深度创新面临的挑战：从
美国学术界到商业界

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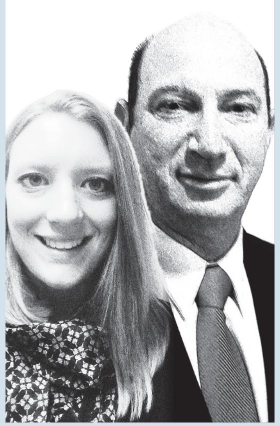


THE CHALLENGES OF DEEP INNOVATION: FROM AMERICAN ACADEMIA TO THE MARKETPLACE

POLICY CASE STUDY

Introduction

Deep Innovation in science and technology, particularly the development of new technologies or products based on scientific discoveries in U.S. academic institutions, has been a challenge for decades. The U.S. government, through its research funding agencies, has addressed this challenge by developing a myriad of funding programs, most notably the Small Business Innovative Research (SBIR) and Small Technology Transfer Research (STTR) programs, which award research grants to small business and academic institutions that aim to advance technology development and commercialization based on basic research discoveries. By law, 2.9% of the budget of each major U.S. research funding agency is allocated to the SBIR/STTR programs and this allocation is expected to grow to 3.2% in the coming years.

DEVELOPMENT OF NEW TECHNOLOGIES OR PRODUCTS BASED ON SCIENTIFIC DISCOVERIES HAS BEEN A CHALLENGE FOR DECADES

The article provides a brief description of the SBIR/STTR programs and their impressive track record in facilitating Deep Innovation, as well as other funding mechanisms that are used to realize this goal. While the SBIR/STTR programs have been highly successful, there is a growing realization that the time gap between the initial scientific discovery and the development and introduction of technologies, or products, to the market remains very long – in many cases about 20 years! This long time period is termed the innovation Valley of Death, since most discoveries ‘die’ during the technology or product development process. Recognizing this challenge, the U.S. National Science Foundation (NSF) and other U.S. funding agencies developed new programs with a specific objective of shortening the innovation Valley of Death. The article describes the newly introduced NSF I-Corps program, which aims to address this challenge by focusing on innovation education.

The Challenge Of Deep Innovation

The process of developing new commercialized technology based on a fundamental research discovery made in academic settings is defined as Deep Innovation. This is often a long, expensive, and frustrating process. While fundamental research discoveries are made in a variety of research settings, this article focuses on basic scientific research discoveries that are made in academic laboratories, typically by research faculty and their postdoctoral research fellows and students. In many instances, it is not possible to immediately identify the commercial potential of a specific research discovery.

DEEP INNOVATION IS OFTEN A LONG, EXPENSIVE, AND FRUSTRATING PROCESS

A well-known example is the discovery and development of Gorilla Glass by Corning investigators in the 1950s. This particular strong or 'muscle' glass technology only showed limited use up until 2005, when Apple asked Corning for a thin, toughened glass, which is now used in cell phones and tablets worldwide. A detailed description of Gorilla Glass technology can be found at http://www.corninggorillaglass.com/. This unique glass is mechanically strengthened through a novel ion exchange process, which is realized by heating molten glass to 400° C (752° F) and pumping glass with high levels of potassium ions. At this high temperature the large potassium ions diffuse deep into the glass to form a compression state, which increases the density of potassium ions in the glass. Increasing the compression state of the glass increases its mechanical strength and damage resistance. Since the wide-scale adaptation of Gorilla Glass as cell phones and tablet screens in 2005, Gorilla Glass has gone through four generations of improvements and updates. Each generation becomes stronger, with unique features such as high-scratch resistance and improved drop performance. Some generations of Gorilla Glass incorporate a silver layer for anti-microbial protection. The Gorilla Glass success story illustrates the importance of investing in basic science – even if the applications of the scientific pursuit are not at all known, or could not even be envisioned, at the time of the study.

At other times, recognizing the commercial potential of basic scientific research discoveries in academic laboratories is hampered by the mere fact that research faculty and their junior researchers do not have the necessary training to recognize the commercial potential of their fundamental discoveries. Even when recognized, many research discoveries with significant commercial potential only result in patents, which are filed by the academic institutions but often left untouched for lack of interest of research faculty in pursuing technology development and commercialization. Leading economists have spent a great deal of time attempting to understand the innovation Valley of Death, and research funding agencies in the U.S. and around the world convened numerous community initiated workshops to discuss and suggest new programs to overcome the phenomenon. While many factors contribute to the slow pace of technology transfer in academia, this article aims to fill an information gap about existing U.S. Government programs, and to highlight the importance of innovation education in academia to overcome barriers for technology transfer and commercialization.

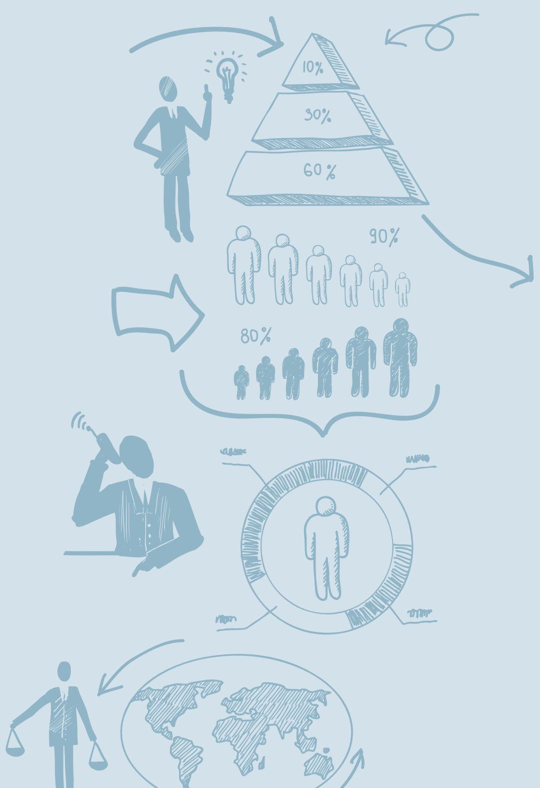
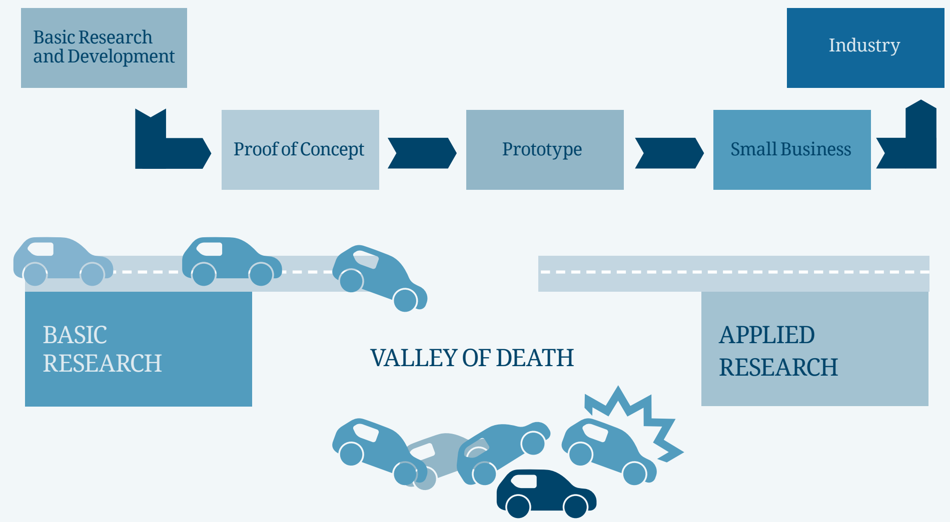


Figure 1: The innovation Valley of Death is illustrated to show the gap, or often the breakdown, between basic research discoveries and the development of technologies or products that are based on these initial discoveries

Source: Author analysis



Mechanisms To Facilitate Deep Innovation

1. **The Small Business Innovative Research (SBIR) and Small Technology Transfer Research (STTR) programs**

   Perhaps the most ambitious U.S. policy action to facilitate Deep Innovation and overcome the Valley of Death was the establishment of the Small Business Innovation Research (SBIR) and the (smaller) Small Technology Transfer Research (STTR) programs by the U.S. Congress in 1982. As described on the SBIR/STTR website (https://www.sbir.gov/), the two programs encourage U.S. small businesses to engage in research that has the potential for commercialization. The programs fill a great need since technology development and commercialization of basic science discoveries is an expensive process, and faculty and student inventors, and academic institutions typically do not have the resources needed to compete with large companies, and effectively pursue technology development efforts.

   Each program administers a competitive review process to select collaborative R&D projects between small businesses and academic institutions, which explore the technological potential of basic research discoveries. The programs fund seed projects, termed Phase I, and continuing projects of successful Phase I projects, termed Phase II.

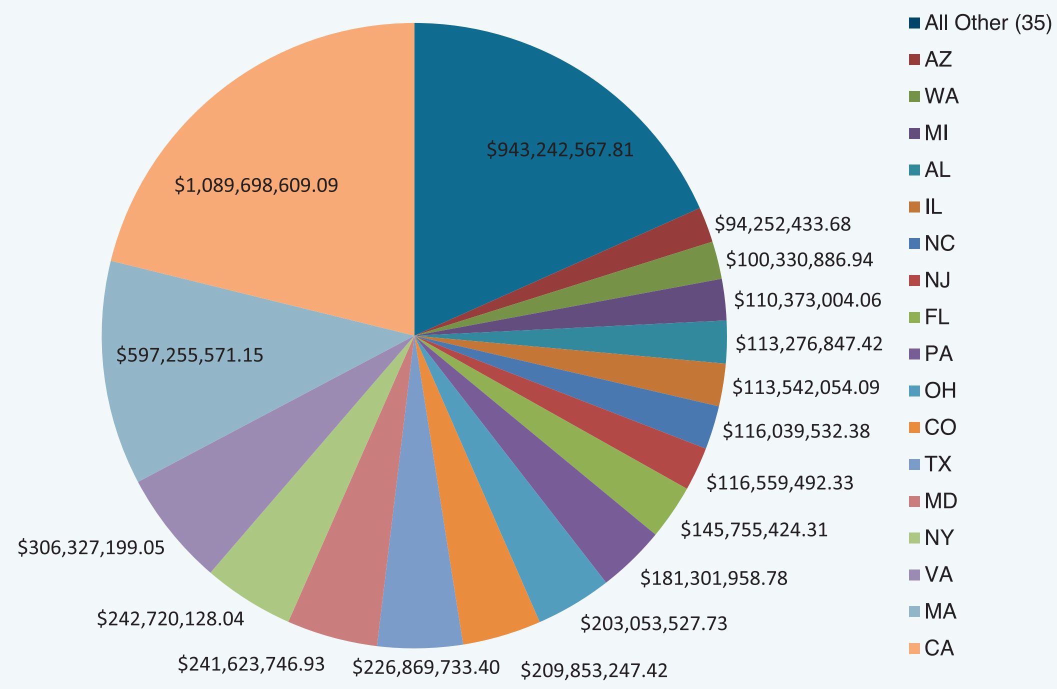
Continuous investment in successful Phase II projects is made by the private sector and such projects are termed Phase III. Each year, major U.S. Federal agencies are required to allocate 2.9% of their R&D budget to their SBIR/STTR programs, and this allocation is expected to grow to 3.2% in the coming years. Currently, the following U.S. Federal agencies participate in the program: Department of Agriculture, Department of Commerce, Department of Defense (DoD), Department of Education, Department of Energy (DOE), Department of Health and Human Services (NIH), Department of Homeland Security (DHS), Department of Transportation, Environmental Protection Agency (EPA), National Aeronautics and Space Administration (NASA), and the National Science Foundation (NSF).

SBIR AND STTR ENCOURAGE U.S. SMALL BUSINESSES TO ENGAGE IN RESEARCH

Since their enactment in 1982, the SBIR/STTR programs have helped thousands of small businesses to compete for federal R&D awards. In 2014, they invested about US$2.5 billion in approximately 6,000 R&D projects, of which 4,000 were Phase I and 2,000 were Phase II. When enacted in 1982, one of the main goals of the SBIR/STTR programs was to facilitate economic development across all regions of the United State. U.S. research funding agencies strived to achieve this goal by pursuing extensive outreach efforts to educate academic institutions and stakeholders in the private sector about the availability, structure, and goals of the SBIR/STTR programs. This undoubtedly became an easier task with the emergence of the internet as an effective tool of communication. Figure 2 shows that these extensive outreach efforts have been quite successful – as evident the broad geographical distribution of SBIR/STTR projects across the U.S.. The SBIR/STTR programs have made significant contributions across all regions of the U.S. that enhanced the U.S. defense, protected the environment, advanced health care, and improved the ability to manage information and manipulate data.

Figure 2: SBIR program investment between 2010 and 2014 by U.S. States. The SBIR program supports research projects that total over US$2 billion annually and this amount is expected to grow in the coming years (image is taken from https://www.sbir.gov/sites/default/files/SBA_OII_SBIR_STTR_Presentation_for_General_Public_3-20-15.pdf)

Source: Author analysis



Qualcomm Inc. is one of the most impressive success stories of the SBIR/STTR programs. In 1985, Qualcomm was a small company of seven co-founders aiming to become a fully integrated, research-to-manufacturing business. The company targeted the

QUALCOMM INC. IS A LIVING TESTAMENT TO THE IMPORTANCE OF THE SBIR/STTR PROGRAMS

transportation industry as a potential major client and spent three years developing a system that would enable trucking firms to closely track their drivers' progress, and enable drivers and dispatchers to send messages to each other. The company encountered a great deal of skepticism about the idea of having a very small, low-cost terminal installed in the back of a truck, that would work over satellites designed for very large terminals, yet it was able to achieve this goal. Qualcomm then secured its first big order from the Schneider National Trucking Company, which provided a much-needed capital infusion. This early success led Qualcomm to take another daring departure from conventional wireless wisdom. In 1989, the Telecommunications Industry Association endorsed a digital technology called Time Division Multiple Access. Three months later, Qualcomm introduced Code Division Multiple Access, a superior technology that would change the global face of wireless communications. In its early days, SBIR grants of US$1.5 million from NSF and DoD played a major role in developing the company's digital communication technology. With a current market share of over US$80 billion, 13,000 patents in telecommunications, and 17,500 employees worldwide, Qualcomm Inc. is a living testament to the importance of the SBIR/STTR programs in catalyzing and facilitating Deep Innovation. More information about other amazing SBIR/STTR success stories and the founder of the SBIR/STTR programs, Roland Tibbetts, can be found at https://www.sbir.gov/about-tibbetts-awards.

2. **The NSF GOALI and NSF–SRC partnership – other modalities to facilitate Deep Innovation**

   While the SBIR/STTR programs are administered by multiple U.S. funding agencies, individual U.S. research funding agencies offer additional funding modalities to facilitate Deep Innovation. For example, the NSF Grant Opportunities for Academic Liaison with Industry (GOALI) (https://www.nsf.gov/funding/pgm_summ.jsp?pims_id=504699) promotes university–industry partnerships by supporting collaborative research projects between academic and industrial scientists. The GOALI program funds transformative research that industry would not normally support.

I-CORPS TEAMS... ARE SELECTED TO PARTICIPATE IN THE I-CORPS PROGRAM CURRICULUM

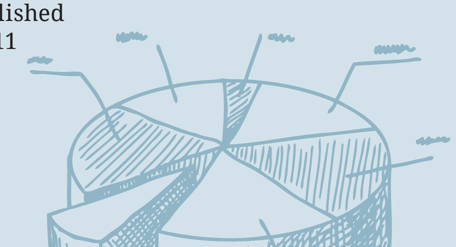
A number of U.S. funding agencies' programs to support thematic Research Centers emphasize close interactions between academia and industry as a means to facilitate Deep Innovation. For example, a unique NSF program involves collaboration with a consortium of semiconductor companies named the Semiconductor Research Corporation (SRC). The NSF–SRC partnership supports Nanoelectronics Research Initiative (NRI) Centers where researchers from academia work closely with researchers from the semiconductor industry and government laboratories to advance new concepts in Nanoelectronics (https://www.src.org/program/nri/nri-nsf/).

Both the GOALI and NSF–SRC partnerships aim to shorten the innovation Valley of Death by enhancing communication between academic and industrial scientists. U.S. funding agencies' investments in these important programs in 2014 was about US$10 million, orders of magnitudes lower than SBIR/STTR programs' investments, which limit their impact.

It is fair to conclude that the SBIR/STTR programs are the main funding mechanism used in the U.S. to facilitate technology transfer from academia to industry, hence Deep Innovation. Despite their great record, U.S. funding agencies recognized that the programs have not been able in many cases to significantly shorten the innovation Valley of Death. Numerous community-led workshops to discuss the problem are quite consistent in their analysis. For example, a 2009 NSF-sponsored workshop titled Assessing and Enhancing the Impact of Science R&D in the United States: Chemical Sciences (https://www.ccrhq.org/innovate/publications/phase-iii-study) listed the high technical risk associated with the underlying R&D, the long time to complete the R&D and commercialize the resulting technology, and difficulty in resolving intellectual property issues as contributors to the innovation Valley of Death. Even more importantly, the lack of innovation education in U.S. academic institutions was viewed as a major hurdle to advancing technology transfer from academic laboratories to the market. The lack of experience and understanding of basic business concepts, and the process of commercialization, significantly limit the ability of faculty and students to successfully engage in technology development and commercialization efforts. In response to these workshop reports, in 2011 the NSF introduced a new innovation education program named I-Corps, which is designed to close the innovation education gap in U.S. academia.

NSF I-Corps Program

The NSF I-Corps program (http://www.nsf.gov/news/special_reports/i-corps/) offers an extensive and rigorous curriculum that aims to demystify the process of technology development and commercialization and prepares scientists and engineers to develop small businesses to commercialize their technologies. The I-Corps program makes extensive use of established entrepreneurs who guide faculty and students as they identify and conduct market analysis, form imperative connections with potential clients and partners, and develop their technology development plans. Through a competitive review process, I-Corps teams, which consist of academic researchers, student entrepreneurs, and business mentors, are selected to participate in the I-Corps program curriculum. A detailed description of the I-Corps curriculum can be found at http://steveblank.com/category/nsf-national-science-foundation/. The program established its first site at Stanford University in 2011 and since then has expanded to include additional sites at Georgia Tech, University of Michigan, University of California Berkeley, University of California at San Francisco, University of Maryland, John Hopkins University, Virginia Tech, George Washington University, New York University, Columbia University, and City University of New York. The primary role of these I- Corps program sites is to catalyze additional groups to explore potential I-Corps team projects and other entrepreneurial opportunities that build on basic research in their geographical areas. The I-Corps program can already point to several successful technology development and commercialization projects which are described at http://venturewell.org/category/nin/. Recognizing the critical role of the NSF I-Corps program in addressing an innovation training gap, the U.S. Department of Energy and the National Institute of Health partnered with NSF in 2014 to expand the program in order to accelerate commercialization of clean energy technologies and biomedical research innovations in the near future. It is highly likely that U.S. Government investment in the I-Corps or similar innovation education programs will grow significantly in the coming years.



Conclusion

Through the SBIR/STTR programs and other funding modalities, in the last 35 years major U.S. research funding agencies have made significant investments in facilitating Deep Innovation in the U.S.. Despite their clear successes, in many cases the SBIR/STTR programs were not able to significantly shorten the time gap between the initial basic science discovery in the academic laboratory and the introduction to the marketplace of new technologies or products based on these basic science discoveries. The lack of innovation education has been recognized as a major contributor to the slow pace of technology transfer from academia to industry. This problem is amplified by an academic culture that generally values basic science discoveries, which are published in leading scientific journals, much more than applied research that leads to technology development and commercialization. Complicated intellectual property, and outdated immigration laws and policies , which, are beyond the scope of this article

also make it challenging for faculty and students – who typically lack entrepreneurial expertise – to engage in commercialization efforts. The NSF I-Corps program aims to provide the missing innovation education needed to address and overcome these issues, but it is too early to assess its overall impact.

A word of caution is warranted. While the process of technology development and commercialization of basic science discoveries could be simplified and shortened, one must remember that the process of Deep Innovation based on basic science discoveries, for example the development of new drugs, is inherently longer and often much more consequential than the development of a new social media website or a videogame app. While a period of 20 years for Deep Innovation might look extensively long from the economic perspective of stakeholders, it is actually short in the scale of societal evolution. While excessive bureaucratic hurdles should be removed, and better innovation education training should indeed be offered, we should resist the temptation to introduce new technologies or products to the market before they are fully vetted, in order to prevent harm to human health and the environment. Lastly, policymakers must be reminded that all technology development efforts today are the result of basic scientific discoveries made decades ago. Resources to facilitate Deep Innovation at a faster pace should not come at the expense of investments in basic scientific research, which are key to the development of future technologies. If anything, the impressive contributions of the U.S. SBIR/STTR programs to the U.S. economy should convince policymakers to increase investment in basic research in order to spur future economic growth.

FURTHER READING

George S. Ford, Thomas M. Koutsky, and Lawrence J. Spivak, "A Valley of Death in the Innovation Sequence: An Economic Investigation", September 2007, Report prepared for the U.S. Department of Commerce.

Steve H. Barr, Ted Baker, Stephen K. Markham and Angus L. Kingon, "Bridging the Valley of Death: Lessons Learned from 14 Years of Commercialization of Technology Education", Academic of Management Learning and Education, 2009, 8(3), 370-388.

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