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AMERICA MAKES: THE NATIONAL ADDITIVE MANUFACTURING INNOVATION INSTITUTE (NAMII) STATUS REPORT AND FUTURE OPPORTUNITIES (POSTPRINT)

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AFRL/RXMS

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14. ABSTRACT
Manufacturing remains the essential core of the U.S. economy's innovation infrastructure and is critical to national defense. However, a gap exists between R&D activities and the deployment of technological innovations in the domestic production of goods and this gap could have long-term negative consequences for the defense industrial base. As global competition to manufacture advanced products intensifies, the performance of these innovation ecosystems must improve. Accelerating innovation and implementation of advanced manufacturing capabilities requires bridging a number of these gaps in the present U.S. innovation system. What is needed is for industry, academia, and government partners to leverage existing resources, collaborate, and co-invest to nurture manufacturing innovation and accelerate commercialization and defense production.

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America Makes: The National Additive Manufacturing Innovation Institute (NAMII) Status Report and Future Opportunities

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Manufacturing remains the essential core of the U.S. economy's innovation infrastructure and is critical to national defense. However, a gap exists between R&D activities and the deployment of technological innovations in the domestic production of goods and this gap could have long-term negative consequences for the defense industrial base. As global competition to manufacture advanced products intensifies, the performance of these innovation ecosystems must improve. Accelerating innovation and implementation of advanced manufacturing capabilities requires bridging a number of these gaps in the present U.S. innovation system. What is needed is for industry, academia, and government partners to leverage existing resources, collaborate, and co-invest to nurture manufacturing innovation and accelerate commercialization and defense production.

The President's Council of Advisors on Science and Technology (PCAST) called for the establishment of a National Network for Manufacturing Innovation (NNMI).[1] Key design tenets for the NNMI are captured within *National Network for Manufacturing Innovation: A Preliminary Design*.[2] NNMI will be composed of Institutes for Manufacturing Innovation. The President proposed up to 45 manufacturing institutes around the country within the next 10 years. Congress is currently considering bills in both houses similar to the President's proposal through the "Revitalize American Manufacturing and Innovation Act of 2013".[3,4] Manufacturing Institutes will bring together industry, academia (four- and two-year universities, community colleges, technical institutes, etc.), and federal and state agencies to accelerate innovation by investing in industrially-relevant manufacturing technologies with broad applications. This will provide the required ecosystem to help bridge the gap between basic research and product development/fielding. It will provide shared assets to help companies, particularly small and medium enterprises, access cutting-edge capabilities and equipment and create an unparalleled environment to educate and train the workforce for advanced manufacturing implementation. Each Institute will have a specific technology or market focus and will serve as a regional hub of manufacturing excellence in that focus area, providing the critical infrastructure necessary to create a dynamic, highly collaborative environment spurring manufacturing technology innovations and technology transfer leading to production scale-up and commercialization. Geographic proximity between large industries, small businesses, laboratories, entrepreneurs, and academia has shown to have strong advantage in creating an environment for collaboration and commercialization.[5] When established, each manufacturing institute will be a public-private partnership via a cooperative agreement. After five to seven years of U.S. Government funding, the manufacturing institutes are expected to become self-sustaining.

In March 2012, President Obama announced the launch of a pilot manufacturing institute using existing funding and authorities. The DoD volunteered to lead the pilot through the Defense Wide Manufacturing Science and Technology Program and selected Additive Manufacturing (or more popularly known as 3D printing) as the technical subject. Working with an interagency team from DOE, NASA, NIST, and NSF, the DoD awarded a cooperative agreement in August of 2012 to a team led by the National Center for Defense Manufacturing and Machining. This team has become America Makes: The National Additive Manufacturing Innovation Institute. America Makes has $50M of government funding available, and each technical project requires 1:1 cost share from non-public sources.

Since the launch of America Makes, the DoD has created two more manufacturing institutes on the topics of Lightweight Metals and Digital Manufacturing and Design. In addition, an institute on Power Electronics was announced by DOE in January of 2013. DoD plans to create two more manufacturing institutes in the near future. Lessons learned from America Makes will be applied heavily to these other institutes to ensure they are also successful.

After more than a year and a half of operations, America Makes is starting to hit its stride in developing technology for 3D printing and in leading the way in how the United States should operate a manufacturing institute. There are several accomplishments to share as well as several opportunities as America Makes heads towards the path of becoming self-sustaining.

The key to a successful start for America Makes was the selection of 3D printing as the technical focus area. A primary tenet in selecting a topic for a manufacturing institute is to ensure it is an area where the United States can gain a technological and economic advantage. In the early 2010's, 3D printing received significant attention in mainstream media outlets as a technology that could impact the greater society. 3D printing offers several benefits including: the ability to customize each part with little cost; tool-less manufacturing leading to reduced lead times; allows more complex part designs than traditional machining operations, enabling reduced part count and increased performance; and supply chain disruption by moving manufacturing closer to the point of use, such as a space station or a battlefield. Applications range from medical, automotive, aerospace and defense, and consumer products.

A significant realization was that America Makes is not a traditional government funded R&D program. In reality, America Makes and all of the manufacturing institutes are startup companies. With that come new issues to worry about such as branding, dealing with the media, and making sure that America Makes is sufficiently staffed, not only to execute the cooperative agreement with the U.S. Government, but also to position itself for future growth. For branding, America Makes realized early that its original name "National Additive Manufacturing Innovation Institute" or "NAMII" was uninspiring to the general public (and its acronym was pronounced the same as the one used by the National Alliance on Mental Illness.) The name change was strategic, with the goal of self-sustainability in mind. As for dealing with the press, traditional defense R&D programs are typically not mentioned in the popular media. Thus, America Makes was surprised by some initial negative media toward the concept of a manufacturing institute. As a result, America Makes has become proactive in a messaging campaign to ensure its story gets out to the general public. Finally, the government had to set aside its traditional view that "staffing overhead" is something to minimize so that most of the funding goes to developing technology. Because America Makes is in company startup mode, ensuring there is both quality and quantity of staff is crucial to near and long term success. Ed Morris, the Executive Director of America Makes, assembled a quality team that has gotten the technical program off the ground and established the America Makes headquarters/Innovation Factory in Youngstown, Ohio.

Another early win was the partnership forged with MAYA Design, a human centered design consultancy and technology research lab in Pittsburgh, Pennsylvania and their sister company, Agency of Trillions. These companies empowered America Makes with tools to develop strategic and technology-specific roadmaps that will make an impact beyond the defense market. In addition, they created the much-buzzed about presence at the 2013 RAPID conference with the unique whiteboard only exhibit booth, and re-launched the America Makes multifaceted web presence.

America Makes has grown since the signing of the cooperative agreement. The Innovation Factory in Youngstown is fully staffed and has over 20 additive manufacturing machines available (both polymer and metal) to the America Makes membership. America Makes today has over 100 members including Fortune 500 companies such as 3M, Boeing, and Alcoa, small businesses, universities, community colleges, non-profit organizations, organic facilities, and federally-funded research and development centers (FFRDCs). These members collaborate on America Makes funded research projects, and the membership enables small businesses to get insight to customers in the Fortune 500 companies as well as exposure to university and federal research that it normally would not be aware of. Members enjoy benefits which include the ability to pool resources surrounding common, pre-competitive technical issues and opportunities. Some of the greatest benefits cited by members include the ability to network in a trusted environment, contribute their interest areas into the technical strategy, link up with partners throughout the supply chain, and benefit from project results including the ability to commercialize developments created within the institute.

As for the development of the technical program, America Makes conducted a series of technology workshops leading to a membership driven technical roadmap to guide the investments. Based on that roadmap, America Makes currently has 22 R&D projects launched with over 90 organizations participating and funded at $13.5M government and $15M cost share. Main themes for these research projects are design for additive manufacturing, additive manufacturing materials, processing and equipment, qualification and certification, and knowledgebase development. Details on the projects can be found at http://americamakes.us/engage/projects. America Makes will ensure that this roadmap continues to be updated through member organization input, especially industry members.

A key difference between a traditional government R&D program and a manufacturing institute is the charter for an institute includes extensive activities in educational outreach and workforce development. America Makes has had a strong emphasis on STEM for the K-12 age group. America Makes has participated in the 2013 and 2014 FIRST Robotics Championships in St. Louis, Missouri, ASM Teachers camps and 3D Printing Summer Camps. America Makes also has a goal of getting "3D printers in every school", which Makerbot and other companies have embraced, using 100% privately funding. Over 500 printer kits to include materials and training have been delivered to schools so far. Continuing programs to engage K-12, community college and college-level students, and also train the current workforce on 3D printing are key aspects of the mission. America Makes will continue to build upon existing programs within the member organizations as well as reach out to other partners with similar goals.

While the there are many things for America Makes to be proud of, there are areas for improvement. As for funding, the NNMI design calls for manufacturing institutes to be funded with $70-$120M of federal funding with at least an equal amount of cost share. As a pilot, America Makes was originally funded at $30M of federal funds. It has since grown to $50M, but is still below the NNMI target of $70-$120M. Concern remains that with only $50M, America Makes might not achieve critical mass for the institute to continue after the conclusion of the cooperative agreement. The technical roadmap developed by America Makes justifies an investment at least on par with the NNMI target. As a result, America Makes is actively pursuing additional funds, as well as alternative funding models such as crowdsourcing projects among the members without the use of government funds and issuing "grand challenges" to have organizations use their own funding to compete to win cash prizes from America Makes.

As for the cost share component of America Makes funding, the institute needs to keep learning as is goes forward and be willing to adjust its membership model as needed to ensure that there is sufficient revenue to counterbalance management costs by August 2017. Examples include some cash minimum membership fee, with appropriate discounts given for small businesses and non-profit organizations.

Another opportunity for America Makes to expand its reach to grow beyond the need for federal investment could be to seek out new classes of members. One approach for America Makes would be to ask itself how it can inspire the individual American. There are two ways to do that. First is to engage with "business to consumer" Fortune 500 companies, brands that consumers know and use. Business-to-consumer Fortune 500 companies are projected to spend $1 trillion in 2015 globally on advertising. Armed with 3D printing capabilities, these companies can shift funding from advertising into innovation to disrupt supply chains and to make better things for the consumer and thus make more money. America Makes has an opportunity to show how these companies can stop trying to get people to "like" them (on Facebook) and instead make products that people like.

Second is for America Makes to consider creating a method for individuals to become members. In *Makers: The New Industrial Revolution,* a book by Chris Anderson (formerly of Wired Magazine) he describes "a new industrial revolution as today's entrepreneurs, using open source design and 3-D printing, bring manufacturing to the desktop. In an age of custom-fabricated, do-it-yourself product design and creation, the collective potential of a million garage tinkerers and enthusiasts is about to be unleashed, driving a resurgence of American manufacturing. A generation of "Makers" using the Web's innovation model will help drive the next big wave in the global economy, as the new technologies of digital design and rapid prototyping gives everyone the power to invent -- creating 'the long tail of things.'"[6] Tim Bajarin of Time Magazine just recently published *Why the Maker Movement Is Important to America's Future* which notes:

According to Atmel, a major backer of the Maker movement, there are approximately 135 million U.S. adults who are makers, and the overall market for 3D printing products and various maker services hit $2.2 billion in 2012. That number is expected to reach $6 billion by 2017 and $8.41 billion by 2020. According to USA Today, makers fuel business with some $29 billion poured into the world economy each year.[7]

With over 530,000 people that attended Maker Faires in 2013 and the White House hosting its first Maker Faire on June 18, 2014, it is clear that we are have entered a third industrial revolution which is commonly referred to as "The Maker Movement." Remember how the personal computer disrupted the main frame? That is what desktop manufacturing can do to traditional manufacturing.

What distinguishes Makers from do-it-yourselfers is the power afforded to them by modern technologies and a globalized economy. Digital software allows makers to design, model, and engineer their creations, while also lowering the learning curve to use industrial-grade tools of production. Makers also have access to sophisticated materials and machine parts from around the world. They form communities, collaborate online, and iterate to reach new levels of performance. Makers get capital funding from crowdfunding sites such as Kickstarter. Inexpensive manufacturing hubs, international shipping, and e-commerce distribution services such as Etsy help Makers commercialize their creations. In short, Makers are the lifeline of the 3rd industrial revolution and America Makes should not overlook them. America Makes has an opportunity to pursue formal relationships between maker-spaces and consider the benefits of offering low-cost individual memberships within America Makes.

America Makes has been an experiment on how a manufacturing institute will work. So far it has been successful. In year one, it stood up the facilities and hired the staff. America Makes also forged partnerships within the membership and with the outside world. Now in year two, America Makes is starting to develop the next generation of 3D printing technology. In years three through five, there is much to do. America Makes needs to move to the next level and become self-sustaining. A key opportunity to do this is to inspire the individual American and consumer Fortune 500 companies to contribute to their mission.

References:

1. PCAST: Report to the President on Capturing Domestic Competitive Advantage in Advanced Manufacturing, President's Council of Advisors on Science and Technology(July 2012), http://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast_amp_steering_committee_report_final_july_17_2012.pdf. Accessed 1 Jul 2014.

2. http://manufacturing.gov/nnmi.html. Accessed 1 Jul 2014.

3. Sen. S. Brown and Sen. R. Blunt, Senate Commerce Committee Hearing. 13 Nov 2013.

4. Rep. T. Reed and Rep. J. Kennedy, House Science Committee, Subcommittee on Research and Technology Hearing. 12 Dec 2013.

5. G. P. Pisano and W. C. Shih, "Restoring American Competitiveness", Harvard Business Review 87 (July – August 2009), http://hbr.org/2009/07/restoring-american-competitiveness/ar/1. Accessed 1 July 2014.

6. Anderson, Chris, Makers: The New Industrial Revolution (2012).

7. T. Bajarin, "Why the Maker Movement is Important to America's Future." *Time* (May 19, 2014), http://time.com/#104210/maker-faire-maker-movement/. Accessed 1 July 2014.