidency of Guy Stever was a major change that had permanent consequences. The launch of the Centennial campus at NC State, which had several godfathers (including a Governor), was another game-changing step. Innovation U progress seems to be built on big jumps in performance.

Intergenerational and InterUniversity Leadership Modeling. One fascinating phenomenon that we observed is the networking of innovation leadership, both concurrently and over time. For example, leaders at universities engaged in the defense science buildup during and after WWII moved on to become pioneers and innovation leaders at other campuses. Fred Terman had been a graduate student at MIT of Vannevar Bush (MIT Dean of Engineering and later President of the Carnegie Institution for Science in Washington, plus an important leader of the Manhattan Project). Terman returned to Stanford with his degree, succeeded handsomely in a faculty role, and then with the outbreak of WW II left campus to become head of the Radio Research Laboratory (RRL) in Cambridge, an R&D operation that dwarfed Stanford. After the war he returned to be Dean of Engineering and then Provost, established the Stanford Research Park, among many accomplishments that included the positive inoculation of people passing through. Before becoming Cal Tech's President, Jean-Lou Chameau had been at Stanford, Purdue, and Georgia Tech. Petit and Clough (Georgia Tech Presidents in different periods) had been at Stanford in faculty and administrative roles for several years, and were exposed to the culture and accomplishments of the Terman era. The former president at the University of Utah (which was one of the schools featured in the 2002 book, as well as this volume) subsequently moved over to the University of Florida where he worked with a talented cohort of innovators to dramatically change that school. There are many other examples. Any university wanting to go down the Innovation U "path" needs to look closely at the lineage of potential leadership hires. One useful selection criterion in hiring for a senior academic position might be what famous and effective leader has the candidate worked with.

Private Sector Operational Lineage. Much of the key performance domains of innovation (industry-university cooperative research, technology transfer, entrepreneurship) will be strengthened if incumbents actually have had successful leadership experiences in the private sector. There are many case examples in positions ranging from tech transfer director, departmental chair, provost, vice president to president. These include: University of Utah President Fletcher, a former aerospace entrepreneur; Stanford's President Hennessy, co-founder of MIPS Computer Systems and Atheros Communication; Bob Langer, famous for the "Langer Lab," at MIT; and the many examples of heads of university-based entrepreneurship centers, or technology transfer programs, who have been serial entrepreneurs themselves. A very effective Senior Director of the Cal Tech technology transfer office had an extensive MIT leadership experience and was was one of the founders, 30 years ago, of the Association of University Technology Managers; the head of the BYU technology transfer office is a serial entrepreneur and venture investor.

The point of these case examples is simple. If one is interested in moving a university into an innovation performance level commensurate with our case study exemplars, leadership is critical, and simply tapping into the modal network of academics or administrators is unlikely to show much in terms of results. However, hiring strategies that are open to a larger and more diverse pool, including non-academics, can make a big difference.

Boundary Spanning is a Key Component

As both a rationale for the study project, and a focus of data-gathering, the notion of "boundary spanning" got a lot of play both in what we described and studied, as well as providing a key explanatory component of innovation. We believe that boundary-spanning across disciplines or domains of behavior is a key component of innovation. Empirical and theoretical understanding of innovation processes[2] assumes that different levels, phases, and modalities of behaviors are involved. Those organizations that "do innovation" better are likely to be more adept at designing and implementing new organizational procedures that bridge disciplines, phases of the innovation process, and their associated structures.

The university cases in this volume are very good at this. Across the dozen universities there are literally hundreds of departments, labs, centers, and institutes. Many of these, perhaps a majority in some settings, are interdisciplinary or multidisciplinary, and often cut across organizational boundaries within the university. Aside from the role that such structures play in fostering technological innovation, these flexible arrangements are also common where the focus is not within the boundaries of existing theory and epistemology. Some universities have established campus-wide boundary spanning strategies. Stanford, for example, has reduced traditional disciplinary and organizational boundaries by successfully bringing together experts from across campus in an effort to increase research productivity, and to address bigger problems. Arizona State reorganized its college and school structure from one based on traditional academic disciplines to one based more on shared interests. It thus devolved to 23 interdisciplinary and transdisciplinary schools and colleges, each "...a unit of intellectual connectivity... around a theme or objective." Faculty members can affiliate with more than one faculty group, which appears to be a more productive approach to teaching, research, and graduate training.

Secondly, disciplinary boundary-spanning is not a sport that is just reserved for faculty members and post-docs conducting large research projects; it is more inclusive. In the Overview section of CMU's 2008 Strategic Plan, a very participative approach to boundary-spanning is suggested: "Building on deeply grounded disciplinary strength, we collaborate across disciplines, and the initiative to do so comes from the ground up, not the top down." Increasingly boundary-spanning is becoming a fact of graduate and undergraduate curriculum, particularly those courses and programs that touch upon innovation, entrepreneurship, and projects conducted in collaboration with companies. Thinking beyond your intellectual home base is strongly encouraged and promoted at Cal Tech. As a Division Chair described it:

> *This principle dictates that the barriers between disciplines, departments and even divisions remains very low so that both faculty and students can cross them, if they wish, without spending unnecessary energy.*

Thirdly, much boundary-spanning among our cases involved partnering with entities external to the university, such as private, public, or non-profit organizations. This occurs more frequently in the context of industry-sponsored centers and research projects, as well as in activities associated with the learning and practice of entrepreneurship, involving both faculty and students. There is also interesting variety in the physical locations where boundary-spanning takes place. Several of our university cases were involved in research parks, physically separated from the main campus, where companies —large and small, including startups—can lease, and sometimes purchase, space and often laboratory facilities. University research organizations are also tenants. Thus Research Triangle Park in North Carolina, the Innovation Hub in Gainesville, the Stanford Research Park, the Purdue Research Park, the University Research Park in Utah, and the Centennial Campus at NC State are all examples.

Finally, notable among our cases has been the growth of boundary-spanning enabling organizations and activities. Heretofore, most universities developed external partnerships on a case-by-case base; several of the universities in this volume have established centralized and consolidated organizations to function as enablers. The Enterprise Innovation Institute at Georgia Tech, headed by a Vice President, coordinates and oversees 14 programs dealing with innovation and entrepreneurship, most of which involve partnerships with external organizations. At MIT the Office of Corporate Relations, particularly its Industrial Liaison Program, provides a "guide" service for companies trying to find their way through the dense organizational underbrush of a very complicated university in order to connect with a professor, department or center to sponsor a research project. Working another angle of these relationships, with faculty and industry seeking each other within Purdue's research management operation, there are two individuals with the title of Managing Director for Launching Centers and Institutes, who work with both companies and faculty members to do just that.

The Rise of Entrepreneurship *Instruction and Practice*

As described in the *Introduction* chapter we felt that entrepreneurship programs were "burgeoning" and needed "expanded coverage." Both of those assumptions turned out to be correct. Our case study institutions take diverse approaches to entrepreneurship education, ranging from formal courses, degrees, majors, and programs (Arizona State and the University of Florida for example); to a more informal approach with limited or no degrees/majors (Stanford, CalTech); to a focus on scientific evidence-based approaches (University of Utah, MIT); to novel cross-disciplinary approaches (CMU, MIT, and Purdue). Most schools seemed to integrate mentoring, co-curricular and extra-curricular activities, and community engagement into their entrepreneurship education programs.

The most robust and most dynamic component of these trends lies in *co-curricular* and *extra-curricular* activities that supplement academic courses in entrepreneurship. The majority of schools sponsored incubators and/or accelerators for student and faculty startups, and most sponsored business plan competitions with sizeable cash awards. A few have established innovation scholar programs, fellowships, university venture and seed funds, and mentoring programs. In terms of the latter, Brigham Young University's Venture Mentoring Services, and MIT's Venture Mentoring Service and its national Enterprise Forum network, are impressive practice examples. Some of the more creative support strategies offered to student entrepreneurs include a mandated course for all entering freshmen (ASU), U of U's *BlockU* program, special summer programs including high school outreach and sessions for incoming student entrepreneurs, and MIT's summer "internships" that allow students to be paid as they start their own ventures.

There are several clear advantages in the increased emphasis on co-curricular and extra-curricular activities. One is the typically slow process necessary to get a new course, major, minor, or concentration approved. More than one faculty member has viewed curriculum committees as the place where good ideas go to die. In addition, aside from more flexibility in launch, co-curricular programs have an easier time of pulling in different disciplinary perspectives, not unlike research centers or institutes. Third, the evolving consensus in entrepreneurship education is that skills and knowledge are best acquired via "learning-by-doing," as opposed to learning *about* doing.

The placement of entrepreneurship within a business school silo is the conventional arrangement, but if it inhibits the ability of any student in any discipline to practice entrepreneurship within that discipline (for example if turf issues limit the number of courses/seats offered), this may not be a good thing. At Cal Tech entrepreneurship outcomes are facilitated by not forcing a boundary spanning discipline (entrepreneurship education) into a disciplinary specialization (such as a business school). Stanford similarly offers ubiquitous entrepreneurship education opportunities even while its degree programs in entrepreneurship are limited by comparison. CMU creates entrepreneurs by providing intensive hands-on instruction across three disciplines simultaneously (design, engineering, and business).

Entrepreneurship education is a relatively recent phenomenon and as such there are no pedagogical standards of practice and little consensus on curricula or approach.[3] In fact this volume's collection of in-depth descriptions of our twelve case institutions' approaches to entrepreneurship education is the first cross-university collection on the subject that we know of. To summarize, it is hard to "do innovation" when students are locked into narrowly construed, discipline-bound programs of study. It is encouraging to hear academic leaders champion fewer restrictions on what classes students take. Clemson makes an entrepreneur-friendly instructional approach explicit with its goals that education at Clemson be "grounded in engagement." In fact nearly all of the schools recognize the importance of university research and teaching in local job creation, although for some the connection was more implicit than explicit. The University of Utah is one of the more explicit examples. Years ago an academic administrator at the University encouraged the campus to engage in "Academic Capitalism" and pursue active relationships with business and industry. The message is still part of the culture and lore of the institution.

Best Practices and Policies are Fungible and Adaptable

A guiding premise of this project was that if we spent a year or so trying to identify worthwhile things that innovation-oriented universities are doing, then *other* universities could adopt those policies and practices, accelerate their own planning processes, and then move rapidly into implementing new ways of doing innovation. We knew that the response of some academic leaders would be: "We could never do what they are doing at X; we are different in these ways and constrained in these other ways."

However, while that response may be accurate for some, others will see opportunity. Yes, we agree that some things are hard to move or change, and the bureaucracies of universities can be unwieldy. High on the roadblock list are culture and leadership. When those shift, things start moving.

We also think that most practices and policies in universities are *fungible*, as in "capable of being replaced in kind, as movables." Change can be incremental, and maybe accelerate later on. For example, one could read about technology transfer policies and practices pertaining to student inventions, for instance from Clemson and Purdue, and fairly quickly have 2 or 3 good ideas that might improve deal flow in one's own school. Make a few phone calls, explore respective web sites, and fairly quickly there could be some specific improvements that might be made in one's own institution.

Moreover, most or all of our case universities are so pleased with what they have accomplished that they will share procedures, lessons, and time. Also, the programs and activities that have been around for a few years, with growing positive impacts, are the ones that are most likely to have procedures manuals, examples of what worked, and so on. To take another example, in the entrepreneurship sections of each case there are various centers and curricular programs *briefly* described, each of which might be a good "fit" with what might work in one's own institution. Same drill: call, email, download, and maybe get on an airplane.

One of the big debates in the literature on organizational innovation is the relative importance of maintaining strict fidelity to the target innovation, versus promoting reinvention or adaptation[4] thereof. In our view, not only are the programs and practices described in the cases fungible, but they are also *adaptable*. That is, most program practices and details can be tuned and changed to be a better fit with the culture and ways of doing things at another institution. Admittedly, it is possible to steer so far off course—in other words to lack fidelity with the organizational or policy innovation described—that outcomes are attenuated. It also may be easier to adopt and adapt program practices from a Georgia Tech to another engineering-intensive institution, and so on.

One implementation issue that cannot be ignored is the requisite staffing level of newly adopted programs and policies. For example, if changes are made to increase invention disclosures (e.g., a more functional Web site) in a technology transfer office, that will impact staffing needs in terms of both quantity and credentials of office personnel necessary in order to move those disclosures along. If new program innovations are in effect "transferred" from another institution, it is useful to understand all the staffing and spending implications.

Becoming an Innovation U?

We do not presume to be able to give readers a surefire path to become more like our case study universities. In fact, even with the mini-histories that are part of each case, causality and paths are obscure. This section can only provide our take on what things might help.

- ***Encourage an External, Private Sector Orientation.*** Being innovative and inculcating that mindset in faculty, students and staff can be tough sledding, and one needs to be more attuned to the world outside the university. That might mean many things: in entrepreneurship education, focus more energies on real-world simulations and experiential coursework, as well as co-curricular experiences; in developing centers and institutes, make sure that a large fraction of the stakeholders and participants are from the private sector; encourage faculty research that has links to both conceptual questions and problems out in the world, and reward and encourage faculty and students accordingly; conduct more use-inspired research, and support entrepreneurial problem-solving initiatives to address them.

- ***Hire Talent.*** Many of the Innovation U stories involve transformational leaders, who are hired and then have major roles in influencing a university to change. If you really want to move a campus into a more energetic embrace of innovation-related activities, you should try to find experienced and proven innovators, who can enhance a function, grow new capacities or organizations (centers, institutes), or lead large swaths of the university. Hire people who have been successful in promoting, championing, and better yet, *doing and inspiring* innovation.

- ***Build a Culture.*** If you are able to develop or hire innovation-oriented leaders, then over time mission statements, goals, core values, and all the rest will begin to cluster around innovation. Try to spread those values and goals throughout the university. Make sure internal policies and procedures are increasingly aligned with those new goals and mission statements.

- ***Practice What You Teach.*** Innovate by reinventing internal operations. At MIT for example, entrepreneurship students are encouraged to identify ways that the university itself could change to better support student innovation. Implement policies that reward innovation mindsets and entrepreneurial practice. Engage with the outside world not only for the sake of innovation but also to help make student learning more effective and relevant. Model the behavior that you are trying to encourage.

- ***Take Advantage of Innovation-Focused Federal and State Initiatives.*** As we pointed out in our Introduction chapter, federal and state agencies have become more proactive in promoting an innovation agenda at universities over the past decade, as reflected in a variety of new program initiatives like the NSF's I-Corps program and the Department of Energy's Public-Private Manufacturing Innovations Institutes. Most of the universities included in this report are well aware of these funding opportunities and have made it a priority to pursue those resources.

- ***Adopt Outcome-Based Orientation.*** Having an outcomes-based orientation allows for the development of quantitative metrics such that you can benchmark your progress toward becoming an Innovation U. Some schools have an outcomes orientation due to historic or cultural values that emphasize concrete, measureable outcomes over process (U of U, Brigham Young). The examples set by Stanford and MIT in conducting huge surveys of *all living alumni* to assess business, career, and innovation outcomes should be replicated widely. Quantifying the economic and social impacts of university innovation-related programs and activities should be routine. Unfortunately, the extent to which impacts and outcomes are assessed varies from not at all to some.

- ***Strategic and Tactical Budgeting***. Many schools realized the futility of trying to be all things to all people and sharpened their innovation profile by strategic and tactical budget decisions that focused investments in core competency areas, while concurrently retiring other areas that were no longer cutting edge. At Clemson, a reorganization, prompted by state budget cuts, tracked the most promising technology clusters within the state, consistent with an "outward focus" orientation. Clemson also implemented courageous *divestments* (which for public institutions can be politically difficult). CMU takes a "comparative advantage" focus, building excellence in core fields; at Cal Tech, specialization has always been a fact of life: *"First, by design we don't cover all areas of engineering and applied science."*

Looking Ahead

We conclude as we began, with a reiteration of why descriptive research on university innovation is important. Innovation is born in university labs, involves inventive professors, and graduate and even undergraduate students. Sometimes it leads to patents and licensing deals with companies; sometimes faculty and students come up with their own ideas about how to apply scientific breakthroughs in the real world. The epistemology of the process by which start-up companies become the byproduct of university-generated new knowledge has been described in a robust literature that we need not summarize here.[5] Suffice it to say that the technology clusters of companies around major research universities are no accident. They are evidence of what happens when boundary spanning between abstract theory and applied science occurs. University innovation matters because it is an important engine to generate entrepreneurial ecosystems within local economies.

The major goals of writing *Innovation U 2.0* as articulated in the Introduction were several: to summarize new or larger domains of innovation activity in universities (particularly entrepreneurship); to look more closely at the roles of leadership and culture to foster university innovation; and to look at some different universities that, for various reasons, were missing from the 2002 case sample. This book is larger and more ambitious than the 2002 volume, and we hope that the additions provide valuable information.

These case studies should not be considered as either "complete" or current. Any major US university is always in the process of trying to make itself better—for its students, faculty members, industry and community partners, and for people whose taxes and checks pay a lot of the bills. If the small fraction of university discoveries that are commercialized today could be increased substantially over the next ten years, the impacts on our public and private universities will be even more apparent and visible, and many more people will benefit. If we, or someone else, were to tackle an *Innovation U 3.0* project in a decade, perhaps we will find order-of-magnitude improvements in the innovation outcomes that matter most—new products, services, companies, and jobs—plus an enhanced quality of life for all of us.

Endnotes

[1] One of the biases of the senior author is to spend more words on institutional histories, since universities often seem to be reliving what transpired long ago. Illustratively, if you ever have the pleasure of visiting the University of Virginia, you will discover that many people there talk about Mr. Jefferson as if they had just lunched with him in the next room.

[2] Rogers, D. M. (2003). *Diffusion of Innovations* (5th edition). New York, NY: Free Press; Tornatzky, L.G. and Fleischer, M. (1990). *The Processes of Technological Innovation.* Lexington, MA: Lexington Books.

[3] Rideout, E. & Gray, D. (2013). Does Entrepreneurship Education Really Work? A Review and Methodological Critique of the Empirical Literature on the Effects of University-based Entrepreneurship Education. *Journal of Small Business Management*, Special Issue: Measuring the Impact of Entrepreneurship Education, 51(3), 329-351.

[4] Mayer, J.P. & Davidson, W.S. (2000). Dissemination of innovation as social change (pp. 421-438). In J. Rappaport & E. Seidman (Eds.). *The handbook of community psychology*. NY: Plenum Press.

[5] Audretsch, D. B. & Keilbach, M. (2007). The theory of knowledge spillover entrepreneurship. *Journal of Management Studies*, 44(7), 1242-1254.

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