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INVESTING IN ACADEMIC TECHNOLOGY INNOVATION AND ENTREPRENEURSHIP: MOVING BEYOND RESEARCH FUNDING THROUGH THE NSF I-CORPS™ PROGRAM

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In 2012, the National Science Foundation (NSF) took ambitious steps to revisit how they invest in academic innovation and entrepreneurship. Rather than increasing financial investments in technology development, it created NSF I-Corps™, an innovation education program and nationwide innovation network for NSF-funded faculty and trainees. Since its launch, NSF I-Corps has trained over 3,000 researchers and has been adopted by nine federal agencies. This paper provides a brief history of government investment in academic innovation, including the conceptualization of the I-Corps program, as well as its goals, growth, and influence on other agencies. The primary data for the paper includes interviews from 13 key individuals involved in the launch of the program and publicly available program data. We conclude with a discussion of challenges and opportunities as I-Corps-related programs look to scale and sustain their efforts going forward. This paper offers government, university administrators, and faculty insight into alternative methods of promoting academic innovation and explores future research areas for entrepreneurial ecosystems and education.

Key words: National Science Foundation; I-Corps; Innovation, Entrepreneurship; Academic innovation

INTRODUCTION

Innovation is viewed as the economic driver of today's knowledge economy. The U.S. federal government has consistently supported innovation through policies, regulations, and funding (1). For years, funding has been viewed as the major factor for the U.S.'s innovation success (2), contributing 20% to 25% of early-stage investments (3). Government investments in early-stage technology development reduces technical uncertainty by bridging the "valley of death" finance gap (4). The phrase "valley of death" is often used to describe the early-stage capital gap between federally funded research and late-stage venture capital financing (2).

In 2012, the National Science Foundation (NSF) launched I-Corps™, drastically changing their approach to stimulating research translation by redefining the role of government funding. Unlike

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traditional early-stage product development government grants, I-Corps was created to bring teams of NSF-funded researchers and industry experts together to enroll in an entrepreneurship and innovation course and complete an opportunity recognition exercise while developing a potential business model. For the first time, NSF was directing funds towards developing the individual innovator, as opposed to the technology itself. With I-Corps, NSF began investing in faculty human capital development and facilitating the creation of closer university-industry ties (5).

The purpose of this article is to provide a retrospective narrative of the I-Corps program, describe how it evolved into the National Innovation Network (NIN), and offer insight into the conception, execution, evolution, and expansion of this unique training and support network for academic researchers. This article also describes the impact of I-Corps and addresses the challenges the program may face in the future.

BRIEF HISTORY OF GOVERNMENT INVESTMENT IN ACADEMIC INNOVATION

The federal government has played a significant role in supporting American innovation since World War II (6). Fueled by the transition into the Cold War, the U.S. government heavily invested in government technological capacities through research and development (R&D) funding, policy support for commercialization and development, and support for learning and diffusion of knowledge (7). All of these efforts were designed to promote innovation and provide infrastructure and capital for research scientists to explore their own research ideas or, more importantly, explore research that supported government-specific needs, such as weapons systems (8).

Government R&D spending has dominated the government's role in innovation (7). Following World War II, the U.S. government established a network of federal research labs focused on government-specific needs and several research funding agencies. The NSF was created in 1950, followed by the Defense Advanced Research Projects Agency (DARPA) in 1958. DARPA was established in response to the Soviet Sputnik launches and relied entirely on extramural researchers (7). DARPA was a unique approach to federal research funding, as it was given the fundamental task of bridging the gap between research and engineering product development (7). Focused on "Blue Sky" thinking, DARPA program officers were able to invest in technologies that would not see a return for at least 10 to 20 years, allowing researchers to experiment with new innovations (6).

In the 1980s, the government facilitated a more decentralized form of industry policy by increasing its support for commercialization and development through direct and indirect means (6). Initially, there were major changes in U.S. patent policies and practices to strengthen patent protection (9). Congress also passed three significant acts to promote technology transfer: the 1980 Stevenson Wydler Technology Act, the 1982 Bayh-Dole Act, and the 1982 Small Business Innovation Development Act. Two of the acts focused on policy with respect to national labs, universities, and non-profits, while the third act set aside funding specific to translation. The 1980 Stevenson Wydler Technology Act required federal laboratories to collaborate directly with state and local governments, universities, and private industry (10). Each national laboratory was mandated to create an Office of Research and Technology Applications (10). The Bayh-Dole Act gave universities and government labs the ability to file for patents and license technology derived from federally funded research (11). The 1982 Small Business Innovation Development Act directed government agencies that spend more than $100 million annually on external research to set aside a fraction of their research budgets (1.25%) to support work from small, independent, for profit small businesses (12). The Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs were most recently reauthorized until September 30, 2022, at a rate of 3.2% and 0.45%, respectively (13). Finally, the government has historically also used tax credits to support innovation: R&D tax credits, tax credits or production subsidies for new technology companies, and tax credits or rebates for new technology customers (7).

Government support for diffusion of knowledge and technology and learning has traditionally been indirect. Similar to policy setting, the government worked to increase knowledge diffusion through codification of technical knowledge, technical standard

setting, publicity, and offering technology extension services (7). As for learning, the government has relied on its financial support of traditional education channels, such as university degree programs (7), and directives for new initiatives, such as science, technology, engineering, and mathematics (STEM) education reform (e.g., Educate to Innovate campaign (14)).

This historical review demonstrates that the overall role of government in innovation has relied on R&D funding and policy development. These two mechanisms have been used to direct intellectual focus towards government relevant needs and to motivate individuals and institutions to pursue research translation. The government innovation system was developed to be highly decentralized during the Reagan years with several overlapping elements (6). According to Block (6), "This complexity is, in part, intentional because the innovation process is highly uncertain; even the best scientists and engineers spend a lot of time wandering down false pathways." But what if we can help scientists reduce the amount of time spent wandering down false pathways? This goal was what the NSF sought to address in the development of the 2012 NSF I-Corps Program.

Rather than developing an infrastructure that relies on researchers to self-select into translatable opportunities and independently seek out relevant translation resources, NSF looked to develop a program that invested in the researchers themselves. By educating NSF researchers in early-stage opportunity identification and connecting researchers with the necessary resources to consider translation, NSF has begun to create a larger pool of innovators capable of developing and pursuing translatable innovations from federal funds.

CONCEPTUALIZATION OF I-CORPS

In 2010, Dr. Subra Suresh was confirmed as the director of NSF and became responsible for one quarter of all federally funded university STEM research (15,16). Despite the fact that university-based programming for innovation had existed for over 30 years, Director Suresh identified two prevalent challenges to national STEM innovation: 1) a programmatic gap between the two flagship government sponsored industry-academe research partnership programs (the Industry–University Cooperative Research Centers (IUCRC) program and the SBIR/STTR programs) and 2) the absence of innovation and entrepreneurship training for STEM innovators (5). Influenced by his experience as the dean of engineering at the Massachusetts Institute of Technology (MIT) and with the MIT Deshpande Center, Director Suresh launched the I-Corps program to catalyze a connection between university basic science research and commercialization. NSF program officers throughout the agency were called upon for feedback and input during program development. Key program officers responsible for operationalizing the program included Errol Arkilic, Don Millard, Rathindra DasGupta, Richard Voyles, and Anita La Salle.

At first, I-Corps was conceptualized as a mentoring program for academic scientists and engineers. Ultimately, I-Corps evolved into a structured, experiential education program for teams of academics and industry experts working together to explore the economic potential of NSF-funded research. Programmatically, I-Corps bridges the gap between IUCRC and the SBIR/STTR programs by providing academics with a level of training not commonly experienced by research scientists. Throughout the I-Corps process, academics are immersed in the commercialization process, educated in entrepreneurship, and provided funding to explore commercialization opportunities.

Like the SBIR and IUCRC programs, the I-Corps program provides researchers with early-stage commercialization funding or use-inspired research, respectively. However, unlike SBIR and IUCRC programs, I-Corps focuses on early-stage venture development, opportunity recognition training, and network support, all of which are critical for realizing the full commercial potential of innovative technologies.

I-CORPS TEAMS AND CURRICULUM

I-Corps three-person teams and its curriculum are the foundation of I-Corps. Teams of three, an Entrepreneurial Lead (EL), an NSF-funded Principal Investigator (PI), and a Business Mentor (BM), are awarded $50,000 to enroll in a six- to ten-week

experiential entrepreneurship curriculum and explore commercialization opportunities for their NSF research. Team formation is prescriptive and based on three fundamental concepts:

a) Focus on the Trainee: Experience with academics in the SBIR program (Personal communication from Errol Arkilic, unreferenced) and research have both demonstrated that it is the trainee or graduate student who often takes responsibility for pursing commercialization opportunities (17). In most cases, the trainee is less risk averse or at a stage in their career where pursuing commercialization opportunities is viable. Thus, the trainee, or EL, is the focus for the program.

b) Embed PIs: Faculty members are viewed as long-term change agents who need be exposed to entrepreneurship, and they help maintain a tie between the university and the start-up. Faculty involvement, as PIs, is critical for large-scale cultural change within universities, and faculty need to be immersed in the I-Corps process to effect such change.

c) Involve Industry: Industry involvement, in the role of mentors, is critical. In addition to business mentoring, BMs are needed to provide teams with immediate access to industry context, insights, and connections.

Only the most recent innovations are eligible for I-Corps, thus research teams must have had an active research award within the past five years.

The architect of the I-Corps curriculum is serial entrepreneur Steve Blank. Based upon his personal experiences with his own start-ups, Blank authored *Four Steps to the Epiphany* (18,19), which developed from his Lean LaunchPad Entrepreneurship course for Stanford University (E245). Blank modified E245 to create a customized entrepreneurship training curriculum for academics in STEM fields. At the core of the course is the concept of "customer discovery" and the business model canvas (20).

According to Blank, entrepreneurs need to directly talk to customers when developing their product, a process he termed "customer discovery." Students are advised to "get out of the building" and derive insights directly from customers (21).

Alexander Osterwalder's Business Model Canvas (BMC) is used as a framework for customer discovery. The BMC is a template that visually captures the customer discovery journey in terms of a company's potential customers, value proposition, and strategies for accomplishing a business plan (20). The foundation of the Lean LaunchPad method is that the customer is the fundamental component of a business model. Teams are instructed to formulate a series of hypotheses about their customers and their potential business model and then challenge their hypotheses through customer interviews. Customer interviews are intended to help teams draw insights that either support or negate their hypotheses.

PILOTING THE I-CORPS CURRICULUM

The first I-Corps course was piloted at Stanford University in May 2011. The pilot course was an immersive 10-week innovation and entrepreneurship course that was largely taught remotely, physically bringing participants together only at the start and finish of the workshop.

Twenty-seven teams enrolled in the pilot course taught by Steve Blank and two venture capitalists. Over a 10-week period, teams were taught each of the nine fundamental pieces of the BMC and were instructed about how to talk with potential customers to gain insights into the marketability of their ideas. The concept of talking to potential customers was coined as "getting out of the building." Teams were instructed to aim for 100 interviews, a number that would later become solidified in the I-Corps curriculum. The 100 interview target proved challenging for participants who were not accustomed to "getting out of the building" or making cold-calls to potential customers. Only a handful of teams completed all 100 interviews in the first pilot cohort.

A second pilot was held in the spring of 2012 and solidified the I-Corps curriculum. Jerry Engel, a faculty member from Haas School of Business at University of California, Berkeley, was designated the national faculty instructor for the national I-Corps Teams Program. With help from Blank, Engel was responsible for training faculty for future I-Corps workshops and writing and managing the adaptation of the curriculum. Short- and long-term metrics of success were defined as training 100 teams, creating a network of 100 mentors, developing a program

with wide geographic reach, and forming companies within five years of program inception.

Building the National Innovation Network

The early success of the I-Corps courses led to the creation of the NIN, a network development plan to address scale. The NIN was created to offer widespread geographical infrastructure support and resources (I-Corps Nodes) and support pipeline development (I-Corps Sites) for individual teams (I-Corps Teams, described above). Resources are defined as a network of instructors and mentors who can identify and build needed commercialization tools, maintain a current curriculum, disseminate knowledge about lessons learned, and carry out research about entrepreneurship and commercialization. Tables 1 and 2 list the active Nodes and Sites as of the date of March 1, 2017. As a collective, the three programs (I-Corps Teams, Nodes, and Sites) are the foundation of NSF's vision for creating an innovation ecosystem for academic institutions.

a) I-Corps Nodes

University of Michigan and the Georgia Institute of Technology became the first two I-Corps nodes in 2012. They were expected to be outward and inward facing, working nationally and regionally, as articulated in the first I-Corps Node solicitation:

> The National Science Foundation plans to build upon the I-Corps program and establish a National Innovation Network comprised of I-Corps Regional Nodes that will support the needs for innovation research and education. NSF is seeking to build a network of regional nodes that will work cooperatively to establish, utilize and sustain a national innovation ecosystem that further enhances the development of technologies, products and processes that benefit society.

The interconnected nodes of this network may be diverse in research areas, resources, tools, programs, capabilities, and in geographic locations — while the network will have the flexibility to grow or reconfigure as needs arise (22).

Two solicitations followed, formalizing the I-Corps Node call for proposals to include three levels of activity (NSF 12-586, NSF 16-539):

- Level 1: Provide a cohort of national instructors to teach the I-Corps curriculum to national and regional cohorts of teams and to offer consistent and frequent support for the duration of the program
- Level 2: Develop and leverage tools and resources that assist with disseminating the I- Corps curriculum, address issues associated with accelerating the diffusion/adaptation/adoption of effective innovation practices within the national ecosystem, and build entrepreneurial capacity within the node's environment
- Level 3: Pursue long-term R&D projects that would lead to the publication of insights on the development of innovation ecosystems resulting from level 1 and 2 activities

I-Corps Node institutions (Table 1) provide a framework for NIN universities to share curriculum and tools and partner with regional institutions to deliver various I-Corps short courses ranging from one day to one semester (16 weeks). Shared resources have included an abridged short course curriculum used as a primer for preparing teams for the national I-Corps Teams program and videos and books that explain the core concepts of the I-Corps curriculum (23,24).

b) I-Corps Sites

The I-Corps Sites program launched in 2013 to develop a pipeline of teams eligible for the national I-Corps program and contribute to the larger national network of mentors, researchers, entrepreneurs, and investors (Solicitation NSF 12-604). Academic institutions with existing innovation or entrepreneurial units are eligible to apply for an I-Corps Sites grant to seed student and/or faculty commercially viable projects with modest amounts of funding ($1,000 to $3,000).

The Sites program exposes local academic teams to I-Corps core concepts, identifies candidate teams for the national I-Corps program, connects teams to investors and industry partners, and provides space to sponsor innovation. Given the growth of new innovation centers nationwide, the number of institutions likely to pursue an I-Corps Sites award is only consistently increasing.

Table 1. I-Corps Nodes

Node Geographical Region	Year(s) Funded	States	University Representation
Midwest-Great Lakes Area	2012, 2016	Michigan	University of Michigan*
		Illinois	University of Illinois at Urbana-Champaign
		Indiana	Purdue University
South	2012, 2016	Georgia	Georgia Technological Institute*
		Alabama	University of Alabama Birmingham
		North Carolina	University of North Carolina Charlotte
		Tennessee	University of Tennessee
Northern California/ San Francisco Bay Area	2013, 2016	California	University of California, Berkeley*
			University of California, San Francisco
			Stanford University
New York City Area	2013, 2016	New York	City University of New York*
			New York University
			Columbia University
Southeast	2013, 2016	Maryland	University of Maryland*
		Washington, DC	George Washington University
		Virginia	Virginia Technological Institute
Southern California/ Los Angeles	2014	California	University of California, Los Angeles*
			University of Southern California
			California Technological Institute
Southwest	2014	Texas	University of Texas at Austin*
			Rice University
		Oklahoma	University of Oklahoma
		Arkansas	University of Arkansas
Upstate New York	2016	New York	Cornell*
			Rochester Institute of Technology
			University of Rochester

I-Corps Nodes that have been formed between FY12 and March 2017. University of Michigan and Georgia Tech served as single institution Nodes in 2012 and later formed the Midwest and South I-Corps multi-institutional Nodes in 2016. (*Lead Institution)

The University of Illinois at Urbana-Champaign, the University of California at San Diego, the University of Akron, and the University of Toledo were the first four I-Corps Sites in 2013. Each institution received $100,000 per year for a three-year term (Table 2). Institutions that request and are awarded $100,000 per year are expected to support 30 local teams per year. The original solicitation was revised and released in FY16 to extend the funding period from three years to five years to provide sites the time to formalize the program at their institutions.

I-Corps Sites teams tend to follow one of three paths. A proportion of teams conduct preliminary customer discovery and recognize that their research products do not have a fit in the marketplace. Other teams identify a fit in the marketplace and are immediately able to attract funding for further development to start companies or to license their products. For example, PhotoniCare, Inc., from the University of Illinois Urbana-Champaign, created a medical device to assist doctors in the selection of antibiotics by identifying ear infection bacterial strains and attracted $2 million in non-dilutive funding after participating in the University of Illinois I-Corps Sites program. Other teams go on to participate in the national I-Corps program to explore additional customer segments and/or develop and vet a minimum viable product. As the program has continued to grow, more national I-Corps Teams are coming from I-Corps Sites institutions. As of March 1, 2017, the percentages of national teams coming from I-Corps institutions include 29% from I-Corps Sites, 18% from I-Corps Nodes institutions, and 11% have come from institutions that are both an I-Corps Node and Site (https://www.nsf.gov/awardsearch/advancedSearch.jsp).

I-Corps Sites institutions have benefited from receiving an award in a number of ways. I-Corps Sites institutions typically produce teams that mirror the industries in their region (e.g., bio-pharmaceutical focus in San Diego or nursing in Milwaukee) and contribute to those ecosystems. I-Corps Sites institutions have credited their ability to attract additional funding to expand infrastructure and activities from donors to their I-Corps Sites awards (Personal communication, University of Chicago, University of Illinois Urbana-Champaign, unreferenced). Finally, I- Corps Sites awards have catalyzed the integration of I-Corps curricular concepts into undergraduate and graduate curriculum, thus broadening the impact of I-Corps beyond individual teams (25).

I-CORPS TO DATE

As of FY17, there are eight NSF I-Corps Nodes (Table 1) and 67 I-Corps Sites (Table 2). An overview of the timeline and evolution of the program is presented in Table 3. I-Corps Nodes are multi-institutional programs anchored in R1 institutions. At the onset of the program, University of Michigan and Georgia Institute of Technology (the first two I-Corps Nodes) were the only single-institution Nodes. Both institutions became multi-institutional Nodes when their grants were renewed in 2016. I-Corps Site institutions vary from large public research institutions to small liberal arts colleges having STEM departments.

From the initial pilot on October 1, 2011, to the end of March 1, 2017, a total of 973 teams have participated in the national I-Corps Teams program from 222 universities in 46 states, resulting in the creation of over 320 companies that have collectively raised more than $83 million in follow-on funding (Figure 1) (26,27).

Given its early track record of success, the Obama Administration called for I-Corps to be scaled across all federal agencies. With this support, the budget for the program grew to $30 million in FY16 from an initial investment of $1 million to fund the first pilot cohort I-Corps Teams (16,27).

As I-Corps continues to grow, the core curriculum and structure is kept consistent across Nodes with the oversight of the I-Corps faculty Kernel Committee, chaired by Engle. Representatives from each Node sit on the committee and submit suggestions and innovations to be addressed by the committee. The committee is responsible for determining which innovations should be widely adopted.

I-Corps teams are still the core of the I-Corps program. One significant change to the structure of the team is who can fill the role of the PI. Initially, teams consisted of an EL, PI, and a BM, where the PI was the NSF-funded research scientist. Now, teams consist of an EL, a Technical Lead (TL), and a BM. The TL can be an NSF-funded PI, a postdoctoral researcher with deep technical knowledge, or an institutional representative who is able to be a designated PI.

Table 2. I-Corps Sites

Site Institution	Year Funded	State
University of Akron	2013, 2017	Ohio
University of California, San Diego	2013, 2017	California
University of Illinois at Urbana-Champaign	2013, 2017	Illinois
University Toledo	2013, 2017	Ohio
Carnegie-Mellon University	2014	Pennsylvania
Massachusetts Institute of Technology	2014	Massachusetts
San Diego State University	2014	California
University of Central Florida	2014	Florida
University of Chicago	2014	Illinois
University of Delaware	2014	Delaware
University of Houston	2014	Texas
University of Minnesota Twin Cities	2014	Minnesota
University of Southern California	2014	California
University of Texas at San Antonio	2014	Texas
University of Utah	2014	Utah
Brigham Young University	2015	Utah
Howard University & Hampton University	2015	DC
Michigan Technological University	2015	Michigan
New Jersey Institute of Technology	2015	New Jersey
Oregon State University	2015	Oregon
Purdue University	2015	Indiana
Rochester Institute of Technology	2015	New York
Stony Brook University	2015	New York
Tulane University	2015	Louisiana
University of Alabama	2015	Alabama
University of California, Los Angeles	2015	California
University of Connecticut	2015	Connecticut
University of Iowa	2015	Iowa
University of Louisville	2015	Kentucky
University of North Carolina at Charlotte	2015	North Carolina
University of Pennsylvania	2015	Pennsylvania
University of Pittsburgh	2015	Pennsylvania
University of Rochester	2015	New York
University of South Florida, Tampa	2015	Florida
University of Washington	2015	Washington
University of Wisconsin–Milwaukee	2015	Wisconsin
Ohio State University	2016	Ohio
Missouri University of Science & Technology	2016	Missouri
Louisiana State University	2016	Louisiana
Wichita State University	2016	Kansas
University of Arizona	2016	Arizona
Oklahoma State University	2016	Oklahoma
Washington State University	2016	Washington
Tennessee Technological University	2016	Tennessee
University of Nevada, Las Vegas	2016	Nevada
Dartmouth University	2016	New Hampshire

University of New Hampshire	2016	New Hampshire
New Mexico State University	2016	New Mexico
Rensselaer Polytechnique Institute	2016	New York
Arizona State University	2016	Arizona
Jackson State University	2016	MIssissippi
University of California, Irvine	2017	California
City University New York	2017	New York
Brandeis University	2017	Massachusetts
New York University	2017	New York
George Washington University	2017	DC
Cornell University	2017	New York
Johns Hopkins University	2017	Maryland
University of Alabama Birmingham	2017	Alabama
University of Georgia	2017	Georgia
University of Massachusetts Lowell	2017	Massachusetts
University of California, Santa Cruz	2017	California
University of Virginia	2017	Virginia
Mississippi State University	2017	Mississippi
Texas A&M Main Campus	2017	Texas
California State University Northridge	2017	California
University of California, Merced	2017	California

I-Corps Sites that have been formed from FY 2012. Beginning in 2013, NSF funded four I-Corps Sites to pilot the program. Afterwards, 11 I-Corps Sites were funded in FY 2014, 21 in 2015, and 15 in 2016. At the beginning of FY2017, an additional 16 Sites were funded. As of FY 2017, there are a total of 67 I-Corps Sites. (Data Source: http://www.msf.gov/awardsearch)

PROGRAM GROWTH

Early success with the program sparked curiosity from its founders and participants. The question was raised, "Would the principles of Lean LaunchPad and the formal curriculum developed for I-Corps be applicable to technologies that were not based on science and engineering?" Another pilot to test the viability of the I-Corps program, but with different programmatic intentions, was Innovation Corps for Learning (I-Corps-L) (28). In 2013, with the help of Steve Blank, I-Corps-L was piloted within NSF's Directorate for Education and Human Resources (EHR) to promote opportunities for widespread adoption, adaptation, and utilization of discoveries and practices stemming from education R&D. I-Corps-L challenged NSF education researchers to think beyond their research results and towards broader adoption of STEM education and learning innovations. That pilot prompted the EHR directorate to sponsor full cohorts each year since the initial education pilot.

While NSF did not create I-Corps to be a required program for SBIR recipients, some government agencies have begun offering I-Corps participation or agency specific I-Corps programs to their SBIR recipients. For example, in 2015 and 2016, the National Institutes of Health (NIH) offered a life sciences I-Corps curriculum for their SBIR Phase I grantees and are planning to schedule cohorts each year moving forward. NSF SBIR recipients are eligible to apply to the I-Corps program, and NSF I-Corps participants are provided information on the NSF SBIR program as an opportunity for commercialization support.

As part of the effort to scale I-Corps across federal agencies, NSF partnered with multiple agencies to create agency specific versions of I-Corps. The first group of agencies included the U.S. Centers for Disease Control; Department of Energy (DOE)/ Advanced Research Projects Agency-Energy; DOE Office of Energy Efficiency and Renewable Energy; U.S Department of Homeland Security; Department

Table 3. Timeline and Evolution of the I-Corps Program

Fiscal Year	Number of Teams	Program Evolution
2011	0	Subra Suresh starts as NSF Director
		Errol Arkilic works with other IIP Program officers, the Senior Advisor to the Director, and Steve Blank to create the I-Corps™ Teams Program
		I-Corps™ Teams Program solicitation launched
2012	101	First pilot I-Corps™ Teams launched at Stanford University in the fall of 2011
		Second pilot I-Corps™ Teams and Train the Trainer launched at Stanford University in the spring of 2012
		Don Millard formulates the I-Corps™ Nodes and National Innovation Network Programs
2013	132	GA Tech (South Node) and Univ. of Michigan (Midwest Node) create the first pilot I-Corps™ Nodes
		Anita La Salle formulates the I-Corps™ Sites Program
		NYCRIN, DC, and San Francisco Bay I-Corps™ Nodes are created
		University of Akron, University of California, San Diego, and University of Illinois at Urbana-Champaign form the first I-Corps™ Sites
2014	166	Southern California and Southwest Node created
2015	196	First Pilot of I-Corps™ @NIH launched
		Bi-directional I-Corps™ Node formed in Mexico
2016	259	Additional Federal Agencies Sign MOUs to host I-Corps™
		MOU signed to establish I-Corps™ in Ireland
		NSF calls for supplements to promote inclusion of underrepresented groups and institution in entrepreneurship through I-Corps™

Summary of the events that led to a formation of the I-Corps program. The events highlighted in this table outline how the program was built and expanded over time. By the end of fiscal year 2016–September 20, 2016–a total of 854 teams participated in the program. This number omits Teams in which the PI transferred to a new institution. (Data Source: http://www.nsf.gov/awardsearch)

of Defense (DOD); NIH; Department of State; Small Business Administration; and the U.S. Department of Agriculture. Building on the existing I-Corps partnerships between NSF and other federal agencies, new expansions were announced in June 2016 at the Global Entrepreneurship summit, including the National Security Agency and National Aeronautics and Space Administration SBIR/STTR programs. A bi-national Node was created in 2015 connecting Mexican universities with the Southwest I-Corps Node. The first Memorandum of Understanding for an international I-Corps collaboration was established to scale the I-Corps program to Ireland (29) in 2016.

I-Corps continues to attract Congressional proponents, including Representative Dan Lipinski (D-IL), Senator Cory Gardner (R-CO), Senator Chris Coons (D-DE), and Senator Deb Fischer (R-NE). Representative Lipinski attended the first two I-Corps pilot courses, and Senators Coons (D-DE) and Fischer (R-NE) wrote the I-Corps program into the American Innovation and Competitiveness Act (30). The bill became law on December 19, 2016 (30). This law authorizes the NSF to encourage the development and expansion of I-Corps and other training programs that focus on professional development, including education in entrepreneurship and commercialization, as well as funding for innovation ecosystem

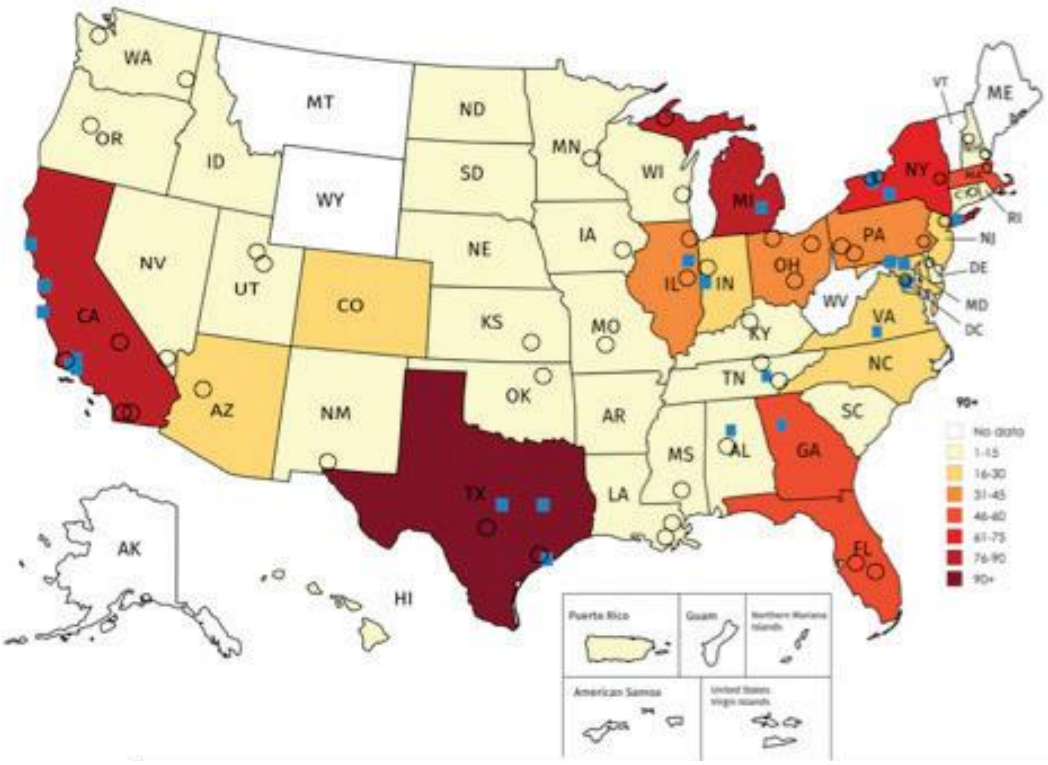

Figure 1. The Geographic distribution of NSF I-Corps Teams award recipients. Geographic map of NSF I-Corps Teams, Nodes (squares), and Sites (circles) awards from October 2011 to March 2017. The distribution includes I-Corps-L teams and PIs that have participated more than once to explore the commercial potential of different technologies (Source: https://www.nsf.gov/awardsearch/advancedSearch.jsp).

development at locations that the NSF designates as regional and national infrastructure for science and engineering entrepreneurship. It also directs the NSF to create partnerships with other federal agencies that enable them to send their grantees to NSF I-Corps program cohorts or to help them create their own versions of the I-Corps program.

Finally, the law authorized the NSF to engage in partnerships with state and local governments, economic development organizations, and nonprofit organizations to provide access to the I-Corps program to support entrepreneurship education and training for researchers, students, and institutions.

CHALLENGES AND OPPORTUNITIES

Although a great deal has been accomplished with I-Corps, a number of challenges remain as the program continues to scale. According to *Women, Minorities, and Persons with Disabilities in Science and Engineering: 2017,* a special report from NSF, scientists and engineers from under-represented populations remain behind in educational attainment and the science and engineering workforce (27,31). Broadening participation of under-represented populations is a well-articulated priority at the NSF (32). NSF defines broadening participation in terms of individuals from under-represented groups as well as institutions and geographic areas that do not participate in NSF research programs at rates comparable to others. Addressing the challenges of broadening participation in STEM is a priority within the I-Corps program. In an effort to address this challenge and promote the inclusion of entrepreneurial founders from under-represented populations in STEM entrepreneurship, NSF mobilized a call for supplements to promote inclusion in entrepreneurship from I-Corps

Nodes and Sites awardees in FY16 for funding in FY17 (Table 3). Eight I-Corps Sites and one I-Corps Node were awarded $30,000 supplemental awards to pilot novel approaches and partnerships that promote inclusive entrepreneurship through I-Corps. The pilot activities will engage differently-abled individuals, first-generation college students, racial and ethnic minorities, and women, as well as Minority-Serving Institutions (33). This effort is just one of many approaches for generating insights to address this complex challenge (34).

Other scaling challenges include managing the consistency of the core I-Corps curriculum. Part of the I-Corps program's success has been the entrepreneurial nature of its development and execution. As attempts to mandate that the I-Corps program exist across all federal agencies, institutionalization may impact the entrepreneurial culture of the program. Each federal agency has its own culture and vocabulary for defining stakeholders and activities. As I-Corps expands to other federal agencies, these differences could potentially impact delivery of the curriculum as it is adopted for teams consisting of SBIR companies and Main Street businesses. Furthermore, mentor matching continues to be a rate-limiting step for onboarding teams. NSF is currently working to address these issues.

Looking to the future, the question remains, "What dictates success for the I-Corps program?" Although the program was able to meet its original metrics for implementation, the impact of its activities is being evaluated with a longitudinal lens. Depending on the audience, be it from a congressional, academic, or federal laboratory perspective, different metrics should be explored. For instance, from an economic development lens, stakeholders may be more concerned with start-up activity, such as levels of funding, density of resources, and number of jobs created. However, from an academic perspective, stakeholders may consider exploring impact on the development of human capital, such as university entrepreneurial culture as well as academic trainee and researcher perceptions of entrepreneurship and commercialization. Identifying stakeholders and the appropriate metrics will continue to be debated as the program continues.

Internally, current evaluations suggest the need to enhance post-I-Corps training. Though the program has been shown to address the gap between academic research and successful commercialization through customer discovery training, there are a number of other critical factors that contribute towards getting a product to market. For example, understanding how to engage investors, manufacture and scale technologies, acquire and manage intellectual property protection, manage and run a business, navigate complicated regulatory environments, and develop strategic partnerships are all skills that would be of value to alumni of the I-Corps Teams program. Therefore, NSF continues to consider how the program should evolve to address the "valley of death."

Within its first five years, the I-Corps program has created opportunities to offer formal entrepreneurship education to academic researchers, graduate students, and community members. Through I-Corps, lessons have been learned about the many barriers to the successful translation of university technology. While I-Corps does not address all barriers, it does address two crucial ones—the education of researchers in the relevance of customer needs in research and the development of an entrepreneurial mindset.

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and 2) Dr. Huang-Saad is a co-PI on the University of Michigan I-Corps Node and has been an I-Corps Canonical Instructor since 2012.

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