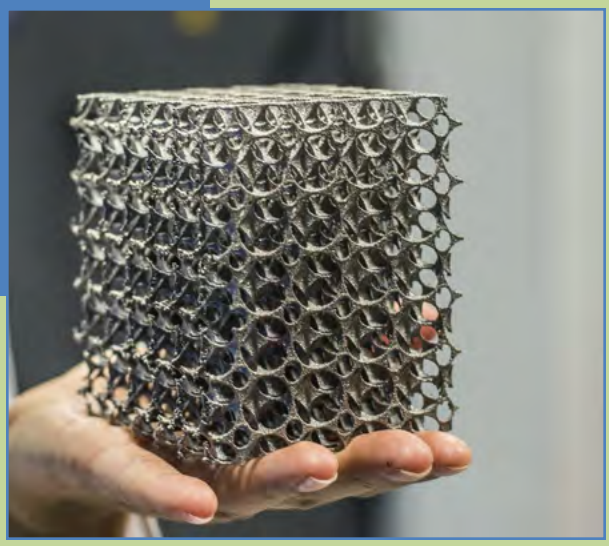
SMALL INNOVATIVE COMPANY GROWTH

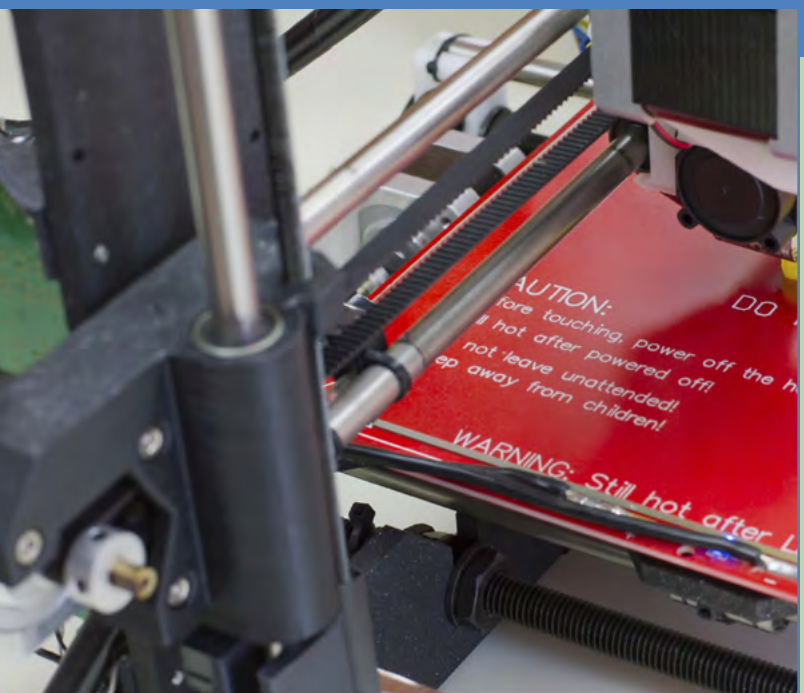
BARRIERS, BEST PRACTICES AND BIG IDEAS

LESSONS FROM THE 3D PRINTING INDUSTRY

BY MARK HARRISON, ENTREPRENEUR IN RESIDENCE
U.S. SMALL BUSINESS ADMINISTRATION
OFFICE OF ADVOCACY

JANUARY 2015





SBA
Office of Advocacy
www.sba.gov/advocacy

SMALL INNOVATIVE COMPANY GROWTH: BARRIERS, BEST PRACTICES AND BIG IDEAS

LESSONS FROM THE 3D PRINTING INDUSTRY

BY MARK HARRISON, ENTREPRENEUR IN RESIDENCE
U.S. SMALL BUSINESS ADMINISTRATION
OFFICE OF ADVOCACY

RELEASE DATE: JANUARY 2015

SBA Office of Advocacy
www.sba.gov/advocacy

THE OFFICE OF ADVOCACY

Created by Congress in 1976, the Office of Advocacy of the U.S. Small Business Administration (SBA) is an independent voice for small business within the federal government. Appointed by the President and confirmed by the U.S. Senate, the Chief Counsel for Advocacy directs the office. The Chief Counsel advances the views, concerns, and interests of small business before Congress, the White House, federal agencies, federal courts, and state policy makers. Economic research, policy analyses, and small business outreach help identify issues of concern. Regional Advocates and an office in Washington, DC, support the Chief Counsel's efforts.

The full text of this report is available on the Office of Advocacy's website at **www.sba.gov/advocacy**. Information about Advocacy's initiatives on behalf of small businesses is widely accessible: Via three Listservs (regulatory communications, news, and research) and social media including a blog, Twitter feed, and Facebook page. All of these are accessible from the Advocacy website, **www.sba.gov/advocacy**.

We welcome your support of Advocacy's efforts on behalf of America's dynamic small business sector.

TABLE OF CONTENTS

FOREWORD

Innovation in the United States has been one of the driving forces in our development as one of the leading economies in the world. Innovations commercialized by U.S. companies have also benefited our society by allowing us to attain prosperity and a good quality of life. While large corporations and the federal government play important roles in the development of innovative products and services, the story is incomplete without the significant contributions and role of individual entrepreneurs and small, agile, high-growth businesses in developing innovative products in the fields of science, technology and engineering. Small companies comprise the overwhelming majority of all businesses in the United States and they must be able to effectively and efficiently bring their innovative products and services to market and grow. Therefore, as the United States moves into the future, we need policies and programs to support the development of an innovation ecosystem that allows small innovative firms to grow, thrive, and create jobs—building the economy and a stronger America.

Implementing effective policies is more critical now than ever if the United States is to remain a leader in today's highly interconnected and hypercompetitive global economy. Both developed and developing countries have and are continuing to implement policies and programs to foster their own innovation ecosystems and economies.[1] However, innovation is not an easy or straightforward task despite the many resources dedicated to it. Small businesses trying to bring innovative technology products and services to market often face unique challenges and barriers not faced by large multinational corporations, and they must often overcome such barriers with fewer resources.

The Office of Advocacy's Innovation Initiative focuses on the needs and concerns of small innovative companies. The Innovation Initiative was designed to investigate the challenges individual entrepreneurs and small high-growth companies face in attempting to commercialize an innovative product or service. This report describes eleven key barriers to small innovative company growth. Each barrier is discussed in three parts:

- ***What We Heard***—Describing the input from entrepreneurs, private industry and other participants in the innovation ecosystem as a result of Advocacy's outreach efforts;
- ***Best Practices***—Identifying best practices or recent activities around an identified barrier; and
- ***Big Ideas and Recommendations***—Highlighting policies or programs that should be considered by the federal government to overcome such barriers.

Developing and exchanging new ideas on innovation is essential to the United States' ability to compete and to lead in the 21st century global economy. As President Obama stated in his 2014 State of the Union address:

"We know that the nation that goes all-in on innovation today will own the global economy tomorrow. This is an edge America cannot surrender."

[1] National Research Council, Rising to the Challenge: U.S. Innovation Policy for the Global Economy (Washington D.C.: The National Academies Press 2012) 201-319.

This report is one piece of this effort. We would like to acknowledge and thank the many individuals who shared their expertise and perspective on the subjects studied here. Special thanks go to the Institute of Electrical and Electronics Engineers for sharing information on the results of its membership survey on challenges to technology company growth.

Winslow Sargeant, Ph.D.
Chief Counsel for Advocacy

Mark Harrison
Entrepreneur in Residence
Office of Advocacy

January 2015

INTRODUCTION

The Office of Advocacy's Innovation Initiative

The Office of Advocacy launched the Innovation Initiative in 2013. The goal of this initiative is to identify the challenges and barriers hindering the growth and development of small innovative companies and offer solutions to surmount such barriers. The Office of Advocacy's Innovation Initiative is comprised of the following components:

- Outreach to innovation and entrepreneurial small business stakeholders,
- Communicating the feedback and concerns to appropriate federal agencies, and
- Reporting the initiative's findings.

Dr. Winslow Sargeant, chief counsel for advocacy, has led a coordinated outreach effort amongst his team, including 10 regional advocates, an Office of Interagency Affairs, an Office of Economic Research and, most recently, an entrepreneur-in-residence. Advocacy has sponsored a series of symposiums titled "Small Business and Government: Maximizing Entrepreneurship, Driving Innovation" aimed at bringing together individuals working in the innovation ecosystem to hear firsthand about the challenges to growing successful businesses. (See sidebar.)

Advocacy's outreach efforts over the past two years provided information and insight into emerging innovation sectors such as green technology, renewable/alternative energy, advanced manufacturing; much of this input falls into one of three categories, which Advocacy terms "the 3 Bs": Barriers, Best Practices and Big Ideas. While Advocacy received feedback on many barriers and industry sectors, most of the concerns centered on the development of new technology by small businesses and advanced manufacturing. In FY 2013, Advocacy continued outreach efforts to the innovation ecosystem looked more closely at issues regarding new technology/product development and advanced manufacturing.

Advocacy focused on one particular innovation/technology industry in order to determine if barriers, best practices, and big ideas found in that industry are instructive for technology industries generally. The technology industry chosen was additive manufacturing (also referred to as 3D printing). The additive manufacturing industry met the criteria for further evaluation in that it is a subset of advanced manufacturing and is experiencing a fast pace of innovation.

INNOVATION AND ENTREPRENEURSHIP SYMPOSIUMS

In 2012, the Office of Advocacy launched a series of symposiums called "Small Business and Government: Maximizing Entrepreneurship, Driving Innovation." These events allow Advocacy staff to hear firsthand about the challenges to growing successful businesses. Symposiums have been held in three cities:

Seattle, Washington
September 2012

Pittsburgh, Pennsylvania
March 2013

New Orleans, Louisiana
May 2014

In addition, Chief Counsel Sargeant and many members of Advocacy's staff have taken part in roundtables and meetings on challenges to innovative company growth. Three of these took place in September 2013 in Wilmington, Delaware; Philadelphia, Pennsylvania; and Camden, New Jersey. Future events are in the planning stages.

The review of data and information on the additive manufacturing industry has been highly qualitative relying on the review of secondary source materials (e.g., research reports, white papers, articles, etc.) from organizations such as McKinsey, Gartner, PriceWaterhouseCoopers, Ernst & Young, universities, research laboratories, trade and business organizations, and the popular and trade press. Advocacy's entrepreneur-in-residence and regional advocates were in direct contact with more than 80 individuals in the additive manufacturing industry and the innovation ecosystem, including entrepreneurs, researchers, government officials, venture capitalists, and angel investors. Advocacy was also given access to data collected by the Institute of Electrical and Electronics Engineers, or IEEE, from its members via an online survey conducted in July 2014 on issues surrounding challenges to growth for technology companies.[2] This collective outreach was crucial to understanding the issues facing small businesses in the additive manufacturing industry and is one of Advocacy's core missions and strengths —providing insights from U.S. small businesses to policymakers on the issues that directly affect them.

Part One of this report focuses on various aspects of innovation as well as the additive manufacturing industry, which provides a framework for analyzing barriers to small innovative company growth. Part Two discusses the 11 barriers to small innovative company growth. For each, it presents relevant best practices or recent activities, as well as program and policy ideas and recommendations for consideration by the federal government.

[2] IEEE is a professional association of persons working in technology fields whose mission is to foster technological innovation and excellence for the benefit of humanity. The IEEE survey had 240 respondents; 90% owned their own business, 99% had less than 99 employees, and 20% were owned by a minority, woman, or veteran.

PART ONE:
AN INNOVATION CASE STUDY

INNOVATION

The federal government sees innovation as the key to future U.S. growth and international competitiveness.[3] According to a PriceWaterhouseCoopers survey, 80% of the participating executives identified growth as a top priority over the next five years and 93% believe that organic growth through innovation will be the primary driver of revenue growth.[4] An innovation is the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organizational method in business practices, workplace organization or external relations.[5] It is important to note that for new products and services to be considered innovations, they must be commercialized—introduced into the market.[6] While there are numerous theories about the number of different types of innovation, we focused on small companies working on breakthrough or radical innovations[7] since these types of innovations present the highest potential to create jobs and new markets, and have substantial impact on the economy.[8]

HOW MANY SMALL HIGH TECH FIRMS ARE THERE?

While small businesses make up approximately 99.7% of the 28.2 million businesses in the United States, only 5.7 million of these small businesses actually have employees. Based on internal calculations of Census data done for this report analyzing the number of firms in certain high technology industry NAICS codes, the Office of Advocacy estimates the number of small businesses in high technology sectors to be between 250,000 and 350,000.

Who are the Innovators?

While the federal government and large corporations play a significant role in innovation in the United States, small businesses make unique and indispensable contributions as well. Media coverage of small high-tech companies developing new products suggests that there are a large number of such firms in the United States; however the Office of Advocacy estimates that around 250,000–350,000 small businesses are involved in high technology sectors.[9] Although relatively small in number, these small technology companies have demonstrated

[3] The White House, A Strategy for American Innovation–Securing Our Economic Growth and Prosperity, February 2011.
[4] PriceWaterhouseCoopers, Breakthrough Innovation and Growth, September 2013.
[5] OECD, 2005, The Measurement of Scientific and Technological Activities: Guidelines for Collecting and Interpreting Innovation Data: Oslo Manual, Third Edition, prepared by the Working Party of National Experts on Scientific and Technology Indicators, OECD, Paris, para. 146, accessed December 22, 2014.
[6] Robert Litan, Andrew W. Wyckoff, and Kaye Husbands Fealing, eds. Capturing Change in Science, Technology and Innovation: Improving Indicators to Inform Policy, (Washington, D.C., The National Academies Press) 2013.
[7] Jake Neilson, Four types of innovation and the strategic choices each one represents, Innovation Excellence blog, January 12, 2014.
[8] Clayton Christensen, We are living the capitalist's dilemma, CNN Website, January 21, 2013. Accessed August 20, 2014.
[9] U.S. Small Business Administration, Office of Advocacy, Frequently Asked Questions, March 2014. Office of Advocacy estimate.

WHAT IS AN INNOVATION?

There are many definitions of "innovation," however the common thread is the commercialization of something new.

What distinguishes an innovation from an invention? Commercialization—or bringing a product or service to market.

Breakthrough innovations are new, bold and substantially superior to the next best available thing. This is what most people have in mind when thinking about innovation.

Radical innovations create drastic changes to the competitive environment for a product or service, or creates new businesses.

Sources: "The Measurement of Scientific and Technological Activities: Guidelines for Collecting and Interpreting Innovation Data: Oslo Manual, Third Edition," OECD, Paris. Capturing Change in Science, Technology and Innovation: Improving Indicators to Inform Policy, Robert Litan, Andrew W. Wyckoff, and Kaye Husbands Fealing, eds. "Four Types of Innovation and the Strategic Choices Each One Represents," Jake Neilson. Breakthrough Innovation and Growth, PriceWaterhouseCoopers.

the ability for significant job creation.[10] However, for these companies to create these jobs and other economic development benefits, they must be growing businesses and not just startups. Thus in order for the United States to obtain the maximum economic and societal benefits from innovation, policies must be in place that allow these small companies to start their firms, innovate, bring new products and services to market, and grow their businesses.

Innovation and Manufacturing in the United States

As stated in the White House report, *Making in America: U.S. Manufacturing Entrepreneurship and Innovation*, the U.S. manufacturing sector is growing and is pivotal to the innovation economy. [11] The report states that the manufacturing sector employs 60% of private sector R&D employees in the U.S. and contributes 75% of private sector research and development. Manufacturing firms introduced a new product or service and new production or distribution method at twice the rate of non-manufacturing firms, and most high-technology manufacturing sectors innovate at twice the rate of all manufacturing firms.[12] Recent manufacturing innovations are providing an advantage to U.S. manufacturing firms by lowering production costs and reducing the time to get products to market. This has led to new manufacturing startups, increased investment in research and development, and increases in manufacturing employment and within related supply chains.[13]

One important manufacturing innovation creating advantages for U.S. manufacturers is additive manufacturing. As part of Advocacy's process of identifying barriers to small innovative company growth, outreach efforts have been focused on companies in the additive manufacturing industry. Reviewing barriers of companies in all technology industries can lead to overly broad conclusions given the differences in characteristics among emerging technologies. Choosing a specific industry enables a better understanding of the challenges small companies face in that industry which are likely to be applicable to the challenges in other technology industries as well.

[10] Hathaway, Ian, Tech Starts–High Technology Business Formation and Job Creation in the United States, The Kauffman Foundation, August 2013.
[11] The Executive Office of the President, Making in America: U.S. Manufacturing, Entrepreneurship and Innovation, June 2014.
[12] National Science Foundation Business R&D and Innovation Survey (BRDIS) 2008.
[13] The Executive Office of the President, Making in America.

The choice of additive manufacturing was driven by three factors:

- The technology is potentially a breakthrough or disruptive one with a significant opportunity for economic impact;
- The industry or technology is showing rapid advancement; and
- There exists or potentially could be significant small business participation.

The McKinsey Global Institute estimates that the economic impact of 3D printing could range from $230 billion to $550 billion by 2025 and noted that the rapidly improving technology is leading to an increase in its use.[14] Additive manufacturing is being used and has the potential to significantly affect many industries. Small businesses are participating in many areas of the industry (3D printer manufacturers, materials, print shops, etc.). In addition, the President has demonstrated strong support of advanced manufacturing in the United States including additive manufacturing. America Makes was founded in 2012 as a national accelerator for additive manufacturing and 3D printing. It was formerly called the National Additive Manufacturing Innovation Institute and is the pilot institute in President Obama's initiative to build a national network for manufacturing innovation. (America Makes is discussed later in Part Two of this report, in connection with barrier no. 2, R&D Support).

ADDITIVE MANUFACTURING

Additive manufacturing (AM) is increasingly being adopted in manufacturing and garnering significant attention in the media.[15] AM is defined as the process of joining materials to make objects from 3D models, usually layer upon layer, as opposed to subtractive methods.[16] While the technology has been around for almost 30 years, improvements in AM technologies are heading towards an inflection point. AM is currently used across diverse industries including those producing consumer, industrial, medical, automotive and aerospace products.

The AM process begins with a digital 3D model generated using computer aided design (CAD) software. The CAD file is then converted to an STL file which instructs the 3D printer to create or "print" the object applying material layer by layer. AM was first and is still primarily used for prototyping and modeling. As the quality of the technology and materials improved AM has been used to create tooling and finished parts. AM's largest potential is its increased use to produce finished parts/products.[17]

AM is a significant innovative technology development. Even if AM is viewed only as a technology for rapid prototyping, modeling and tooling, it is significantly affecting manufacturing by reducing the time and cost in the manufacturing process. However, as AM technical capabilities improve and it is increasingly used in the production of finished parts, the impact of AM will be even greater

[14] McKinsey Global Institute, Disruptive Technologies: Advances That Will Transform Life, Business, and the Global Economy, May 2013. Others have estimated the additive manufacturing market to reach between $21 billion and $200 billion. Wohlers Associates, The Wohlers Report 2014.
[15] Wohlers Associates, The Wohlers Report 2014. This report is the source of most of the background and statistics on the additive manufacturing process and industry in this section.
[16] As defined by the ASTM International Committee F-42 on Additive Manufacturing, a standards development organization.
[17] According to the Wohlers Report 2014, 29% of survey respondents are using additive manufacturing for finished or functional parts; 37% for prototyping/modeling ; 5.6% for tooling components; and 6% for education/research..

affecting product quality and functionality, business models, supply chains, manufacturing footprints, product logistics, etc.

The Additive Manufacturing Industry

The AM industry is growing. According to the Wohlers Report 2014, the compound annual growth rate for global revenues for all additive products and services during the last 25 years is 27%. In 2013, global revenues from all products and services were $3.07 billion which were almost evenly split between product revenue ($1.55 billion) and service revenue ($1.52 billion). There are wide ranging estimates of the size of the industry by 2020 from $21 billion to $230 billion; however today, AM is 0.03% of the $10.5 trillion global manufacturing market.

The market is global, with AM systems being produced and used in many countries located in Africa (South Africa, Egypt), Asia (China, India, and Japan), Europe (Germany, France, UK, and Russia), as well as in Brazil and Canada. However, the United States is the leader with 38% of installed industrial additive systems worldwide with Japan, Germany and China representing 9.5%, 9.1% and 8.8% respectively. Israel is the leader in production and sales of industrial additive systems with 54.7% of the market, followed by Europe at 21% and the United States at 18.6%.[18]

ADDITIVE MANUFACTURING OR 3D PRINTING?

While the term "3D printing" has become synonymous with additive manufacturing, 3D printing is one of seven different processes for additive manufacturing recognized by the ASTM International Committee F-42 on Additive Manufacturing.

Source: The ASTM International Technical Committee F42 on Additive Manufacturing Fact Sheet.

The AM service industry is also growing. The typical AM service provider may specialize in one or two AM processes (each process requires a different machine) and can provide a range of services from production of prototypes to final parts. Two trends in the service industry are system manufacturers beginning to offer production services and an active M&A market for service providers.[19] In addition, there are new business models being created involving service providers and individual consumers. The development of 3D print shops where individuals can have an object 3D printed as a service is an opportunity for small businesses and is being piloted by large companies such as Office Depot, Staples and UPS. Another model is bringing together 3D designers, parts producers and consumers through the Internet. There are variations but basically 3D designers can post or sell their designs for an object (e.g., jewelry) for consumers to purchase and potentially print themselves or have the parts producer print the object and send it to the consumer. Companies in this space include Shapeways, Thingiverse, Cubify, and i.materialise.

[18] This is a bit misleading in that Stratasys, a U.S. based company which had 54.7% of global unit sales of industrial systems, merged with an Israeli company in December 2012 with the new entity choosing to register as an Israeli company. Stratasys maintains significant operations in the U.S. Prior to 2013, the U.S. produced almost 61% of industrial systems. Wohlers Associates, The Wohlers Report 2014.

[19] Stratasys acquired two service providers in 2014 (Harvest Technologies and Solid Concepts) and 3D Systems, a publicly traded U.S.-based 3D printing system manufacturer, acquired Medical Modeling as well as Robtec which is based in Brazil. The Wohlers Report 2014.

Personal 3D printers—The Maker Community

The growth in sales and use of personal 3D printers is evidence of a movement in the United States of people who actually want to make things themselves.[20] Personal 3D printers generally cost less than $5,000 and use only plastic as build material.[21] There are hundreds of manufacturers of 3D printers. One factor in the increasing growth in personal 3D printers is the expiration of the patent for fused deposition which is the process used by almost all personal 3D printers. These machines generally are not used for manufacturing or industrial purposes but mostly used by hobbyists and students.

However, as the quality of these printers improves they are increasingly being used for professional uses by small businesses. Similar to the improvement in quality of the cell/smart phone, these personal 3D printers will continue to decrease in cost but increase in capabilities and in quality, making AM more accessible to small businesses. Another difference between large industrial AM systems and personal 3D printers is that the personal printers tend to operate in an open source environment in terms of operating software, materials, etc. This can be attributable to the nature of the Maker movement. The Maker movement is generating a lot of interest. The White House hosted a Maker Faire in June 2014 that included 3D printing among the processes featured.[22] Despite not having a large impact on business applications, the Maker movement has given the public some idea of the potential capabilities of AM and thus has likely positively affected the pace of development of industrial printer systems.

Benefits of Additive Manufacturing

AM is increasingly being used for final product/part production. However the majority of people interviewed in connection with this report believe that AM is a complement to conventional manufacturing processes, and not a replacement for them.

Seven advantages of AM may result in lower total production expenses and faster times to market. These include:

- Design freedom: AM allows a designer to create complex shapes and complex parts that cannot be produced using conventional manufacturing processes. Designers are not constrained by the rules of design for conventional manufacturing processes. This results in advantages like part consolidation which results in less product assembly, less labor, and less production time.
- Eliminating tooling: The AM process requires no tooling thus eliminating a major expense in the manufacturing process and shortening the lead time needed to begin production.
- Shortened time between design and production: Manufacturers are able to iterate numerous designs allowing them to “fail quickly” and determine proper design for product. Once a product is designed, manufacturers are able to move to production much faster than with conventional production methods.

[20] Estimated growth rate of sales of personal 3D printers was 171% over the last 3 years. The Wohlers Report 2014.
[21] There are efforts being made to develop a personal 3D printers that use metals as build material. Michael Molitch-Hou, A sub-$4,000 metal 3D printer? 3D Printing Industry, September 23, 2014. Michael Molitch-Hou, Michigan Tech releases open-source 3D metal printer for less than $2,000? 3D Printing Industry, December 9, 2013.
[22] White House Maker Faire website, June 2014.

- Increased customization: AM allows for customization of product design because there is no need to retool the system to accommodate design changes. This makes design variations, whether simple or complex, essentially free. Manufacturers can customize products more easily and less expensively than with traditional manufacturing methods and are able to offer customers more product variations.
- Reduced inventory requirements: AM allows a company to produce products on a just-in-time basis which lessens inventory requirements.
- Distributed manufacturing: Final parts can be produced and distributed faster since the digital CAD file can be sent to an AM system anywhere in the world. Manufacturers could produce parts closer to their customers' locations reducing shipping expense and lead time.
- Altered structures: AM designs can often lead to complex structures that can perform the same function as a conventionally made part but with less weight. This process, called "lightweighting," is a major attraction for the aerospace industry. Lightweighting can be accomplished using topological optimization, which uses computational power to determine optimal product shape, size, and strength. In addition, AM manufactured parts, in many cases, can require less assembly. For example, NASA was able to reduce the number of parts of a rocket engine injector from 115 to two using AM.[23]

Challenges for Additive Manufacturing

Aside from barriers that are similar to others experienced by small innovative companies discussed in this report, there are several technical or industry specific challenges to the increased use of AM.

- Cost of AM systems and materials: Industrial AM systems, particularly systems producing metal parts, are expensive. Systems can cost from $50,000 to over $1 million. Materials can also be expensive on industrial systems costing from $100–$300 per kilogram for some plastics and $300–$1,000 per kilogram for metals.
- Slow build speed: AM systems build products at a slow speed. Depending on the part complexity, the process from production to final part could take over 24 hours. The build platform is also relatively small limiting the size of products produced.
- Repeatability: Parts produced using AM should be consistent since they are based on a digital design. However, the same design on different systems using different batches of the same material will not always produce an identical part. This is a larger issue when manufacturing metal products/parts compared to those made from plastic. The AM processes for metal products involves the heating, binding and cooling of metals which may be altered for any number of reasons (e.g., laser power spiking that adds more heat to the metal during part of the build process) leading to lack of consistent part production. The industry is working to increase its knowledge of the thermal dynamics of building metal parts using different additive processes, materials, etc. In addition, the lack of tools to monitor the consistency of the part during the build process means defective products are not discovered until a post processing inspection.
- Lack of materials: Plastics and metals are the two primary materials used in AM. Some composites and ceramic materials are being used in certain applications, and this is a growing area of development. However, the lack of a range of build materials was consistently cited in interviews for this report. In addition, system manufacturers are

[23] NASA, NASA tests limits of 3-D printing with powerful rocket engine check, NASA blog, August 2013.

requiring that companies use their proprietary materials with their systems. Failure to use the proprietary materials could void the system's warranty.

The impact of these challenges is that AM, when used to make final products, make products that are relatively small, high value, customized and complex. Solutions to these issues are rapidly being developed. As these issues become less of an issue for manufacturers, more products will be eligible to be made using AM due to decreasing production costs and production speeds, and increasing product quality and repeatability.

Moving Forward

AM is part of an industry trend towards digital manufacturing. In digital manufacturing computers are used to aid and/or control the manufacturing process. This is not a new trend—digital manufacturing has been used for decades. An example of digital manufacturing is computer numerical control (CNC) machines which use a computer to control machine tools to cut and/or shape material. Manufacturing is increasingly becoming an integrated process. Products move faster and more efficiently through the design to final product process, or from the "virtual to the physical," as manufacturing equipment and software, as well as design software get more powerful and sophisticated and as the use of automation increases.[24] Manufacturers are gaining the ability to design, model and test a product and the production process quickly and less expensively before a product is actually made. AM is important to digital manufacturing in that AM allows for rapid prototyping, modeling, etc. during the product development stage and for complexity and customization into final products without significant additional cost or time loss.

The next step in the development of digital manufacturing is its integration with the "Internet of things." Gartner, Inc., an IT research and advisory firm, defines the Internet of things (IoT) as "the network of physical objects that contain embedded technology to communicate and sense or interact with their internal state or the external environment."[25] For manufacturers, this means the development of smart factories. A manufacturer can connect devices (e.g., sensors, equipment, products in process, etc.) and network them over an Internet infrastructure, allowing the manufacturer to monitor, in real time, the activities and processes in the factory. [26] The manufacturing equipment will communicate with the products in process to ensure quality standards are met and that the production process is efficient. This is all monitored through computer software and will allow the manufacturer to take any required actions to improve efficiency to the extent that the networked system does not adjust itself.[27] The network could even be extended to gather information from the supply chain and customers. Cisco estimates that IoT

[24] Helmuth Ludwig and Eric Spiegel, America's real manufacturing advantage, *strategy + business*, January 20, 2014, accessed August 20, 2014.
[25] John Barber and Jim Tully, Emerging Market Opportunity: The Internet of Things, Gartner, Inc., June 24, 2014 (webinar presentation).
[26] Researchers at Microsoft have developed a technology, called InfraStructs, that allows information to be embedded into 3D printed objects during the production process that can be read by external scanners. This is similar to radio frequency identification codes (RFID) except that no security cards or keys are required because the information is embedded in the object. Rakesh Sharma, Microsoft researchers introduce technology for an internet of things in 3D printing, Forbes Magazine, September 12, 2013, accessed August 20, 2014.
[27] Greg Gorbach and Andy Chatha, Information-Driven Manufacturing, ARC Strategies, February 2013. Ludwig and Spiegel, America's Real Manufacturing Advantage.

will generate $19 trillion in value over the next decade.[28] A word of caution—as with any product or process becoming increasingly digitized and reliant on software, manufacturing companies will need to address issues around the storage, security and privacy of company data.

The movement towards digital manufacturing and AM will heighten some of the barriers to the growth and development of small innovative companies. For example, the need for more engineers and individuals with advanced manufacturing job production skills, the so-called skills gap, will grow with increasing amounts of digitalization and automation in manufacturing processes. As noted in a report drafted by the President and CEO of Siemens and the CEO of Siemens Industry USA, "to succeed in advanced manufacturing workplaces, workers need to possess the production skills to set up, monitor, and control the manufacturing processes, and the process design and development skills to continuously improve them."[29] The challenge for small companies to find, recruit and retain a skilled advanced manufacturing workforce will become even more difficult than it is currently.

The overall equipment costs and expenses for small businesses is another barrier that will be exacerbated due to the rise in digital manufacturing. As AM technology improves (e.g., faster production speeds, increased part size and better finish, more materials, etc.) costs will become lower and increase the range of products that can be made using AM. In addition, as the technology improves, the expense of AM systems should decrease potentially making small business entry into AM less challenging. However, these cost reductions will be accompanied by new ones, as small firms have to replace legacy equipment and upgrade infrastructure to fully participate in the digital manufacturing supply chain. In addition, the small companies will also need resources to address the data storage, security, and privacy issues attendant to digital manufacturing.

As digital manufacturing and AM technologies improve and industries develop, there will be new opportunities and casualties for U.S. small businesses. In the near future, small business will have opportunities as service bureaus, product designers, 3D print shops, online design/print firms, repair shops and retail (e.g., jewelry). Other higher end opportunities include the development of AM materials, products/parts, and medical devices. As the use of digital manufacturing and AM increases, there is likely to be significant disruptions within traditional manufacturing supply chains. Small businesses involved in storing products or inventory management (e.g., distributors, warehousemen, job shops, wholesalers), and those firms transporting products (e.g., shipping companies, import and export companies) will likely be adversely affected.

THE INNOVATION PROCESS

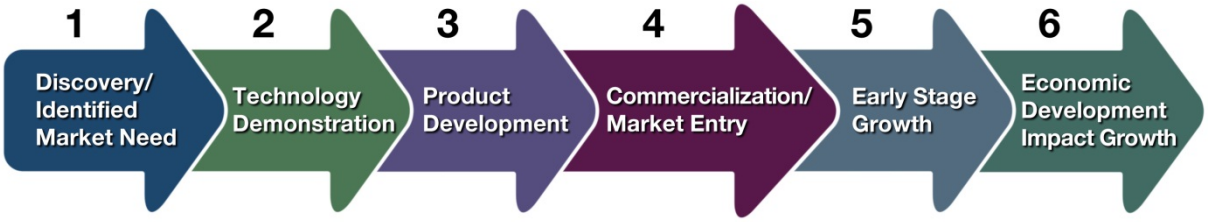
Understanding small business development and the innovation process is important when evaluating barriers to small innovative company business growth. Understanding the process will provide insights into the stages at which the barriers are occurring, possible reasons for the barriers, and potential solutions. While there are many ways in which small innovative companies grow their

[28] Joseph Bradley, et. al., The Internet of Everything: Top 10 Insights from Cisco's IoE Value at Stake Analysis for the Public Sector, Cisco Systems, 2013, accessed August 20, 2014.
[29] Ludwig and Spiegel, America's Real Manufacturing Advantage, page 48.

businesses, we have set forth a model innovative company development process with six stages, shown in Figure 1 and outlined as follows:[30]

- Discovery/Identified Market Need: The small business has an idea for an innovation. The idea could be based on one or several sources: new or existing research; previous development activities; the entrepreneur's determination of a market need; or customer feedback.[31]
- Technology Demonstration: The small business performs research on its idea. Activities include: experimenting, developing prototypes, testing and evaluating, assessing the market opportunity, etc.
- Product Development: The small business builds on the potential solution identified during the technology demonstration stage to develop a specific product or other innovation. Activities include: confirming research results, product design, pilot testing, establishing production processes, and developing go-to-market strategies. By this stage, the small business has likely filed for patent protection of its idea.
- Commercialization/Market entry: The small business has finalized its product and is ready to begin selling product into the market. There is an emphasis on sales and marketing as well as establishing certain business metrics such as cost effective manufacturing processes. The company is generating revenues between $0–$2 million.
- Early Stage Growth: The small business is growing generating up to $10 million in revenue and hiring additional employees.
- Economic Development Impact Growth: The small business is generating over $10 million in revenue, and has increased hiring employees, potentially made investments in land and buildings, has increased tax obligations and undertaken other actions that positively affect the economy (e.g., philanthropy).

Figure 1. The Innovation Process



There are a few things to note about this process:

- A company must reach the Economic Development Impact Growth stage in order to have the maximum impact on the economy and job creation. The economy will also benefit if the

[30] Adopted from Deborah Jackson, What is an Innovation Ecosystem? (working paper 2011) Arlington, VA, National Science Foundation, and Byron Clayton, "Scaling, Accelerating and Sustaining the Innovation Pipeline," (presentation and interview at NorTech headquarters, Cleveland, Ohio, February 19, 2014).
[31] Ralph Landau and Nathan Rosenberg, The Positive Sum Strategy; Harnessing Echnology for Economic Growth, (Washington, D.C., The National Academies Press) 289-294, 1986.

innovation creates a new or expands an existing market requiring other businesses to participate in such a market directly or in a supporting capacity.

- It is natural for the number of companies or ideas/products being developed to decrease as it moves through the process. All ideas don't necessarily get researched, all research does not get developed or commercialized and all companies don't grow to the point where they are having economic development impact.
- The process dynamic—it is rarely linear and is subject to numerous inputs. The entrepreneur will develop an innovation based on his/her knowledge base, existing external research, internal research, failed development attempts, existing products, market feedback, customer feedback, etc.[32] Entrepreneurs will move forward in the process, potentially stall (e.g., technical issue), will need to go back in process (e.g., more research or development activities), etc. This process can result in additional costs, the need for more or different resources and delayed commercialization/market entry.
- Delays in the process through commercialization/market entry can negatively affect companies attempting to develop new technology. Different technologies will move through the process at different speeds. Traditionally, products such as pharmaceuticals—one of the most heavily regulated industries—have long research, development and commercialization times (up to 15 years). Software, on the other hand, can be commercialized much faster (less than three years). Excessive delays in moving through the process for any reason (e.g., technical problems, lack of capital, legal or regulatory issues, etc.) can put a small company at risk for competitors with similar or competing technology moving through the process with greater efficiency to gain market share.
- There are many players involved in company and technology development who comprise our innovation ecosystem (which can be defined as individuals and entities that have influence and impact over innovation development and adoption).[33] Participants in the process include entrepreneurs, researchers, universities, federal laboratories, non-profit organizations, engineers, scientists, technical employees, small businesses, large corporations, angel investors, venture capital, crowdfunding providers, banks, incubators, accelerators, state and federal government as well as other support institutions and organizations.

THE ROLE OF THE FEDERAL GOVERNMENT IN INNOVATION

The United States has many characteristics that make for a strong innovation ecosystem including the presence of world class universities, efficient capital markets for debt and equity, engineering talent, a large marketplace, and a strong legal system protecting intellectual property rights (IPR) as well as investor rights (e.g., bankruptcy laws, contract laws, etc.).

However, as previously noted, many countries are improving their innovation ecosystems meaning that the United States cannot afford to stand still. The federal government has taken steps to improve the innovation ecosystem, and many of these steps are highlighted in this report. However, the United States does have some growing problems which need to be addressed such as its workforce skill gap, reduced government spending on research and development, and an aging infrastructure (e.g., and the need to increase broadband accessibility, high speed transportation,

[32] Landau and Rosenberg, The Positive Sum Strategy.
[33] Jackson, What is an Innovation Ecosystem? Litan, Capturing Change in Science, Technology and Innovation.

etc.). In addition, efforts among participants are not always coordinated, leading to inefficiencies within the innovation process.

The federal government is a critical participant in the growth of innovative companies and the development and commercialization of new technologies. Many technologies used today can be traced back to research initiatives of or funding by the federal government including global positioning systems (GPS), microprocessors, the Internet, modern medicine, etc. In fact, the federal government, particularly the National Science Foundation (NSF), has played a pivotal role in the development of AM. The NSF has awarded almost 600 grants amounting to over $200 million for AM research and continues to play an important role in surmounting the technical challenges to AM.[34] The federal government's role is critical because its programs and policies generally affect all participants in the innovation ecosystem. Funding U.S. basic research, providing small business financial support through the SBA's loan guaranty and Small Business Investment Company programs, and purchasing small business products and services are just a few of the roles the federal government takes in support of small, innovation businesses.

Although the federal government plays a critical role in our innovation ecosystem, leadership of America's innovation process and ecosystem is dispersed among public and private sectors. Notwithstanding, the federal government should use its standing to make the innovation process work as open and efficiently as possible; this will help create a technical and business climate that provides innovative companies with opportunities to be successful. The government has many options to have an impact on and improve the U.S. innovation ecosystem including:

- Supporting funding for research and development, small business capital access, and education/job skills training either through direct financing or tax policy;
- Disseminating and providing access to government information;
- Organizing and facilitating cooperative interaction between participants in the innovation ecosystem;
- Supporting business opportunities and access to markets for small companies; and
- Enacting laws and regulations that support innovative company growth and technology commercialization.

The innovation process and ecosystem are fluid, and proposed changes to one part affects other aspects of the process or ecosystem. For example, access to capital has been a long standing problem for small innovative companies in growing their businesses. However, providing access to capital alone will not solve the problem. While no one would expect the government to move as quickly as inevitable changes in technology and the innovation process, it is important for government to be nimble and forward thinking when it comes to its innovation policies. Actual methods used by the federal government should be reviewed and changed as needed given the dynamics of the 21st century global economy.

[34] Christopher L. Weber, et. al, The Role of the National Science Foundation in the Origin and Evolution of Additive Manufacturing in the United States, IDA Science & Technology Policy Institute, November 2013.

PART TWO:
BARRIERS, BEST PRACTICES, AND BIG IDEAS

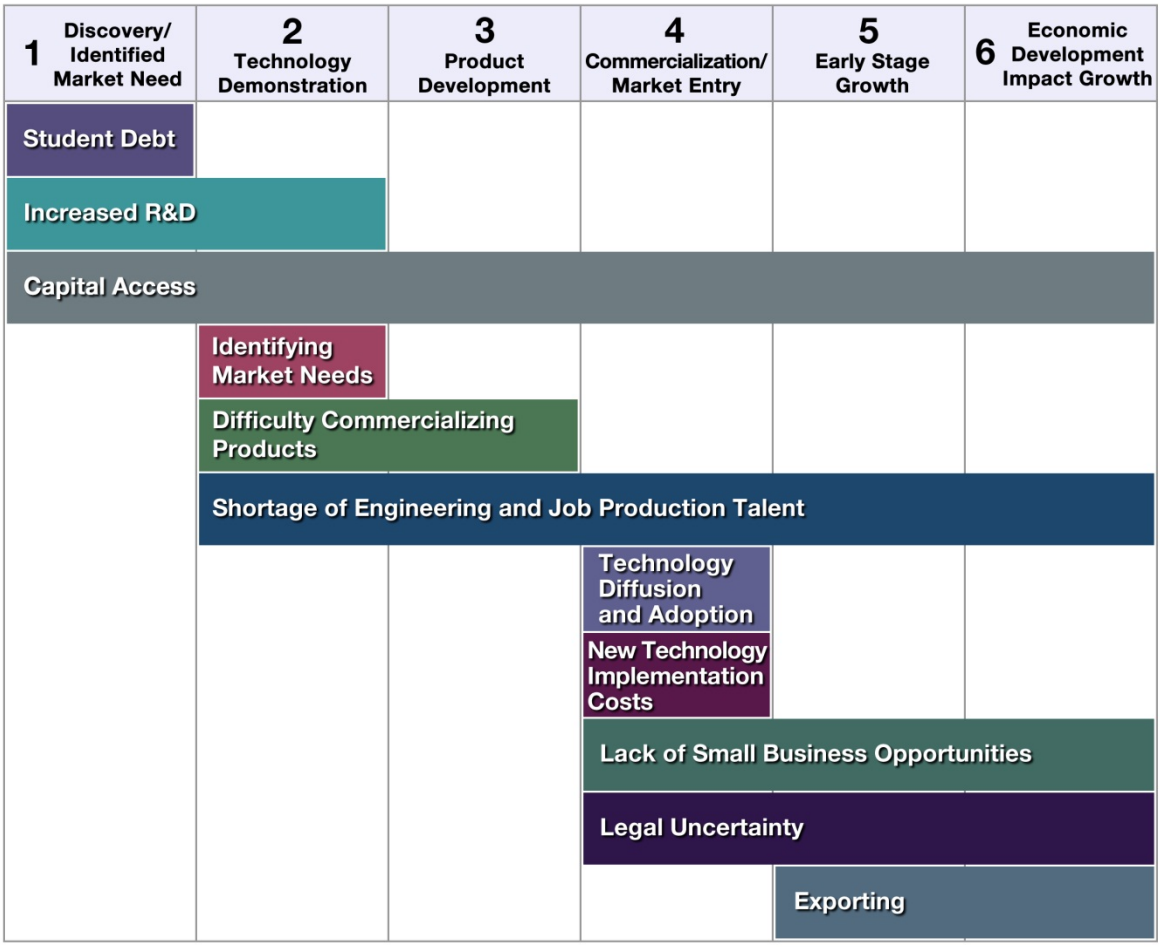
The barriers discussed below are based on the feedback Advocacy received from companies, researchers, government agencies, universities, venture capitalists, lawyers, crowdfunders, consultants, trade groups, incubators, and other support organizations in the AM innovation ecosystem. This section identifies barriers and challenges specific to small companies attempting to commercialize a breakthrough technology product or service and grow their firms. The barriers identified are:

- The amount of student debt held by graduating students prevents them from pursuing entrepreneurial opportunities.
- The amount of funding and support of research and development in the United States needs to increase to ensure continued innovation.
- Entrepreneurs often lack information regarding market needs and product research and development efforts.
- There is a shortage of engineering and production job talent.
- Access to capital still remains a large barrier for small businesses growth.
- Small innovative companies have difficulty in commercializing products.
- Technology diffusion and adoption is harder for small businesses.
- The high costs of acquiring equipment and implementing a new technology is a barrier to entry for small businesses.
- Small companies need access to more business opportunities.
- Innovations often result in legal and/or regulatory challenges or uncertainty.
- Small companies continue to face challenges to exporting their products and services.

The barriers are in order of when they might be first encountered during the innovative company development process (See graphic below).[35] Many barriers affect companies in more than one stage of the innovative company development process with issues around access to talent and capital affecting all stages. While most of the barriers identified occur between the Discovery stage through the Commercialization/Market Entry stage, the importance of growing and scaling these small businesses for maximum economic impact cannot be overstated.

[35] The barriers were those identified in the AM industry that we believe are applicable to many small innovation firms. Thus, they are set forth as general statements not specifically barriers to growth in AM.

Figure 2. Barriers Along the Innovation Process Timeline



Two other issues, immigration policy and infrastructure improvements, which are typically part of any discussion regarding challenges for growing small innovation firms, were not noted as major issues in the AM industry. These issues are not discussed in this report, since it is based solely on the feedback we received. However, implementing new policies and programs concerning immigration and improving U.S. infrastructure will only advance the goal of growing small innovative companies.

Each barrier is discussed in three parts:

- "What We Heard" from the people we interviewed and other background information,
- "Best Practices" regarding the barrier, and
- "Big Ideas and Recommendations," or potential proposed solutions to the barriers.

BARRIER 1:
THE AMOUNT OF STUDENT DEBT HELD BY GRADUATING STUDENTS PREVENTS THEM FROM PURSUING ENTREPRENEURIAL OPPORTUNITIES.

1 Discovery/ Identified Market Need	2 Technology Demonstration	3 Product Development	4 Commercialization/ Market Entry	5 Early Stage Growth	6 Economic Development Impact Growth
Student Debt					

What we heard: Many college graduates are not pursuing entrepreneurial opportunities due to their outstanding student loans. College costs have been steadily rising over the last 10 years requiring many students to fund all or part of their education through student loans. Between 1995 and 2013, the share of families with education debt rose from 12 percent to 20 percent.[36] Total student debt outstanding for individuals under 30 years old in fourth quarter 2012 was $322 billion; this was distributed among 15 million borrowers for an average outstanding debt of $21,400.[37]

A person with significant outstanding student debt may forgo entrepreneurship for two reasons. First, the individual would be unable to meet their student loan payments because the entrepreneurial opportunity would not pay sufficient compensation. Second, the entrepreneur may have more difficulties raising money for their business due to the amount of their outstanding student debt (i.e., being over-leveraged). This may be a significant reason for the 23% drop in business starts by individuals aged 25 or under between 2002 and 2012.[38] There is a need for relief from student loans to allow talented graduates to pursue entrepreneurship.[39]

Individuals can receive student loan deferment or forbearance for reasons such as: enrollment in graduate school, active military service, unemployment or economic hardship (for up to 3 years), Peace Corps service, certain teaching positions, certain national service positions (e.g., AmeriCorps), etc. However, graduates wishing to pursue entrepreneurship are unable to defer their student loan obligations.

BEST PRACTICES

Income-Based Repayment Plan: President Obama has worked to improve the income based repayment (IBR) plan that allows student borrowers to cap their repayments for federal student loans to 10% of their discretionary income if they make their payments in a timely manner. The program lowers the amount of the monthly payment for those borrowers who have high levels of student debt relative to their income.[40]

Rhode Island plan: The State of Rhode Island is considering a plan to defer or greatly reduce the monthly amount of student loan repayments for up to two years for those persons who launch or go

[36] U.S. Small Business Administration, Office of Advocacy, Student debt among young entrepreneurs, fact sheet, November 2014. Federal Reserve Board, Survey of Consumer Finances, 2013.
[37] Federal Reserve Bank of New York, Student Loan Debt by Age Group, March 29, 2013.
[38] Office of Advocacy, Frequently Asked Questions about Small Business, March 2014.
[39] Merra Lousi, Student debt puts young entrepreneurs on hold, Businessweek, June 20, 2013; Phyllis Korkki, The ripple effects of rising student debt, New York Times, May 23, 2014,
[40] The White House blog, Income based repayment: everything you need to know.

to work for a startup in the state. If adopted, this appears to be the first program to use student loan deferment as a way to encourage entrepreneurship.[41]

Venture for America (VFA): VFA is a two-year fellowship program that prepares recent college graduates for entrepreneurship by providing training and having the fellows work for startup companies. VFA will introduce its VFA Opportunity Award for Loan Assistance that will provide up to $5,000 to four fellows in the program to pay student loans during the first year of the program.[42]

BIG IDEAS–RECOMMENDATIONS

Entrepreneurship Student Loan Deferment: Similar to deferments to attend graduate school, the entrepreneurship student loan deferment would allow students to defer their student loan payments if they start or work for a qualified company. A qualified company would be any firm in business less than 4 years and has less than $5 million in revenue for each of its last 2 fiscal years. This program would be specifically targeted to allow students to pursue entrepreneurial opportunities without the immediate burden of repayment of student loans. Individuals starting or working for startup companies are likely to be working for little or no salary and need to commit as much of their resources as possible to building their business. While the IBR plan is a significant benefit for student borrowers, those pursuing entrepreneurship need special incentives for the risk they take.

BARRIER 2:
THE AMOUNT OF FUNDING AND SUPPORT OF RESEARCH AND DEVELOPMENT IN THE UNITED STATES NEEDS TO INCREASE.

1 Discovery/ Identified Market Need	2 Technology Demonstration	3 Product Development	4 Commercialization/ Market Entry	5 Early Stage Growth	6 Economic Development Impact Growth
Increased R&D					

What we heard: Research and development is a critical step in the innovation process. Research, particularly basic research, is just as valuable to the process as development. Basic research adds to the general body of knowledge about an area of study, usually with no regard for any potential commercial application. However, basic research has been the building block for subsequent breakthrough innovations. The federal government is the largest funder of basic research in the United States. Basic research is mostly performed by universities and colleges. Individuals working on or attempting to commercialize products based on basic research were concerned about a slowdown in federal research spending due to federal budget constraints. Everyone wanted increased federal spending but there was a split of opinion regarding whether the federal government should begin funding more applied research and commercialization activities and decreasing the amount of basic research it supports. It should also be noted that other benefits of research activities include: (1) training of skilled scientists and engineers and (2) the development of new processes or equipment to perform the required research.

[41] Michael B. Farrell, Rhode Island may defer loans for young entrepreneurs, Boston Globe, August 27, 2013, accessed August 20, 2014.
[42] Venture for America website; VFA Opportunity Awards Guidelines.

Businesses and the federal government are the largest funders of R&D in the United States.[43] Businesses fund and perform most applied research and development activities.[44] Federal spending for basic research has remained relatively flat and while R&D by business has increased, policies should be implemented to encourage additional private sector spending on R&D. Such policies should enhance the ability of small businesses, often the sources of innovative products but financially and resource constrained, to be active participants in R&D activities.

U.S. support of R&D is important in light of such activities by our global competitors building their innovation economies. The United States has been the world leader in R&D activities, spending $424 billion in 2011[45] and forecast to be the leader through 2014 and to continue modest growth through 2020.[46] However, Asian countries, particularly China, are expected to increase their share of global R&D while the U.S. and European shares are expected to decrease. In fact, at their current respective growth rates, China is expected to pass the U.S. in R&D funding by 2022.[47]

The government should strongly support U.S. based R&D activities not only to maintain and enhance our ability to innovate and out of concern for the increased spending and growing capabilities of other countries, but for the potential economic impact and jobs created as a result of these activities.[48] While R&D is necessary for innovation, the government's and industry's future ability to support of R&D initiatives will depend, in part, on the state of our economy.

BEST PRACTICES

President's FY 2015 budget: The President understands the role federally funded research plays in innovation in the United States and has shown his commitment by increasing total federal R&D spending from $130.3 billion in FY 2013 to an estimated $133.7 billion in FY 2014 and is proposing an increase to $135.4 billion in his FY 2015 budget.[49] The President's proposed FY 2015 budget also includes a 1% decrease in spending on basic research, a 1.8% increase in applied research and a 2.3% increase in development activities by the federal government over estimated 2014 amounts.[50] The proposed FY 2015 budget also includes a provision to make the R&D tax credit permanent.

[43] Total U.S. R&D expenditure was $424.4 billion in 2011 with business and the federal government funding $267.2 billion and 125.7 billion respectively. NSF Science and Engineering Indicators 2014, Table 4-1.
[44] Businesses do little basic research because the results are often far removed from product development. Businesses spend their time and money on creating products that can improve their bottom line. Spending on applied research and development increased from 0.6% of GDP in 1953 to 2% of GDP in 2011.
[45] NSF Science and Engineering Indicators 2014, Table 4-1.
[46] Batelle, 2014 Global R&D Funding Forecast, R&D Magazine, December 2013.
[47] Batelle, 2014 Global R&D Funding Forecast.
[48] Batelle, 2014 Global R&D Funding Forecast. Batelle projects the U.S. will spend $465 billion in 2014 which will result in direct employment of 2.7 million U.S. residents in the public and private sectors and supporting an additional 6 million U.S. jobs .
[49] White House Office of Science and Technology Policy, The 2015 Budget: Science, Technology, and Innovation for Opportunity and Growth, March 2014.
[50] White House Office of Science and Technology Policy, the 2015 Budget. Basic research would decrease from $32.4 billion to $32 billion, applied research would increase from $32 billion to 32.6 billion, and development would increase from $66.5 billion to $68 billion.

Global Innovation Initiative: Part of enhancing the quality of the research done in the United States is facilitating networking and cooperative work opportunities for U.S. researchers. An example of one such program is the Global Innovation Initiative.[51] The goals of this initiative are to build up the research talent pool and encourage collaboration between university researchers, faculty, students, and administrators in the United States, the UK, Brazil, China, India and Indonesia. The administration should continue to foster different collaborative opportunities.

America Makes: Based in Youngstown, Ohio, America Makes is an extensive network of nearly 100 companies, non-profit organizations, academic institutions and government agencies from all over the United States. America Makes was founded in August 2012 as the first National Network for Manufacturing Innovation (NNMI) Institute (see sidebar). It is focused on helping the United States develop and grow capabilities and strength in AM. America Makes supports and facilitates research collaboration among leaders from business, academia, non-profit organizations and government. Its research efforts are aimed at enabling technology transition from universities and government (i.e., basic research) through to commercialization. Its mission statement outlines five interrelated goals to increase the use of AM and help the U.S. manufacturing industry become more globally competitive:

- Fostering a highly collaborative infrastructure for the open exchange of AM information and research.
- Facilitating the development, evaluation, and deployment of efficient and flexible AM technologies.
- Engaging with educational institutions and companies to supply education and training in AM technologies to create an adaptive, leading workforce.
- Serving as a national institute with regional and national impact on AM capabilities.
- Linking and integrating U.S. companies with existing public, private or not-for-profit

AMERICA MAKES

America Makes was founded in 2012 as a national accelerator for additive manufacturing and 3D printing. Also called the National Additive Manufacturing Innovation Institute, it is the pilot institute in President Obama's initiative to build a national network for manufacturing innovation. It is based in Youngstown, Ohio, and has an extensive network of nearly 100 companies, nonprofit organizations, academic

THE NNMI INSTITUTES

President Obama has proposed building the National Network for Manufacturing Innovation (NNMI), consisting of regional hubs that will accelerate development and adoption of cutting-edge manufacturing technologies. In addition to America Makes, there are three other NNMIs:

Next Generation Power Electronics Manufacturing Innovation Institute, headquartered at North Carolina State University;

Digital Manufacturing and Design Innovation Institute in Chicago; and

Lightweight and Modern Metals Manufacturing Innovation Institute,Detroit Michigan.

Two additional institutes have been proposed: one focused on clean energy manufacturing for composites materials and structures led by the Department of Energy, and a biomanufacturing innovation institute led by the Department of Agriculture.

[51] The Global Innovation Initiative website.

industrial and economic development resources, and business incubators, with an emphasis on assisting small- and medium-sized enterprises and early-stage companies (startups).

BIG IDEAS–RECOMMENDATIONS

R&D tax credit: We recommend the R&D credit be modified to allow more small businesses to take advantage of the credit by:

- making the credit permanent,
- simplifying the credit so that there are fewer disputes between the IRS and corporations using the credit,
- adjusting the amount of the credit to make the United States competitive with other world markets,
- allowing the amount of the credit to be higher for small companies and allowing small firms to deduct the credit against their payroll taxes, and
- making the credit transferable.

There seems to be some bipartisan support for positive changes to the R&D tax credit. The House of Representatives approved a bill in May 2014 making the R&D tax credit permanent and simpler to use.[52] The Senate Finance Committee approved a bill retroactively extending the R&D tax credit through 2015 and includes provisions for small businesses to offset the credit against their payroll taxes.[53] We make no recommendation as to the amount of the credit but it should be competitive with other countries taking into account the respective corporate tax rates and other tax incentives.[54] Allowing the credits to be transferable will allow small companies to improve their cash flow by selling the credits over and above their tax liability to firms that have income which can be offset by the credit.

A well-crafted R&D tax credit would help small companies participate in R&D activities.

[52] H.R. 4438, the American Research and Competitiveness Act which was approved by the House of Representatives in May 2014, would give companies a 20% credit on a portion of their research expenses that exceeds their average ongoing research spending over the previous few years and makes the credit permanent.

[53] The Expiring Provisions Improvement Reform and Efficiency (EXPIRE) Act (S. 2260) was sent to the Senate for consideration in April 2014. The bill extends for two years the 20% traditional research tax credit and the 14% alternative simplified credit. It also allows startup businesses to claim unused credits against their payroll tax after applying the credit to income tax liability. The benefit is capped at $250,000 per year and available only to companies less than five years old with less than $5 million in gross receipts. U.S. Senate Finance Committee, Final Summary of the Expire Act as reported.

[54] The U.S. R&D tax credit rate is a maximum of 20% with a top corporate tax rate of 35% compared to other countries: Australia – tax credit rate is 45% for companies with revenue under AU.S. $20 million and corporate tax rate of 30%, Ireland – tax credit rate is 35% and corporate tax rate 12.5%. China, Japan, Singapore and the UK have corporate tax rates of 25%, 28%, 17%, and 23% respectively as well as combinations of other tax incentives such as super-deductions on R&D expenditures, tax credits, and patent box rates on certain IP products developed in country. Laughlin Cutler, et. al, Global R&D incentives compared, Journal of Accountancy, June 2013.

BARRIER 3:
ENTREPRENEURS OFTEN LACK INFORMATION REGARDING MARKET NEEDS AND PRODUCT RESEARCH AND DEVELOPMENT EFFORTS.

1 Discovery/ Identified Market Need	2 Technology Demonstration	3 Product Development	4 Commercialization/ Market Entry	5 Early Stage Growth	6 Economic Development Impact Growth
	Identifying Market Needs				

What we heard: Many entrepreneurs in startup companies attempting to commercialize technology based on basic research often lack information on what products the market needs and wants. Many of these entrepreneurs are researchers commercializing technology that may be valid intellectual property (IP) but has no demand from customers in the market. Small business entrepreneurs that are commercializing technology based upon customer feedback or their experience have better insight into the market demand but, similar to the startup entrepreneur, often have no information about current or previous research or development efforts for a similar product. Both types of entrepreneurs are also often unaware of relevant existing patents that might affect their efforts despite the availability of databases with patent information.

Entrepreneurs could make more informed decisions about their commercialization activities by having access to this information. Imagine a startup entrepreneur learning early in the development process that there is no current demand for their technology in the market. Learning this information early allows the entrepreneur to make informed decisions about moving forward: Can I pivot and develop a product the market wants? Can my technology enhance another firm's technology providing a potential partnership opportunity? Do I stop my development efforts? This informed decision making makes the commercialization process more efficient because time and money are not spent on technologies that don't have a place in the current market.

BEST PRACTICES

National Science Foundation (NSF) Innovation Corps (I-Corps) Program: The NSF I-Corps Teams Program prepares scientists and engineers to focus beyond the laboratory by providing them access to resources to help determine the readiness to transition technology developed by previous or current NSF projects.[55] The program lasts about seven weeks and provides entrepreneurial training through a combination of guidance from experienced entrepreneurs, online curriculum, and group meetings.

[55] National Science Foundation, I-Corps program website.

The I-Corps Team program is open to teams that apply and are chosen to participate. Each team is comprised of a principal investigator, usually a professor who has done the research which is the basis for the I-Corps project, an entrepreneurial lead, usually a post doctoral or graduate student, and business mentor. The I-Corps curriculum provides real-world, hands-on immersive learning about what it takes to successfully transfer knowledge into products and processes that benefit society.[56] The goal is to get team members out of the university/laboratory setting and engage the market (i.e., address the market risk).

The NSF runs the program a few times a year in "cohorts," with each cohort accommodating 21-24 teams. Each participating team receives a $50,000 grant to fund their activities during the program. NSF has taken steps to expand the program by implementing five I-Corps Nodes as well as I-Corps Sites.[57] The NSF and National Institutes of Health (NIH) are collaborating on a pilot program to speed biomedical research technologies to market.[58]

BIG IDEAS–RECOMMENDATIONS

Expand NSF I-Corps Program: The I-Corps Program not only helps the innovation process by providing researchers with entrepreneurial training, but it also reduces investment risk by helping to identify those technologies with stronger commercial potential. Based on conversations with individuals at the program, approximately 40% of I-Corps teams go on to start a company. Many pursue licensing opportunities, a handful of companies have received private funding and at least one has been acquired. Expanding this program to other agencies funding research can lead to an increase in technologies that ultimately are commercialized. While it is difficult to quantify a negative, the time and money saved as a result of technologies determined not to be commercially viable is another significant benefit.

Entrepreneur's Government Assistance Website: A website could be created where entrepreneurs can find information on technologies and tech industries that would assist them in deciding how to move forward with development efforts for their technology. The website would include information such as: current and recently funded research, current and soon to be expired patents, government generated market information, government financing resources and technology development programs and emerging technology briefings. (See discussion under Barrier Number 7, Technology Diffusion).

The goal is to create a one-stop location for this information presented in a way that it is assessable to and actionable by entrepreneurs. Having access to this information would assist entrepreneurs in assessing their proposed solution against other technologies being developed with the assistance of

THE NSF I-CORPS

The National Science Foundation's Innovation Corps program (I-Corps) is a set of activities and programs that prepares scientists and engineers to expand their focus beyond the laboratory. The program aims to broaden the impact of select, NSF-funded, basic-research projects. I-Corps is an excellent example of a program bridging the distance between basic research, technology proofing, and product commercialization, a key mode of progress in the innovation ecosystem.

[56] The I-Corps curriculum is built on a special, accelerated version of Stanford University's Lean LaunchPad course with additional elements designed just for I-Corps grantees. The Lean LaunchPad curriculum was developed and is currently taught by serial entrepreneur Steve Blank.
[57] The NSF website expands on these: the five I-Corps nodes and I-Corps sites.
[58] The NSF and NIH Biomedical Pilot Program website.

federal funding. This information would also assist entrepreneurs identify potential partners or other technologies that could help commercialize their product. Since all of the information is government generated, it is currently available to the public. Thus, the raw data is available but needs to be presented in a manner so an entrepreneur can easily review and use the information. There are similar online initiatives such as: BusinessUSA.Gov, which is creating a centralized, one-stop platform to make it easy for businesses to access services to help them grow; the Federal Laboratory for Technology Transfer website, which allows individuals to search for expertise or technologies ready for licensing at federal labs; and SBIR.Gov, which contains information about the SBIR and STTR programs as well as open SBIR solicitations. [59]

BARRIER 4:
THERE IS A SHORTAGE OF ENGINEERING AND PRODUCTION JOB TALENT.

1 Discovery/ Identified Market Need	2 Technology Demonstration	3 Product Development	4 Commercialization/ Market Entry	5 Early Stage Growth	6 Economic Development Impact Growth
	Shortage of Engineering and Job Production Talent				

What we heard: There is a general consensus among technology firms that there is a shortage of engineering and production job talent which can slow company growth. The challenge is not only finding individuals with the requisite science, engineering (S&E) education and experience but also individuals with skills to work in production jobs (e.g., technicians, etc.). The mix of S&E and production job talent within any small company will vary depending on the particular technology industry and stage of company development. For small companies in the AM industry, the focus was more around the need for highly skilled production job workers than S&E workers. While the lack of individuals to fill these highly skilled positions will continue to be a problem, two important issues for small businesses in particular are: (i) how do they recruit and retain these skilled workers, and (ii) how do they get their employees access to the necessary training needed.

There are many efforts being made to increase student participation in science, technology, engineering and math which will help address the shortage of S&E workforce talent. Most small AM manufacturers we contacted indicated they were able to find individuals for scientific and engineering (S&E) jobs without much difficulty except for CAD engineers. The CAD engineer is the person actually using software to design the AM product. Geography has some impact in that firms located near technology hubs (e.g., Silicon Valley) are able to find these engineers easier than other areas of the country. However, the shortage of CAD engineers can lead to increasing competition for their services and subsequent salary inflation making it difficult for small companies to pay market salaries. Small firms' ability to recruit and retain engineering talent is becoming increasingly important.

As is likely the case in many new innovative technologies, including AM, small businesses may also need to retrain their current S&E workforce which may be challenging given their limited resources. Many individuals we spoke with agreed that design engineers must begin to think about creating designs that can take maximum advantage of AM processes. With conventional manufacturing processes, the design engineer must account for the requirements and capabilities of the

[59] BusinessUSA.Gov website; Federal Laboratory for Technology Transfer website; SBIR and STTR program websites.

manufacturing method and tools when designing a product. AM eliminates this concern, thus allowing the design of products with complex shapes and properties that can't be made using conventional manufacturing methods—a primary benefit of AM. Small business recruitment, retention and training of a skilled workforce is also an issue regarding production job workers.

Small businesses' ability to find individuals to fill skilled production jobs (e.g., technicians) often depends on the complexity of the parts or products being manufactured. The more complex the product (e.g., metal part for aerospace application) the higher the skill set required by the technician. Technicians may be required to check the CAD design, monitor the printer during build process, test product for spec compliance, and/or perform finishing work on a part. There are limited numbers of individuals with this skill set and many are expected to retire from the labor market over the next 10 years. Faced with a shortage of job production talent, some small manufacturers have turned to training their own employees. A number of small businesses we contacted that were training people for production jobs expressed a desire for a tax credit to offset all or a portion of their training expenses.

The talent gap challenge will loom even larger in the future due to the advent of digital manufacturing and rapidly changing manufacturing technology. As the technology improves, companies may find ways to streamline operations, increase automation, and/or change business models, all of which may affect the skill set required in manufacturing a product.[60] Further, as manufacturing software improves, individuals working in manufacturing will need additional training in computers and software as well as creative problem solving skills. Digital manufacturing and AM are growing; however the talent gap remains a major barrier to growth for many small businesses. It is critical that any training programs, apprenticeships or other solutions are providing individuals with the necessary skills to function in digital manufacturing.

BEST PRACTICES

Community college programs: There are many community colleges across the United States with technical training programs for AM and other jobs within advanced manufacturing and other innovation industries. Community colleges can often better tailor their training to the needs of a specific employer or industry. Individuals participating in these programs benefit by earning a portable credential and skills that allow them to earn a good salary.

NSF Engineering Research Centers:[61] The National Science Foundation's Engineering Research Centers (ERCs) are a group of centers located at universities across the United States that have partnered with one or more industry partners to work on various long range engineering challenges. An ERC provides an opportunity for industry to collaborate with faculty and students on innovations to address an identified challenge. The centers provide faculty and students with an excellent opportunity to gain experience working with business professionals that leads to constructive exchanges of ideas between academia and industry which benefits both.

Executive Action: In spring 2014, President Obama and Vice President Biden announced federal initiatives to support job training for individuals to help address the existing U.S. skills gap. The initiatives encourage business, community colleges, unions, state and local governments, non-profit companies and other training organizations to partner to develop "job-driven" i.e., training

[60] Deloitte and the Manufacturing Institute, Boiling Point? The Skills Gap in U.S. Manufacturing, September 2011.
[61] NSF Engineering Research Centers website.

programs to prepare U.S. workers for the current and future job market. [62] While the initiatives are different, they have consistent goals so that the programs developed are: job-driven (i.e., responsive to the needs of employers); scalable, either national in scope or representing a best practice for other organizations; and providing participants with a career advancement path.

The three initiatives include:

- A job training competition administered through the Department of Labor. The competition's goal is to develop job training programs and it has received almost $500 million in funding;
- The American Apprenticeship Grants program which will award up to $100 million in funding to partnerships developing apprenticeship models; the program emphasizes models in high-growth sectors such as advanced manufacturing, information technology, technology services, and healthcare; [63] and
- The Registered Apprenticeship College Consortium which encourages agreements between colleges and registered apprenticeship programs to allow graduates of such programs to receive college credit for their apprenticeship training.[64]

The Workforce Innovation and Opportunity Act (WOIA): Signed into law July 22, 2014, by President Obama, the WOIA aligns certain federal programs and resources to assist job seekers gain employment as well as the education, training and support services required to succeed in the current and future job market, and help match skilled workers with employers. The Act was approved by a wide bipartisan majority and is the first legislative reform in 15 years of the public workforce system.[65]

Manufacturing Universities Act of 2014: Senator Christopher Coons (D.-Del.) introduced this bill to the Senate July 31, 2014. The legislation allows up to 25 universities to be designated as "manufacturing universities" and thus eligible to receive $5 million per year over four years to modify university engineering programs to emphasize advanced manufacturing. Manufacturing universities would have goals such as:

- increasing the number of students receiving undergraduate and graduate degrees in engineering or an applied science related to manufacturing,
- improving engineering curricula to focus on manufacturing,
- increasing the number of joint projects with private sector manufacturing firms, and
- increasing the number of students participating in internships. The manufacturing universities would also oversee interdisciplinary programs across its colleges, programs, and departments to advance manufacturing productivity and innovation.[66]

[62] Pursuant to the Presidential Memorandum on Job-Driven Training for Workers, Vice President Biden led a review of the U.S. workforce and job training programs and developed recommendations to make system more job-driven. For information, see: The White House, Ready to Work: Job-Driven Training and the American Opportunity, July 2014.
[63] See Department of Labor, Registered Apprenticeships–Frequently Asked Questions, accessed August 15, 2014.
[64] See Department of Labor, Registered Apprenticeship College Consortium–Frequently Asked Questions, accessed August 15, 2014.
[65] See the Department of Labor WOIA Resource Page and Department of Labor WOIA Fact Sheet.
[66] Senator Coons announces bill to boost manufacturing education at universities, Senator Coons' blog, accessed August 15, 2014. Robert Atkinson, Manufacturing universities: A catalytic step toward revitalizing American manufacturing, Industry Week, accessed August 15, 2014. The bill did not pass (see Govtrack.us website).

Small Innovative company Apprenticeship Participation: The government should support and encourage the development of apprenticeship program models that facilitate Small Innovative company participation. Efforts are being made by various organizations to develop scalable apprenticeship models for advanced manufacturing.[67] Small businesses may face challenges participating in apprenticeship programs such as:

- lack of information about how to participate and the benefits of participating,
- lack of financial resources to fund apprentices, and
- too large an administrative burden to participate.

The government should support programs that include outreach strategies to small businesses as well as administrative requirements that are straightforward, may be done over the Internet and are not otherwise unduly burdensome. The government should consider providing a tax credit for small businesses participating in apprenticeship programs to incentivize their participation. The tax credit should be based on a percentage of compensation paid to the individual during the term of their apprenticeship and continue for up to two years should the individual be permanently hired by the small company providing the training. We believe the multi-year engagement between apprentices and small companies combined with a tax incentive will lead to increased and better recruitment, training and retention results for small firms.

Specialized Manufacturing Extension Partnership (MEP) Centers:[68] A select number of MEP centers should have increased capacity (e.g., equipment, personnel, etc.) for advanced/digital manufacturing processes and technologies (e.g., AM) to allow hands on training as well as access to equipment for small businesses. In the case of AM, a number of existing or newly created MEPs would specialize in AM. These MEPs would receive industrial AM systems capable of prototyping and parts manufacturing.[69] These specialized MEPs would provide a platform for both S&E and production job workers at small businesses to gain experience on AM equipment and processes. These centers could also serve as a facility where individuals getting training in AM from community colleges and technical schools could gain some hands-on experience. The government could defray some costs by seeking contributions of AM equipment, software and materials from AM system manufacturers.

[67] One such effort is the Minnesota Advanced Manufacturing Workforce Pilot, led by South Central Community College. This group of 24 community colleges and employers is developing scalable apprenticeship models in mechatronics, as well as computer integrated machining and welding (accessed August 20, 2014).
[68] The National Institute of Standards and Technology's Hollings Manufacturing Extension Partnership (MEP) is a national network of centers located in all 50 states and Puerto Rico that works with small and mid-sized U.S. manufacturers to help them increase their efficiency by providing services focused on productivity improvement, product and workforce development, business practices and technology transfer.
[69] There are 60 MEP centers across the country with 5-7 centers with AM systems for prototyping.

BARRIER 5:
ACCESS TO CAPITAL STILL IMPEDES SMALL BUSINESS GROWTH.

1 Discovery/ Identified Market Need	2 Technology Demonstration	3 Product Development	4 Commercialization/ Market Entry	5 Early Stage Growth	6 Economic Development Impact Growth
Capital Access					

What we heard. Access to capital remains a major problem for small businesses. Access to capital was the top impediment to small business growth cited by 36.8% of the respondents in the IEEE Survey. It was also cited as one of the biggest challenges for bringing a product to market according to 44.8% of IEEE Survey participants. Small innovative companies are often able to access government funding to develop their product through the proof of concept and/or technology demonstration stage.[70] However, they face major challenges finding capital to move from proof of concept to completing product development and introducing the product to the market (commonly referred to as the "valley of death"). Institutional investors (e.g., venture capitalists) traditionally don't invest in companies during this period because of the risk that the product may not be commercialized and the resulting loss of their investment.

However, venture capital funds with less than $50 million in assets under management (micro VC funds) that invest in seed/early stage companies have been gaining in popularity over the last few years. Over 50% of venture capital deals that closed during the six-month period from November 2013 through April 2014 were made by funds with assets under management of less than $50 million, and 65% of them had less than $100 million.[71] While the growth of micro VC funds is a positive development, they tend to invest in Internet and mobile computing businesses rather than capital intensive industries.[72] Angel investors and crowdfunding have become increasingly important financing sources for small innovative companies.

Once companies have entered the market, they will need access to additional capital, both debt and equity, to grow their business. Angel investors and venture capital funds are active investors at this stage. It is still not easy to raise equity funding even though there is probably more capital available to small innovative companies at this time due to the advent of crowdfunding, and increasing angel investment and venture capital activity (including micro VC funds and corporate VC funds). Small innovative companies have challenges accessing bank financing because they often have little collateral besides their intellectual property (IP) to support their loan application and they may not have the financial performance required to qualify for a loan. The lack of collateral and lack of operating history or poor performance were the top reasons cited in the IEEE Survey why small innovative companies are unable to get funding.

[70] Startups may get financing from SBIRs/STTRs or other federally funded government research grants. Some states also have programs that provide funding for startups. In the private sector, startups may get funding from angel investors, VC funds focused on startups, or their own savings (self-financing).
[71] The micro VC glut, CB Insights, May 6, 2014.
[72] Micro VC rising: Analyzing trends and the top investors in the micro VC ecosystem, CB Insights, June 19, 2014.

Manufacturers of personal 3D printers have had some success with crowdfunding with at least seven companies raising over $750,000 on the crowdfunding site Kickstarter in the last two years. One of these companies, MD3 LLC, located in Bethesda, Maryland, raised $2.9 million in May 2014. In July 2014, Kickstarter had 274 crowdfunding campaigns involving 3D printing technologies. Seed and angel investment represented 64% of AM company financing.[73] Venture capitalist increased their investments in AM in 2013. As of 2014 Q1, there was $79 million invested in 15 deals representing growth in investment activity of almost 320%.

BEST PRACTICES

SBA loan process: The SBA has streamlined some of its underwriting requirements used by banks for small loans hoping to increase the number of SBA loans going to small businesses. Banks can now omit doing a cash flow analysis or reviewing the debt-service coverage on loans of $350,000 or less if the business owner satisfies the agency's other credit standards. The SBA hopes that by streamlining the process more banks will increase the number of small loans approved. While touted as a way to get loans to minority businesses, this change can also help small innovative companies, many of which have little collateral and weaker financial performance, gain access to capital as well.

Government venture investing: As part of the President's Startup America initiative, the SBA has developed and begun licensing early stage small business investment companies (SBICs) that focus on investing in high growth companies.[74] Early stage SBICs will invest at least 50% of their capital into early stage companies that are not yet profitable at the time of investment and the other 50% in small companies as defined by the SBA.

There are a number of states that have programs providing capital to early-stage innovative companies. Examples include the Maryland Venture Fund, the Innovate New York Fund, and the Michigan Pre-Seed Fund Loan Program.[75]

The Jumpstart Our Business Startups Act of 2012 (JOBS Act): The JOBS Act amended securities laws to relax the rules and expand the methods for small companies to raise capital. The JOBS Act included equity crowdfunding, a new Regulation D provision allowing the general solicitation of purchasers of company stock under certain conditions, and an increase in the Regulation A exemption from $5 million to $50 million (Regulation A+). There has been criticism of the JOBS Act, particularly regarding the crowdfunding provisions, that the proposed rules are still burdensome on small businesses trying to raise capital. In fact, final rules for crowdfunding and Regulation A+ have not been implemented as this report was being finalized and it is not clear how much the Regulation D general solicitation offerings are being used. There have been discussions and proposed bills for a JOBS Act 2.0. While the intention to facilitate capital formation for small business is good, implementation of this law is proving frustrating to the small business and investment community.

[73] VCs warm up to 3D printing, CB Insights, April 22, 2014.
[74] SBICs are privately owned and managed investment funds, licensed and regulated by SBA, that use their own capital plus potential additional funding from the SBA in the form of SBA guaranteed debentures to make equity and debt investments in small businesses. The SBA does not invest directly into small business through the SBIC Program, but provides funding to qualified investment management firms with expertise in certain sectors or industries.
[75] The Maryland Venture Fund website; the Innovate New York Fund website; the Michigan Pre-Seed Fund Loan Program.

Explore the Creation of an SBA IP Loan Guaranty Program: This program would guarantee loans to small innovative companies that have little to no collateral except for their IP. IP and other intangible assets are becoming more important to company growth and value. However, unlike physical assets, companies are rarely able to use their IP to secure a loan or investment potentially leading to increased capital costs. IP represents a growing source of capital (in the form of royalties and licensing fees) generating approximately $120 billion for all U.S. firms globally.[76] The problem is banks are uncomfortable lending against this asset class. Issues regarding valuation, obtaining a valid security interest and liquidation of the assets upon default are legitimate concerns by a potential lender.[77] To offset these risks, lenders may be extremely conservative underwriting such loans resulting in small companies receiving financing with a low loan-to-value ratio for their IP.[78] The SBA guaranty would allow the company to receive additional loan proceeds. The SBA should work with IP lenders, IP valuation experts, lawyers, etc. to determine if such a guaranty program could be implemented.

If the SBA decided to move forward with an IP guaranty program, it should convene regulators, bank industry groups, etc. to begin a campaign to educate the market about using IP and intangible assets to finance businesses. In an increasingly knowledge based market where IP will play an important part, U.S. companies need to be able to unlock the value of their IP to grow their businesses.

Support Angel Investors: Angel investors are a key source of funding for seed and early stage companies. In 2013, angel investors invested $24.8 billion into startup and seed stage companies (45% of total angel investment) with an average deal size of $350,000.[79] Policies should be adopted to incentivize angel investors to keep providing this critical source of capital to innovative companies. Recommended policies include:

- Accredited investor definition: Beginning in 2014, the Securities and Exchange Commission (SEC) must review the definition of accredited investor to determine if it needs to be modified for the protection of investors every 4 years pursuant to the Dodd-Frank Financial Reform Act. Any increase in financial thresholds in the current definition will lead to a decrease in the number angel investors.[80] According to the SEC, an increase in the net worth requirement from $1 million to $2.5 million would decrease the number of eligible accredited investors by 60%.[81] The Angel Capital Association has indicated that 25% of their 12,000-plus members would become ineligible. The loss of this many angel investors will be highly detrimental to small innovative company fundraising. It is recommended that the SEC be required to consider the potential adverse impact on the number of angel investors should it change the financial thresholds in the definition of accredited investor. No change should be adopted by the SEC if it will result in a potential decrease of more than 10% of

[76] NSF, Science and Engineering Indicators 2014, U.S. Bureau of Economic Analysis, U.S. International Services–Cross-Border Trade in 2012 and Services Supplied Through Affiliates in 2011, October 2013. Index Mundi, United States-Royalties and Licensing Fees.
[77] UK Intellectual Property Office, Banking on IP? The role of Intellectual Property and Intangible Assets in Facilitating Business Finance, 2013.
[78] Kenan Jarboe, Intangible assets innovative financing for innovation, Issues in Science and Technology, November 2013.
[79] Jeffery Sohl, The Angel Investment Market in 2013: A Return to Seed Investing, Center for Venture Research, April 2014.
[80] An accredited investor is currently defined as an individual with $1 million in net assets excluding their primary home, or income of $200,000, if single and $300,000 if married.
[81] SEC Release No. 33-9415 Eliminating the Prohibition Against General Solicitation and General Advertising in Rule 506 and Rule 144A Offerings, Economic Analysis.

eligible households that would qualify as accredited investors under the current definition. If the SEC does change the definition causing a 10% decrease or more, it should then consider alternative methods for individuals to qualify as accredited investors such as relying on an investment professional, possession of a professional certification, etc.

- Angel investor tax credit: The U.S. should enact a national tax credit for investments by angels into small companies working in high technology fields. Investors would receive a 20% credit if they hold the equity for a minimum of three years with the credit being allocated as follows: year 1—0%, year 2—10%, and year 3—10%. Investors in companies working on designated technologies that take longer to develop (LD technologies) such as biotechnology and pharmaceuticals would receive a 40% credit if the equity is held a minimum of five years with 10% of the credit being allocated in years 2 through 5. The higher credit should incentivize investors to invest in LD technologies which need higher amounts of funding to get to market. In addition, given the issues of access to capital for minority and women entrepreneurs, the amount of the credit would increase by 5% in the final year for angels investing in minority- or woman-owned technology company.[82] To increase the attractiveness of the tax credits, they should be tradable and not be eliminated by the alternative minimum tax. The American Opportunity Act of 2011 that was introduced in the Senate (S. 256) contained an angel tax credit proposal that never became law but could be a starting point for drafting legislation.

Technology Commercialization Assistance Fund: This fund would add to existing commercialization assistance tools, such as SBIR Phase III.[83] This new fund would invest in companies that have successfully completed a SBIR Phase II project that needs additional financing for commercialization activities. Limiting potential investment applicants to successful SBIR candidates allows the government to vet the technology and management team before committing to investing additional funds. The investment would be a royalty-backed security, secured by the company's IP. The government would receive total payments of between 125% and 200% of the investment amount over a repayment period of 10 to 12 years. The amount of the repayment would increase the longer the company takes to repay. This incentivizes the company to repay the investment sooner. The cap on the repayment amount should also be attractive to current or potential equity investors because they know the fixed repayment amount to the government and do not have to share in the upside of the potential increased equity value in the future. By requiring repayment, the government can use the investment proceeds to help fund future commercialization efforts. The fund does not conflict, in letter or spirit, with the Bayh–Dole Act because the fund is specifically funding commercialization activities and not research. Fifty-four percent of respondents in the IEEE survey believed it would be fair if the government receives a return on investment for funding a company's commercialization activities.

Improve and re-implement SBA Participating Securities: The SBA licenses and regulates SBICs that are privately owned and managed investment funds that use their own capital plus additional

[82] Sohl, Angel Investment Market in 2013. In 2013, minority-owned companies represented 7% of firms pitching to angel investors with 13% receiving funding. Women-owned companies represented 23% of firms pitching to angel investors with 19% receiving investment. The investment yield rate has been high the last two years, averaging 21.5%, but traditionally it has been around 15%.

[83] SBIR Phase III is the commercialization phase, in which a project moves from prototype to production through agency contracts for the specific item. The SBIR website describes it as follows: "The objective of Phase III, where appropriate, is for the small business to pursue commercialization objectives resulting from the Phase I/II R/R&D activities. The SBIR program does not fund Phase III. Some Federal agencies, Phase III may involve follow-on non-SBIR funded R&D or production contracts for products, processes or services intended for use by the U.S. Government."

funding from the SBA in the form of SBA guaranteed debentures (known as "leverage") to make equity and debt investments in small businesses. SBICs are eligible to receive two dollars in leverage (SBA debentures) for every dollar of private capital raised. The SBA debentures generally have a maturity of 10 years with semi-annual interest payments.

In 1992, the SBA created a new form of leverage known as a "participating security" which essentially gave the SBA a preferred limited partnership interest in the SBIC. The SBA was entitled to a preferred return and a share of the profits but did not receive regular periodic payments unlike the interest payments current SBICs make using the debenture leverage.[84] The participating security leverage was discontinued in 2004 after the technology bubble of 2002.

Re-implementing the participating security leverage would make it easier for SBIC funds to provide equity capital to growing small businesses. SBIC fund managers would be able invest in the equity of small businesses, which typically does not have a regular payment requirement, without having to be concerned about making an interest payment to the SBA (as required by the debenture leverage). This would be the same as standard venture/growth capital equity investments. Adjustments should be made to the terms of the participating securities to reduce the risk of loss to the SBA (e.g., only fund managers with early stage equity investment experience should be eligible for participating securities). Bringing back the participating security may lead to an increase in experienced managers in the SBIC program and an increase in available sources of equity capital for small growing innovative companies.

BARRIER 6:
SMALL INNOVATIVE COMPANIES HAVE DIFFICULTY COMMERCIALIZING PRODUCTS

1 Discovery/ Identified Market Need	2 Technology Demonstration	3 Product Development	4 Commercialization/ Market Entry	5 Early Stage Growth	6 Economic Development Impact Growth
	Difficulty Commercializing Products				

What we heard. Many small companies have difficulty commercializing (i.e., begin to sell to market) their technology products. The primary reasons challenges identified include these four:

- Management inexperience: During the development period before commercialization, the entrepreneur/management is not only finalizing technical aspects of their product but also taking steps to introduce and begin selling it in the market. Many researchers and small entrepreneurs may have experience building products but not necessarily taking a product to market.
- Lack of resources: The resource cited as most lacking by entrepreneurs was capital but other resources such as expertise, testing equipment, product designers, etc. can also lead to problems bringing a product to market.
- Lack of time: Many small companies already selling products into the market are challenged to finding the time and development resources to work on commercializing new products because they are so focused on growing their existing lines of business.

[84] Michael B. Staebler, Description of the small business investment company program participation by funds using debentures, November 1, 2013, accessed August 15, 2014.

- Incomplete product or no market: Many products based on research ideas fail to reach the market because they are only part of a full commercial product or solution or there is no current market for the product. However, these "failed" products may be picked up by another researcher or entrepreneur in the future when the product can be a critical part of a new commercial product.

Many small businesses also expressed reservations about partnering with large companies to develop their technologies. While acknowledging the many benefits of working with large companies such as access to personnel, equipment, financial resources, etc., entrepreneurs were concerned about protecting their IP or being able to negotiate an equitable split on any IP developed as a result of the collaboration.

BEST PRACTICES

NSF I-Corps Program: This program, discussed under Barrier Number 3, would also help strengthen companies' commercialization efforts.

Collaborative work environments: These include accelerators, clusters, manufacturing institutes, andMEPs. Entrepreneurs consistently state that being able to brainstorm or collaborate with colleagues is extremely helpful in solving technical and business problems.

BIG IDEAS–RECOMMENDATIONS

Expand the NSF I-Corps Program: See discussion under Barrier Number 3

Commercialization training program: A program should be developed, similar in structure to the NSF I-Corps Program, to teach small firm management teams about the product commercialization process. The program would be available for teams that have been awarded a SBIR Phase II grant. Focusing teams on commercialization planning early during the product development stage will lead to better odds of the product reaching the market. There are examples of agencies providing some commercialization training, providing an opportunity for collaborative efforts and sharing of best practices. These include the Department of Defense (DARPA Small Business Planning Tool), Department of Energy (Commercialization Assistance Program) and NIH (Niche Assessment Program).[85] As part of the program, a database should be developed of CEOs who have successfully commercialized a product through the SBIR process and who are willing to serve as mentors or consultants to teams to assist them commercialize their product.

Commercialization assessment: A commercialization assessment should be performed on technologies after the first year of the SBIR Phase II grant. The assessment would evaluate the strength of the team's technology or product against what is currently in the market, the strength of its IP position, and potential market barriers and opportunities. As a result of the assessment, teams can improve their commercialization plans as well as determine how to best allocate resources going forward. The assessment may also save time and money for the team and the sponsoring agency if there appears to be little likelihood of commercialization. The committee performing the assessments would consist of agency representatives as well as outside professionals experienced in the technology and product commercialization. All SBIR Phase II awardees would be required to go

[85] See DARPA Small Business Planning Tool website; DOE Commercialization Assistance Program website; and NIH Niche Assessment Program website.

through an assessment except those that either have received funding from and institutional investor or have established an affiliation with a large corporation.

BARRIER 7:
TECHNOLOGY DIFFUSION AND ADOPTION IS MORE DIFFICULT FOR SMALL BUSINESSES.

1 Discovery/ Identified Market Need	2 Technology Demonstration	3 Product Development	4 Commercialization/ Market Entry	5 Early Stage Growth	6 Economic Development Impact Growth
			Technology Diffusion and Adoption		

What we heard. Technology diffusion is the process of building awareness and distributing technical information and know-how about a technology for later adoption and use in the market by customers. Small businesses are often challenged learning about a new technology.[86] In the case of AM, many small companies have read or heard about AM but do not understand the technology's capabilities and are not clear about the benefits to the business.[87] Some of the barriers to AM diffusion and adoption by small businesses include:

- Technology evaluation: Small firms may not have the in-house personnel to evaluate AM technology and potential applications.
- Lack of time: Small firm management may not have sufficient time to evaluate AM due to focus on current business.
- Business case: Small firms may not have access to information or the proper in-house framework to evaluate the business case for adopting AM (e.g., cost-benefit analysis, return-on-investment).
- Cost: Small firms may not have a sufficient budget to experiment and evaluate a new technology particularly if such activities require a large financial commitment as is the case with AM. There is a fear of wasting time and money if the technology doesn't work for their business.
- Workforce skills gap: Small firms may not have the personnel with proper skill sets to adopt AM.
- Reluctance to change: Companies may have already invested in assets and infrastructure supporting conventional manufacturing processes and will not want to abandon those lines of business. Further, a new technology like AM may affect the company's business model and its relationship with suppliers and customers. Management may not want to pursue AM due to these potential disruptions.

Entrepreneurs who lack access to information about the capabilities of any technology, including AM, and its benefits are then faced with the challenge of determining which external sources of information to believe and trust or who can help them.

[86] Phillip Shipira, Stuart Rosenfeld, An Overview of Technology Diffusion Policies and Programs to Enhance the Technological Absorptive Capabilities of Small and Medium Enterprises, background paper prepared for the OECD Directorate for Science, Technology and Industry, August 1996.
[87] Daniel L. Cohen, Fostering mainstream adoption of industrial 3D printing: Understanding the benefits and promoting organizational readiness, 3D Printing, vol. 1, no. 2, 2014.

The challenge of technology diffusion and adoption is clearly a barrier for those companies considering incorporating a new technology into its business. However, it is also a barrier for small firms that commercialize new technologies because if the technology is not adopted by the market, the commercializing firms will be unable to grow.

Like many other instances when new technologies come to market, another barrier for companies adopting AM has been the lack of standards regarding AM materials and processes. AM processes involve building an item layer by layer by binding materials (e.g., metal, plastics) using heat. Researchers and industry are trying to determine the impact of the thermal dynamic processes and properties and attributes of products made from different materials, particularly of metals, that are subject to various AM processes. For example, does a metal part made using one AM process have different characteristics from the same part using a different AM process? Is one part stronger? More malleable? Do they react to temperature changes differently? AM parts and processes must have known and predicable qualities and be repeatable in order for AM to gain widespread acceptance. This is especially important in any industry (e.g., aviation) where the manufacturing process is required to be certified (in addition to the parts themselves). Standards to test for these characteristics also need to be developed. The industry is well aware of this issue and standards are currently being developed.

In 2009, the ASTM International Technical Committee F42 on Additive Manufacturing was established for "the promotion of knowledge, stimulation of research and implementation of technology through the development of standards for additive manufacturing technologies."[88] The ASTM F42 Committee has partnered with the ISO Technical Committee 261 on Additive Manufacturing to develop standards. The ASTM F42 Committee has over 200 members from 16 countries; it has approved 10 AM standards and another 20 are being developed. The standards are available for consideration by all global markets. Their development will help increase the adoption rate of AM and move the industry forward by providing a common set of rules, definitions, processes, and guidelines which will improve product quality and safety. The development of standards and cataloging of material properties of the various AM processes will also help identify which ones are best suited for a particular application. Standard-setting will help small companies make the informed choices regarding equipment and materials to use for their business.

BEST PRACTICES

The National Institute of Standards and Technology's Hollings Manufacturing Extension Partnership (MEP): MEP is a national network of centers located in the 50 states and Puerto Rico that work with small and mid-sized U.S. manufacturers to help them increase their efficiency by providing services focused on productivity improvement, product and workforce development, business practices and technology transfer.[89] The MEP's technology scouting program works with small and medium-size manufacturers to help find technology solutions to product or production problems.[90] For this program to be more effective for manufacturers interested in AM, more MEP facilities would need to add equipment and expertise for both AM prototyping and product production. (Also see the discussion of specialized MEP centers under Barrier Number 4, shortage of engineering talent.)

America Makes: See the discussion of America Makes, under Barrier 2, increasing R&D support.

[88] The ASTM International Technical Committee F42 on Additive Manufacturing Fact Sheet.
[89] NIST's Manufacturing Extension Partnership website.
[90] MEP's Technology Scouting Program website.

Small business technology diffusion strategy: The government should develop a strategy specifically focused on the diffusion of manufacturing technologies to small businesses. Many of the barriers to diffusion involve lack of access to information. The government is positioned to have access to much information about technical capabilities and business metrics surrounding new technologies. What information it does not have, it can certainly develop itself or in partnership with the private sector. To effectively disseminate the information, one or more "trusted sources" must be created. In the case of AM, America Makes is a natural choice. All research information about AM that has been developed or sponsored by the government should be housed at America Makes or other trusted sources, and it should be made available in a searchable database accessible to small businesses. The information can include technical capabilities as well as impact studies of AM on return-on-investment, business models, energy consumption, and other key concerns. In addition to trusted sources, the strategy must include getting the information out to small businesses. The government and trusted sources should develop specific content for small businesses and leverage existing networks like MEP centers to disseminate the information. Finally, adoption rates should be continuously monitored to determine the effectiveness of the strategy.

Emerging technology briefings: The government or other institution, potentially in partnership with the federal government, should take the lead in publishing a briefing directed at small businesses on technical capabilities, business metrics, and applicable laws and regulations specific to emerging technologies key to the U.S. economy. These briefings would provide small businesses with concise information on a new technology such as current and potential applications, market information, cost models, as well as the legal and regulatory landscape for those developing or adopting the technology. This information would provide an excellent starting point for small businesses trying to decide whether or not to pursue the development or adoption of a particular technology. The briefings would be available on the websites of the appropriate government agencies and the trusted sources.

Coordination among NMIIs: The technologies being studied at the various NMIIs cut across many applications thus providing opportunities for technological interaction. The diffusion of all the technologies involved would be enhanced with some coordinated effort among the NMIIs. For example, America Makes should coordinate efforts with the Digital Manufacturing and Design Innovation Institute and the Lightweight and Modern Metals Manufacturing Innovation Institute, both of which started operations in February 2014. Increased coordination between the NMIIs could also lead to focused research initiatives that may enhance the technologies being studied.

BARRIER 8:
HIGH EQUIPMENT COSTS ARE A BARRIER TO ENTRY FOR SMALL BUSINESSES IMPLEMENTING NEW TECHNOLOGIES.

1 Discovery/ Identified Market Need	2 Technology Demonstration	3 Product Development	4 Commercialization/ Market Entry	5 Early Stage Growth	6 Economic Development Impact Growth
			New Technology Implementation Costs		

What we heard: In some technology sectors (e.g., software), equipment costs have decreased significantly making it easier for small businesses to enter the market. However, in advanced manufacturing and AM, equipment cost can still be a barrier to technology implementation and growth. The cost of industrial AM systems is increasingly making it difficult for small businesses to enter the market. The average selling price for an industrial system was $90,370.[91] Prices of high-end systems capable of producing metal parts can be over $1 million. In addition, material prices and system maintenance costs also drive up the expense of using AM. Over time, the costs of industrial systems, along with material and maintenance costs, are expected to decrease even as the capabilities of these systems improve.

Many small businesses are using lower-end industrial systems or personal 3D printers to experiment with the technology. This level of capability is suitable for some businesses.. There are companies establishing networks of 3D printers around the world. [92] Customers are able to upload an STL file, receive quotes and choose among geographically dispersed networked members that own a 3D printer to make the object. The networks appear to be comprised mostly of individuals and small firms using 3D printers, not large industrial AM systems; they are being used for prototyping, modeling and do-it-yourself or hobby projects. The networked printer model can help some small companies enter the AM market and would become more powerful as the capabilities of the 3D printers improve. However, for those small businesses trying to enter the market for finished AM parts, the expense associated with AM technology will remain a potential barrier. In addition, small firms will also incur costs to make their equipment and processes compatible with digital manufacturing requirements including issues surrounding data storage, security, and privacy.

BEST PRACTICES

None identified.

BIG IDEAS–RECOMMENDATIONS

Innovation Equipment Lease Guaranty: The SBA should create a program whereby it would guaranty certain equipment leases by small businesses. The small business must be leasing new equipment that is an upgrade to its current equipment. The lease must involve total equipment cost of at least $50,000. An upgrade would include equipment with new capabilities and functionality enabling the

[91] Wohlers Associates, The Wohlers Report 2014, page 111.
[92] For example 3D Hubs based in Holland and Makexyz based in New York.

production of higher quality products. It would not include replacing older model equipment with the newest version. For example, a small manufacturer that was either new to AM or had been experimenting with personal 3D printers could use the program if it was adding a new lower-end industrial AM system. That same business could also qualify if it then wanted to lease a higher-end industrial system that used metal materials.

BARRIER 9:
SMALL COMPANIES NEED ACCESS TO MORE BUSINESS OPPORTUNITIES.

1 Discovery/ Identified Market Need	2 Technology Demonstration	3 Product Development	4 Commercialization/ Market Entry	5 Early Stage Growth	6 Economic Development Impact Growth
			Lack of Small Business Opportunities		

What we heard: Small companies want the government to make a stronger effort to buy more goods and services from them. Many small innovative companies believe that government can do more to support small firms selling innovative products and services. Government procurement can involve the purchase of existing products and services, pre-commercialized products and services requiring some level of R&D (e.g., Phase III SBIR), and newly created products and services that did not previously exist.[93] Government procurement of innovative technology products and services can help develop the market for such products and services. Government use and acceptance of the product or service can also help lower the perceived risk of adoption by the private sector.

For small businesses, the challenge most often cited was the complexity and administrative burden of government contracting. This included businesses selling existing products and services as well as those selling pre-commercialized products. Many small firms noted that the amount of time, money and effort required to respond to government contract opportunities is simply unfeasible, particularly as there is no guarantee the firm will get a contract.[94]

For its part, the government has similar challenges to adopting an innovative product as the private sector. These include technical risk such as whether the product will perform as required or even be fully developed, and organizational risk such as aversion to trying a new technology, compatibility issues with current equipment or processes, and costs associated with new product fitting within budget.[95] Government must also balance the need to help small innovative companies through procurement with the need to wisely spend taxpayer dollars and make smart purchases to help government provide quality services to U.S. citizens.

BEST PRACTICES

RFP–EZ: RFP-EZ was a pilot program designed to make it easier for small innovative companies, which historically have not done business with the government, to find and submit bids or proposals on federal contract opportunities less than $150,000.[96] The goals of RFP-EZ were to reduce

[93] OECD, Innovation Procurement Schemes, The Innovation Policy Platform, accessed August 20, 2014.
[94] In the effort to meet the annual small business goal of 23% of federal procurement, small firms are awarded some $80 billion in federal procurement awarded annually.
[95] OECD, Innovation Procurement Schemes citing Tsipouri, L., et al., (2010): "Risk Management in the Procurement of Innovation," Report of an Expert Group for the EU Commission, Brussels.
[96] The RFP-EZ website.

administrative costs, improve opportunities for small businesses, increase contracting efficiency, and decrease the burden on small business and contracting agencies. It would be worthwhile to evaluate how effective this pilot program was, in particular in decreasing contracting time and increasing contracts to small technology companies.

Challenge.gov: Challenge.gov contains a list of challenges and prize competitions run by more than 50 agencies across the federal government.[97] Government agencies solicit innovative solutions from the public to address mission focused technical and scientific problems. It essentially is the government procuring products/solutions that don't currently exist. Since 2010 federal agencies have held over 280 challenge and prize competitions. A recent review of the website showed challenges ranging from zero (i.e., nonmonetary prizes) to $15 million. These competitions provide an opportunity for small innovative companies to submit their solutions and potentially begin selling to the federal government.

BIG IDEAS–RECOMMENDATIONS

Follow up and strengthen RFP-EZ and Challenge.gov: Since the RFP-EZ pilot has ended, follow-up evaluation is needed to assess its effectiveness. We recommend increased use of a tool such as RFP-EZ by federal agencies and an increase in the contract limit to $2 million. An increase in the complexity of the tasks and award sizes would increase the likelihood of participation by small businesses. The amount of the award needs to be enough to entice an entrepreneur or small company to submit a proposal. In addition, websites like Challenge.gov, focused on opportunities for small innovative companies, will benefit these businesses.

Create a small innovative company database: A database of small innovative companies should be created containing comprehensive profiles relevant to government contracting for each firm. These profiles should be set up to allow a company's information to populate all contracting forms from various government agencies should the firm decide to pursue a specific contract opportunity. The ability of small firms to complete various agency contracting forms from its profile would substantially decrease the time and effort required to pursue government contracts. The database would also allow government agencies to search for firms with particular capabilities and invite them to bid on contract opportunities instead of only relying on firms that respond to a request for proposal.

Expand use of agency "other transaction" authority: Other transaction (OT) authority allows certain agencies to buy innovative products from small businesses. This tool should be expanded to other agencies. .

Certain federal agencies use OTs to obtain or advance R&D or prototypes. An OT is not a contract but a special vehicle that allows the government the flexibility to get access to leading edge R&D and prototypes outside the requirements of the federal procurement regulations.[98] This OT authority is meant to attract companies that are not traditional contractors or do not comply with the federal procurement regulations.[99] The following agencies have OT authority: [100]

[97] See the Challenge.gov website.
[98] L. Elaine Halchin, Other Transaction (OT) Authority, Congressional Research Service, August 2011.
[99] GAO, Report to Congressional Committees, Homeland Security–Further Action Needed to Improve Management of Special Acquisition Authority, May 2012. Information on OTs is difficult to track due to a lack of specific reporting obligations but it appears that some agencies have been using it with traditional contractors (i.e., large companies). While

- Department of Energy
- Department of Transportation,
- Department of Defense,
- Department of Homeland Security,
- Federal Aviation Administration,
- NASA,
- National Institutes of Health, and
- Transportation Security Administration.

The agencies with OT authority could use it now with small companies for R&D and prototypes.

In brief, we are suggesting two things: expanding OT authority for any product or service from a small innovative company, and giving additional federal agencies permission to use OTs to purchase from small companies. Small innovative companies would benefit greatly by simply expanding this existing vehicle for providing products and services to the government outside of the normal federal contracting procedures.

BARRIER 10: TECHNOLOGY INNOVATIONS OFTEN RESULT IN REGULATORY UNCERTAINTY AND LEGAL CHALLENGES.

1 Discovery/ Identified Market Need	2 Technology Demonstration	3 Product Development	4 Commercialization/ Market Entry	5 Early Stage Growth	6 Economic Development Impact Growth
			Legal Uncertainty		

What we heard: There was strong agreement among the entrepreneurs and organizations contacted that the U.S. legal system strongly protects IP rights and contract rights which is important to innovation. IP was very important to 32% of small businesses participating in the IEEE Survey. Companies that are developing personal 3D printers and/or AM industrial systems or using them in their operations are not currently facing any significant legal or regulatory issues or burdens. Small companies we contacted indicated the only regulatory issues involved those around worker safety and the environment which they believed was adequately addressed by the current regulations. This is likely due in part to the relatively small size of the industry at this time. As AM grows, the level of scrutiny on the industry, its participants, the technical processes and various product applications will increase leading to additional laws and regulations being passed. In this regard, AM is like most new technologies with innovations around a new technology preceding regulation of its uses. While different technologies will trigger different legal issues, there were a few issues regarding AM that could limit small company growth due to legal and/or regulatory uncertainty.

Patents: The primary concern expressed among small innovative companies regarding patents was that the expense to patent a product is burdensome. small innovative companies incur patent costs

there is no quantitative evidence that OT increases the use of non-traditional contractors, most contracting managers believe it is an effective tool. Halchin, Other Transaction Authority.

[100] Certain other agencies may use OT under certain conditions and if approved by the director of the Office of Management and Budget. Halchin, Other Transaction Authority.

prior to generating any revenue from the product, thus requiring the companies to find a source of funding for the patent expenses. Although not technically a legal issue or uncertainty, high patent expense is mentioned here because almost every entrepreneur we contacted cited this as a barrier despite the USPTO requiring lower patent fees for small and micro entities.

Patent infringement lawsuits among AM manufacturers have increased in the last few years.[101] The potential threat of a patent lawsuit may have a chilling effect on small innovative companies attempting to commercialize a product; an actual lawsuit against a small innovative company could impair the firm's ability to survive and grow. However, to date, patent infringement entities or patent trolls have not appeared to cause significant problems in the AM industry, but they have become a problem in many other technology sectors.

Another issue is the impact of AM on IP rights and protection. An exhaustive discussion on the range of issues on this subject is beyond the scope of this report.[102] However, one of the core issues is how do you protect the rights of patent and copyright owners when AM technology provides a means for unfettered infringement? How this issue is resolved, either through court cases or legislation, will significantly affect the AM industry and its small business participants.

Liability: Liability for injury caused by an additive manufactured product is still somewhat an open legal question. The question of whether the CAD file designer, the AM system manufacturer, or the product producer, etc. is liable for an injury is likely to be resolved in due course via the legal system. The issue is less clear when the producer of the product is not in the business of manufacturing which is becoming a likely scenario as the personal 3D printer industry continues to grow.[103]

Stifling Technology Development: For all of AM's positive applications, it also has the ability to help individuals commit bad or illegal acts such as counterfeiting, weapon production, etc.[104] Policymakers and regulators should bear in mind that people have been doing bad or illegal acts for a long time, and AM is just another technology that can be used to facilitate such acts. As they consider the proper policies to enact, policymakers must balance society's need for protection against bad acts against the societal benefits from the technology's full development. It's important that policymakers try not to put in place measures that can stifle the development of the technology. For example, instead of enacting policies limiting 3D printer functionality to render

[101] *3D Systems vs. Formlabs* in 2012, and *Stratasys vs. Microboards Technology (dba Afinia)* in 2013. Each case involves a publicly traded manufacturer of AM systems and 3D printers suing a smaller company producing or distributing a different brand of 3D printer. The Stratasys case is of note because it is claiming infringement on patents regarding improvements to fused deposition modeling technology which is the technology used by almost all 3D printer manufacturers. Should Stratasys prevail, there are potential huge consequences for the 3D printer industry. See, Michael Weinberg, Afinia responds to Stratasys: Your patents are invalid and your threats are anticompetitive, Public Knowledge Blog, January 3, 2014.

[102] For good discussions on this topic, see Melba Kurman, Carrots, not sticks: rethinking enforcement of intellectual property rights for 3D-printed manufacturing, 3D Printing vol.1 no.1, 2014,; Michael Weinberg, It will be awesome if they don't screw it up: 3D printing, intellectual property, and the fight over the next great disruptive technology, Public Knowledge Blog white paper, November 2010.

[103] Nora Freeman Engstrom, 3-D printing and product liability: identifying the obstacles, University of Pennsylvania Law Review Online.

[104] Gartner.com predicts 3D printing will result in the loss of at least $100 billion per year in intellectual property globally by 2018.. Given the development of the technology at this point, the most vulnerable markets would one where the products are small and made of plastic (e.g., toys). The counterfeiting of metal products is unlikely due to the expense to produce product (i.e., AM system, materials, etc.), the expertise required to build parts and the limited number of AM metal product manufacturers and the relatively small supply chain for such products.

them incapable of printing certain items, consider requiring methods, such as steganography technologies, that will allow the attribution or tracking of products back to the 3D printer that created it.[105] It is also important that any policies enacted to counteract bad acts not place burdensome administrative requirements or monetary obligations on small firms trying to develop AM or other technologies.

Limiting Market Access: Imposing export controls on certain technologies can impair a small innovative company's growth potential. Export controls limit the number of countries a small business may sell its product. The potential consequences for limiting the market for certain technologies may include fewer firms pursuing development efforts for that technology and fewer investors providing funding for companies pursuing that particular technology. These are just a couple of examples of potential unintended consequences when an emerging technology is limited by law or regulation.[106] (This is taken up again in the discussion under Barrier 11 regarding export controls).

BEST PRACTICES

Recent Executive Action: On February 20, 2014, President Obama announced three new initiatives to encourage innovation and strengthening the patent system. Those initiatives, which will be implemented by the U.S. Patent and Trademark Office, are crowdsourcing prior art, having more robust technical training and expertise at the USPTO, and providing patent pro bono and pro se assistance.[107]

AM partnership meetings: For the last two years, the USPTO has hosted AM partnership meetings at its headquarters in Alexandria, Virginia. The goal of the program is for industry leaders, USPTO personnel and other stakeholders to exchange ideas and experiences about the state of the AM industry. This type of engagement should lead improved patent reviews by USPTO. Similar USPTO-industry working groups can be established for other emerging technologies.

BIG IDEAS–RECOMMENDATIONS

Technology Commercialization Assistance Fund: An investment from this fund could be used to pay patent filing expenses. See discussion under of the fund under Barrier 5 regarding access to capital.

Expand pro bono services: Allow small companies to take advantage of the USPTO's pro bono services in connection with the defense of the company's IP. Small firms could use the service if another company was accusing the small firm of patent infringement or the small firm wanted to prosecute an infringement claim against another company. Small companies are vulnerable to patent infringement and, in many cases, unable to defend or prosecute such claims due to the expense of patent litigation. The patent offers no benefit if the company is unable to enforce it.

Approve reasonable legislation dealing with patent trolls: The Innovation Act (HR 3309) was passed by the House of Representatives in December 2013.[108] The bill seeks to combat the issue of patent

[105] Cameron Naramore, Could your 3D printer someday spy on you? 3Dprinter.net, October 2012.
[106] Michael Weinberg, Undetectable firearms law passes without 3D printing, Public Knowledge blog. Recounts how restrictions were almost placed on AM technology in connection with the renewal of the Undetectable Firearms Act.
[107] On June 4, 2013, President Obama announced five executive actions "to help bring about greater transparency to the patent system and level the playing field for innovators." For a full description of all executive actions see http://www.uspto.gov/patents/init_events/executive_actions.jsp#heading-6
[108] The Innovation Act (HR 3309) summary.

trolls, which are companies that don't create or sell any products but acquire patents for the purpose of initiating patent infringement lawsuits against firms using technologies possibly related to the patent. Several groups, including, had reservations about the bill due to the ramifications for small inventors.[109] The issue of patent trolls should be addressed by a new bill that does not negatively affect small inventors.

BARRIER 11:
SMALL COMPANIES CONTINUE TO FACE CHALLENGES EXPORTING THEIR PRODUCTS AND SERVICES.

1 Discovery/ Identified Market Need	2 Technology Demonstration	3 Product Development	4 Commercialization/ Market Entry	5 Early Stage Growth	6 Economic Development Impact Growth
				Exporting	

What we heard: Small companies are becoming increasingly interested in and, in fact, participating more in exporting.[110] The most often heard issue was that it was still difficult for small innovative companies to find clear direction on what steps to take to begin exporting. Many small businesses we spoke with are unaware of the various government export assistance programs. Those businesses aware of the programs are often confused about which of the six agencies involved in exporting can provide the specific assistance needed for their firm (Department of Commerce, Export-Import Bank, Overseas Private Investment Corporation, Small Business Administration, U.S. Trade Development Agency, and the U.S. Trade Representative). This particular problem was recognized by President Obama when he sought authority to consolidate export activities of the different agencies.[111]

A related issue is that small businesses often do not have the resources (e.g., expertise and systems) to export because of its complex nature. Many small businesses must hire consultants to help with their exporting activities. Difficulty accessing specialized financial products to facilitate international sales was also noted. The Export–Import Bank does have small business products that provide for faster administrative processing and financial support for firms exporting. Another barrier noted as constraining exports was transportation costs. Small firms generally are not shipping in bulk and therefore their transportation cost structure is not as favorable as it is for large corporate exporters. The cumulative effect of these various expenses is that some small firms determine that exporting is too complex, expensive and not profitable so they decide not to do it.

Export controls can have significant impacts on small businesses and on technology industries. The potential impact can be seen by looking at export controls and AM. There is a possibility that the government ma place export controls on AM equipment, materials, and processes related to the production of metal parts/products. Export controls may have an adverse impact on the metal AM sector for two reasons: firms will be limited to exporting only to signatories to the Wasennaar

[109] See letter from Chief Counsel for Advocacy Winslow Sargeant to Sen. Mary Landrieu dated March 12, 2014.
[110] Small and medium-size enterprises (with fewer than 500 employees) represent almost 98% of the 302,360 firms that exported in 2011. Similarly SMEs made up 97% of U.S. manufacturers exporting representing 19% of the total value of manufacturing exports. Department of Commerce, International Trade Administration, U.S. Exporting Companies 2011.
[111] The White House, Government Reorganization Fact Sheet, January 13, 2012.

Agreement[112] (i.e., limited export markets) and U.S. firms will be required to obtain a license to export to Wasennaar countries. Current licensing times are range from 30 to 120 days or more, which is longer than in other member countries.

Export controls impede all companies in transacting business. Controls may be warranted in cases where the technology has potentially special or sensitive applications and limited foreign availability. This is not the case for AM. In fact, there are already experts and manufacturers of AM industrial systems that make metal products in a number of Wasennaar countries (e.g., Germany, France) and in countries not party to the treaty (e.g., China).

The effect on small businesses is often disproportionate when export controls are implemented. Small firms cannot afford to have compliance systems in place to manage their licensing, tracking, and reporting responsibilities like large companies. Small innovative companies are further burdened by the slow pace of export licensing determinations. Many firms simply cannot afford the carry costs of a delayed sale while they wait to be informed whether or not they will receive a license to export the product. Further, small companies are at risk of the customer purchasing from another country's manufacturer whose licensing process is faster or from another country without any export restrictions. They also run the risk of their product becoming technically obsolescent during the approval period.

There have been occasions where export controls have had the unintended consequence of negatively affecting entire U.S. industries such as satellites and five axis machine tools.[113] The U.S. is a leader in the growing AM technology industry. Hopefully that leadership will not be derailed by export controls.

BEST PRACTICES

Export Control Initiative: Launched in 2009, the Export Control Initiative attempts to simplify and make compliance requirements less burdensome under export laws and regulations by reviewing, reclassifying and combining into one list items subject to export controls.[114]

Export.gov: Export.gov is the federal government's export promotion and finance portal. The portal is targeted to small and medium-sized U.S. companies to provide them with information on exporting and export services. The portal combines information from many U.S. agencies and some

[112] "The Wassenaar Arrangement has been established in order to contribute to regional and international security and stability, by promoting transparency and greater responsibility in transfers of conventional arms and dual-use goods and technologies, thus preventing destabilising accumulations. Participating States seek, through their national policies, to ensure that transfers of these items do not contribute to the development or enhancement of military capabilities which undermine these goals, and are not diverted to support such capabilities. The decision to transfer or deny transfer of any item is the sole responsibility of each Participating State." There are 41 other countries besides the U.S. party to the arrangement.

[113] National Air and Space Intelligence Center, Briefing of the Working Group on the Health of the U.S. Space Industrial Base and the Impact of Export Controls, Center for Strategic and International Studies, February 2008 (satellites); Richard A. McCormack, U.S. precision machine tool industry is no longer a global competitive force, Manufacturing and Technology News, March 5, 2010.

[114] Export Control Reform Initiative website. Currently, the export of military items that are listed on the U.S. Munitions List (USML) is the responsibility of the State Department's Directorate of Defense Trade Controls pursuant to the International Traffic in Arms Regulations (ITAR). The export of certain commercial or duel use items that are listed on the Commercial Control List (CCL) is the responsibility of the Department of Commerce's Bureau of Industry and Security pursuant to the Export Administration Regulations. The Export Administration Regulations are, among other things, combining the USML and CCL into a single list of items subject to export control.

private sector companies and is meant to be a starting place for companies interested in starting or expanding their exporting activities.

State Trade and Export Promotion (STEP) Grant Program: The STEP program is a three-year pilot program that makes matching grants to states to assist small businesses begin and succeed in exporting. Services under the program are provided by state government organizations and administered at the national level by the SBA. Some of the services offered through STEP include supporting small business participating in foreign trade shows and foreign market sales trips, website translation, assistance in international marketing efforts, subscription to services provided by the Department of Commerce, export trade show exhibits, training, and other efforts aligned with program goals. There is broad support from the small business community to make STEP a permanent program.[115]

National Export Initiative/Next (NEI/NEXT): In 2010, the President initiated a government-wide effort to assist U.S. businesses increase exports and expand into new markets called the National Export Initiative (NEI). NEI has helped increase U.S. exports for four consecutive years reaching an all-time high of $2.3 trillion in 2013 and supporting 11.3 million jobs.[116] Building on the success of NEI, the Administration announced the launch of NEI/NEXT in May 2014. NEI/NEXT is a data-based, customer service-driven initiative designed to further support U.S. companies exporting by: [117]

- providing export assistance to connect with overseas customers,
- facilitating trade by streamlining government processes and reporting requirements to make export shipments easier and less expensive,
- expanding access to export financing,
- expanding state and local partnerships to include exporting and attracting foreign investment as part of their economic development strategy, and
- working with foreign economies to improve their business environment and open markets so that American companies can more easily export abroad.

BIG IDEAS - RECOMMENDATIONS

Promotional campaign for federal trade agencies: The federal agencies with trade responsibilities and Export.gov provide much-needed export assistance to small firms via their respective websites, but based on our outreach, this information is not getting out to small businesses. The agencies should create and execute a promotional campaign to advise small businesses about their programs and capabilities. Higher utilization of these agency tools will help small innovative companies export.

Export counselors: The government should create a division of export counselors that are cross-trained with in depth knowledge about all government export programs that can assist small businesses. These counselors can serve as an entry point for small businesses ready to begin exporting that have submitted a profile detailing company information and exporting goals. Export.Gov is a great portal for entrepreneurs to learn about exporting. However, given its complex nature, many entrepreneurs would likely prefer being able to discuss their plans with a live person who can provide direct assistance.

---

[115] State Trade and Export Promotion (STEP) Grant Program website, accessed August 15, 2014.
[116] Department of Commerce International Trade Administration, Fact Sheet, National Export Initiative/NEXT, accessed August 15, 2014.
[117] U.S. Trade Promotion Coordinating Committee and Export Promotion Cabinet, National Export Initiative/NEXT–Strategic Framework, May 13, 2014, accessed August 15, 2014.

Cross training allows the counselors to assess the needs of the company and recommend the proper program(s) at the appropriate agency or agencies. This centralized entry point for exporting would allow the agencies to decrease the level of their individual outreach activities. In addition, those programs that are being utilized most can be expanded or improved while those that are not can be revised or eliminated.

The program should use customer relationship management software (CRMS) to track companies that apply and use government programs to export. The CRMS will allow any counselor or any program manager at an export agency to see a history of federal export assistance a company has received and review the company's progress. This will allow government personnel to direct businesses to get the proper resources based on the company's stage of business development and export experience. The CRMS will also allow the government to capture data which can be used to improve its export programs and serve small businesses better. The CRMS must be carefully designed to allay the privacy concerns of the participating small businesses.

CONCLUSIONS

The Office of Advocacy's Innovation Initiative was charged with identifying the challenges and barriers hindering the growth and development of small innovative companies, and offering actionable solutions that may be implemented by or in conjunction with the government to surmount such barriers. The 11 barriers cited were never intended to be an exhaustive list of the barriers we heard about from the entrepreneurs and organizations interviewed. They are, however, the most often cited barriers, and collectively, they illustrate the complexity of the challenges to small innovative company growth and their dynamic, multidisciplinary nature. This broad examination of 11 barriers to innovative company growth has highlighted dozens of institutions and programs that are worth supporting and replicating in the goal of strengthening America's innovation ecosystem. Two additional general recommendations cut across most all of these areas toward the goal of facilitating small innovative company growth.

Pilot programs: For those agencies involved in the innovation process, a small portion of their budgets should be reserved to allow agency heads to implement initiatives or pilot programs to facilitate innovation or innovative company growth. Reserving funds for pilot programs gives agency heads latitude to experiment and try new things and will help eliminate inaction due to fear of failure. Innovations don't always work, and these pilots won't always be successful. However, fostering an environment that encourages new ideas and risk taking will benefit federal agencies seeking to assist innovative companies.

Coordination of innovation initiatives: Fostering an environment where small innovative companies can grow is a complex undertaking. It involves multiple disciplines including education, R&D, workforce development and training, finance, and law. If we believe that innovative companies are important drivers of our economy, then we need to increase the coordination of government resources, programs and initiatives to ensure a robust innovation ecosystem exists in the United States. President Obama recognized the need for greater efficiency in 2011 with his Government Reform for Competitiveness and Innovation Initiative. [118]

Other commentators have echoed the need for increased coordination of government innovation efforts. The Center for American Progress put forth a proposal in 2012 to streamline and integrate various government programs and infrastructure to focus on U.S. competitiveness and innovation.[119] Similarly, an expert panel looking at challenges to commercializing federally funded R&D recommended the creation of a new Office of Innovation and Federal Technology Partnerships. This office would coordinate, implement, and monitor government efforts to commercialize federal R&D.[120] The panel stated that this office "must be placed at the highest level [within government] to

[118] The White House, Presidential Memorandum on Government Reform for Competitiveness and Innovation, March 11, 2011; an initiative to streamline executive branch agencies in order to increase trade, exports, and U.S. competitiveness.
[119] Jonathan Sallet and Sean Pool, Rewiring the Federal Government for Competitiveness: A New Cabinet Department for the 21st Century, Center for American Progress, January 2012, accessed August 20, 2014.
[120] White House Lab-to-Market Inter-Agency Summit: Recommendations from the National Expert Panel, May 20, 2013, accessed August 20, 2014. This summit convened by the White House Office of Science and Technology Policy and the National Institutes of Health, National Heart, Lung and Blood Institute consisted of 20 federal agency representatives and outside experts who examined the challenges to commercialization of federal R&D and recommended solutions.

affect its multi-agency authority and oversight." Their suggestion was to place it within the Office of Management and Budget or create a new cabinet-level position, the U.S. Secretary for Innovation.

The government should also perform an extensive review of its own activities affecting innovation. This review will reveal opportunities for increased efficiency (e.g., eliminating duplicative or outdated programs). Next, the programs should be tracked for their respective impact on innovation and the development and growth of innovative companies. Tracking these programs' impact will create a large amount of data which should be analyzed for insights into the U.S. innovation ecosystem. With this knowledge, the White House, agency heads, and Congress will be able to better coordinate government innovation efforts, improve government programs, and allocate resources more effectively.

This report represents the findings of outreach to hundreds of individuals, businesses, and institutions. We hope it will be widely read within government and in the broader innovation ecosystem. We welcome all input at **advocacy@sba.gov**. The Office of Advocacy will continue to listen to America's small innovators and voice their concerns within government.

OTHER READING

Robert D. Atkinson, Understanding the U.S. National Innovation System, The Information Technology and Innovation Foundation, June 2014.

Bourell David L., Rosen David W., and Leu Ming C. (eds.), Roadmap for Additive Manufacturing: Identifying the Future of Freeform Processing, The University of Texas at Austin, Laboratory for Freeform Fabrication, Advanced Manufacturing Center, 2009.

Thomas Campbell, Christopher Williams, Olga Ivanova, Banning Garrett, Could 3D Printing Change the World? Technologies, Potential, and Implications of Additive Manufacturing, The Atlantic Council, October 2011.

Daniel Cohen, Matthew Sargeant,and Ken Somers, 3D printing takes shape, McKinsey Quarterly, January 2014.

Scott Crump, Direct digital manufacturing part three: How to identify opportunities, Stratasys, accessed September 11, 2014.
http://www.stratasys.com/resources/~/media/09545949F30740EBA3A3D4746D093224.pdf

Helen Delaney, Choosing Standards Based on Merit: Liberalizing Regulation, Trade and Development, ASTM International, 2010.
http://www.astm.org/ABOUT/images/Choosing_Standards.pdf

John R. Dearie and Courtney C. Geduldig, Where the Jobs Are: Entrepreneurship and the Soul of the American Economy, (Hoboken, N.J.: John Wiley & Sons, Inc.) 2013.

Nora Freeman Engstrom, 3-D Printing and Product Liability: Identifying the Obstacles, 162 University of Pennsylvania Law Review Online 35, 2013.

Ewing Marion Kauffman Foundation, State of Entrepreneurship Address: Towards America's New Entrepreneurial Growth Agenda, Ewing Marion Kauffman Foundation, February 12, 2014.

John F. Hornick, 3D printing and the future (or demise) of intellectual property, 3D Printing and Additive Manufacturing. March 2014, 1(1): 34-43.

Barry Jaruzelski, John Loehr, and Richard Holman, The Global Innovation 1000: Navigating the digital future, Strategy + Business Magazine, October 2013.

Kevin Jurrens, Measurement Science for Additive Manufacturing, National Institute of Standards and Technology–U.S. Department of Commerce, March 2013.
http://www.nist.gov/el/msid/infotest/upload/Jurrens-NIST-AM_Projects_March2013.pdf

Lagorio-Chafkin, Christine, "Clay Christensen: The wrong kind of innovation," Inc. Magazine, October 2, 2013. http://www.inc.com/christine-lagorio/clayton-christensen-capitalist-dilemma.html

McKinsey Global Institute and Mckinsey Operations Practice, Manufacturing the Future: The Next Era of Global Growth and Innovation, McKinsey & Company, 2013.

McKinsey Global Institute, Game changers: Five opportunities for U.S. growth and renewal, McKinsey & Company, July 2013.

National Economic Council, Council of Economic Advisers and Office of Science and Technology Policy, A Strategy for American Innovation: Securing Our Economic Growth and Prosperity, February 2011.

National Science Foundation, National Center for Science and Engineering Statistics, Science and Engineering Indicators 2014, Arlington, VA (NSB 14-01), February 2014.

Ben Olinsky and Sarah Ayers, Training for Success: A Policy to Expand Apprenticeships in the United States, Center for American Progress, December 2013.

The OECD and the World Bank, The Innovation Policy Platform website, https://www.innovationpolicyplatform.org/

Ivan Pope, The coming 3D ecosystem: Part 4, 3D Printing Industry, July 2014, accessed September 12, 2014. http://3dprintingindustry.com/2014/07/07/coming-ecosystem-3d-printing-part-4/

PricewaterhouseCoopers, Innovation: Government's Many Roles in Fostering Innovation, PricewaterhouseCoopers, 2010.

PricewaterhouseCoopers, Rethinking Innovation in Industrial Manufacturing: Are You Up for the Challenge? PricewaterhouseCoopers Global Innovation Survey 2013: Industrial Manufacturing Perspectives, 2013.

PricewaterhouseCoopers, Breakthrough Innovation and Growth, PricewaterhouseCoopers Global Innovation Survey 2013, 2013.

Justin Scott, Nayanee Gupta, Christopher Weber, Sharon Newsome, Terry Wohlers and Tim Caffrey, Additive Manufacturing: Status and Opportunities, IDA Science and Technology Policy Institute, March 2012.

Technology CEO Council, High Impact: How IT is Empowering the Next Generation of Entrepreneurs, Technology CEO Council, 2012.

U.S. International Trade Commission, Small and Medium Sized Enterprises: U.S. and EU Export Activities, and Barriers and Opportunities Experienced by U.S. Firms, USITC Publication 4169, July 2010.

Michael Weinberg, What's the deal with copyright and 3D printing? Public Knowledge blog, white paper, January 2013.

Charles W. Wessner, ed., Committee on Capitalizing on Science, Technology, and Innovation: National Research Council, An Assessment of the Small Business Innovation Research Program, (Washington D.C.: The National Academies Press) 2008.

Garrett White and Daniel Lynskey, Economic Analysis of Additive Manufacturing for Final Products: An Industrial Approach, University of Pittsburgh-Swanson School of Engineering, April 13, 2013.

ABOUT THE AUTHOR:
MARK K. HARRISON, OFFICE OF ADVOCACY ENTREPRENEUR IN RESIDENCE

Mark K. Harrison joined the Office of Advocacy in summer 2013 as its entrepreneur in residence. Harrison's background combines experience in government, the private sector, and law. Prior to joining Advocacy, he was president of the Business Consortium Fund, a not-for-profit corporation affiliated with the National Minority Supplier Development Council. The fund provides financing, business advisory services, and educational programs to minority entrepreneurs. In that capacity, he developed and implemented two new financing programs, an advisory service, and an educational program.

Harrison served as deputy director of the Investment Financing Group (IFG) for the Maryland Department of Business and Economic Development in Baltimore; there he managed programs making venture capital investments in early and seed stage technology companies. He served as a Maryland assistant attorney general and legal counsel to the IFG from 1994 to 1999 and worked with the U.S. Securities and Exchange Commission from 1990 to 1994.

Harrison earned his law degree from the University of Maryland School of Law in Baltimore and a bachelor of science in business and marketing management from Cornell University.