CHAPTER 5

Industry as a Catalyst of Innovation

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THE CHANGING LANDSCAPE

Success today hinges on our abilities to harness human potential, combine creativity with new knowledge and ensure economic impact is quickly derived from money spent on research. U.S. strength continues to lie in the ability to master innovation, but the future increasingly depends on our ability to also collaborate, optimize resources and align parties around common national agendas.

It is also clear that industry continues to be a critical force in the innovation equation, but the role that industry plays has changed dramatically over the last 30 years. Only through clear understanding how this innovation ecosystem has evolved over time can we hope to capture the true nature of sustainable success in the 21st century.

This paper reviews the evolution of the private sector's contribution to innovation over the last 40 years; it illustrates this shift through case study examples of successful innovation and extracts best practices as food for thought going forward.

Recent studies have indicated that the source of high-level innovations has changed considerably in two key ways. "First, large firms acting on their own account for a much smaller share of award-winning innovations, while innovations stemming from collaborations with spin-offs from universities and federal laboratories make up a much larger share. Second, the number of

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innovations that are federally-funded has increased dramatically." (Block & Keller, 2008) The conclusion from this study is that the U.S. innovation system has become more collaborative in nature and federal funding now plays a more catalytic role.

A recent data analysis of the top 100 R&D awards over the past 40 years, conducted by the Information Technology and Innovation Foundation, indicates that a significant majority of these award-winning U.S. innovations in the 1970s came from corporations acting on their own.

Over the last two decades the majority of innovations have shifted and now come from partnerships involving universities, business and government, including federal labs and federally funded university research. The figures are 80% vs. 66% respectively. In sum, the innovation ecosystem is much more collaborative than it was several decades ago and the federal government is now playing a much more integral role.

There are several factors which have created this outcome: "(1) growing global competition is shrinking technology life cycles; (2) the complexity of emerging technologies is beyond the internal R&D capabilities of even the largest firms; (3) the expansion of R&D capability in more industries is causing R&D investments to spread vertically in high-tech supply chains, which increases the potential for the loss of value added from a single domestic economy; and (4) a growing number of nations are responding to these trends by implementing new mechanisms that increase the efficiency of R&D." (Tassey, 2007)

From an economic viewpoint, the period of the last 40 years has demonstrated the growing importance of scientific and other knowledge in the innovation process, while at the same time the sophisticated nature of technological advances increasingly requires close cooperation across multidisciplinary, possible geographically disperse, teams. In some ways, the old distinction between "basic science" and "applied science" has become obsolete, with proof of concept work being more the norm.

After World War II, the U.S. was dominated by large corporations. These oligopolies allowed higher levels of risk and subsequently investment in more radical and higher payoff technologies. In the 1950s and 1960s, this resulted in large central research labs in firms such as AT & T, General Electric, IBM, RCA and Xerox. However, in the period that followed, foreign firm competition, decreased government regulation, increased computerization, shifts in consumer preference away from standardized products and shifts in the financial marketplace to prioritize increasing short-term returns to shareholders, fundamentally changed the way long-term research was managed. Perhaps the biggest change was the closing down of corporate research laboratories or a significant reduction in in-house R&D budgets. Increased outsourcing and a need for external partnerships followed.

The innovation ecosystem was further impacted by changes in Federal Government policy and practice. Policies to increase the commercial impact

of research (mostly in response to Japanese competition), the passing of the Bayh-Dole Act which allowed universities to commercialize research, investment programs such as the Small Business Innovative Research (SBIR) program, Advanced Technology Program (ATP), Manufacturing Extension Program (MEP), National Nanotechnology Initiative and SEMATECH are all examples that emerged during this period. They were then followed by similar examples from the Department of Energy (DOE) and the National Institute of Standards and Technology (NIST). The National Science Foundation (NSF) and the military supported a more decentralized system of university laboratories that build localized networks of collaboration with groups of industry partners. During this time NSF launched a series (17) of Engineering Research Centers which are interdisciplinary, located at universities and operated in close partnership with industry. (Block & Keller, 2008)

These various initiatives launched in the 1980s essentially coalesced into a system or "triple helix" of university-industry-government collaboration that has become central for innovation (Etzkowitz, 2003). This centrality of networks has played a major role in the effectiveness of the U.S. innovation process, and there are several reasons this approach has worked. First, the need to assemble all relevant forms of expertise under a single organization is impracticable and expensive. Second, the connections between the knowledge embodied in one or more organizations are most critical for the innovation process. The sparks produced when these different approaches combine facilitate effective new approaches (Hargadon, 2003).

THREE CASE STUDIES: NORTHEASTERN U. CENSSIS; UCSD CALIT2; EFTA

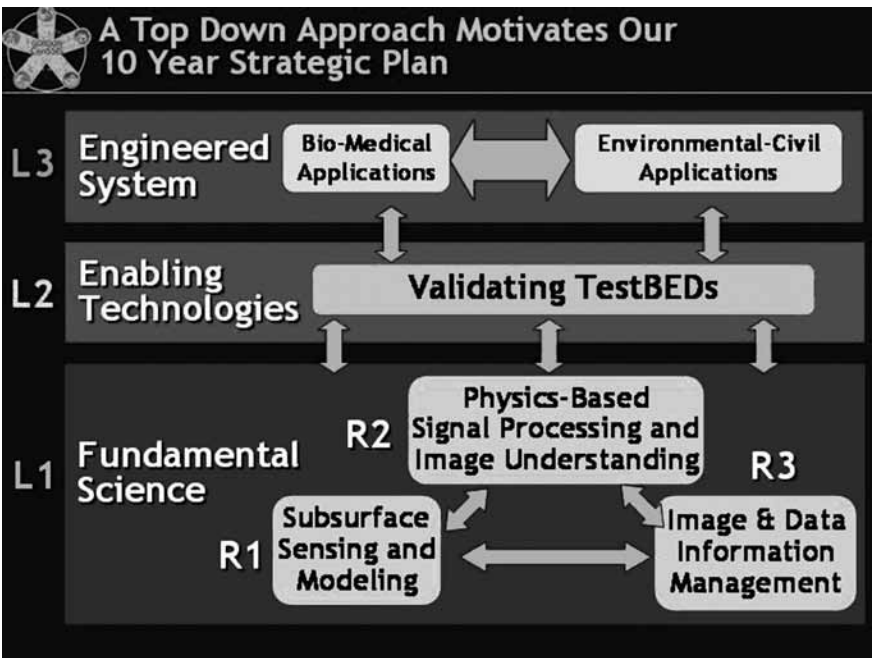
Looking at the role that industry plays in the innovation process, it is helpful to review Case Studies that illustrate why the private sector partnerships are critical for successful innovation. Three programs have been selected, each representing a different strategy for impacting innovation.

The first case study, the Northeastern University Center for Subsurface Sensing and Imaging Systems (CenSSIS), is an NSF-funded Engineering Research Center (ERC). This is an example of a long cycle (10 years) investment, with industry playing a key role from conception. The second case study, the University of California San Diego Calit2 — "A Systems Approach to the Future of the Internet and its Transformation of our Society" — involves a state-funded initiative based on an integrated strategy of complex partnerships. The third case study — Engineering for the Americas — illustrates far-sighted investments by the private sector in the creative side of the innovation ecosystem itself. This capacity-building initiative has worked to enhance the innovation ecosystem of the Americas by capacity-building in

engineering. Hemispheric competitiveness depends on technology and innovation — through EftA, governments, universities and industries have partnered to address systemic changes with economic results.

Center for Subsurface Sensing and Imaging Systems

The Northeastern University Center for Subsurface Sensing and Imaging Systems (CenSSIS) was awarded in 2000 by the National Science Foundation as part of its Engineering Research Center (ERC) program. Funded in two portions, the program will last 10 years and ultimately receive $37M from NSF. Matching funds from the University total $12M over this period. Since its inception eight years ago, it has been considered one of the most successful examples of the ERC Program. Its beginning was less promising.



It started out as an unsuccessful proposal with feedback that Northeastern could not expect to perform this level of research as an R2 school. Enter a new Dean of Engineering and a committed corporate partner and that changed everything.

Alan Soyster was appointed Dean of Engineering in 1999. He came from Penn State where he was a Department Chair. Assessing the NSF rejection letter, he realized that Northeastern could not win a research program of this scope alone and that he needed a core industry partner to drive the initiative. Raytheon Company fit the bill.

Raytheon was a long-standing partner who hired many Northeastern engineering graduates and coops. Its President was an engineering alumnus and the subject area was core to its defence technology and recent interest in environmental sensing. Raytheon was also an aerospace contractor, familiar with how to win federally funded programs by delivering compelling proposals.

Addressing the concern that Northeastern did not have the capacity to perform all of the multidiscipline research, a strategy of partnership was developed wherein Boston University (acoustics), RPI (video imaging) and the University of Puerto Rico (satellite spectral imaging) were added to the team. The President of Northeastern also committed to invest $500,000 to seed the proposal.

For a medium-sized R2 university, this kind of activity represents a large gamble, but the clear role of Raytheon as proposal manager, research collaborator and contributor played a major role in winning the program. As important as winning the program was to the partners, however, it was the subsequent involvement by senior leaders from Raytheon and other industry participants that led to the outstanding string of successes that CenSSIS is known for today.

The goal of the Center was to revolutionize the ability to detect and image biomedical and environmental-civil objects or conditions that are underground, underwater or embedded within cells or inside the human body. A unified, multidisciplinary approach combining expertise in wave physics, sensor engineering, image processing and inverse scattering with rigorous performance testing to create new sensing system prototypes that are transitioned to industry partners for further development. Some of the most difficult and intractable problems in sensing and imaging involve detecting, locating and identifying objects that are obscured beneath a covering medium. Mapping pollution plumes underground, detecting a tumour inside the body, and identifying developmental defects in the interior of a multi-celled embryo all share the problem of distinguishing the effect of a dispersive, diffusive, and absorptive medium from the desired details of the subsurface structure and functionality. The problem is similar whether the wave probe is electromagnetic or acoustic, whether the medium is soil or tissue or whether the target is a land mine or a tumour.

Ultimately, to address the research barriers common to advanced biomedical and environmental-civil applications of subsurface sensing and imaging, CenCISS combined the four universities already mentioned with four affiliated hospitals and research institutions: Lawrence Livermore National Laboratory, Massachusetts General Hospital, Brigham and Women's Hospital and Woods Hole Oceanographic Institution.

Now fast forward to 2009. The CenSSIS program has received $37M from NSF as compared to the original estimate of $28M. In addition, a total of $12M in university matching funds has been achieved over the 8-year period. In 2006 a $20M gift from the Gordon Foundation was made to sustain R&D

infrastructure and create the Gordon Engineering Leadership Program. Over the 8-year period, corporate partners have won 11 R&D proposals totalling $40.4M from key agencies including Department of Homeland Security, DoD, NASA, Army SBIR, NIST and ALION. This represents a clear "Return on Investment" to the Center's industry partners. University partners have been successful in winning over $20M for additional research from NSF (IGERT), DHS, NIH, NIST and NIEHS.

The commercialization of Center technologies has provided additional revenues from: a portable confocal microscope for skin cancer detection; autonomous underwater vehicle; IR-based explosives detection; NVIDIA chip acceleration of tomosynthesis; new CT techniques to detect cardiovascular blockages and cell counting for reliable in vitro fertilization. There are currently 15 industrial members, including Raytheon, the Idaho National Engineering and Environmental Laboratory, AFOSR, Analogic, Lockheed Martin, Sloan Kettering Cancer Center, Mercury Computer Systems, Textron, Siemens and American Science and Engineering. Lastly, Raytheon Company has been awarded a Department of Homeland Security contact in excess of $400M based upon technology developed in the Center.

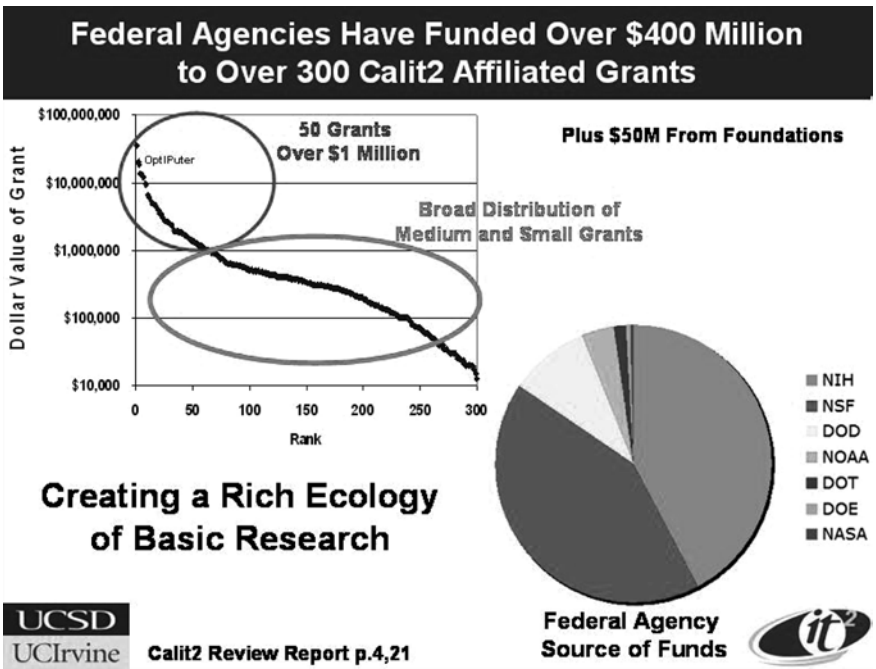
There are several conclusions that can be drawn from this set of accomplishments. One which has not been discussed is the importance of the excellent leadership of the PI from Northeastern, Michael Silevitch who has led the program from proposal to the current day. Not only have the research and commercial outcomes been spectacular, but so have the impacts on education. From K-12 outreach to opportunities for undergraduate research hundreds of students have benefited. The recent NSF IGERT grant in Puerto Rico continues this work.

Looking at the private-sector contribution, it is clear that the diverse group of partners has enriched the research outcomes and provided the marketplace grounding necessary for commercialization. Key to this success has been an industry-driven three-level strategy that enables the solution of diverse problems by coupling a tops-down approach that integrates fundamental science with enabling technologies and engineered systems. The industrial advisory board has played a key role from the first review, with hard-hitting SWOT analyses that were transformative to the program's success. The end result was that system applications were built around real world problems with biological-medical applications and environmental-civil applications.

California Institute for Telecommunications and Information Technology (Calit2)

The state of California took a noteworthy approach to innovation and collaboration early in the new century. In December of 2000, Governor Gray Davis proposed the creation of up to four California Institutes for Science and Inno-

vation to be jointly funded with industry and having the goal of integrating research in California universities with industry and economic impact.



This state-level strategy was intended to "ensure that California maintains and expands its role at the leading edge of technological innovation in the 21st century" and to "give rise to world-class centers for strategic innovation that combine excellence in cutting-edge research with collaborations and training for our next generation of technological leaders". The subjects chosen were explicitly cross-disciplinary: biomedicine and bioengineering, nanosystems, telecommunications, and information technology. The price tag wasn't high. Each institute had to find private sector matching funds of at least twice the level of state support and had to be hosted by at least two campuses. (Kao, 2007)

Since that time, the California Institute for Telecommunication and Information Technology (Calit2) was formed. Calit2 has focused research on addressing large-scale societal challenges through a multidisciplinary approach intended to connect theory and ideas with partners in industry to accelerate innovation and encourage development of ideas. By striving to move beyond traditional research and integrate with practice, Calit2 has impacted real-world solutions in contexts ranging from large, established companies to start-up spin-offs.

From their website: Calit2 represents an experiment in inventing the university research environment of the future to continue to fuel innovation in the global economy. It:

- Builds horizontal links among departments to foster multidisciplinary studies.
- Creates research teams consisting of members who can be located anywhere because of the Internet.
- Supports involvement by faculty, students, industry, government and community partners.
- Enables prototyping in Calit2 "living laboratories."
- Provides technical professionals as the bridge between academia and industry.

Calit2 has demonstrated sustained success and the ability to act as a catalyst for impacting the California economy. Today UC San Diego and UC Riverside count over 350 faculty involved in Calit2 from over two dozen departments. Activities impact faculty, students and the community and are focused on integrating technology consumers and producers. Over $100M in building funding has allowed Calit2 to create "living laboratories" in areas of technical convergence.

Campus life has been greatly impacted due to the increased ability to integrate research into teaching. Students are now exposed to challenging questions faced in research facilities while faculty reaps the benefits of greater industry involvement (and the associated increase in support). Partnerships with industry have resulted in joint grant application, fellowships, internships, endowed Chairs, an emphasis on entrepreneurship in campus cultures and an expanded palette of intellectual pursuits.

But on the Industry side, returns are even more impressive. Myriad research centers and institutes have formed or become involved in Calit2 activities including networked systems, wireless communications, machine perception, microscopy and imaging, and structural genomics, to name a few.

From this traditional model, Calit2 also enables industry by providing access to state-of-the-art facilities, allowing industry to have access to unique resources and capabilities. Examples in this are the new clean rooms at UCSD, the *Leading Edge Photonic Laboratory* and the *Machine Perception Lab* in which company partners play visible, active roles in research areas of business import.

Calit2 has also continued to evolve industrial offerings in other areas. Today, cooperative test beds exist on power transistor tradeoffs, power amplifier tradeoffs, and digital signal processing tradeoffs and provide vendor neutral analysis opportunities and a forum for discussing shared problems. Other innovative efforts include a Nano-Bio-Info Innovation Library.

Outcomes have been impressive with Calit2 affiliated proposals winning over $400M in federal funding and another receiving $93M in Industry sup-

port. In one example, Qualcomm has invested over $22M in Calit2 projects, faculty and students.

Calit2 is an excellent examples of the successful strategy embarked on by Gov. Davis and committed to by the leaders and legislatures of California since. A culture of research integrated with economic outcomes is ideal and, through investment in these institutes, California has taken proactive action to ensure relevance of its universities, health of its industries, and a solid foundation for employment of the workers of their state.

Engineering for the Americas (EftA)

Innovation is not always about products and services. Innovative partnerships can also address more fundamental questions of workforce creation, talent formation, and the balance between the creative needs of industry and priorities of academe. This technical innovation example is concerned with exactly those issues: how can we develop an innovation ecosystem able to improve competitiveness while equitably managing opportunity?

Engineering for the Americas (EftA) is an initiative of technical capacity building in engineering for the hemisphere of the Americas in order to facilitate the attraction of foreign direct investment (primarily from multi-national companies), the stimulation of small technology based businesses by entrepreneurs, and creation of high-quality/high-salary employment in the region for socio-economic development.

In collaboration with the Organization of American States (OAS), endorsement of this thrust was obtained from the Ministers of Science and Technology of the 34 countries in the Hemisphere, in November 2004. Through funds provided by the U.S. Trade Development Agency and several leading corporations (Hewlett-Packard, Cemex, Microsoft, National Instruments), a major conference was held in Lima at the end of November 2005, bringing together leaders from academia, industry, governments, and NGOs to discuss technical capacity-building in the Hemisphere and to lay plans for its implementation (for example through loans and grants from the International Financial Organizations — IFOs).

A Provisional Executive Committee has been established to pursue the recommendations and plans from the conference, including the organization of workshops in the region, pilot projects, research and survey studies, and sustainable funding on engineering education, accreditation and quality assurance, as well as technological businesses and job-creation.

Since its creation in 2004, EftA has made great progress in solidifying interests among the countries of the Americas and in including stakeholders from all sectors and all geographies of the hemisphere. Enabled by multiple sources and totalling over $3M of invested and leveraged funding, EftA has embarked on a series of awareness-generating activities, invested in partnership outreach and development, and facilitated construction of proposals and ideas designed to harness the resources of the IFO world on behalf of engineering as a basis for sustainable social and economic development.

Engineering for the Americas Progress: Over the course its initial incarnation, the Provisional Executive Committee embarked on several activities including the creation of a strategic plan and activities in support of EftA objectives. The three core strategies and associated activities have been:

Engineering Education Improvement: EftA has produced and delivered workshops in support of educational improvement in Chile, the Dominican Republic and Peru. These workshops focus on the need for engineering curriculum to incorporate project-oriented lessons and address the needs of industry through lessons enhanced with practice and real world context.

EftA also sponsored and supported many education conferences and events including an entire track of the Global Colloquium on Engineering Education held in Rio de Janiero in October 2006. A partial list of conference participation includes annual meetings of ASEE '06, ASEE '07, GCEE '06, LACCEI '05, LACCEI '06, and UPDAI '06. Through these visibility-raising investments, EftA has elevated the discussion and brought focus to international engineering education collaborations throughout the hemisphere.

Accreditation and Quality Assurance: Acting as a catalyst, EftA created a partnership committed to founding a regional accreditation system for engineering in the Greater Caribbean. Panama, Jamaica and the Dominican

Republic aligned together to submit a proposal to the Inter-American Development Bank (IDB) *Regional Public Good* funding window in October of 2006. This winning proposal received nearly US$750,000 in IDB and partner support. Since 2007, countries of the Greater Caribbean are collaborating to improve the brand and credentials of the engineering graduates of their region.

Job Creation: EftA has worked to identify, engage, and involve local industry. One common challenge is the apparent disconnect between academia and industry in Latin America.

To address this issue, in 2007 EftA facilitated collaboration among the Deans of Engineering in Chile, Argentina and Brazil to create programs and curriculum around entrepreneurship to the engineering education experience in the Southern Cone. Together with their respective governments, industry, and broader community of universities, Argentina submitted a proposal to IDB on behalf of Chile and Brazil to establish a cross-border partnership in this area. In 2008, IDB awarded this project and nearly $2M in IDB and partner funding is now working to enhance education and shape a more entrepreneurial culture in the South.

Summary of EftA Accomplishments: Since the Ministers and other High Authorities committed to engineering as a pathway to sustainable opportunity in the Lima Plan of Action, Engineering for the Americas has made great progress in creating collective understanding of the importance of engineers to economic health and the critical nature of engineering education to future national competitiveness.

Engineering for the Americas established a comprehensive partnership, established political will within the hemisphere of the Americas, engaged with constituents and development finance organizations, and succeeded in generating funding based on public-private partnerships and co-investment strategies.

EftA has catalyzed the discussion within the Development Finance community, with Ministers and governments, among educators, and with the enthusiastic support of Industry practitioners. Today, discussions of "Competitiveness" and "Innovation" include sensitivity about talent creation. Investments are being made to ensure a robust and healthy engineering community engages in creating the talent that our economies will need to succeed in a global market.

CONCLUSIONS & RECOMMENDATIONS

Since World War II, the evolution of research and innovation clearly points to an increasing need for collaboration between the industry, government and university sectors. The impact and selection of government funding is also

critical. These "Open Innovation" models succeed only when there is a true partnership that delivers winning outcomes to all participants.

Recent work funded by the Kauffman Foundation and supported by the Sasakawa Peace Foundation, reviewed over 90 case studies of University-Industry partnerships in four countries: Japan, the U.K., Canada and the U.S. The report provides insights into an evolved understanding of business-university relationships:

- The process through which economic and social value is most likely to be added is through a partnership between industry and universities.
- The process of knowledge exchange that involves businesses and universities working together adds the most value: the old paradigm of fundamental research moving to applied research needs to be rethought.
- The metrics which encourage knowledge exchange need to reflect this understanding.
- The development of open innovation models will also require changes to how government measures the condition of university research.
- A need for knowledge transfer practice to work more flexibly and with speed in interacting with businesses (large companies and SMEs).
- The need to understand and support the relational as well as the transactional aspects of collaboration between universities and business; building trust and mutual understanding really matters and this takes time.
- The capacity and capability of business to interact with universities is just as important as the willingness and ability of universities to work with industry; universities need to take these variables into account when developing their own knowledge transfer strategies.

As the Kauffman-funded study illustrates, the new landscape of the global economy demands that we examine the processes at work to understand what strategies for competitiveness might work. This should be an ongoing process, part of a dialogue, wherein industry, academe and governments work together toward a common vision of national success. Clearly knowledge will be critical and talent creation is vital to economic results.

These case studies and many others have shown that collaborations really do work. Industry has proven to be catalytic in forming sustainable, relevant partnerships. Increasingly it is the holistic collaborations that master innovation and have lasting impact in the global market. Today, competitiveness and quality of life derive from success in innovation. At this we must excel.

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