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FROM LAB TO MARKET: A REVIEW OF NSF INNOVATION CORPS

HEARING

BEFORE THE

SUBCOMMITTEE ON RESEARCH AND TECHNOLOGY

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

HOUSE OF REPRESENTATIVES

ONE HUNDRED FIFTEENTH CONGRESS

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FROM LAB TO MARKET: A REVIEW OF NSF INNOVATION CORPS

Wednesday, December 6, 2017

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON RESEARCH AND TECHNOLOGY
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY,
Washington, D.C.

The Subcommittee met, pursuant to call, at 10:07 a.m., in Room 2318 of the Rayburn House Office Building, Hon. Barbara Comstock [Chairwoman of the Subcommittee] presiding.

LAMAR S. SMITH, Texas
CHAIRMAN

EDDIE BERNICE JOHNSON, Texas
RANKING MEMBER

Congress of the United States
House of Representatives
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From Lab to Market: A Review of NSF Innovation Corps

Wednesday, December 6, 2017
10:00 a.m.
2318 Rayburn House Office Building

Witnesses

Dr. Dawn Tilbury, Assistant Director, Directorate for Engineering, National Science Foundation

Mr. Steve Blank, Adjunct Professor, Management Science and Engineering, Stanford University

Dr. Dean Chang, Associate Vice President, Innovation and Entrepreneurship, University of Maryland; Lead Principal Investigator, DC I-Corps Regional Node

Dr. Sue Carter, Professor, Department of Physics, Director, Center for Innovation and Entrepreneurial Development, University of California, Santa Cruz

U.S. HOUSE OF REPRESENTATIVES
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

HEARING CHARTER

December 6, 2017

TO: Members, Subcommittee on Research and Technology

FROM: Majority Staff, Committee on Science, Space, and Technology

SUBJECT: Research and Technology Subcommittee Hearing:
"From Lab to Market: A Review of NSF Innovation Corps"

The Subcommittee on Research and Technology of the Committee on Science, Space, and Technology will hold a hearing titled *From Lab to Market: A Review of NSF Innovation Corps* on Wednesday, December 6, 2017 at 10:00 a.m. in Room 2318 of the Rayburn House Office Building.

Hearing Purpose:

The purpose of the hearing is to review the National Science Foundation's Innovation Corps (I-Corps) program and its goal of preparing scientists and engineers to extend their research from lab to market, to examine the successes and challenges of the program, and to discuss recommendations for the future of I-Corps and its role in the innovation ecosystem.

Witness List

- **Dr. Dawn Tilbury**, Assistant Director, Directorate for Engineering, National Science Foundation
- **Mr. Steve Blank**, Adjunct Professor, Management Science and Engineering, Stanford University
- **Dr. Dean Chang**, Associate Vice President, Innovation and Entrepreneurship, University of Maryland; Lead Principal Investigator, DC I-Corps Regional Node
- **Dr. Sue Carter**, Professor, Department of Physics, Director, Center for Innovation and Entrepreneurial Development, University of California, Santa Cruz

Staff Contact

For questions related to the hearing, please contact Jenn Wickre of the Majority Staff at 202-225-6371.

Chairwoman COMSTOCK. The Committee on Science, Space, and Technology will come to order. Without objection, the Chair is authorized to declare recesses of the Committee at any time.

Good morning, and welcome to today's hearing entitled "From Lab to Market: A Review of NSF Innovation Corps," I–Corps. I now recognize myself for five minutes for an opening statement.

The purpose of today's hearing is to review the National Science Foundation's I–Corps program and its goals of preparing scientists and engineers to extend their research from lab to market. The hearing will examine the successes and challenges of the I–Corps program, and the Committee will hear recommendations for the future of I–Corps and its role in the innovation ecosystem.

In research labs today are the seeds for breakthroughs in new fields like quantum computing, artificial intelligence, and bioengineering, breakthroughs that will continue to transform our lives and the world we live in. Many scientists and engineers are not trained for commercializing those ideas because most did not go to business school or take any business development classes as part of their training. So how do we give them the tools to be successful entrepreneurs? How do we help scientists and engineers turn their innovations into products and services?

In 2011, NSF established I–Corps to help fill that need. I–Corps is a National Innovation Network of eight nodes across the country, which connect academic researchers with the private sector and trains them to be entrepreneurs. NSF funds teams of researchers to go through a seven-week I–Corps curriculum that provides a real-world, hands-on, immersive learning experience. Today, I–Corps is taught at 86 colleges and universities in the United States, and over 1,000 teams have been through the program.

I welcome Dr. Dawn Tilbury, the new Assistant Director for Engineering at NSF, to discuss what NSF has learned from over five years of running the program and collecting data and information.

We are also fortunate to have Mr. Steve Blank on the panel, the architect of the NSF I–Corps curriculum. He will explain how his approach trains scientists and engineers to be entrepreneurs in a short period of time, and his vision for the future of I–Corps.

We also have on the panel Dr. Dean Chang from the DC. Area I–Corps node to discuss the innovation ecosystem in the Virginia, Maryland, and DC. region. The 10th District—the 10th Congressional District which I represent has a robust and growing technology sector, while Virginia, D.C., and Maryland boast some of the top research universities in the country. I look forward to learning how I–Corps contributes to building connections between academic researchers and the private sector to create more companies and more jobs.

Finally, I look forward to hearing from Dr. Sue Carter on her experience participating in three I–Corps teams and creating successful companies.

Through research and activities like I–Corps supported by NSF, we have the opportunity to boost our economy, enhance our national security, strengthen our cybersecurity infrastructure, and create a STEM-job-ready workforce, not a small task, and we appreciate your role in all of that.

[The prepared statement of Chairwoman Comstock follows:]

COMMITTEE ON
SCIENCE, SPACE, & TECHNOLOGY
Lamar Smith, Chairman

For Immediate Release
December 6, 2017

Media Contacts: Thea McDonald, Brandon VerVelde
(202) 225-6371

Statement from Barbara Comstock (R-Va.)

From Lab to Market: A Review of NSF Innovation Corps

Chairwoman Comstock: The purpose of today's hearing is to review the National Science Foundation's Innovation Corps (I-Corps) program and its goal of preparing scientists and engineers to extend their research from lab to market.

The hearing will examine the successes and challenges of the I-Corps program and the committee will hear recommendations for the future of I-Corps and its role in the innovation ecosystem.

In research labs today are the seeds for breakthroughs in new fields like quantum computing, artificial intelligence and bioengineering; breakthroughs that will continue to transform our lives and the world we live in.

Many scientists and engineers are not trained for commercializing those ideas because most did not go to business school or take any business development classes as part of their training. So how do we give them the tools to be successful entrepreneurs?

How do we help scientists and engineers turn their innovations into products and services?

In 2011, NSF established I-Corps to help fill that need. I-Corps is a National Innovation Network of eight nodes across the country, which connects academic researchers with the private sector and trains them to be entrepreneurs.

NSF funds teams of researchers to go through a seven week I-Corps curriculum that provides a real-world, hands-on, immersive learning experience.

Today, I-Corps is taught at 86 colleges and universities in the United States, and over 1,000 teams have been through the program. I welcome Dr. Dawn Tilbury, the new Assistant Director for Engineering at NSF, to discuss what NSF has learned from over five years of running the program and collecting data and information.

We are also fortunate to have Mr. Steve Blank on the panel, the architect of the NSF I-Corps curriculum. He will explain how his approach trains scientists and engineers to be entrepreneurs in a short period of time, and his vision for the future of I-Corps.

We also have on the panel Dr. Dean Chang from the DC Area I-Corps node to discuss the innovation ecosystem in the Virginia, Maryland and D.C. region.

The 10th Congressional District I represent has a robust and growing technology sector, while Virginia, D.C. and Maryland boast some of the top research universities in the country. I look forward to learning how I-Corps contributes to building connections between academic researchers and the private sector to create more companies and more jobs.

Finally, I look forward to hearing from Dr. Sue Carter on her experience participating in three I-Corps teams and creating successful companies.

Through research and activities like I-Corps supported by the National Science Foundation, we have the opportunity to boost our economy, enhance our national security, strengthen our cybersecurity infrastructure and create a STEM-job ready workforce.

Chairwoman COMSTOCK. And I now recognize the Ranking Member, the gentleman from Illinois, Mr. Lipinski, for his opening statement.

Mr. LIPINSKI. Thank you, Chairwoman Comstock, for—and Chairman Smith for holding this hearing. It's a hearing that I have been wanting to have for a number of years. I'm glad that we've got here. And as everyone knows, I've spent a lot of time on this committee talking about the Innovation Corps or I–Corps, so I'm very pleased to be holding this hearing, the first one we had since we had a field hearing in Chicago back in 2012 on I–Corps.

I'd like to think the 2012 hearing helped to win over some of my more skeptical colleagues at that time. The program was in infancy back then in the summer of 2012, having been launched by NSF in 2011. Now, we are seven years in and the program has not just grown and expanded at NSF, it has been adopted and adapted by several other agencies including NIH, DOE, and even DOD.

While I help to build support in Congress to see I–Corps funded and expanded, agency, university, and national lab leaders alike embraced the potential and worked hard to implement it as effectively as possible. As a result, we are starting to see exactly the kind of outcomes that we hoped for back in 2012. Over 1,000 companies have completed a national I–Corps course, and we're seeing many of the alumni go on to start successful businesses.

There are some notable research institutions who started creating a culture of entrepreneurship decades ago such as MIT and Stanford. There are many more universities both public and private that have actively sought to learn from and implement many of the best practices from those pioneering universities. Unfortunately, many of them have had a hard time securing the funding and the right expertise to successfully undertake these efforts. There are also some institutions of higher learning that have simply not made this a priority. We know that institutional culture is a hard thing to overcome.

Our world-class research institutions around the Nation excel at conducting cutting-edge research and educating the next generation of scientists and engineers. There is fear among some that promoting entrepreneurship would compromise the important basic research mission of the institutions. I believe there's plenty of evidence to the contrary. It is clear that students and faculty across the country are eager to see the research breakthroughs further developed into commercial products and processes for the benefit of society and our economy.

In addition, because we now graduate far more Ph.D.'s than we have faculty jobs, entrepreneurship provides a viable career option for the more than 50 percent of Ph.D.'s who will not be able to pursue academic careers.

With a very modest investment, I–Corps helps address the lack of funding from the private sector to develop entrepreneurial capacity at institutions of all sizes and types. It also helps to strengthen the SBIR program, shift institutional culture, and ultimately pay the American taxpayers back many times over in the form of commercialized products that would otherwise collected dust on a laboratory shelf.

By the end of an I–Corps course, participants make the go/no-go decision. Those that decide to go or to start a company have some market research to back up their decision. And those that either pivot to a new idea or choose no-go save themselves the effort of starting a company that would have been likely to fail.

Just a few examples of companies that have developed from teams that participated in I–Corps training at the University of Chicago in recent years are Conduit, a company that speeds up the development and improves the quality of software for Internet of Things devices; Qualia Health, which makes a health assessment and monitoring app; and ClostraBio, which is developing therapeutics to combat food allergies. These companies are all making very real contributions to our economy, job market, and well-being, and these are only from one site out of many around the country.

I remain a committed champion of this program and never cease to be amazed by how successful it has been and continues to be, but we can't rely on past successes to keep I–Corps strong into the future, so I plan to introduce new legislation very soon to expand upon the I–Corps authorities already in law. My bill, the Innovators to Entrepreneurs Act, will open up I–Corps courses to participation by many more entrepreneurs than are currently taking advantage of them. Currently, the nodes that teach these courses are operating below capacity, which is a missed opportunity both for their faculty and for the companies that could be taking advantage of their training. My bill will also direct NSF to offer a new course that goes beyond the current I–Corps curriculum to focus on how to attract investors and grow a business.

Since 2011, we have learned that the I–Corps curriculum does a great job of teaching aspiring entrepreneurs how to do customer discovery and vet their ideas, but once they decide to start a company and begin the commercialization process, it doesn't teach them how to take the next steps like how to develop financial projections and build a winning team.

Some of the same visionaries who developed the current I–Corps curriculum recognize this need and developed a new pilot course they've been calling I–Corps Go. The results so far have been promising, and demand for this type of training is high. Therefore, my bill directs NSF to develop I–Corps Go into an official I–Corps course and to offer it nationally to interested companies through the nodes that offer the current curriculum. I hope my colleagues will take a look at my bill and agree to cosponsor it.

I also want to make sure that I mention the great job that NSF has done with I–Corps over these years and the work that they continue to do, and I want to welcome Dr. Tilbury in as leading the Engineering Directorate, so it's good to have you there at NSF in this position. I look forward to our discussion and yield back.

[The prepared statement of Mr. Lipinski follows:]

OPENING STATEMENT
Ranking Member Daniel Lipinski (D-IL)
of the Subcommittee on Research and Technology

House Committee on Science, Space, and Technology
Subcommittee on Research and Technology
"From Lab to Market: A Review of NSF Innovation Corps"
December 6, 2017

Thank you Chairwoman Comstock for holding this hearing and thank you to the witnesses for your participation in this important discussion. As my colleagues may have noticed, I take every relevant opportunity to talk about and promote the Innovation Corps, or I-Corps, program. So I am especially pleased that we are having the first hearing dedicated to the I-Corps program since a field hearing in my hometown of Chicago in 2012.

I'd like to think the 2012 hearing helped win over some of my more skeptical colleagues at the time. But the program was in its infancy then, having been launched by NSF in 2011. Now we are 7 years in, and the program has not just grown and expanded at NSF, it has been adopted and adapted by several other agencies, including NIH, DOE, and even DOD. While I helped build support in Congress to see I-Corps funded and expanded; agency, university, and National Lab leaders alike embraced the potential and worked hard to implement it as effectively as possible. As a result, we are starting to see exactly the kind of outcomes that we hoped for back in 2012: over 1,000 companies have completed a national I-Corps course and we're seeing many of the alumni go on to start successful companies.

There are some notable research institutions who started creating a culture of entrepreneurship decades ago, such as MIT and Stanford. There are many more universities – public and private alike – that have actively sought to learn from and implement many of the best practices from those pioneering universities. Unfortunately, many of them have a hard time securing the funding and the right expertise to successfully undertake these efforts. There are also some institutions that have simply not made this a priority.

Institutional culture is a hard thing to overcome. Our world class research institutions around the nation excel at conducting cutting edge research and educating the next generation of scientists and engineers. There is a fear among some that promoting entrepreneurship would compromise the important basic research mission of these institutions. I believe that there is plenty of evidence to the contrary. And it is clear that students and faculty across the country are eager to see their research breakthroughs further developed into commercial products and processes for the benefit of society and our economy. In addition, because we now graduate far more PhDs than we have faculty jobs, entrepreneurship provides a viable career option for the more than 50% of PhDs who will not be able to pursue academic careers.

With a very modest investment, I-Corps helps address the lack of funding from the private sector to develop entrepreneurial capacity at institutions of all sizes and types. It also helps to strengthen the SBIR program, shift institutional culture, and ultimately pay the American taxpayer back many times over in the form of commercialized products that would have otherwise collected dust on a laboratory shelf.
By the end of an I-Corps course, participants make the "go/no-go" decision. Those that decide to "go," or to start a company, have some market research to back up their decision, and those that either pivot to a new idea or choose "no-go" save themselves the effort of starting a company that would have been likely to fail. Just a few examples of companies that have developed from teams that participated in I-Corps training at the University of Chicago in recent years are Conduit, a company that speeds up the development and improves the quality of software for Internet of Things devices; Qualia Health, which

makes a health assessment and monitoring app; and ClostraBio, which is developing therapeutics to combat food allergies. These companies are all making very real contributions to our economy, job market, and well-being. And these are only from one site out of many around the country.

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I look forward to today's discussion about the status of I-Corps, what we know about its outcomes to date, and how we can continue to strengthen the program and expand its reach. I thank all of the witnesses for being here today, and I yield back.

Chairwoman COMSTOCK. Thank you. And I now recognize Ms. Johnson for her opening statement.

Ms. JOHNSON. Thank you very much, Chairwoman Comstock, and good morning. I appreciate you holding for this hearing, and thank you for the expert witnesses for being here this morning to share their insights with us.

The research carried out at our nation's universities and national laboratories creates the foundation upon which our entire innovation economy is built. However, in order to benefit society, the science must find a way out of the laboratory. These societal benefits may be varied. Science itself across all fields serves as inspiration for the public and a tool for educating the next generation of scientists and engineers.

Science can also be used to strengthen our national security or to inform better and more effective policies for the public good. However, sometimes a scientific development holds the promise of new commercial products or process and that is where the National Science Foundation Innovation Corps, or I–Corps, programs have the biggest role to play.

Unfortunately, the path from the laboratory to the market has rarely been smooth or easy. While the challenges are sometimes technical, they often are cultural and financial. Scientists and engineers trained to be academics speak a very different language than business people. Too often, as we will hear in today's testimony, this leads to researchers spending extensive time and money developing technologies that nobody wants to buy. Even when the idea has a well-defined customer, the private sector may be unwilling to invest until the concept is more fully developed.

Over the last several years, the National Science Foundation has been a leader in addressing the cultural barriers impeding commercialization while also making small investments in the proof-of-concept work. The I–Corps program stands out as an example of the excellent return we can achieve on a modest investment when we implement and scale-up proven practices.

The—when NSF launched I–Corps in 2011, some of my colleagues were skeptical about the need or the appropriateness of having this program at NSF. Many in the university community were concerned that the program might harm NSF's core research mission. I believe there has been a sea change in the response from the university community that reflects the pent-up demand from researchers, the dedication of NSF staff, and the clear benefits of this program. So as a result, this is one little program that may be helping to transform the entrepreneurial culture at universities well beyond their initial expectations.

I hope my colleagues also see the benefit of this program and remain committed to supporting it, and I hope my colleagues also remain committed to supporting the long-term foundation of U.S. science and technology by continuing to invest in our research agencies, including NSF. I look forward to today's discussion, and I yield back the balance of my time.

[The prepared statement of Ms. Johnson follows:]

OPENING STATEMENT
Ranking Member Eddie Bernice Johnson (D-TX)

Committee on Science, Space, and Technology
Subcommittee on Research and Technology
"From Lab to Market: A Review of NSF Innovation Corps"
December 6, 2017

Thank you Chairwoman Comstock for holding this hearing and thank you to the expert witnesses for being here this morning to share your insights with us. The research carried out at our nation's universities and national laboratories creates the foundation upon which our entire innovation economy is built. However, in order to benefit society, the science must find a way out of the laboratory.

Those societal benefits may be varied. Science itself, across all fields, serves as inspiration for the public and a tool for educating the next generation of scientists and engineers. Science ca also be used to strengthen our national security, or to inform better and more effective policies for the public good.

However, sometimes, a scientific development holds the promise of a new commercializable product or process. And that is where the National Science Foundation Innovation Corps, or I-Corps, program has the biggest role to play. Unfortunately, the path from the laboratory to the market has rarely been smooth or easy. While the challenges are sometimes technical, they often are cultural and financial. Scientists and engineers trained to be academics speak a very different language than business people. Too often, as we will hear in today's testimony, this leads to researchers spending extensive time and money developing technologies that nobody wants to buy. Even when the idea has a well-defined customer, the private sector may be unwilling to invest until the concept is more fully developed.

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I believe there has been a sea-change in the response from the university community that reflects the pent-up demand from researchers, the dedication of NSF staff, and the clear benefits of the program.
As a result, this one little program may be helping to transform the entrepreneurial culture at universities well beyond initial expectations. I hope my colleagues also see the benefit of this program and remain committed to supporting it. And, I hope my colleagues also remain committed to supporting the long-term foundation of U.S. science and technology by continuing to invest in our research agencies, including NSF.

I look forward to today's discussion, and I yield back the balance of my time.

Chairwoman COMSTOCK. Thank you. I'll now introduce our witnesses today. Our first witness is Dr. Dawn Tilbury, Assistant Director for the Directorate for Engineering at NSF. She joined NSF in June while maintaining her appointment as professor of electrical engineering and computer science at the University of Michigan. A professor at Michigan since 1995, her research interest is in the area of control systems, including applications to robotics and manufacturing systems. She received a Bachelor's of Science degree in Electrical Engineering from the University of Minnesota, as well as a Master's of Science and Ph.D. in Electrical Engineering and Computer Sciences from the University of California Berkeley.

Mr. Steve Blank, I now recognize Mr. Lipinski to introduce his—this witness.

Mr. LIPINSKI. Thank you. Steve Blank is an adjunct professor at Stanford University, a lecturer at the University of California at Berkeley, and a senior fellow at Columbia University, but he is perhaps better known as one of the godfathers of Silicon Valley for his prolific blog and books on innovation, entrepreneurialism, and how to run a startup, including The Four Steps to the Epiphany and The Startup Owner's Manual. Going back a second to the blog SteveBlank.com, I recommend The Secret History of Silicon Valley for everyone to take a look at the role that the government played in really creating Silicon Valley that a lot of people don't know about.

Steve has won numerous awards, including honors for his teaching at Stanford and Berkeley and appears on a Thinkers50 list of the world's top management thinkers for several years running.

Steve helped develop I–Corps, drawing on the principles of the Lean Startup movement, which he helped launch in Silicon Valley. He has since started other innovation and entrepreneurship programs, including Hacking for Defense, which was federally authorized in fiscal year 2018 NDAA bill and works to solve urgent problems for the Department of Defense and intelligence community.

Through his work with the armed services intelligence agencies he has helped advance the concept of dual-use products, those that may be developed for defense applications but can also be sold commercially and attract private capital.

Steve hails from Pescadero, California. It's good to have him here today.

Chairwoman COMSTOCK. Thank you.

And now our next witness is Dr. Dean Chang, Associate Vice President for Innovation and Entrepreneurship at the University of Maryland and Lead Principal Investigator of DC. I–Corps.

Prior to joining UMD, Dr. Chang spent 15 years in Silicon Valley where he served as the Chief Technology Officer of Immersion Corporation. He holds over 40 U.S. and international patents.

Dr. Chang earned his Bachelor's degree in Mechanical Engineering from MIT, a Master's in Business Administration from the Wharton School at the University of Pennsylvania, and his Ph.D. in Mechanical Engineering from Stanford.

Dr. Sue Carter is our final witness, and she is professor of physics and Director of the Center for entrepreneurship at the University of California Santa Cruz. She also serves as the Director of the NSF I–Corps site in Santa Cruz.

Previously, she worked as a research staff member at several companies and served as the Chief Technical Advisor and scientific founder at four startups. Dr. Carter holds six patents and one patent pending. Her research focuses on film technologies, biosensors, solar energy, and agriculture technology.

Dr. Carter earned a Bachelor of Arts in Mathematics, Chemistry, and Physics from Kalamazoo College and a Ph.D. in Chemistry from the University of Chicago.

I now recognize Dr. Tilbury for five minutes to present her testimony.

TESTIMONY OF DR. DAWN TILBURY,
ASSISTANT DIRECTOR,
DIRECTORATE FOR ENGINEERING,
NATIONAL SCIENCE FOUNDATION

Dr. TILBURY. Chairwoman Comstock, Ranking Member Lipinski, and Ranking Member Johnson, Members of the Subcommittee, thank you for inviting me to participate in today's hearing on the National Science Foundation's Innovation Corps or I–Corps. My name is Dawn Tilbury, and as mentioned, I'm the Assistant Director for Engineering at NSF.

The NSF I–Corps program started through the convergence of several trends in the economy in the understanding of startup formation and through NSF's experience with seeding startups through the SBIR and STTR programs.

I–Corps was adapted from Steve Blank's Lean Launchpad course at Stanford University. Steve's course provided Lean Startup training to NSF scientists and engineers so they could quickly determine whether their technology or product had commercial potential. I'm very pleased to see Steve here today. Thank you for your leadership and support of this important program.

I'm also pleased to see Dr. Dean Chang from the University of Maryland, D.C., and Virginia node and Dr. Sue Carter from the University of California Santa Cruz. You'll hear from them shortly.

The purpose of I–Corps is to accelerate U.S. innovation. It leverages results from fundamental science and engineering research into translational activities of potential commercial and societal benefit. I–Corps helps scientists and engineers gain entrepreneurial skills and identify valuable product opportunities that can emerge from academic research.

Each I–Corps team has a technical lead, an entrepreneurial lead, and an I–Corps mentor. During their intensive training, the I–Corps teams determine whether they have a viable product or service with a fit in the market. At the end of the training, if the answer is yes, teams have a clear understanding of the next steps to move their technology into the marketplace. Those steps could be to pursue licensing their technology or to launch a startup.

By addressing the challenges inherent to the early stages of the innovation process, NSF investments strategically strengthen the innovation ecosystem in the United States. To help accomplish this, we draw on many partners in that ecosystem. Academic institutions play a critical role in I–Corps, as does the private sector. Technology developers, business leaders, venture capitalists, and experienced entrepreneurs serve as mentors, sharing their knowl-

edge and expertise with the I–Corps teams. This network enhances the ability of NSF-supported researchers and their students to turn scientific results into potentially successful technologies.

Since our first cohort of 21 teams in 2011, the program has expanded across the country. I–Corps now has eight regional nodes involving 28 universities and 86 sites that provide infrastructure, resources, networking, and training to move scientific discoveries from university labs into the marketplace. The I–Corps model has been adopted by nine other federal agencies and the State of Ohio. The national I–Corps curriculum has trained more than 1,000 teams to date. More than 450 of these NSF I–Corps teams have created startups.

Although I–Corps constitutes far less than one percent of the NSF annual budget, recent data shows that I–Corps teams have collectively raised over $250 million in seed capital. For the team members, it has been truly transformational to think in a more entrepreneurial way.

I–Corps is a way to unlock the economic potential of creative ideas in American colleges and universities generated by NSF investments. To lay the groundwork for future expansion, NSF has two pilot programs underway. First, we are funding eight I–Corps sites to increase participation and promote inclusion of underrepresented populations in entrepreneurship. These sites will pilot novel approaches and partnerships to engage differently abled individuals, first-generation college students, racial and ethnic minorities, and women, as well as minorities-serving institutions.

Second, in collaboration with the NSF, SBIR, and STTR programs, we launched the I–Corps for Phase Zero pilot. This pilot supports nonacademic teams that are developing game-changing technologies. The Phase Zero teams receive national I–Corps training and participate in a follow-on curriculum called I–Corps Go that addresses some of the more common issues in startup formation.

As we look to I–Corps' next five years, we see continued urgency and motivation for the program. Several studies suggest that U.S. startup rates have not fully recovered from the Great Recession. With NSF-supported researchers continually creating and developing cutting-edge technology, we see the I–Corps program as a key tool to help with our broader goals to increase American innovation.

Thank you for your interest in this program and for giving me the opportunity to speak. Thank you.

[The prepared statement of Dr. Tilbury follows:]

Testimony of

Dr. Dawn Tilbury, Assistant Director
Engineering Directorate
National Science Foundation

Before the

U.S. House of Representatives
Committee on Science, Space, and Technology
Subcommittee on Research and Technology

Hearing on "From Lab to Market: A Review of NSF Innovation Corps"

December 6th, 2017

Chairwoman Comstock, Ranking Member Lipinski, and distinguished Members of the Subcommittee, thank you for inviting me to participate in today's hearing on the National Science Foundation's (NSF's) Innovation Corps, or I-Corps. My name is Dawn Tilbury, and I am the Assistant Director for Engineering (ENG) at NSF.

The NSF I-Corps program started in 2011 through the convergence of several trends in the economy, in the understanding of startup formation, and through NSF's experience with seeding startups through the Small Business Innovation Research and Small Business Technology Transfer (SBIR/STTR) programs.

These trends strongly resonated with NSF's experience. Our data showed that of the new startups in the SBIR/STTR programs, many of which were academic spinouts developing cutting edge, state of the art deep technologies, the greatest challenge to success was more typically market failure, not technical failure that they had to overcome. We wanted to work with these trends to try something new that might better support translating cutting-edge innovations from the lab to the market.

Against the backdrop of the Great Recession, the economy was seeing a longer-term decline in startup formation at the same time research was showing that startups were needed as the largest contributor to net new jobs. A decline in startups – the drivers for net new economic activity and jobs – was a worrying trend.

Through the work of Steve Blank and others in the Lean Startup movement emerged a body of knowledge about what practices might lead to a higher probability of startup success. Instead of generating static, multiyear business plans, it is better to think of startups as a search for a viable

business model. Active customer discovery can guide this search and create a framework to communicate it to the company, investors and other stakeholders.

I-Corps was developed and adapted from Steve Blank's Lean Launch Pad course at Stanford University, with the goal of providing Lean Startup training to NSF scientists and engineers so they could quickly determine whether their technology or product has commercial potential.

Each I-Corps Team consists of an Entrepreneurial Lead (EL), an I-Corps Team Mentor (IM) and a Technical Lead (TL). The EL could be a post-doctoral scholar, graduate or other student or other personnel with relevant knowledge of the technology and a deep commitment to investigate the commercial landscape surrounding the innovation. The IM will typically be an experienced entrepreneur with proximity to the institution and experience in transitioning technology out of Academic labs. The I-Corps Teams' IM must be a third-party resource and may be recommended by the proposing institution. The TL will typically be a faculty member, senior research scientist or post-doctoral scholar with deep and direct technical expertise in the actual core technology about which the I-Corps team is exploring commercial potential.

Each I-Corps Team participates in a curriculum designed to provide real-world, hands-on, immersive learning about what it takes to evaluate commercial opportunity around the innovation. The curriculum consists of an approximately seven-week program that involves an in-person entrepreneurial curriculum immersion Kickoff, a weekly online curriculum, and an in-person Lessons Learned report-out. The Kickoff and Lessons Learned are both held on-site at the cohort location. The weekly online sessions are a combination of instructor and team presentations and active interactions between the teams, instructors and other teams in the cohort. In addition to scheduled cohort events, the main activity of the program is customer discovery where the Team leaves the lab to evaluate potential product-market fit and the wider business model. At the end of the curriculum, Teams are expected to have performed at least one hundred (100) face-to-face interviews with potential customers and potential partners from their proposed target market(s). The Team's progress in customer discovery will be shared with the entire cohort to facilitate group learning.

Teams that come to a "Go" decision at the end of the program have been deemed to have significant commercial viability. Of equal benefit are the teams that get to a "No Go" decision at the end of the curriculum, who recognize that their technology was not addressing market needs or perhaps needed additional development at the university before being considered for a spin out. We wanted to stop the cardinal sin of startups, "Developing something nobody wants."

NSF I-Corps is managed within NSF's ENG Directorate Division of Industrial Innovation and Partnerships (IIP), but is an agency-wide program. NSF has seen over 450 companies develop out of I-Corps teams. These companies have collectively raised over $250 million in seed capital. Traditionally, these types of companies take 5-10 years to fully develop into commercial successes. Early fundraising and improved success rates in SBIR/STTR programs are a testament to I-Corps' value in improving the preparation of early stage startups.

Another, often overlooked, outcome of I-Corps is the opportunity cost of teams that decide after only seven weeks that their cutting-edge technology cannot be wrapped into a viable business

model and so do not start a company. Failing fast is the mantra of Silicon Valley and a tenet of I-Corps. As much as we relish the successes of startups emerging from I-Corps, we applaud the teams that declare a "No Go" in the program and decide to either adapt their technology or product back at the university, or decide to pursue another innovation altogether. NSF has programs, such as the Partnerships for Innovation (PFI), that are particularly well suited to support technology development that needs additional time and support at the university prior to commercialization. Similarly, the NSF SBIR/STTR program is focused on primarily supporting deep technology startups, many of whom were the "Go" teams emerging from I-Corps Teams.

I-Corps has its genesis in many of the Foundation's long-standing innovation ecosystem programs. Those existing NSF innovation research alliances include consortia such as Engineering Research Centers (ERC), Industry University Cooperative Research Centers (IUCRC), PFI, Science and Technology Centers (STC), Nanoscale Science and Engineering Centers (NSEC) and Materials Research Science and Engineering Centers (MRSEC). They are also exemplified by the Grant Opportunities for Academic Liaison with Industry (GOALI) program, and the SBIR/STTR program. Many of these programs have been part of the NSF investment portfolio for decades. For example, SBIR is a government-wide program initiated at the NSF in 1976. These programs complement our other significant investments in fundamental scientific and engineering research by offering multiple pathways to moving discovery to innovative technologies.

Most closely related to I-Corps is the PFI program in the ENG Division of IIP which also started in FY 2011. The PFI program:

- encourages the translation of the numerous, technologically-promising, fundamental discoveries made by NSF researchers, while drawing upon and building the entrepreneurial spirit of the researchers and students; and
- fosters connections between existing NSF innovation research alliances.

Both I-Corps and PFI are designed to strengthen the U.S. innovation ecosystem.

To build a national "culture of innovation" we not only need sustained research investment but also skillful and deliberate catalysts to hasten the application of scientific discoveries. A robust innovation ecosystem could also help us conceive novel research questions and shift Science and Engineering knowledge paradigms altogether. That, in effect, is what we seek to accomplish through the I-Corps program.

There are four distinct components of the I-Corps program today:

- Teams – These are the actual teams that participate and are funded to go through the NSF National I-Corps Teams Program. The teams are comprised of at least three members, including a technical lead, the scientist or engineer as entrepreneurial lead, and the industry Mentor. This is an entrepreneurship program for scientists and engineers to learn how to evaluate market opportunity created by their technology. I-Corps does not fund the R&D itself. It funds the validation, or invalidation, of the product (or technology)-market fit.
- Nodes – These are regional hubs for education, infrastructure, and research that engage academic scientists and engineers in innovation regionally. Nodes provide the backbone

to support the Teams program and work to adapt the training to new partners and audiences.

- Sites – These are awards to single academic institutions intended to catalyze the engagement of local teams in technology transition and strengthen local innovation ecosystems.
- National Innovation Network. - Collectively our Nodes, Sites, Teams, other agency partners and others comprise a network to work cooperatively to build, utilize, and sustain the national innovation ecosystem.

I-Corps Highlights:

- 8 Nodes involving 28 universities
- 86 Sites
- 1000+ Teams funded by NSF (Since 2011)
- 450+ startups created
- 9 MOUs with other Federal Agencies. I-Corps programs have been adopted and adapted in partnerships with a growing number of Federal agencies, including the National Institutes of Health (NIH), Department of Energy (DOE), Department of Defense (DOD), National Security Agency (NSA), United States Department of Agriculture (USDA), Department of Homeland Security (DHS), Advanced Research Projects Agency – Energy (ARPA-E), National Aeronautics and Space Administration (NASA), and the Small Business Administration (SBA).
- The I-Corps model has been adopted by the state of Ohio.

Additional primary outcomes for the I-Corps program center on those tangible measures that relate directly to the societal application realized from NSF's investments in basic research. For example, successful completion of the I-Corps grant would be expected to contribute to one or more of the following:

- New start-up businesses;
- Licensing;
- SBIR/STTR proposals;
- A business opportunity suitable for review by third-party investors;
- Students prepared to be entrepreneurially competitive; and
- Researchers able to evaluate market potential and better able to align research directions with commercial opportunity.

Next Steps

Training scientists and engineers to evaluate market opportunity and to get out of the lab to speak with potential customers and stakeholders in industry is the main contribution of the I-Corps program. We are excited to move the program forward into its next phase. NSF has pilot programs currently underway to lay the groundwork for this expansion. In collaboration with the NSF SBIR/STTR program we have launched the I-Corps for Phase 0 pilot. Through this pilot we are supporting non-academic teams of very early startups or pre-startups that are developing game-changing technologies. These Phase 0 Teams will receive national I-Corps training as well

as participate in a follow-on curriculum called "I-Corps Go" that addresses some of the more common issues in startup formation, including incorporation, licensing and negotiation of intellectual property, and fundraising. "I-Corps Go" will allow NSF to work with startups on more than just the problem of "Developing something nobody wants."

As we look ahead to the next five years of I-Corps, we see the continued motivation for the program. Startup rates are still down in the United States. With NSF-supported researchers continually innovating and developing cutting edge technology, we see the I-Corps Program as a key tool to help with our broader goals to:

- Leverage NSF's investments and broaden the impact of NSF-funded research,
- Prepare scientists and engineers to expand their focus beyond the laboratory into entrepreneurship and commercialization,
- Promote the commercial success and societal benefit of new technologies funded by the US Government,
- Turn ideas into companies,
- and Change the lives of researchers and the cultures of academic institutions.

Summary

NSF's primary mission is to advance the frontiers of science and engineering through basic research. The I-Corps program is an integral part of the NSF strategy to stimulate innovation and address societal needs through the commercialization of the results of fundamental research. I-Corps uses customer discovery and business model development to validate commercialization opportunities, and I-Corps projects with product market fit will be well positioned for business formation.

I-Corps is designed to create a national network of scientists, engineers, innovators, business leaders, and entrepreneurs to accelerate and strengthen our national innovation ecosystem. I-Corps taps into the American entrepreneurial spirit to identify opportunities. The idea is not to take money away from basic research, but rather to look at research already completed that can be leveraged with a little nudge into translational activities of potential commercial benefit. I-Corps targets the critical gap that occurs just before researchers have advanced their ideas sufficiently to determine whether they have a product with market fit that justifies the formation of a company that will request SBIR/STTR funding. In that sense, this is a 'pre-seed' investment. NSF investments strategically strengthen the innovation ecosystem by addressing the challenges inherent in the early stages of the innovation process.

NSF participation in I-Corps includes every Directorate of the Foundation. The I-Corps Team award mechanism includes funding for the team to go through the rigorous entrepreneurship training, mentorship, and focused instruction in a hypothesis-driven approach to evaluating potential commercial viability of completed scientific and engineering research. Academic institutions are key partners in the I-Corps national network, as is the private sector. Technology developers, business leaders, venture capitalists, and experienced entrepreneurs serve as mentors, providing critical support by sharing knowledge and experience. This network operates to

enhance the ability of NSF-supported researchers to turn scientific results into potentially successful technologies. I-Corps also provides students with opportunities to participate.

The I-Corps program has been a significant positive addition to the NSF investment portfolio. Even though it constitutes less than one-third of one percent of the NSF budget recent data shows I-Corps teams have collectively raised over $250 million in seed capital. For the teams who have participated, it has been truly transformational to thinking in a more entrepreneurial way. An enormous and significantly underutilized storehouse of creative ideas with potential economic benefit exists in our nation's colleges and universities, and I-Corps is simply a way to help unlock and unleash some of those ideas generated by current and previous NSF investments. I thank the committee for their interest in this exciting program, and for giving me the opportunity and the privilege to testify before you today. I would be happy to answer any questions.

Dr. Dawn M. Tilbury

Dawn M. Tilbury received the B.S. degree in Electrical Engineering, *summa cum laude,* from the University of Minnesota in 1989, and the M.S. and Ph.D. degrees in Electrical Engineering and Computer Sciences from the University of California, Berkeley, in 1992 and 1994, respectively. In 1995, she joined the Mechanical Engineering Department at the University of Michigan, Ann Arbor, where she is currently Professor, with a joint appointment as Professor of EECS. Her research interests lie broadly in the area of control systems, including applications to robotics and manufacturing systems. In June of 2017, she became the Assistant Director for Engineering at the National Science Foundation, while maintaining her position at the University of Michigan. She has published more than 150 articles in refereed journals and conference proceedings. She was elected Fellow of the IEEE in 2008 and Fellow of the ASME in 2012, and is a Life Member of SWE.

Chairwoman COMSTOCK. Thank you. And now, we'll hear from Mr. Blank.

TESTIMONY OF MR. STEVE BLANK,
ADJUNCT PROFESSOR,
MANAGEMENT SCIENCE AND ENGINEERING,
STANFORD UNIVERSITY

Mr. BLANK. Thank you, Chairwoman Comstock, and thank you, Ranking Member Lipinski and Ranking Member Johnson. Thank you for inviting me to participate in this hearing.

Six years ago, the NSF recognized that scientists who received government commercialization grants were having a real hard time getting to the next step of raising private capital. And so the genesis of this I–Corps program is pretty simple. First, figure out why this was. Why were scientists having a hard time getting private capital, and why are they having a hard time building successful companies? And once we figured it out, then can we teach them the skills that they were missing?

And it soon became apparent that they were having a hard time raising money is that the scientists simply couldn't speak the language of private capital investors. University scientists believe that just having innovative technology was enough to make a successful business. The reality is that's just plain wrong. Great technology is just one part of a successful company. Private investors, venture capitalists, and angel investors needed to hear more than just the technology.

To speak to VCs or angel investors, scientists needed to learn things that weren't in their Ph.D. program. They needed to figure out how to turn their innovations in the lab into product that people actually wanted to buy. They had to figure out who their customers were going to be and how the product would be sold. They needed to talk to regulators and understand patents and licensing issues and understand how to create customer demand. How much would it cost to make their product and how many would they sell and what price?

In the past, when a scientist started a company, they'd write up all these answers to these questions, put it in a business plan, hire the people, build the product, and only find out years later into the company that their assumptions, their guesses what the customer wanted were wrong.

Now, I–Corps starts with the premise that, on day one, all an entrepreneur has is a series of untested hypotheses, which is a fancy word for they're just guessing, about each part of their business. We teach I–Corps in a way that's pretty extraordinary. When we teach scientists all the theory about starting a company, we also make them get their hands dirty by having them get out of their labs and test their hypothesis by talking to 10 to 15 customers a week. And they use the feedback from those customers to improve multiple versions of their product. By the time the class is over they've talked to over 100 people. We now know the I–Corps method of teaching scientists to get out of the building and talk to people turns theorists into capitalists.

And our scientists actually love this I–Corps learning process because what they're doing is actually running the scientific method,

this time with potential customers rather than test tubes in a lab. So when you hear the phrase "I–Corps is a bridge to private capital," you know that means that we teach our best scientists to learn a new set of skills that help them raise money to build companies. And these are companies that could create not just new products but new jobs, and not just in Silicon Valley but in districts like yours.

Now, having spent 21 years building companies, my first instinct was this type of education should be done by existing private incubators and accelerators, not the government. However, our observation six years ago is still true today. While the NSF-funded technologies can turn into future companies, most don't fit the model of grow into a billion-dollar valuation in three years that private incubators and accelerators are looking for.

The teams that I–Corps teaches require the patience and the long-term vision that the NSF brings. NSF-funded scientists and engineers are working on what we call deep tech, really long-term, geeky technology like new material, new devices outside of the mainstream of social media and smartphone apps. Yet for our country, turning these innovations in a products might have the biggest payoff.

We now know that, without I–Corps training, most of our advanced technologies would never turn into companies. There's one other thing about these deep technologies that's becoming more evident. Many are potentially dual-use technologies, meaning they have potential commercial companies, but their products can be also used for the Department of Defense and our intelligence community to keep our country safe and secure.

So America is better for having I–Corps. It's made turning our government-funded science into companies more efficient. We should do more of I–Corps. We can make it broader and better, reaching more people and teaching more skills. First, keep in mind that, today, I–Corps is for university scientists funded by the NSF, but if you're outside a university, you can't take this class, and that's a shame. Since we now know we have an effective program, we ought to share it with all Americans, not just the few in universities. We ought to open the I–Corps to innovators and entrepreneurs who have ideas in every part of the country whether they're in a university or a garage that aren't yet ready for private capital.

The second way to make I–Corps better is to improve on what we've learned over the last six years. One of our biggest learnings is that even after teams have been through the I–Corps, they need to learn additional skills like how to hire and build teams that know how to sell and market the product, how to grow in scale a company, and how to find investors who want deep technology. NSF is currently testing this follow-on class, as you've heard, called I–Corps Go.

I hope everyone in this Committee is proud of the I–Corps program that you've created and supported. It's one of the programs that continues to make America great. Thank you.

[The prepared statement of Mr. Blank follows:]

Chairman Smith, Chairwoman Comstock, Ranking Member Lipinski, Ranking Member Johnson. Thank you for inviting me to participate in this hearing on NSF's Innovation Corps, or I–Corps.

As you know, for over 70 years the National Science Foundation has funded basic research in universities. And for the last 30 years, 3% of the NSF budget gave grants –money with no strings attached – to scientists in any field who wanted to turn their basic research into a company. This is known as the Small Business Innovation Research, or SBIR program. Six years ago, the NSF recognized that scientists who received government grants were having a hard time getting to the next step of raising private capital.

The genesis of the I-Corps program is pretty simple – figure out why scientists were having a hard time getting private capital and building successful companies, then teach them the skills they were missing.

It soon became apparent that the reason they were having a hard time raising money was that scientists couldn't talk the language of private capital investors.

University scientists believed that just having innovative technology was enough to make a successful business. The reality is that's wrong. Great technology is just one part of a successful company. Private investors – Venture Capitalists and angel investors - needed to hear about more than just the technology.

To speak to venture capitalists or angel investors, scientists need to learn a few things that weren't in their PhD program. They needed to figure out how to turn their innovations in the lab into products that people want to buy. They had to figure out who these customers would be and how the product would be sold. They needed to talk to regulators, understand patents and licensing issues, understand how to create customer demand, how much would it cost to make their product, and how many they would sell, and at what price.

In the past, a scientist starting a company would write up all the answers to these questions in a business plan, hire the people, build the product and only find out years into the company that their assumptions about what customers wanted were wrong. I-Corps starts with the premise that on day one all an entreprenuer

have are untested *hypotheses* – a fancy word for guesses – about each part of their business.

We teach I-Corps in a way that's pretty extraordinary. While we teach scientists the theory about starting a company, we also make them get their hands dirty, by having them get out of their labs and test their hypotheses by talking to 10-15 customers, regulators and partners each and every week. And they use the feedback from potential customers to improve multiple versions of their product. By the time the class is over they've talked to over 100 people. We now know that the I-Corps method of teaching scientists to "get out of the building and talk to people" turns theorists into capitalists.

And our scientists love this I-Corps learning process because what they are doing is running the scientific method, this time with potential customers rather than test tubes in a lab.

So, when you hear the phrase that I-Corps is a "bridge to private capital" you know that means that we teach our best scientists to learn a new set of skills that help them raise money to build companies.

Companies that can create not just new products but new jobs. Not just in Silicon Valley but in districts like yours.

Having spent 21 years building companies, my first instinct was that this type of education should be done by existing private incubators and accelerators, not the government. However, our observation 6 years ago is still true today – while these NSF funded technologies can turn into future companies, most don't fit the model of "grow to a billion-dollar valuation in three years" that private incubators and accelerators are looking for. The teams that I-Corps teaches require the patience and long-term vision that the NSF brings. NSF-funded scientists and engineers are working on "deep tech" – really long-term, geeky technology like new materials, new devices - outside of the mainstream social media, smartphone apps. Yet for our country, turning these inventions into products might have the biggest payoff. We now know that without I-Corps training our most advanced technologies would never turn into companies.

There's one other thing about these "Deep Technologies" companies that is becoming more evident - many are potentially "dual-use" technologies. Meaning that they have potential as

commercial companies, but their products can also be used for our Department of Defense and Intelligence community to keep our country safe and secure.

As you've heard from Acting Director of Engineering Tilbury, the I-Corps program is now taught at 86 colleges and universities in the U.S. There is likely an I-Corps site in each of your districts. Over 1,000 teams of the country's best scientists and engineers have been through the national training program, and many thousands more have interacted with local I-Corps sites.

America is better for having I-Corps. It's made turning our government-funded science into companies more efficient.

We should do more of I-Corps. We can make it broader and better, reaching more people and teaching more skills. First, keep in mind that today I-Corps is for university scientists funded by the NSF. But if you're outside a university you can't take this class. And that's a shame, since we have an effective program we ought to share with all Americans not just the few in universities. We ought to open the I-Corps to innovators and entrepreneurs who have ideas in every part of the country,

whether they are in a university or a garage, that aren't yet ready for private capital.

The second way to make I-Corps better is to improve on what we've learned over the last six years. One of our biggest learnings is that even after teams have been through I-Corps they need to learn new skills like how to hire and build teams that know how to sell and market the product, how to grow and scale a company and how to find investors looking for Deep Technologies. NSF is currently testing a follow-on class called I-Corps Go that does just that.

I hope everyone on this committee is proud of the I-Corps program that you've created and supported. It's one of programs that continues to make America great.

Steve Blank is an Adjunct Professor at Stanford University, a Lecturer at the University of California at Berkeley, and a Senior Fellow at Columbia University.

Steve's work on Customer Development is the foundation for the *Lean Startup* movement. Lean revolutionized how innovation is taught and implemented in startups, companies and government agencies. Steve's 2011 class on innovation at Stanford was adopted by the National Science Foundation and is the curriculum for the *Innovation Corps* (I-Corps.)

I-Corps is now taught at 86 colleges and universities in the U.S. Over 1,000 teams of the country's best scientists and engineers have been through the program.

His follow-on class, *Hacking for Defense* (part of the 2017 National Defense Authorization Act), allows students to work on solving urgent problems for the Department of Defense and intelligence community. The class is currently offered at nine other universities.

Prior to becoming an educator, Steve spent 21 years as an entrepreneur in eight Silicon Valley startups.

Steve served in the U.S. Air Force during the Vietnam war.

Chairwoman COMSTOCK. Thank you. I now recognize Dr. Chang.

TESTIMONY OF DR. DEAN CHANG,
ASSOCIATE VICE PRESIDENT,
INNOVATION AND ENTREPRENEURSHIP,
UNIVERSITY OF MARYLAND;
LEAD PRINCIPAL INVESTIGATOR,
DC I-CORPS REGIONAL NODE

Dr. CHANG. Good morning, Chairwoman Comstock, Ranking Members Johnson and Lipinski, and distinguished Members of the House Science Subcommittee. I'm greatly appreciative of the opportunity to testify and engage in a discussion with all of you about the NSF I–Corps program.

My name is Dean Chang. Sometimes it helps if I clarify that Dean is my name, not my title. I'm the Associate V.P. for Innovation Entrepreneurship at the University of Maryland. And we've already heard from my fellow witnesses about the lab-to-market impact that I–Corps has had. So as a Lead Principal Investigator for the NSF I–Corps node for the D.C., Maryland, and Virginia area—we like to call it the DMV node—I'd like to use my five minutes to highlight two specific areas of impact of I–Corps.

Area number one, the impact of I–Corps on the regional and national level; and area number two, the impact of I–Corps on undergraduate education. Area number one, NSF has created a National Innovation Network with eight I–Corps nodes across the country. What is a node, you might ask? Well, nodes are basically charged with rallying and marshalling together the many universities, investors, entrepreneurs, and industries in our geographic regions and getting everyone to work together as one. It's my observation that this has been one of the hallmarks and most impactful contributions of the NSF I–Corps program. In the past, critical startup knowledge of what worked and what didn't often lived in the heads of a few expert individuals. Most universities didn't have easy access to these individuals, and that's really all changed now with I–Corps nodes.

Here in the DMV node we have built up a strong bench with over a dozen I–Corps instructors from University of Maryland, Johns Hopkins, Virginia Tech, George Washington, Howard University. Once or twice a year, NSF sends us about 25 teams for the national I–Corps training, but the rest of the year our dozen I–Corps instructors continue to teach in various versions of the I–Corps program throughout the region to 200 teams each year and these—those instructors even travel to other schools to provide this I–Corps training to teams from George Mason, from University of Virginia, Virginia Commonwealth, Morgan State, and even outside the DMV to schools in Pennsylvania and North Carolina.

This means that a team from just about any school in our region can get access to any instructor from our node. For instance, if you're a team from Morgan State, you now have access to our instructor from Johns Hopkins, who specializes in life sciences; our instructor from Maryland, who specializes in virtual-reality, augmented reality, and UAVs; our instructor from Virginia Tech, who

specializes in DOD-funded companies; or our instructor from George Washington, who specializes in international markets.

And this picture I paint for our DMV node is the same at the other nodes as well. In the Midwest, the University of Michigan collaborates with Purdue and University of Illinois and other schools in that region. In the Southeast, Georgia Tech does the same with Universities of Alabama and Tennessee and other schools in their region. And the same for the nodes in the Northeast, the West Coast, the Southwest. So this National Innovation Network of nodes created by NSF really has an "all for one and one for all" sense of community across the regions and across the country.

Area number two, the curriculum and methods in the national I–Corps training are also widely being integrated—being widely integrated into undergraduate education. At the University of Maryland, key components of I–Corps training have been incorporated into over 50 courses reaching over 7,000 students each year. One of those classes is the senior capstone course in bioengineering in which students spend the year working with doctors to design medical devices. Before incorporating I–Corps into the course, some beautiful devices were designed and manufactured with little regard to validating a business model. Now, the students spend time in customer discovery and learn how improved health care also requires purchasing, reimbursement, regulatory, and other issues be part of any successful business model.

Two students in the course, Shawn Greenspan and Stefanie Cohen said, quote, "I–Corps finally put us on the road to real customer discovery. Our initial business plan started with an incorrectly identified buyer, value propositions that were wrong, and guesses everywhere else. Fortunately, after 67 interviews, we now have a developing revenue model. We still lots of work to do, but we now know where our answers lie: outside the building."

Shawn is now working at Palantir Technologies, and Stefanie works for a spinal surgical implant company, and both Shawn and Stephanie site I–Corps as a formative experience that gave them the essential skills to be able to accelerate technology into the market, skills that they are both using in their jobs today. Many of the over 100 colleges teaching I–Corps have similar stories of the impact I–Corps is having on undergraduate education.

In conclusion, I–Corps has created a significant culture change across campuses both among students as well as faculty. Faculty who go through the national I–Corps training get connected to the tremendous resources of the National Innovation Network and come back eager to apply I–Corps principles to their entire research portfolio, as well as to their teaching. That in turn better prepares and better equips students to make an impact on the economy and in society, whether it be at a startup, at a large company, or even at a nonprofit or in government.

Lastly, one of the things that made I–Corps so successful has been the flexibility for I–Corps nodes to experiment and innovate with the I–Corps program itself. In I–Corps we push scientists to go beyond their comfort zone to find the unexpected opportunities, so we need to continue to push ourselves out of our comfort zone to keep making I–Corps better. Thank you.

[The prepared statement of Dr. Chang follows:]

ACADEMY FOR INNOVATION & ENTREPRENEURSHIP
Edward St. John Teaching & Learning Center, Suite 1130, College Park, MD 20742

TESTIMONY OF DR. DEAN CHANG
Associate Vice President for Innovation & Entrepreneurship
University of Maryland

Before the
House Committee on Science, Space, and Technology
Subcommittee on Research and Technology
Hearing Titled
"From Lab to Market: A Review of NSF Innovation Corps"
Wednesday, December 6, 2017

Good morning, Chairwoman Comstock, Ranking Member Lipinski, and distinguished members of this House Science Subcommittee. I am greatly appreciative of the opportunity to testify and engage in a discussion with all of you about the NSF I-Corps program.

My name is Dr. Dean Chang. Sometimes it helps if I clarify that Dean is my name, not my title. I'm the Associate Vice President for Innovation & Entrepreneurship at the University of Maryland. We've already heard a lot from my fellow witnesses about the lab-to-market impact that I-Corps has had. So as the lead principal investigator for the NSF I-Corps Node for the DC, Maryland, and Virginia area (the DMV Node), I'd like to use my five minutes to highlight two specific areas of impact of I-Corps:

- Area #1: Impact of I-Corps on the regional and national level
- Area #2: Impact of I-Corps on undergraduate education

Area #1: Impact of I-Corps Nodes on the regional and national level

NSF has created a National Innovation Network with seven I-Corps Nodes across the country. What is a Node? Nodes are basically charged with rallying and marshalling together the many universities, investors, entrepreneurs, and industries in our geographic regions and getting everyone to work together as one. It is my observation that this has been one of the hallmarks and most impactful contributions of the NSF I-Corps program.

In the past, critical startup knowledge of what worked and what didn't often lived in the heads of a few expert individuals, and most universities didn't have easy access to those individuals. That's all changed with I-Corps Nodes.

Here in the DMV Node, we have built up a strong bench with over a dozen I-Corps instructors from UMD, JHU, VT, GWU, and Howard. Once or twice a year, NSF sends us about 25 teams for the national I-Corps training. But the rest of the year, our dozen I-Corps instructors continue to

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teach in various versions of I-Corps programs throughout the region to another 200 teams each year. Those instructors even travel to other schools to provide I-Corps training to teams from schools like George Mason, UVA, VCU, Morgan State, and even outside the DMV to schools in Pennsylvania and North Carolina.

This means a team from just about any school in our region can get access to any instructor from our Node. For instance, if you're a team from Morgan State, we can connect you with our instructor from JHU who specializes in life sciences; or our instructor from UMD who specializes in VR/AR, and UAVs; or our instructor from VT who specializes in DOD-funded companies; or our instructor from GWU who specializes in international markets.

This picture I paint for our DMV Node is the same at the other six Nodes. In the Midwest Node, the University of Michigan collaborates with Purdue and University of Illinois and other schools in that region. In the Southeast Node, Georgia Tech collaborates with University of Alabama and University of Tennessee and other schools in that region. The same for the Nodes in the Northeast, West Coast, and Southwest. This National Innovation Network of Nodes created by NSF really has an "All for one, one for all" sense of community across regions and across the country.

Area #2: Impact of I-Corps on undergraduate education
The curriculum and methods in the national I-Corps training are also being widely integrated into undergraduate education.

At the University of Maryland, key components of I-Corps training have been incorporated into over 50 courses reaching over 7,000 students each year. One of those classes is the senior capstone course in bioengineering in which students spend the year working with doctors to design medical devices. Before incorporating I-Corps into the course, some beautiful devices were designed and manufactured with little regard to validating a business model. Now the students spend time in customer discovery and learn how improved healthcare also requires purchasing, reimbursement, and regulatory to be part of any successful business model.

Two students in the course, Shawn Greenspan and Stefanie Cohen, said, "I-Corps finally put us on the road to real customer discovery. Our initial business plan started with an incorrectly identified buyer, value propositions that were wrong, and guesses everywhere else. Fortunately after 67 interviews we now have ... a developing revenue model. We still have lots of work to do ... but now we know where our answers lie: outside the building."

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Shawn is now working for Palantir Technologies, and Stefanie works for a spinal surgical implant company. Both Shawn and Stefanie cite I-Corps as a formative experience that gave them the essential skills to be able to accelerate technology into the market, skills that they are both using in their jobs today.

Many of the 85 other colleges teaching I-Corps have similar stories of the impact I-Corps is having on undergraduate education.

Conclusion

In conclusion, I-Corps has created a significant culture change across campuses among both students as well as faculty. Faculty who go through the national I-Corps training get connected to the tremendous resources of the National Innovation Network and come back eager to apply I-Corps principles to their entire research portfolio as well as to their teaching. That in turn better prepares and better equips students to make an impact on the economy and in society, whether it be at a startup, at a large company, or even at a non-profit or in the government.

Lastly, one of the things that has made I-Corps so successful has been the flexibility for I-Corps Nodes to experiment and innovate with the I-Corps program itself. In I-Corps we push scientists to go beyond their comfort zone to find the unexpected opportunities, so we need to continue to push ourselves out of our comfort zone as well to keep making I-Corps better. Thank you for your time, and I'm eager to hear your thoughts and questions.

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BIO FOR DR. DEAN CHANG
Associate Vice President for Innovation & Entrepreneurship
University of Maryland

Dr. Dean Chang's passion is helping students and researchers discover and cultivate the innovator and entrepreneurial mindset inside of them. He is the University of Maryland's (UMD) founding Associate VP for the Academy for Innovation & Entrepreneurship (AIE), reporting to the President and Provost and tasked with engaging all 37,000 students in all 12 colleges in innovation. He is a PI and instructor in the National Science Foundation's (NSF) I-Corps Node program. He develops and teaches I&E curriculum for high school and college students, university researchers, and government agencies.

Prior to UMD, Dean spent 15 years in Silicon Valley where he served as the Chief Technology Officer of Immersion Corporation, a venture-backed, Stanford University robotics lab spinout that later became a publicly traded (NASDAQ: IMMR), world-leading licensor of haptics technology with customers that included Microsoft, Sony, BMW, and Samsung.

Dean holds over 40 U.S. and international patents and has a bachelor's degree in mechanical engineering from MIT, a PhD in mechanical engineering from Stanford, and an MBA from Wharton.

Chairwoman COMSTOCK. Thank you, Dr. Chang.

And now, we'll hear from Dr. Carter.

TESTIMONY OF DR. SUE CARTER, PROFESSOR, DEPARTMENT OF PHYSICS, DIRECTOR, CENTER FOR INNOVATION AND ENTREPRENEURIAL DEVELOPMENT, UNIVERSITY OF CALIFORNIA, SANTA CRUZ

Dr. CARTER. Thank you. Chairwoman Comstock, Ranking Member Lipinski and Johnson, and Members of the Subcommittee, it's an honor to appear before you today. My name is Sue Carter, and I am a three-time participant in the NSF I–Corps program and currently run the NSF I–Corps site at the University of California Santa Cruz.

In addition, I'm a physics professor who has transitioned basics research out of the lab into startup companies three times. Consequently, I can provide you my experience with NSF I–Corps as a student and teacher of the curriculum and as a faculty member and entrepreneur.

The strength of NSF I–Corps program is that it pushes researchers to get out of the lab and into the community to talk to potential customers, enabling them to better understand the societal value or lack thereof that their research has. For me as a faculty member, the insight has resulted in doing much more impactful applied research. Similarly, as an entrepreneur, the NSF I–Corps program has resulted in me spending substantially less time and money to get a product to market.

Let me provide some—a few concrete examples. I have been a principal at four startup companies: Add-vision, Solexant, Soliculture, and the IRIS Science Academy. The first two companies are before I had NSF I–Corps training, and the last two are after I went through NSF I–Corps training. At Add-vision, we raised over $6 million in funding both from strategic partners and government grants. We used this funding to develop a printable organic light emitting diode technology to meet commercial specs given to us by our partner, but we never fully identified a customer for the product, and thus, we ended up selling the company to Sumitomo, a Japanese company.

If I had had the experience of the NSF I–Corps program, I believe we could have identified customers much earlier on and grown our vision into a U.S.-based company that could have been a leader in organic light emitting diode technology, creating hundreds of U.S. jobs.

At Solexant, we raised over $30 million in venture capital funding. This money was focused on developing a thin-film solar cell technology and building a manufacturing line in Oregon. However, yet again, we failed to identify a customer and value proposition for the product that was developed, which ultimately led to the manufacturing facility never being built. After burning through much of the initial multimillion dollar investment, the company was taken over by new management who understood that the value that we provided to our companies was the low-cost manufacturing process

that made the solar cells rather than—I'm sorry, to our customers—rather than the solar cells themselves.

If we had the experience of the NSF I–Corps program, I'm confident we would have come to the correct product decision two years earlier, enabling us to direct the initial $30 million to ensure U.S. solar industry's leadership in thin-film technologies rather than losing much of this market share to China.

The two companies I started after NSF I–Corps resulted in us being able to sell commercial product to customers with much less time and funding, namely less than $2 million in the case of Soliculture and less than $10,000 in the case of the Science Academy. The efficiency directly resulted from our many conversations with the potential customers and key partners that the NSF I–Corps program largely forced us to do. While it's too early to know how many jobs Soliculture will generate, its pathway to selling commercial product was many years faster than my two previous companies.

Needless to say, I'm convinced that the small cost of the NSF I–Corps training pays for itself many times over in reducing startups time to market. For startups that receive funding through the SBIR or STTR program, which I've also received funding from, this also gives U.S. taxpayer money—this also saves U.S. taxpayer money as it allows the principal investigators to use the funding much more efficiently to develop a technology that someone is willing to pay for.

Given my positive experience as a faculty member in the NSF I–Corps program, I decided to offer the curriculum to students at my university through a summer entrepreneurship academy. While only a few of the students going through the program actually start companies, the training has proven invaluable to students as they seek employment after they graduate. Students have come back to tell me that this is the most valuable course they took at UCSC and received their job offer because they had taken the I–Corps course.

Understanding how to listen to your customers and make changes to a product so that it fulfills their needs is important in almost any job but something that academia is very bad at teaching students as we find ourselves sometimes stuck in the echo chamber of a university.

I want to conclude with how the program can move forward to better benefit students and entrepreneurs. So I'm running out of time. I'm going to basically say that I'm a strong proponent of I–Corps Go that is expanding our training so that students can learn how to talk to VCs, how to form teams, and how to understand the legal context behind their startups.

The other major issue is that the training is largely limited to students, faculty, and their mentors, so I'd like to see the program open up to our entrepreneurs, many of whom are likely to be willing to pay to take the course. I know I would have been. Some of our top young entrepreneurs received funding through the SBIR/STTR program, so that might be an excellent vehicle to expand the offering.

So, Madam Chairwoman, this completes my testimony, and I'm looking forward to your questions.

[The prepared statement of Dr. Carter follows:]

Carter Testimony for hearing titles "From Lab to Market: A review of NSF Innovation Corps," on Wednesday, December 5th, 2017 at 10 am

Summary: My name is Sue Carter and I have been a 3-time participant in the NSF I-Corps program and currently run an NSF I-Corps site at the University of California, Santa Cruz. In addition, I am a Physics professor who has transitioned basic research out of the lab into start-up companies three times. Consequently, I can provide my experience with NSF I-Corps as a student and teacher of the curriculum, and as a faculty member and entrepreneur who has started companies both before and after going through the NSF I-Corps program.

In my view, the NSF I-Corps program's strength is that it pushes researchers out of the lab and into the community to talk to potential customers, enabling them to better understand the value, or lack their of, that their research has on these customers. For me, this insight has resulted in doing more impactful applied research with less time and money because I can focus my research in areas that can positively impact the lives of US citizens. Similarly as an entrepreneur, the NSF I-Corps program has resulted me in spending substantially less time and money to get a product to market.

Experience at Start-ups before and after taking NSF I-Corps: Let me provide a few examples. I have been a principle at four start-up companies, Add-vision, an organic LED company, Solexant, a photovoltaic company, Soliculture, an advanced greenhouse company, and IRIS, a science academy. The first two companies are before I had I-Corps training and the last two are after I went through I-Corps training.

At Add-vision, we raised over $6 million in funding, mostly from our strategic partners but we also had some support from DOE and NSF SBIR program. We used this funding to develop a printable organic LED (shown in Figure 1) that could be used in a wide variety of back-light and signage applications and which could meet the commercial specs given to us by our partner. However, we never fully identified a customer for this product and ended up selling our company to Sumitomo, a Japanese Company. If I had had the experience of the NSF I-Corps program, I believe we could have identified customers much early on and grown Add-vision into a US-based company that could have been a leader in organic LED technology, employing hundreds of people in the US.

Figure 1: Add-vision's fully printed OLED technology. Sold to Sumitomo in 2011.

At Solexant, we raised over $30 million dollars, mostly in Venture capital and a few SBIR grants. This funding was focused on developing the thin film PV technology (see Figure 2) and building a thin film PV manufacturing line in the Oregon. However, yet again we failed to identify a customer and value proposition

for the product that was developed which ultimately led to the manufacturing facility never being built. After burning through much of the initial multimillion dollar investment, that company was taken over by new management who understood that the value that we provided to our customers was the low cost highly efficient manufacturing process that made solar cells, rather then the solar cells themselves. Siva Power recently raised new investment to scale their manufacturing process and are poised to become a leading supplier of thin film solar cells. If we had had the experience of the NSF I-Corps program, I'm confident we would have not blown through the $30 million dollars on a fruitless path towards manufacturing a product that our customer wasn't interested in but would have instead focused it on a R&D direction on a product with considerably more customer demand, greatly accelerating product launch and helping to assure US dominance in manufacturing processes for thin film solar cells. While Siva Power may still grow to the leading thin film PV provider, generating thousands of jobs, we have lost valuable market share to China with in the intervening time.

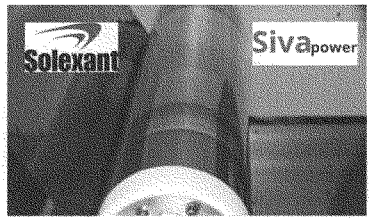

Figure 2: Solexant's printable thin film PV technology. Solexant reemerged as Siva Power to focus on thin film PV manufacturing process and tools.

The two companies I started after NSF I-Corps resulted in us being able to sell a commercial product to customers with much less time and funding, namely less then $2 million in the case of Soliculture and less then $10,000 in in the case of IRIS. This efficiency directly resulted from our many conversations with potential customers, and key partners, that the NSF I-Corps program largely forced us to do. While its too early to know how many jobs Soliculture will generate, its pathway to selling commercial product was many years faster then the two previous companies that work in similar commercial space. Needless to say, I'm convinced that the small cost of the NSF I-Corps training pays for itself many times over by reducing start-ups time-to-market. For start-ups that receive funding through the SBIR/STTR program, this also saves US tax payer money as it allows the principle investigators to use the funding much more efficiently to develop a technology that someone is willing to pay for.

NSF I-Corps Curriculum at UCSC: Given my positive experience as a faculty member in the NSF I-Corps program, I decided to offer the NSF I-Corps curriculum to students at my university through a summer entrepreneurship academy, which uses a hybrid on-line/in person approach very similar to the NSF I-Corps national curriculum. We use Launchpad Central which greatly decreases the time we need to prepare material, saves the students funding on textbooks, and allows us to provide regular feedback to the students. While only a few of the students going through the program actually start companies, the training has proven invaluable to students as they seek employment after the graduate. Students have come back to tell me that this is the most valuable course they took at UCSC and that they received their job

offer because they had taken the I-Corps course. Understanding how to listen to your customers and make changes to a product so that it fulfills their needs is important in almost any job, but its something that academia is very bad at teaching students as we find ourselves sometimes stuck in an the echo chamber of a university.

Future Directions: I want to conclude with how the program could move forward to better benefit students. For student entrepreneurs who want to move their company forward, and even for some who don't, its very helpful for them to know how to approach to and talk to VCs and other investors. They also need to understand the legal contexts behind their start-up. This training is not currently in the NSF I-Corps curriculum but would be easy to add and in doing so create a universal course that could be used to accelerate US innovation by supporting early training of our entrepreneurs. The other major issue is that the training is largely limited to students, faculty and their mentors. This is very limiting as many of the entrepreneurs who could most benefit from the program do not fall into these categories. Even recently graduated students who are ready for I-Corps can't participate as they have already graduated. So, I'd like to see the program open up to other entrepreneurs, many of whom are likely to be willing to pay to take the course. I know I would have been. Some of our top young entrepreneurs receive funding through the SBIR/STTR program so that may be an excellent vehicle to expand the offering.

Prof. Sue Carter, Ph.D
Professor, Physics Department, UC Santa Cruz

She Carter is Professor of Physics, Associate Dean of Graduate Studies, and the Director for the Center for Innovation and Entrepreneurial Development at the University of California, Santa Cruz (UCSC). She holds a Ph.D. in Chemistry from the University of Chicago, and a BA in Mathematics, Chemistry, and Physics from Kalamazoo College. She has worked as a research staff member at several companies, including ARCH Development, General Motors, UpJohn (now Pfeizer), AT&T/Lucent Bell Laboratories (Murray Hill) and IBM Almaden Research Center. Over the last decade, Carter has served as the chief technical advisor and/or scientific founder at four start-up companies, including Add-vision (sold in 2011), Solexant (now Siva Power), Soliculture and IRIS Science Academy (both founded in 2012) and has also served as a scientific advisor to companies like Nitto Denko, Abengoa, and Integrated Biometrics. Carter holds six patents and one patent-pending. She is currently the director of the NSF I-Corps site at UCSC. With more than 100 publications, Carter's research focuses on thin film optoelectronic technologies, solid state lighting, biosensors, solar energy, and agriculture technologies. She is a recipient of the 1996 Packard Fellowship and is a Fellow of the American Physical Society.

Chairwoman COMSTOCK. Thank you very much.

Well, on that note then I think I would like to ask how are some—you know, we have community colleges. We also often have weekend programs that are adjunct like the Darden School does in UVA, so George Mason. Lots of our universities have that capacity to do that. How could we implement this program with them, and are there any limitations right now to doing that?

Dr. CARTER. Do you want me to address that? Well, I mean, I can tell you right now that there's nothing that limits us from working with community colleges. I have a lot of community colleges in my area that—and I include those students in our curriculum, so it just involves building a network and reaching out to those colleges, so I don't think there's any limit at all.

Chairwoman COMSTOCK. Or and like—since we're talking about——

Dr. CARTER. Right.

Chairwoman COMSTOCK. —people not even having to be in a curriculum but just having the facility where they can go so they can get the program.

Dr. CARTER. Right. Yes.

Chairwoman COMSTOCK. Okay. And, Dr. Chang, did you want to——

Dr. CHANG. Sure. And so I kind of alluded to this earlier, that we've got this great bench of over a dozen instructors who have worked at startups who have this experience that we're talking about in teaching I–Corps, and when they're not teaching in the official NSF I–Corps cohorts, we put them to work to go to other schools in the region or even outside the region. And what we've seen is that partly solves this problem, so we can offer cohorts on the campus at UVA or wherever else to help those—help the teams there.

But long-term what we really need to do is kind of like what NSF does with the national program of train the trainer so the somebody at UVA or somebody—actually they have pretty good capacity already but some of these schools can develop their own people that can continue to teach it more often they know their own campuses better. They know what resonates with their faculty and what's going to get them to come to increase participation as well. So, you know, train the trainer has been a centerpiece of the national program, and it's a point of emphasis in the regional programs and needs to continue to be more of a point of emphasis among regional programs.

Chairwoman COMSTOCK. And by doing that train the trainer program, you really could then have a self-sustaining program wherever they've done that because I know at UVA, for example, the Darden School makes money for the school is my understanding——

Dr. CHANG. Yes.

Chairwoman COMSTOCK. —so if they're able then to attract and people can, you know, go and do that there or other universities——

Dr. CHANG. Absolutely.

Chairwoman COMSTOCK. —it's a money generator that would support the whole education program.

Dr. CHANG. Yes, absolutely. And you hit one of the key challenges I'll say but it's the—but we're seeing some successes in that the universities that can offer this kind of training need to figure out a way how they can continue to provide it not just as volunteer work.

So if it can be sustainable, if there's a business model, whether it's like Darden's executive education model or even partnering with economic development agencies, whether it's Virginia Center, CIT, or Maryland TEDCO, the state economic development agencies, if they fund some of these programs to—for these instructors, now, you've got like the self-sustaining ecosystem which helps the economic development agencies because the money, the grants, the investments they make in their companies are going to pay off—be more likely to pay off if they've had this I–Corps-like training. So we're starting to see some of that, but formalizing that is really critical.

Dr. CARTER. I want—I was going to add one more thing here. I mean at UC Santa Cruz we actually started the course before we actually had the funding, so I had to come up with a way to fund it. And the way we did it is it's actually part of our required—it's a course that students can take to fulfill the requirement for graduation, so it's—you know, they pay tuition and fees. It's called "Creative" believe it or not. Its focus on—it fills our creative general credit, and so students can take it to help them graduate with their degree.

Chairwoman COMSTOCK. All right. And then as part of sort of the whole regional innovation ecosystem, what other places could we plug this in? Because I'm thinking—we have throughout my district we have sort of startup areas, but what I hear from young people who want to leave here and go to California or Colorado or someplace where they feel is a little bit more startup-friendly, that there's more sort of just like say your local chamber or your local county government has sort of these, you know, centers where you can go and have that type of innovation ecosystem. Is there a way—I mean, there's nothing preventing us from plugging that into whatever type of startup center or innovation center that you might have in your area, right?

Dr. CHANG. Absolutely not. In fact, you know, I think one of the really—the real valuable things about doing the customer discovery that we've all talked about going to talk to customers is sometimes you might find that the only viable customer might be in a different location, in which case the prudent thing would be to go there, but oftentimes you might find there are some customers right in your backyard that you never knew about, and it wasn't until you got out of the building and talked to them and understood their needs that you realize that there's basically this goldmine in your backyard that you never really investigated. Absolutely.

Chairwoman COMSTOCK. Okay. Great. Well, thank you.

And I now yield to Mr. Lipinski for five minutes.

Mr. LIPINSKI. Thank you, Chairwoman.

I wanted to in some way sort of follow up on that with a question of how can this help—how can I–Corps be leveraged for, you know, economic revitalization in areas that—you know, we're talking about doing this in areas that, you know, are already pretty—doing

pretty well, especially if you have a big university, but how about economically depressed regions of the country? How could this have an impact? And I'll start with Mr. Blank.

Mr. BLANK. Well, Congressman, I think that's a great question. If—but if you remember, not only are there eight nodes, there are 86 sites across the country that now teach the I–Corps class and methodology. And many of them are in communities where they're past clusters, whether it was manufacturing or other past 20th-century industries have collapsed. And now for the first time this can be a seat around this college and university of training entrepreneurs that don't have to go to Boston or New York or Silicon Valley to actually stay in their local communities and start building companies. And as Dr. Chang mentioned, these universities and colleges are figuring out how to partner with their own regional economic development organizations to actually get the capital to scale to the next level. And so what we've started to see is I–Corps is kind of the rejuvenation of innovation and entrepreneurship in places that historically have just been bypassed in the last decade or so, and we're kind of proud of this consequence of the program.

Dr. TILBURY. Can I——

Mr. LIPINSKI. Dr. Tilbury?

Dr. TILBURY. Yes. I would just add that the I–Corps teams come from almost every State in the country, so even though the nodes are—there's eight of them in 86 sites, as he mentioned, there are teams coming from almost every corner of the country, and they can take their learning that they had in the I–Corps program back to their home district to start their company if that's really the right place for it, as was mentioned.

Mr. LIPINSKI. Thank you. Dr. Carter, you want to add something?

Dr. CARTER. I wanted to say that the University of California Santa Cruz it might sound like it's near Silicon Valley, but we're actually sitting in the middle of Salinas Valley. We have the highest youth crime rate within an hour of us. We're also one of the highest poverty areas in California. So we're a Hispanic-serving institution, so we're mainly servicing those students that are underprivileged and have had very difficult circumstances growing up. We have a lot of first-generation students in our programs.

And I would like to say that in terms of diversity, STEM diversity, I see more diversity in I–Corps than I do with our science and engineering classes. I think that the first-generation students, the students that don't have the privileged backgrounds, realize how important it is for them to learn entrepreneurial skills, be able to create their own jobs, and so they are very much attracted to those courses, more so than the standard STEM students who just think they're going to go get a job in Silicon Valley and they're going to be done with it, right? So I think that this is a way to actually get underrepresented minorities involved in STEM careers.

Mr. LIPINSKI. Thank you. I want to ask about the—you know I—well, I'll just say obviously, the—one of the strongest arguments in favor of I–Corps is it's transformative. You know, you have a small amount of government investment in education yielding huge results in terms of the ability of participants to learn entrepreneur-

ship, attract follow-on funding, hopefully achieve their—and some have—certainly achieved their commercialization goals. So expanding the program, I want to ask Mr. Blank. How do you think that the expanded curriculum would be similarly transformative?

Mr. BLANK. Thank you, Congressman. You know, one of the things we've now learned over six years is that this program does a spectacular job of teaching scientists things they thought they could precomputed like who a customer should be and how do I price it and where do we sell it. And as—for the last—previous 30 years we've discovered, no, you can't precompute that without getting out of the building. Now that we got them to understand who customers are, we realize that the next step is teaching them how to actually raise money and build teams and actually turn this into a scalable company. And that's after we've kind of raised the bar. We just realized we need to raise the bar again. And the NSF has pioneered these prototypes of I–Corps Go classes that I think are doing just that to actually accelerate these teams to the next step in commercialization. And I think this is spectacular for the country.

I should also mention, by the way, this I–Corps curriculum has become the gold standard not only in our federal research agencies but now in the DOD and intelligence community as well. It's now being adopted in almost every agency and across the world as well, just an amazing program and kudos to the NSF.

Mr. LIPINSKI. Thank you. My time is up. I yield back.

Chairwoman COMSTOCK. Thank you. And I now recognize Mr. Webster.

Mr. WEBSTER. Thank you, Madam Chair.

Mr. Blank, I heard another definition of hypothesis. That is a wild guess carried out to two decimal places. But, Dr. Tilbury, I had a question. I'm from Central Florida, the University of Central Florida. They're one of the sites. And are all of the sites universities?

Dr. TILBURY. Yes, I believe all the sites are universities, but they serve the broader population of their region.

Mr. WEBSTER. So are they usually housed in some—one or more colleges of that university or are they housed in a separate center or how does it usually work?

Dr. TILBURY. I think it depends on the university. It could be housed in, say, the College of Engineering or the Vice President for Research or even a center for entrepreneurship if there is one at the university. I don't think there's a standard.

Mr. WEBSTER. So there's no real—there's just a framework but not a big——

Dr. TILBURY. It's a framework, and each university who applies to be a site talks about what niche they intend to fill with their site and how that will work for them. Maybe Dr. Carter could talk about—she has a site at UC Santa Cruz.

Mr. WEBSTER. Okay. Let me ask you something. Dr. Carter, is yours external to the university or a separate entity?

Dr. CARTER. Ours is internal. Ours is actually under the division of graduate studies, which means it can represent every—all the disciplines equally. But we also work with undergraduates, too, even though we're in the graduate studies.

Mr. WEBSTER. Before you got the grant, did you have a similar program or something that would be a cousin to that ongoing?

Dr. CARTER. Not exactly. We had some starting pieces of it, but we do not have any business school or law school at University of California Santa Cruz, so this is our—this is basically the training our students get to launch their businesses. So the funding really helped us. We wouldn't be able to do what we do today without the funding.

Mr. WEBSTER. So—but if there were some things were working that would kind of be a cousin to that, did those remain or did you just to begin focusing on——

Dr. CARTER. They remained.

Mr. WEBSTER. They did?

Dr. CARTER. Yes.

Mr. WEBSTER. So tell me a little bit about the governance of it.

Dr. CARTER. Sure. So in our case we have a—I'm the director of the center. We have an executive leadership board, which has all the deans from the campus that oversee what we're doing, and also we have a faculty advisory board that contains faculty and staff that advise our program. And then underneath us we run about four different other entrepreneurial sites that were kind of the framework, but their centers focus on social and creative entrepreneurship, on STEM-based entrepreneurship, on art-based entrepreneurship, and we help those three programs also, providing them the instructors they need to run their courses.

Mr. WEBSTER. So is the team or teams—I guess you have more than one team——

Dr. CARTER. Yes.

Mr. WEBSTER. —are they led by a faculty member?

Dr. CARTER. No, they are—they're advised by a faculty member and a mentor. So I have an open-door policy. Any team that wants—I meet with all the teams regularly to give them advice to how to move forward. I set them up with mentors that they may need to get help. If there's another faculty member that I think can help them, I will send them directly to the other faculty member or sometimes it's a staff member. So we make sure that we meet with them regularly and they get the resources they need to get the—move their thing forward.

Mr. WEBSTER. Dr. Tilbury, is there a cutoff point where, okay, there are these teams, they're working on an idea, they want to turn it into a business, they want to be entrepreneurs. Is there a cutoff point or some way where you decide it'll either happen or it won't happen or is that done by money, just you can get any money, or what?

Dr. TILBURY. So the I–Corps training, the formal training is about six weeks, and at the end of that six weeks, each team should have a decision, yes, we're going to go ahead and commercialize the technology or no, it's not ready yet, we need to go back to the lab and improve it in order for it to be ready or there's really no customer who is interested in this so you——

Mr. WEBSTER. So the team could start all over with a new idea or a modified idea?

Dr. TILBURY. They could absolutely start all over. It might—but rather than starting the company and investing a lot of money to

find out that we've developed this product that there's no customer for, it's better to determine that within this boot camp, the six-week time frame.

Mr. WEBSTER. I'm familiar with the University of Central Florida a little bit and their program there. It's a pretty awesome thing, and they're trying to train entrepreneurs, a great thing.

Dr. TILBURY. Great.

Mr. WEBSTER. I support it. By the way, they're the only undefeated Division I football team in the country. I yield back.

Chairwoman COMSTOCK. Okay. And I now recognize Ms. Esty for five minutes.

Ms. ESTY. Thank you, Chairwoman Comstock and Ranking Member Lipinski. And I want to thank the four of you for joining us today on this really important topic, which I see as critical to U.S. competitiveness and to diversification of our STEM workforce, and those two things are related. So I want to say that I'm probably from Connecticut where accelerate UConn is in fact one of these nodes and is already proving to be incredibly successful. And in fact I was pulled out by our local contact from the Department of Commerce to talk about some of these issues and more things we need to do in our State to better link the world of work and the world of commerce, as Dr. Blank—Mr. Blank talked about, with what's happening in the lab.

So I wanted to—Mr. Blank, you talked about something that I think is really important for Americans to understand and frankly for a lot of my colleagues to understand the critical role that I–Corps is playing in that deep tech. I grew up sort of in the Silicon Valley area, and I think there's still a lingering assumption here that that's what's happening now in Silicon Valley rather than the dramatic change that happened with the chase for unicorns and a fast turnaround so that without government support not only for basic research but government support and help to guide the scientists who are engaged in that deeper tech, so, for example, what intersects with DARPA, what intersects with other parts of the military. Could you expand on that a little bit?

Mr. BLANK. Yes, Congresswoman. That's in fact a great insight. You know, in the 20th century, venture capital, that is, investors in Silicon Valley and national interests actually were pretty well aligned. We invested in medical technology, we invested in computers, we invested in things that actually made the country better, safer, secure. In the 21st century they're—I will contend they're unaligned. Venture capitalists can make a ton more money than investing in short-term, you know, bitcoin investments or smartphone apps or social media, which are great for their investors, but one could argue that the money would be better spent on other things like genetic editing for healthcare or applications in other places.

And this un-alignment has really created kind of a gap between what gets invested that requires patience and long-term vision. And in fact the few agencies in the country that do that, one of them is the National Science Foundation that invests in what we call deep tech that requires long-term investment and patience for basic materials science, basic health care at the NIH, et cetera. And I think this Innovation Corps program is part of that deep vi-

sion, deep patience in the long-term investment that just private capital does not do anymore.

Ms. ESTY. Thank you. I really appreciate that.

Dr. Tilbury and Dr. Carter, you should know that actually Chairwoman Comstock and I earlier this year had bills signed into law Promoting Women in Entrepreneurship Act and really wanted to focus a little bit on the particular role and importance of something like I–Corps in diversifying our STEM workforce and ensuring—because we've found that women in the STEM fields and women generally are having more challenges making that leap into the entrepreneurial space, fewer mentors, less access to capital, and that I–Corps is actually playing a really important role. And, Dr. Carter, you talked about the difference that made in your own experience.

Dr. Tilbury, could you expand a little bit more systematically of what we've learned because I think Dr. Carter's testimony speaks to the reality of what it meant for her in getting that training?

Dr. TILBURY. So absolutely. At the National Science Foundation we're absolutely committed to broadening participation in all aspects of science and engineering and in particular in the I–Corps. So some of the pilot sites that we've started are focused on broadening participation. Some of them focused on including more women in startup companies; some of them focused on including underrepresented minorities or even people with disabilities. And they have unique vision into what the needs are for women, for disabled people that can really have an opportunity to create very successful companies. So we feel this is a good investment. It's still a pilot, but we're looking for good results to come out of these investments.

Ms. ESTY. Dr. Carter?

Dr. CARTER. Yes. You know, I mean, I will say that, you know, women are most—are generally attracted to solving problems that affect their communities, so I think this is a natural fit to bring women into the STEM fields and to get them included in our entrepreneurial ecosystem, so I see it—I mean, we're trying to hit 50 percent numbers in our programs for women entrepreneurs, and I anticipate that we'll hit that.

Ms. ESTY. Thank you. And the last thing I wanted to mention again, Mr. Blank, you talked about the hands-on entrepreneurship, and I think that is so critical. We've learned, for students, hands-on learning is the best. Hands-on science learning works better but that—taking that same insight and translating it into entrepreneurship I think is something we need to remember that I–Corps is championing, and we want to support you in any way we can in these endeavors.

Thank you very much and I yield back.

Chairwoman COMSTOCK. Thank you. And I now recognize Mr. Marshall for five minutes.

Mr. MARSHALL. Yes. Well, good morning. Kind of running back and forth between a couple committee meetings, as is usual for us, so thank you for your testimony, so proud of what the—what you all are doing. One of our jobs in Congress is always to figure out what's working well and to reemphasize this, and I was able to take the Chairman of this Committee, Chairman Smith, to Wichita State University and share with him some of the things happening

on their innovation campus as well, so very proud to see how this is working.

I would just like to hear a few more positive stories and give you all a chance just to share positive stories about how this is happening, and maybe just start with Dr. Tilbury and go down the line, you know a great real story that you would share.

Dr. TILBURY. So I can tell you the story of one of my colleagues, Professor Awtar from the University of Michigan, mechanical engineering. So when he started as an assistant professor, he got his NSF career award, which is for junior faculty, and then he got another basic fundamental research award from the Engineering Directorate. And he developed a new way to kinematically re-map your hand movements into the edge—end of an end-effector for remote surgery purely mechanically, no electric controls required.

So he got an I–Corps grant and started a company and then got an SBIR and built this company that's building these medical devices, very low-cost, very safe, to be used in multiple dimensions. And now, I'll be happy to say he's back on campus and got another fundamental research award, and so we'll see if he—now that this company is launched, we'll see if he develops another new technology. We're very excited.

Mr. MARSHALL. Well, great. I keep telling everybody that innovation can do more to drive the cost of health care down than any piece of legislation we can write if the Federal Government would just get out of the way.

Mr. Blank?

Mr. BLANK. Yes, Congressman. I'm going to give you a story, probably one that doesn't get told often, and that's about failing fast.

Mr. MARSHALL. Yes.

Mr. BLANK. One of the great things about the I–Corps program is that it's hard to avoid bad news because it's in front of your face. Our best example is when we taught the class at UCSF, University of California at San Francisco, for life sciences the chief of surgery of UCSF said, "Well, I'll set up a team, too, just so I can act as a role model for my students." And he had an invention that he'd been working on for three years in the lab, hernia repair. And Dr. Hobart Harris said, "Well, this will be pretty easy. I'll just get out of the building and I'll talk to the other surgeons. I've been working on this for two or three years with my co-surgeons. Obviously, everybody will love this." The third week of class he comes back and his face is pale. He said, "No one else wants it." And in fact at the end of the class he said, "You know what, this isn't a viable commercial technology." And he still, four years after the class, is proselytizing the fact that not only can this help you build a company, it could also help you not waste years of your time and tens of millions of dollars of both government capital and private capital.

Mr. MARSHALL. Thanks. Dr. Chang?

Dr. CHANG. So I mentioned the bioengineering class earlier, but I'll give another story that also ties into engineering so—but starts with research. There's a professor named David Tilley in our School of Agriculture, really innovative research, and he went through an introductory—introduction to I–Corps program that we offered locally, saw, wow, this is how I can explore whether I can

apply my technology in the marketplace and with the national cohort in Texas. That was about a year ago. They've launched the company. They've since gotten follow-on funding from the Maryland State economic development agencies, so all the things you'd like to see.

But the big sea change for him was also that he wanted to apply throughout his entire research portfolio and get his other colleagues in the School of Agriculture to also be looking for applications and applying at I–Corps. So he's actually teaching this in his classes. He teaches a class now where he teaches I–Corps principles, and he's applying for an NSF grant that is an interdisciplinary addressing—a grant addressing multiple areas from technology, but a big emphasis is training graduate students. A key part of his proposal is training our graduate students in these I–Corps principles so that they can learn these and take it forward as well.

Mr. MARSHALL. Okay. Thank you. Dr. Carter?

Dr. CARTER. Yes, I want to give an example of an undergraduate because we hadn't heard very many undergraduate stories yet. And I've had students—my site just got funded like this year so it's just started, but we did some pre-I–Corps classes and I had students through that, so I'll show an example. One of them is this guy Sukh Singh who basically had a technology where he had—basically was taking kids' handwriting, you know, when they were 4 or 5, six years old and letting them convert that over to Java code, JavaScript.

And he went through the program and realized that the really big need that was there was that teachers don't know how to treat—teach computer programming, right? They have no concept of how to do that, especially at the, you know, younger ages. However, they had no problem teaching basic math, so what he was able to do is pivot his company in order to create a product that allowed students—teachers to teach their kids the basics of JavaScript programming through math——

Mr. MARSHALL. Yes.

Dr. CARTER. —by having them do math work and having them create games and objects and artwork. And he was able to—with no money invested whatsoever, he's expanded now to I think five or six schools in Santa Cruz bringing in $20–30,000 of revenue a month now to keep his company supported and is looking at growing nationally, and said he did this all just——

Mr. MARSHALL. Yes.

Dr. CARTER. —bootstrapped.

Mr. MARSHALL. Thanks for sharing your stories.

Dr. CARTER. Yes.

Mr. MARSHALL. I yield back.

Chairwoman COMSTOCK. Thank you. I now recognize Mr. Beyer for five minutes.

Mr. BEYER. Thank you, Madam Chair, and thank you very much for introducing us all to this concept and its remarkable success.

Dr. Tilbury, Peter Drucker, the famous business writer, said that "Nothing happens until the sale is made." I was impressed that this is—you point that this is about—more about market failure than technical failure, but it was also noted that you said that "The

entrepreneurial lead in that three-person team was typically a postdoctoral scholar with a deep commitment to investigating the commercial landscape." I'm trying to think if I've ever known a postdoctoral scholar who knew anything about marketing, sales, service, or the like. Why is that a particularly good person to be the entrepreneurial lead?

Dr. TILBURY. So thank you for your question. It's usually a postdoc or a graduate student who's deeply engaged in the technology, so there the person in the team that is most deeply understanding of the technology. The faculty advisor has the broader perspective of the technology, and then there's an entrepreneurial mentor, the third person of this three-person team, and it's the entrepreneurial mentor that will help the team understand what they need to do to make this technology a commercial success. But you need someone on the team who is willing to put in the 40, 60, 80-hour weeks to build the technology and get it out of the lab, make it ready for commercialization.

Mr. BEYER. And, Mr. Blank, thank you very much for providing all the intellectual drive for this whole I–Corps movement. You said, "Part of the big thing is how to hire and build teams that know how to sell and market products." That sounds like all of America or all business in general. How do you do that?

Mr. BLANK. Well, I'm going to answer that, but I want to answer your first question.

Mr. BEYER. They're almost the same question.

Mr. BLANK. Yes, but it's really interesting because if you think about it, you go, wait a minute, why do we have to train those entrepreneurial leads to do this? They should just hire a V.P. of sales, and they take the tech and go out and sell it. And that's not their skillset; it's someone else's skillset. And it turns out that's where we went wrong. We went wrong because we assumed that just because they had an idea, you could now slap a salesperson on it and sell it. It turns out that almost always their initial idea of who to sell it to, how to package it up is almost always wrong. And the only people to figure out whether it's wrong or right is not a salesperson; it's actually the technologist themselves. And we've now learned that the initial people who go make the first sales and try to understand that are best done by the technologists.

So it's easier to train a technologist to understand customers than it is to train a salesperson to understand deep tech. That's the big lightbulb. That's the whole idea here is, wait a minute, let's train the scientist. You know, with all due respect, business can be figured out quicker than you could figure out biotech or some of these arcane sciences. That's the key idea about I–Corps. And in fact, once you train them that this is nothing more than testing guesses or hypotheses, that's what they do in the lab all the time. I don't know if I answered your question.

Mr. BEYER. You did. You remind me that in—I've been selling for more than 40 years, and it was discouraging to realize that I knew all the math I needed to know by third grade to sell.

Dr. Tilbury, Dr. Carter talked about she'd seen great diversity in the I–Corps teams themselves, but there is historically huge underrepresentation of women and minorities in startups. Silicon Valley

is legendary. So do you use this as a metric from the National Science Foundation how I–Corps is able to expand diversity?

Dr. TILBURY. Thank you. As I mentioned earlier, NSF is absolutely committed to broadening participation in all aspects of science and engineering, including in I–Corps, and we have funded some pilot sites that are specifically targeted to increase the representation of women, underrepresented minorities, and people with disabilities in the entrepreneurial innovation ecosystem.

Mr. BEYER. Very cool. And, Dr. Chang, who is not a Dean or is a Dean, you talked about pushing scientists to go beyond the comfort zone, which is once again the challenge for all of us in life. How hard has that been to get people who love to be in labs and think deep thoughts to get out there and talk to real people on the street?

Dr. CHANG. It's extremely challenging. I mean, you know, you can ask any university, the numbers will be about the same, but it's a very small number of faculty who actually want to start a company. You know, maybe it's five percent, maybe ten perhaps but—to actually start the company. But almost all faculty want to see what they're doing have an impact. And one of the beauties of I–Corps—and Dr. Tilbury kind of talked about it with your question related to entrepreneurial lead is it doesn't have to be the faculty member that takes this forward. The faculty member just has to be supportive of the efforts to explore where it can go forward.

And so if you've got, as Congressman Lipinski mentioned, only half of Ph.D. students entering academic fields, what are the other half going to do? Well, if they can explore these opportunities to find out where can the sale be made, they aren't actually necessarily tasked with the ones at the end of the day closing the sale, but if they can identify where the sales can be made and shape the direction of the technology development, I mean, some of our most successful I–Corps stories, they're—they went through I–Corps three years ago because what they learned fundamentally changed not their core expertise but the direction that they were going to apply it. And it took a long time to build the technology. And you can imagine over three years being slightly off course where they'd end up three years later.

So, you know, I think for faculty just kind of thinking about it may not be you, but your research is going to have a greater impact and you want to help your students find jobs, and if half of them aren't going to be in academia, this is a great way to help your students find jobs.

Mr. BEYER. Thank you very much.

Chairwoman COMSTOCK. Thank you. And I wanted to ask, do you have a percentage of women who are participating in the program?

Dr. TILBURY. I don't have that number at my fingertips, but I could get that for you.

Chairwoman COMSTOCK. Okay. Because I'd be interested in that and overall diversity, as well as what is done to recruit in particular to help those numbers, to get more in the pipeline because I know I've had a young woman's leadership program that I've just run informally in the summer, and we've had to very aggressively recruit to make sure we are getting young women from different communities that maybe their parents aren't saying, hey, why

don't you do this. You know, and we're reaching kids in junior high and high school, so we're really trying to get them into a leadership program that opens up to some exposure for them to other women leaders and to ideas. But we really have to go into particular communities to kind of pull them out, and so I just would be interested in what methods you might use to enhance that and make sure that they are participating in a program like this.

Dr. TILBURY. So thank you. I think that's one of the purposes of these pilot sites that we have that are focused specifically on trying to increase the representation of women or minorities or disabled people in the entrepreneurship.

Chairwoman COMSTOCK. Right.

Dr. TILBURY. So that's their focus.

Chairwoman COMSTOCK. Good.

Dr. TILBURY. And we'll look forward to seeing their successes.

Chairwoman COMSTOCK. Okay. And it would just be helpful if we could get some of those numbers, too, because—and make sure—and best practices that might apply for us in other areas, so thank you.

And I now recognize Mr. Banks for five minutes.

Mr. BANKS. Thank you, Madam Chair. And thanks to each of you for being here. This has been an enlightening discussion for me, learning more about I–Corps.

I wonder, though, to start with, Dr. Tilbury, as the curriculum has been developed and the program has been launched, how can the private sector invest more and take on more responsibility for sustaining the program?

Dr. TILBURY. So thank you. I think there is an opportunity for the private sector. Many people who participate in the teams, the entrepreneurial mentors come from the private sector. Most of the programs are offered through universities, and some of them have partnerships with the private sector to fund those programs. So I think there's many different opportunities. I don't have a specific——

Mr. BANKS. So there are mechanisms for the private sector to invest their own funding? That can already occur?

Dr. TILBURY. I think through the universities would be the way to go. Do you have another——

Dr. CHANG. I was just going to add, so the SBIR program, for instance, I–Corps has started to be used—actually not started—it's been a couple years now it's been incorporated into the SBIR phase 1 awardees from NSF, and that's been transformational for the program but also, as I understand it, there's a phase 2B, a component of that SBIR program where not only do you get funding from NSF, but it's a side-by-side investment with a private institution. So you're sort of meeting halfway because the technology still needs to be developed and you're kind of sharing that risk, and if it ends up where you think it will, now the private company that was a partner in that is going to go all in.

Dr. CARTER. And I can tell you what we do. Our center—except—the NSF I–Corps site—our center is completely privately funded. We get donations from alumni and various people in the community who really want to see our students be successful and move forward. We also introduced something known as the founders'

pledge, which basically allows—it's no firm commitment but basically says if the students go off and do really well and make money that they will commit giving money back to the program that we can use to then support future students. So I see this being self-supporting.

Mr. BANKS. Mr. Blank?

Mr. BLANK. And if I can, I should maybe circled this back to the intent of I–Corps Go. The current I–Corps NSF program funds universities and university nodes. The intent of I–Corps no is to take this—I–Corps Go is take this great curriculum and open it up to the larger community. And that would allow funding to go directly from private capital entities into these startups, which not necessarily would be deep tech. Remember, the NSF program is essentially for these orphaned technologies that have a hard time crossing this ditch of death between government basic science funding and private capital who wanted to see something more advanced. I–Corps Go would actually expand it to a much greater community with a proven curriculum that actually works well.

Mr. BANKS. Okay. So, do you think, in light of that, do you think that startup companies would see value in spending their own capital, their own money, to go through the training if it were available to them?

Dr. TILBURY. I'd say absolutely. That's what Dr. Carter said. She would have paid for it.

Dr. CARTER. I would have paid for it, yes, no problem.

Mr. BANKS. Okay. So we all agree with that? Okay. Thank you. I yield back.

Chairwoman COMSTOCK. Thank you. And I now recognize Ms. Bonamici for five minutes.

Ms. BONAMICI. Thank you, Chairwoman Comstock, and thank you to the witnesses. I regret I was not able to hear you deliver your testimony. There's an Education Committee happening at the same time, and I'm trying to be at more than one place at once. But I did read the testimony with interest.

I represent northwest Oregon, and we have certainly a lot of tech startups and accelerators and a lot of incubators, and this is a really interesting topic to me.

I wanted to start, Dr. Tilbury, you cited some data in your testimony about companies that were formed and then funding for teams that have been through the I–Corps curriculum. So what is the full extent of the data that you have on outcomes? Are there data that you're in the process of collecting so that we could know what metrics we should be using for a full understanding of the return on investment in I–Corps?

Dr. TILBURY. So thank you. There is absolutely a data collection ongoing. I believe through the AICA Act we have a biannual reporting to Congress, so sometime within a year—I think January of 2019. Correct. So we are collecting data as much as we can to understand.

Many of the startups that are coming out of NSF-funded basic research are in this deep technology area that Mr. Blank mentioned, and they might take five or even ten years to show the results of their company. It's not just writing software. You have to build something and maybe build a manufacturing plant to make

it. And so these timelines are much longer than you might expect to see in something that's starting an app for a smartphone.

Ms. BONAMICI. Of course. Right. Thank you. So to the whole panel, you know, our U.S. universities continue to lead the world in basic research and in education. I just want to note, as we're in the midst of discussion about the tax reform bills that there are provisions that are of great concern to our universities, particularly the—treating tuition waivers has taxable income. Our universities are very, very concerned about that, and I hope that when the conference committee meets, they get the message that that's going to set us back as a leader in innovation and research.

In some cases, universities can be slow to change and adapt to emerging challenges and opportunities. I came from our state legislature and, you know, I know that some of that happens. So where do things stand now with respect to the sort of cultural and institutional obstacles to expanding the entrepreneurial culture at universities, and how has I–Corps helped, you know, model some of the changes that—even in the last few years where lessons could be learned at the university level and what steps can federal agencies and institutions themselves take to continue to expand entrepreneurship without compromising the critical mission in research and education?

Mr. BLANK. If——

Ms. BONAMICI. I'll start with Mr. Blank.

Mr. BLANK. If I can, I think that's a great question, and the insight I'll offer with a smile is that in universities, I–Corps is typically offered in the engineering school, not the business school, which is a big idea. You know, one would have thought that business schools would have led with this type of entrepreneurial education, but in fact business schools historically have been focused on large corporations and the execution of a current business model, and that is how to make current corporations better. And so for 100 years that's what business schools did.

But this idea of innovation and entrepreneurship in the engineering school was actually a new idea, and in fact is kind of the breakthrough that's happened in the last six years with I–Corps is that the engineering is actually now leading, the thought leaders in the country for innovation entrepreneurship.

Dr. CHANG. Also I'd like to add to that. So what's—my job at the University of Maryland five years ago—I was appointed by the President to aspirationally engage all 37,000 of our students in innovation entrepreneurship, and that's an impossible task. But——

Ms. BONAMICI. But a good challenge.

Dr. CHANG. But a good challenge. And I'll say that the leans—or the I–Corps principles that we teach at startups, those are exactly the same methods and principles I've used in that mission. And that's the only way to succeed because at the end of the day we teach our startups you have to figure out where people spend their time and their money and you need to go to where they are and offer a better solution in the way that they're doing things because it's hard to change behavior. That's even more so at colleges and universities.

And so the places where students are—let's focus on the students for the moment—they're taking general education courses. They're

taking the prereqs for their major. They're taking their required upper-level junior- and senior-level courses, so embedding it—and initially, whether it's in engineering or even in other majors as we've started to do, embedding these kinds of methods and principles in those courses are the way to spread it because going and asking for more funding or more volunteers or more whatever is not going to get you as far.

And the same thing is true on the faculty side, and faculty are motivated by getting tenure, they publish in journals, respected journals, and go to conferences, so we need to weave in innovation entrepreneurship into things they have to do along the path.

Ms. BONAMICI. Thank you. And in my remaining few seconds I just want to mention that this Congress and the last Congress passed the Every Student Succeeds Act, which is the rewrite of No Child Left Behind, so at the K–12 level there are attempts being made to make sure that students get a more well-rounded education, and hopefully, we are educating before they get to college and universities, students to be more creative and innovative.

And we've seen that in schools that, for example, are adopting STEAM rather than STEM and integrating the arts and making sure that people can think creatively and communicate about what they're creating. So hopefully, when students get to colleges and universities, they will be more able to have that well-rounded approach and communicate what they are in fact inventing. So there are efforts to start earlier to make sure that we have a more creative and innovative workforce.

So thank you, and I yield back the balance of my time.

Chairwoman COMSTOCK. Thank you. And I thank our very esteemed and knowledgeable witnesses for their testimony, for your experience, for your wisdom and how we can really make this innovative field grow, so it's very exciting and look forward to continuing to work with you.

The record will remain open for two weeks for additional written comments and written questions from Members, and this hearing is now adjourned.

[Whereupon, at 11:31 a.m., the Subcommittee was adjourned.]

Appendix I

Answers to Post-Hearing Questions

ANSWERS TO POST-HEARING QUESTIONS

Responses by Dr. Dawn Tilbury

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"From Lab to Market: A Review of NSF Innovation Corps"

Dr. Dawn Tilbury, Assistant Director, Directorate for Engineering, National Science Foundation

Questions submitted by Ranking Member Daniel Lipinski, House Committee on Science, Space, and Technology

1. In your testimony you cited some data about companies formed and follow-on funding for teams that have been through the I-Corps curriculum. What is the full extent of data NSF has on program outcomes? What kinds of data is the agency in the process of collecting and what is the timeline for being able to report on program outcomes? Ideally, what metrics should we be using for a full understanding of the return on investment in I-Corps, including the program's impact on the broader university culture and capacity for promoting and supporting entrepreneurship?

   Answer: The NSF Innovation Corps (I-Corps™) program works with an NSF grantee to conduct evaluations of the national NSF I-Corps™ Teams program. These include pre- and post-training surveys as well as longitudinal surveys. A "time 1" longitudinal survey is conducted approximately 1 year after the cohort training, and a "time 2" longitudinal survey is conducted approximately 3–5 years after the training. The first "time 2" survey is now being administered by the NSF grantee to 2011–2012 I-Corps™ Team participants.

   The different surveys collect data in three main areas:

   - Economic Development: Surveys collect data on startups directly linked to the I-Corps™ Team and project; company formation; fund-raising; status of products, services, or processes in the market; status of intellectual property; and related items.
   - Entrepreneurial Mindset: Surveys collect data on knowledge gains from I-Corps™ training; the I-Corps™ learning environment; impacts of I-Corps™ training on career trajectories of I-Corps™ participants; and related areas.
   - Academic Culture Change in Entrepreneurship and Innovation: Surveys collect data on faculty mentoring, teaching, and research; external partnerships formed between academia and industry connected to the I-Corps™ training; impacts on career trajectories of participants; and related activities.

   In response to the American Innovation and Competitiveness Act, NSF will provide a biennial report on I-Corps™ program efficacy, including program metrics; the first report will be issued in 2019.

2. Some experts have raised the question as to whether the current allowance for I-Corps Teams of $50,000 is the right number. How is the $50,000 typically allocated by teams? Would it be possible to decrease the per-team funding in order to make room in the budget for more teams, without meaningfully compromising the opportunities or outcomes of the Teams program to individual teams?

   Answer: The NSF I-Corps™ Team award of $50,000 supports participation in, and travel to, the cohort and supports customer discovery travel for the team during the I-Corps™ cohort in order to interact with over 100 potential customers and stakeholders. Support for customer discovery travel continues after the cohort training for the duration of the 6-month award. The I-Corps™ program's post-training surveys suggest that the funding level is appropriate and sufficient for these activities.

   The "I-Corps™ for SBIR Phase Zero" pilot activity provides a lower award level, $25,000, to non-academic teams to support participation in cohort training and customer discovery, as they determine the commercial readiness of their technology concept and identify the key obstacles they must overcome to launch their product into the marketplace. The Phase Zero teams are being supported substantially through the Nodes to ensure that they get the same experience as the regular I-Corps™ Teams. The pilot will help us understand the right level of funding needed to ensure the best I-Corps™ experience for all participants. An evaluation of this lower amount will be made upon conclusion of the pilot.

3. NSF is currently running an "I-Corps Go" pilot program in which the Nodes are developing different models for curriculum that addresses topics such as incorporation, intellectual property, and fundraising. How long will this pilot phase last? Is NSF encouraging sharing and collaboration among Nodes as the pilot is running? What are NSF's plans for gathering and disseminating best practices and outcomes data from the different Nodes at the conclusion of the pilot? What is the process for determining whether I-Corps Go and potential future pilot programs warrant subsequent development into national courses, and how are those courses developed?

   Answer: The "I-Corps™ for SBIR Phase Zero" pilot, of which I-Corps™ Go is a component, is expected to run through calendar year 2018. Through this program, each of the participating NSF I-Corps™ Nodes will support non-academic teams to help determine the commercial readiness of their technology concept and identify the key obstacles they must overcome to launch their product into the marketplace. Teams will receive national I-Corps™ training as well as guidance on some of the more common issues in startup formation, including incorporation, licensing and negotiation of intellectual property, fundraising and others. These training programs will help Phase Zero I-Corps™ Teams better prepare a Small Business Innovation Research (SBIR) or

Small Business Technology Transfer (STTR) proposal. This new initiative is a collaboration between the NSF I-Corps™ and NSF SBIR/STTR programs.

The Nodes have been communicating with each other and coordinating throughout the initial planning and first execution phases of their pilots, and they will continue to interact throughout the pilot phase. Each of the Nodes has proposed an evaluation plan to track and report the outcomes and impacts of their project. Upon receiving these reports, NSF will assess next steps. We expect to share information about these pilot activities in 2019.

4. NSF created the National Innovation Network to encourage collaboration and information sharing among the I-Corps Nodes and sites. There are many benefits to such collaboration, including maintaining consistent quality in implementation of the I-Corps program across Nodes and sites. How specifically is the network designed and being managed to encourage such collaboration? Will NSF continue to support the annual meeting of Node and site leaders? What other mechanisms is NSF using or planning to use to promote collaboration and sharing of best practices?

   Answer: NSF built the National Innovation Network (NIN) to bring together I-Corps™ institutional grantees and other stakeholders looking to adopt the lean startup methodology for STEM-based researchers and startups. The NIN is managed by the NSF I-Corps™ program and through an I-Corps™ grantee. The network involves regional meetings, online collaborations, as well as a national meeting of I-Corps™ Nodes, Sites and other stakeholders in the broader innovation community. NSF is now evaluating how the NIN may be adapted to best address and support the scaling of the I-Corps™ Teams program. We plan to support an annual NIN meeting starting in 2019, contingent on available resources. In addition to participation in the Network, NSF programmatically facilitates interactions between the I-Corps™ institutional grantees (such as between Sites and Nodes) as part of their NSF grants.

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"From Lab to Market: A Review of NSF Innovation Corps"

Dr. Dawn Tilbury, Assistant Director, Directorate for Engineering, National Science Foundation

Questions submitted by Representative Jacky Rosen, House Committee on Science, Space, and Technology

1. One of my top goals since coming to Congress has been to champion policies that broaden young students' participation in STEM education and activities. In fact, I've introduced two separate bills directing NSF to focus their efforts on young students, and specifically encourage girls to participate in computer science and STEM to fill the major gaps in our workforce.

    a. Has I-Corps had any success in broadening participation for girls and underrepresented minorities? Are there improvements to metric-tracking that can be made to help this disparity?

    Answer: In 2017, NSF began funding eight Innovation Corps (I-Corps™) Sites to increase participation and promote inclusion of underrepresented populations in entrepreneurship. These Sites are piloting novel approaches and partnerships to engage differently-abled individuals, first-generation college students, racial and ethnic minorities and women, as well as Minority-Serving Institutions. These Sites will report to NSF on the outcomes of these pilots in their final project reports, at which time they will be shared with the rest of the National Innovation Network.

    The NSF I-Corps™ program works with a NSF grantee to track the gender and ethnicity of I-Corps™ participants through voluntary surveys as part of a broader assessment program. Overall, results through 2016 (the latest data compiled) are roughly consistent with the diversity in "Science and Engineering Occupations" reported in the NSF publication on "Women, Minorities, and Persons with Disabilities in Science and Engineering."

2. U.S. universities continue to lead the world in basic research and in education. In my home state, the University of Nevada, Las Vegas recently received an I-Corps Team award to implement creative and unique kid-friendly content that teaches young students STEM and applied technology skillsets. I-Corps awards such as this one support the national innovation ecosystem and help some of America's brightest researchers test the commercial potential of their discoveries. Currently, I-Corps follows a fixed model, so each team receives $50,000 for customer discovery actions.

    a. Is this award amount appropriate? Has there been any discussion of the need to increase or even decrease it?

    Answer: The NSF I-Corps™ Team award of $50,000 supports participation in, and travel to, the cohort and supports customer discovery travel for the team during the I-Corps™ cohort in order to interact with over 100 potential customers and stakeholders. Support for customer discovery travel continues after the cohort training for the duration of the 6-month award. The I-Corps™ program's post-training surveys suggest that the funding level is appropriate and sufficient for these activities.

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Responses by Mr. Steve Blank

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"From Lab to Market: A Review of NSF Innovation Corps"

Mr. Steve Blank, Adjunct Professor, Stanford University

Questions submitted by Representative Jacky Rosen, House Committee on Science, Space, and Technology

1. U.S. universities continue to lead the world in basic research and in education. In my home state, the University of Nevada, Las Vegas recently received an I-Corps Team award to implement creative and unique kid-friendly content that teaches young students STEM and applied technology skillsets. I-Corps awards such as this one support the national innovation ecosystem and help some of America's brightest researchers test the commercial potential of their discoveries. Currently, I-Corps follows a fixed model, so each team receives $50,000 for customer discovery actions.

    a. Is this award amount appropriate? Has there been any discussion of the need to increase or even decrease it?

    Answer: When NSF established the amounts for the award, it was based on experience they had with the SBIR program. NSF was trying to provide enough funds for the recipient teams to "get out of the building" which is heavy on time and *effort*, but not so much that the recipient teams would be able to spend it meaningfully on additional research "inside the building" which is heavy on time and *money*.

    After 5 years of the program and over 1000 teams, it turns out that approximately 1/3 of the recipients end up not spending their entire award during the 6 months of the grant and have to ask for more time, approximately 1/3 end up having a clear need for slightly more capital to get to a go/no go decision and approximately 1/3 are right on.

    Given this, I think $50K for these full I-Corps projects continues to about right given the tasks we're asking them to complete."

    Other thoughts worth mentioning:

    - *$50K as an amount is easy to write off if a team is totally worthless (so the program can default toward "inclusion" as opposed to "getting it right")
    - *$50K is small enough the the Universities are/were okay in limiting their overhead to $5K for these awards. If it goes up, the Universities are going to want their normal 60% indirect costs

Responses by Dr. Dean Chang

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"From Lab to Market: A Review of NSF Innovation Corps"

Dr. Dean Chang, Associate Vice President, Innovation and Entrepreneurship, University of Maryland

Questions submitted by Representative Jacky Rosen, House Committee on Science, Space, and Technology

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    a. Is this award amount appropriate? Has there been any discussion of the need to increase or even decrease it?

    Answer: Even though NSF solely decides the amounts of the Team awards, I can certainly weigh in on the question with my opinion based on what I've seen over my five years of I-Corps experience. I actually do believe that there should be both smaller Team awards and larger Team awards for different flavors of the I-Corps program (there is currently only one flavor, which awards $50k). Smaller amounts could allow faculty researchers who might not want to start a company but would still like to learn some very basic I-Corps concepts to participate in a shorter, less-demanding version of the program. And larger amounts could be awarded to those researchers and projects who have done enough initial work with enough validation to justify spending more time in an even more intense version of the program. I-Corps has matured to a point where multiple versions of the program designed for different levels would accelerate adoption and impact even faster than the "one size fits all" $50k Team Award.

Responses by Dr. Sue Carter

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"From Lab to Market: A Review of NSF Innovation Corps"

Dr. Sue Carter, Professor, Department of Physics, Director, Center for Innovation and Entrepreneurial Development, University of California, Santa Cruz

Questions submitted by Representative Jacky Rosen, House Committee on Science, Space, and Technology

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    a. Is this award amount appropriate? Has there been any discussion of the need to increase or even decrease it?

    Answer: Yes, the award amount of $50,000 is appropriate. The $50,000 is enough to do a thorough job of the customer discovery over the six months of the proposal. The funding is just sufficient enough to support the time of the entrepreneurial lead to focus a majority of their time on the proposal, to cover the travel costs and course costs of the three team members to participants in the NSF I-Corps program, and to cover the additional travel costs needed to do the customer discovery portion. It is not enough funding to really develop a minimum viable product, but that is not the purpose of the grant. I am not aware of any discussion to increase or decrease the award size

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