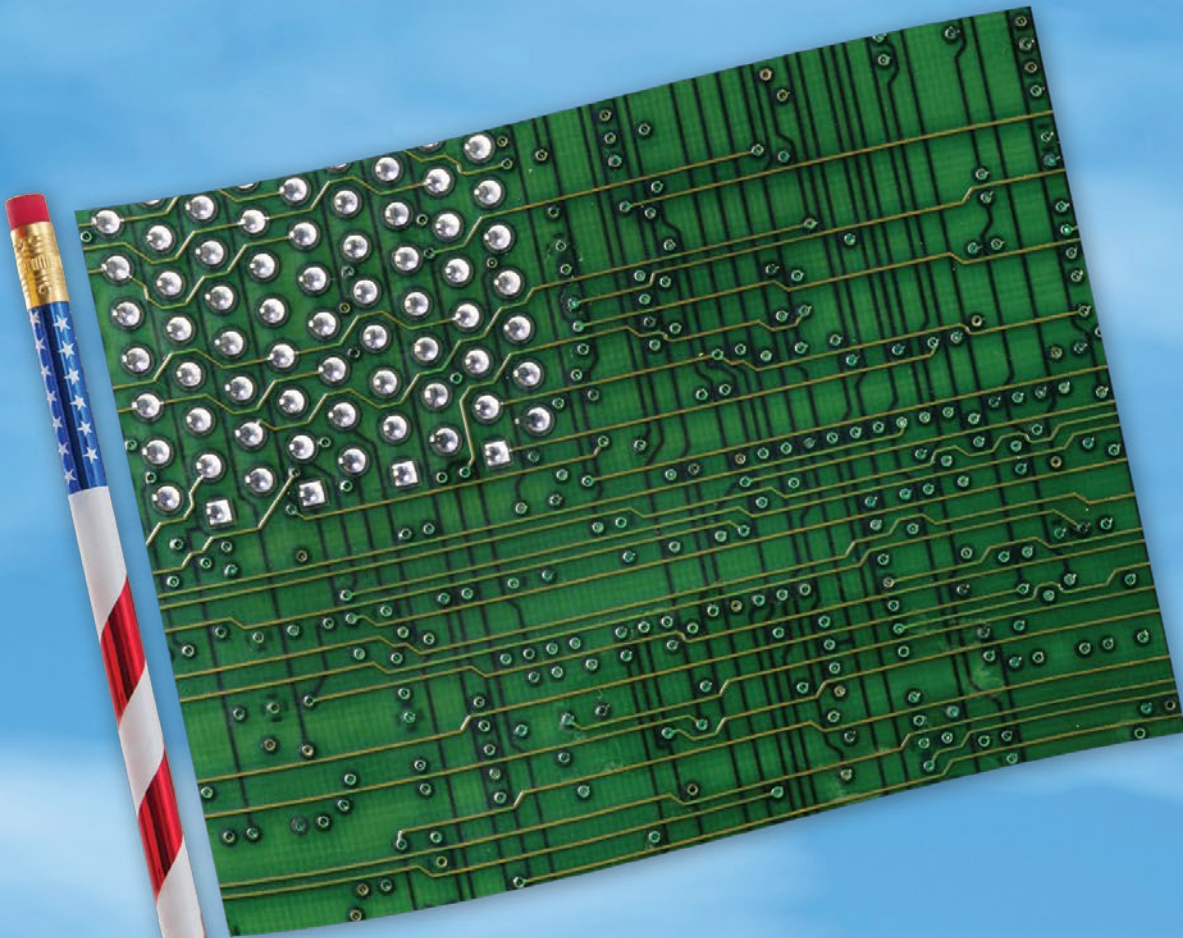

Inside America's Bold Plan to Revive Manufacturing

After the Great Recession—and the loss of nearly 6 million manufacturing jobs—a coalition of concerned academic, business and government leaders crafted a plan to restore U.S. leadership in manufacturing for the 21st century. This year, they are rolling out the centerpiece of that proposal, a new federal program whose proposed budget now surpasses $2 billion. But can the U.S. really be the world's manufacturing leader again?

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It's All About the Technology

Official White House Photo by Pete Souza

President Barack Obama greets manufacturing workers in August 2010, following his remarks at Ford Motor Co.'s Chicago Assembly Plant.

As vital as it is, manufacturing—the art, science and business of making things—has not always been fully appreciated for its impact on the American economy.

The proof of that fact may be in the debates about manufacturing's economic value that waxed on decade after decade as the industry, and eventually the economy, tumbled toward collapse.

While many within industry warned about manufacturing's slide—first in production work, then in jobs and then in the technologies used to make things—it was the Great Recession of 2007-2009 that, for many, served as a climax, a brutal wake-up call, to those long-feared ramifications. The staggering number of lost jobs. Sagging wages. Damaged communities. A wilted view of the future.

With renewed understanding since then—and a hint of "we-told-you-so" in their step—a focused network of academic, business, and government leaders across this nation has been quietly working to fix this mess. They have crafted an ambitious strategic plan for a once-in-a-generation investment in manufacturing that could serve as the centerpiece for a new high-tech industrial era in America.

Surprisingly, this plan has received a level of bipartisan support that has not been seen for years, if not decades, for manufacturing.

A Manufacturing Moonshot

Since the end of the Great Recession, much of the public's attention on America's manufacturing renaissance has centered on the return of a significant, but relatively small, number of manufacturing jobs. More than 5.7 million manufacturing jobs were lost between 2000 and 2011, as more than 65,000 U.S. manufacturing establishments closed their doors, according to the Bureau of Labor Statistics. Since then, more than 660,000 direct manufacturing jobs, or 11.5% of those lost, have been added back, bringing manufacturing employment to a total of 12.2 million.

Given that direct manufacturing employment peaked in 1979 at 19 million, critics of manufacturing investments like to point at today's relatively low numbers as proof that industry will never serve up the big employment levels it once did.

While job figures are one indicator of manufacturing's health as a sector, the Obama Administration, along with a growing coalition of leaders, has been working diligently to repair an often overlooked cause of America's decline in manufacturing: its waning competition in manufacturing technologies.

The result is the new National Network for Manufacturing Innovation, or NNMI. The total current and proposed investment in this effort, according to a review of the proposed 2016 federal budget, now surpasses $2 billion. It's an investment that only begins to convey the program's lofty ambitions, which, in some ways, evoke our nation's goal in the 1960s of putting a man on the moon.

While this complex project is far less understood by the general public, it is a moonshot—with lofty scientific ambitions—aimed at restoring America's leadership in manufacturing and securing it for the 21st Century.

Under President Barack Obama's planned approach, the NNMI will ultimately be a large network of linked public-private hubs that each focus on specific technology areas that are necessary for American economic competitiveness, such as 3D printing, digital manufacturing, wide bandgap semiconductors and lightweight materials. Each will oversee applied research, development and collaboration, and enable workforce training, in its area of manufacturing technology.

This network, which will consist of nine hubs by the end of 2015, and aspires to grow to 45, aims to put the U.S. on the cutting edge of some of the most challenging and important scientific issues confronting global manufacturing today and in the future. Among the long list of opportunities:

- Can we convert waste, say recycled aluminum cans, into materials that can then be used to 3D print other products? Could this create a new era of recycling?
- How do we inspect 3D-printed parts, say titanium airplane components, to ensure their microstructures are as strong as conventionally manufactured parts? Or, better yet, can we 3D-print parts that are even stronger with less waste? Can we scale 3D printing to be a viable economic strategy for more applications?
- How do we protect the security of our digital design and manufacturing data as factory machines and equipment are increasingly operated through networked computers, often using cloud computing? Can this lead to better ways of protecting everyone's data? Can we weave a digital thread in a part's lifecycle?
- Are there new ways to capture and store clean energy that surpass all the batteries on the market today?
- Can we create electronics that use and waste less energy?

This once-in-a generation investment in manufacturing is a moonshot at restoring America's technology leadership in manufacturing.

Rep. Joseph P. Kennedy III, D-MA (left); Rep. Tom Reed, R-NY. The Revitalize American Manufacturing and Innovation Act, which created the National Network for Manufacturing Innovation, was passed with overwhelming bipartisan support not seen in years for manufacturing.

The first phase of this project has already been approved. The Revitalize American Manufacturing and Innovation Act, which supported an expansion of NNMI after a pilot phase, was cosponsored by 51 Democrats and 49 Republicans in the House–the Senate version also received bipartisan support–and RAMI was signed into law in December 2014.

In today's age of biting partisanship, the support for RAMI was a rare display of collaboration that conveyed the urgency for this project felt on both sides of the aisle.

"This bill represents how Congress is designed to work … to formulate policy that will move our country forward," said Rep. Joseph P. Kennedy III, D-MA, and a bill cosponsor.

Rep. Tom Reed, R-NY, another cosponsor, pointed to the legislation as the kind of work "I came here to do … that will grow the American economy and put people back to work."

Manufacturing Technology Matters

Indeed, part of the NNMI's goal is to bring even more manufacturing home and develop workers with high-demand

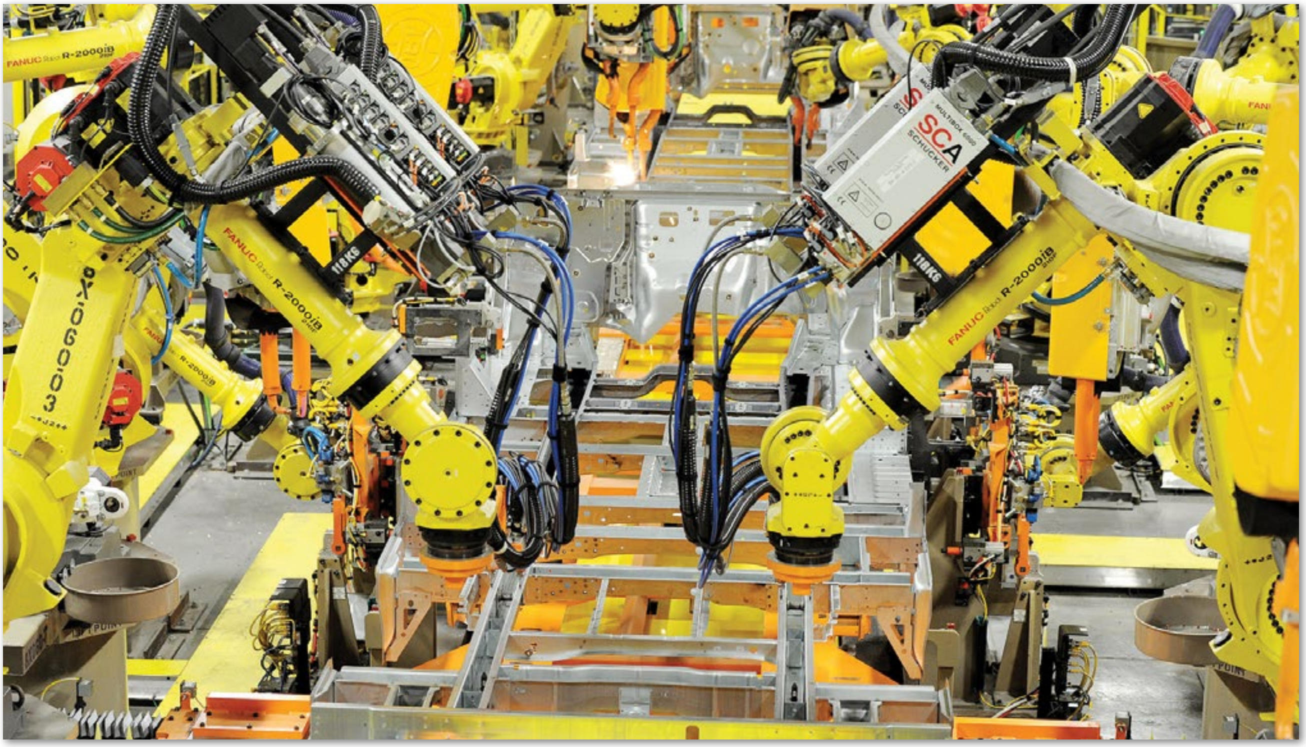


Photo courtesy Sam VarnHagen/Ford Motor Co.

Ford Motor Co.'s Kansas City Assembly Plant, shown here, manufactures the 2015 Ford Transit van. This photo shows how Ford uses technology from the Japanese company FANUC, as well as from SCA Schucker, a German company, to build the vehicle. A number of manufacturing technology providers and suppliers opened facilities and offices near the factory to support its production.

advanced manufacturing skills.

But the real heart of this effort is targeted at rebuilding America's strength in the manufacturing technologies that undergird today's modern manufacturing facilities, many of which are no longer "factories" in the classic sense.

That's because manufacturing technologies, and America's competitive strength—or weakness—in them, have been a widely overlooked part of the broader manufacturing story in the U.S. While it's been easy to blame low-wage countries and trade agreements for the U.S. decline in manufacturing, the nation's diminished competitiveness in these technologies has also played an enormous role.

> "The United States has been losing its competitive advantage in those sectors and technologies that it needs to drive growth in the twenty-first century."

In some ways, America's lack of understanding about manufacturing technologies—what they are and what they do—was one reason why many dismissed the value of preserving the manufacturing industry in the U.S. years ago.

Yet manufacturing's critics are paying attention to industry now because advanced manufacturing technologies are growing demonstrably more important as they materially change the way things are made now and in the future.

Today, these technologies aren't just replacing labor, but they are also making it far more productive. From an economic impact perspective, these technologies may ultimately be more valuable than the final good they help produce. So, creating the laser-wielding robot that welds the car together may, in many ways, be more economically valuable to a community than the final car production itself.

A Web of Profitable Processes

So, just what are these technologies?

First, it's important to remember that manufacturing any part or product usually involves a series of distinct processes, such as cutting a material to a near-perfect shape, making sure the surface is finished to specifications and joining materials together in a way that is durable.

Making an airplane, car, medical device or smartphone today requires a series of highly engineered processes on the long path from converting raw materials into finished parts that will then be joined and assembled into a final product.

As one looks across a vast factory floor today, it is full of machines, equipment, tools and software—individual manufacturing technologies—and each and every one is the subject of scientific research and development somewhere.

People unfamiliar with manufacturing work don't often realize that companies around the world commercialize and sell these technologies, and manufacturers such as Apple Inc., General Motors Corp., Caterpillar, Inc. and the Boeing Co., buy them to make the products they sell.

From every corner of manufacturing, a raft of technological advances have been made over the past decade.

These advanced processes are precisely the valuable offering that the NNMI seeks to develop and sell.

While most people have heard of Apple and GM, the companies that make the manufacturing technologies in their factories are usually not household names, even though they are powerful global companies. When legendary investor Warren Buffett bought one such company, Israeli toolmaker ISCAR, for $6 billion between 2006 and 2013, few people outside of manufacturing had likely ever heard of the cutting-edge company, but it employs 6,000 employees around the world and spends millions every year on R&D.

A Wide Spectrum of Readiness

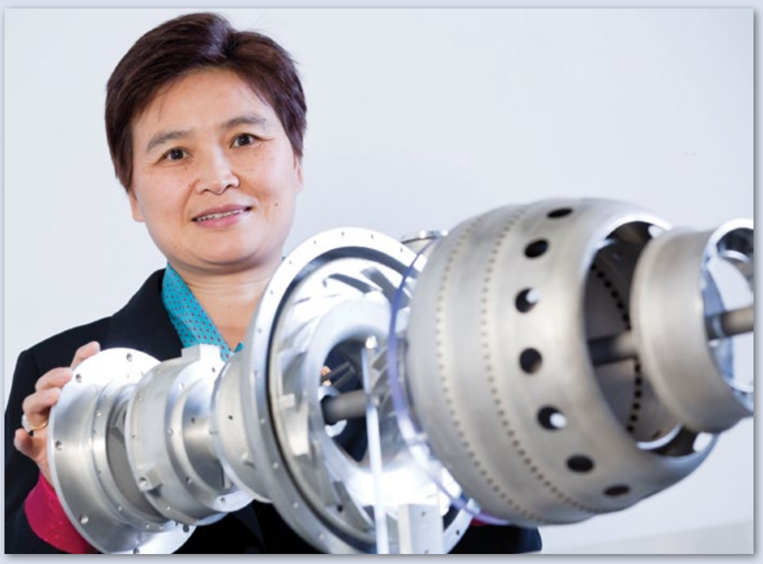
The advanced manufacturing technologies of today and tomorrow, and the companies that make them, such as ISCAR, are all in various states of maturity.

Some are considered emerging technologies. That includes 3D printing, also known as additive manufacturing (AM), which gets a great deal of attention for the idea that one could, someday, print any object in any material.

In AM, an object is built from a digital design file by printing one layer of material at a time. But even within 3D printing, a wide range of processes are used to build objects, such as selective laser sintering, electron beam melting, and fused deposition modeling, just to name a few. Each of these technologies has a number of limitations and challenges that

The 3D Race is On

In 2009, Stratasys (Minneapolis & Rehovot, Israel) and Autodesk (San Rafael, CA) unveiled the first full-scale turbo-prop aircraft engine model produced using Stratasys FDM (Fused Deposition Modeling) technology, a form of AM.



In Australia in 2015, Prof. Xinhua Wu, a professor of materials engineering at Monash University in Melbourne and director of the Monash Centre for Additive Manufacturing (MCAM), led the team that has created the world's first 3D-printed jet engine using selective laser melting (SLM).

Like many technologies, the flat-screen TV was invented in a manufacturing environment; GE was trying to figure out how to convey radar information to an airplane. But making new inventions a reality is a manufacturing challenge that takes a lot of time and money. It took about four decades of manufacturing research to make the now-popular product scaleable at an affordable price. Today, most flat screen TVs are made in Taiwan.

must be overcome in order to make AM more marketable. This research requires advanced knowledge about materials, lasers, software and more.

The field of advanced manufacturing also consists of older technologies that have grown very sophisticated over time, with the help of software and other developments.

Take grinding. In medieval times, knives and swords were created after forged metal, usually banged into shape by a hammer, was sharpened on a grindstone as it revolved in circles. Today, five-axis CNC (computer numerical control) grinding machines make some of the most complex parts with smooth surfaces used in aircrafts, cars, and in medical devices. Modern grinding machines use highly engineered grinding wheels made from a matrix of bonding and cutting materials, such as diamond. These machines and their wheels can cut through metal as if sculpting butter.

Even more importantly, the way these technologies are now being integrated, or linked, is growing. Sensors and software are enabling machines to record critical data that may prove useful in everything from product recalls to machine maintenance to helping machines communicate with one another in an effort to be more productive. And they are helping to usher in a new era of robotics, where machines can use those visual, touch and other data inputs to make decisions or even learn how to do something without complicated programming.

In fact, from every corner of manufacturing, a raft of advances have been made over the past decade, driven by software, sensors and maybe, even, from the lull in manufacturing that occurred during the Great Recession. Some manufacturing technology companies used those years of downtime to be productive, researching new ways of making things and solving nagging old problems while business was slow.

"We think the advancements in shop-floor programming over the past 10 years have been nothing short of remarkable," Todd Drane, marketing manager, Fagor Automation Corp. (Elk Grove Village, IL) recently told SME. "What was once thought to be impossible to do at the CNC keyboard can now be accomplished in a matter of minutes in front of the machine."

Manufacturing to Innovate

Many people may not realize it, but a deep understanding of these manufacturing technologies, and how they work together to make things, is actually necessary to design many of the cutting-edge products of today and the future. This fact was one of the key arguments of a 2012 book, "Producing Prosperity: Why America Needs a Manufacturing Renaissance," by Harvard Business School professors Gary P. Pisano and Willy C. Shih.

In this book, Pisano and Shih argued that as America loses its so-called industrial commons, or communities of knowledge built around these manufacturing technologies, the nation will lose its ability to successfully innovate.

The relationship between manufacturing technologies and product innovation can sometimes be as enigmatic as the question about whether the chicken or egg came first. That's because the knowledge about how to make things is central to innovation—if it can't be made, it's just an idea—and usually it is the development of manufacturing technologies that actually leads to the new widgets and gadgets of the future.

Take the flat-screen TV. In the 1950s, General Electric came up with the original engineering proposal for the idea, which stemmed from its manufacturing work in another area. GE was exploring how to convey radar information to an airplane; its plan consisted of miniature components and closely spaced wire grids that would reproduce a transmitted image in a picture frame.

Manufacturing matters: If it can't be made, it's just an idea.

Any number of life-improving technologies originated in ways such as this, and today, that is a reason for concern. "The loss of manufacturing competencies should deeply worry Americans," Pisano and Shih wrote. "The United States has been losing its competitive advantage in those sectors and technologies that it needs to drive growth in the twenty-first century."

Their book implored U.S. leaders to "abandon the grand experiment in de-industrialization before it's too late."

The U.S. is an Importer of Manufacturing Technology

Just a few decades ago, the U.S. was a leader in manufacturing technologies. But today, a sobering number of manufacturing technologies come from other countries, usually Germany, Japan, China, Italy, South Korea and Switzerland.

This unhealthy trend was summarized in an October 2014 report from The President's Council of Advisors on Science and Technology (PCAST), an esteemed group that includes thought leaders such as Eric Schmidt, Chairman of Google Inc. "U.S. strengths in manufacturing innovation and technologies that have sustained American leadership... are under threat from new and growing competition abroad," it wrote.

Ed Morris, the Director of America Makes, also known as the National Additive Manufacturing Innovation Institute, was more blunt. His NNMI manufacturing hub is focused on 3D printing technologies, and although that technology arguably originated in the U.S. in the 1980s—Colorado native Chuck Hull is widely regarded as its inventor—it is now seriously debatable whether the U.S. or Europe is regarded as the current leader in this technology, and China is investing aggressively in it.

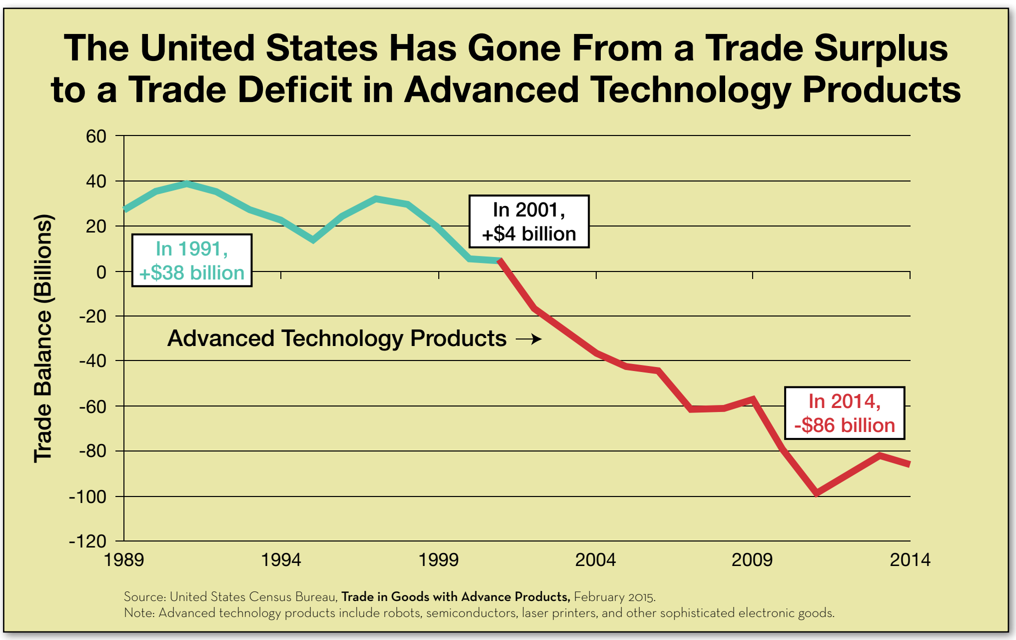
"We've forfeited our manufacturing strengths," Morris said, "and it is imperative to recapture. ... We're playing catch-up."

Consider this: In 2014, the U.S. imported $11.4 billion in metalworking machine tools, which are used to craft everything from planes and tanks to medical devices, according to international trade data from the U.S. Census Bureau. At the same time, the U.S. exported just $7.5 billion, a decrease of about $189 million from the prior year.

That's largely because America has just a handful of major machine tool makers left—such as Haas Automation Inc.; Gleason Corp.; Hardinge Inc.; and Hurco Companies Inc., among a few others—after a large number went out of business or were reorganized during the last century.

Machine tools are just one area of manufacturing technology. In all, the U.S. trade deficit for "advanced technology products," a category that includes robots, semiconductors and more, has been in decline since the late 1990s, when the U.S. enjoyed a trade surplus. By 2014, the U.S. trade deficit in this category was $86 billion.

The challenge in industrial robotics is particularly striking



Source: United States Census Bureau, **Trade in Goods with Advance Products,** February 2015.
Note: Advanced technology products include robots, semiconductors, laser printers, and other sophisticated electronic goods.

A Q&A with the Leaders of the U.S. Manufacturing Hubs

SME: Why does the United States need the National Network for Manufacturing Innovation?

Brown: After more than a century of dominance in manufacturing, the U.S. manufacturing business climate was under substantial pressure from competition around the globe. As manufacturing left U.S. shores, the expertise and know-how to innovate that manufacturing soon followed – over time the structures within industry and government to support that innovation became disconnected, stagnant and inefficient. The Great Recession shined a bright light on the needs of U.S. manufacturing to invest in advanced processes and new technologies.

SME: Why should the U.S. government help commercialize manufacturing technologies?

Bartles: These problems are too big for any one company to solve by themselves. You're going to have to come up with a model that pulls together the right resources.

Morris: These projects are too risky for industry to fund by themselves. It helps to have a combination of public-private money.

SME: Why is this a good deal for taxpayers?

Brown: Institutes have been funded initially with seed money from federal government sources and industry matching dollars. Over the long-term, the institutes will have to be self-sustaining. If there is demand for their services in the marketplace, they can survive and thrive. The structure of these institutes implies a risk-sharing arrangement that is good for industry and good for the country. New technology investment can be expensive and there is no guarantee of success. This is a smart leverage of a nation's intellectual and financial assets.

SME: Tell me what your particular institute does and why it's important? Will the various institutes collaborate on their technologies in any way?

Larry Brown,
Executive Director of LIFT (Lightweight Innovations for Tomorrow), in Detroit.

Ed Morris,
Executive Director of America Makes, in Youngstown, OH.

Dean Bartles,
Executive Director of DMDII (Digital Manufacturing & Design Innovation Institute), in Chicago.

Dennis Kekas,
Interim Executive Director of Power America in Raleigh, NC.

Morris: We're chartered for 3D printing. Game-changing is a totally overused word, but it's not when it comes to additive manufacturing. It has the potential to be beneficial to every application you can think of.

Brown: Lightweight metals are an enabling technology for many products in the transportation and defense sectors. The ability to lightweight a vehicle reduces its energy or fuel consumption. The challenge is understanding how these metals perform across a variety of manufacturing processes and how those processes or equipment might need to be modified to accommodate the new properties. This is a grand challenge faced by all manufacturing sectors.

Kekas: Wide bandgap semiconductors technology. It's time to bring it out of the labs and make it real ... Wide bandgap power electronics have the ability to shave two percentage points off the world's electric energy usage. It's a huge savings. We could make the world far more efficient while enabling new applications. ... It's not an easy task, but nothing worth doing is easy to do.

Bartles: We're looking at cutting-edge digital technologies that are fueling advanced manufacturing – intelligent machining, modeling and simulation, the cloud. Cybersecurity is a major, major concern.

SME: How optimistic are you that the U.S. can catch up in manufacturing?

Brown: A coordinated and optimized approach to advanced manufacturing is key to unleashing American ingenuity in a productive and targeted fashion. LIFT has no doubt about the ability of U.S. firms to dominate global manufacturing. This once-in-a-generation investment in manufacturing is the catalyst.

because this technology plays an increasingly important role in making things. In fact, North American sales of industrial robotics hit all-time records in 2014.

Just like 3D printing, robots were invented here. New York City native Joseph F. Engelberger created the first industrial robot, the Unimate, in the late 1950s. General Motors bought the technology and used it at its die-casting operations in New Jersey in the 1960s.

Since then, America has fallen terribly behind in industrial robotics. The U.S. supplied less than 16% of the industrial robots in the world in 2013, according to the International Federation of Robotics. About 60% of the world's industrial robots came from Asia, primarily China, Japan and Korea. Another fourth come from Europe, primarily Germany, Italy and Switzerland.

In fact, America has just a handful of companies left that produce industrial robotics, such as Adept Technology Inc., founded in 1983 and based in Pleasanton, CA. Collaborative robot builder Rethink Robotics in Boston is a new player, launched this decade. Most other U.S. robotics companies build robots for defense systems and personal use, such as vacuums or toys.

Because China has invested so heavily in developing a manufacturing technology infrastructure, making high-tech products in that country is now fairly straightforward compared to the U.S., where it's fairly difficult to do.

The U.S. supplied less than 16% of the industrial robots in the world in 2013, according to the International Federation of Robotics.

That's why, as it has been well reported, Apple went to China when Steve Jobs demanded a glass face for the iPhone that wouldn't scratch. The technology required to cut and grind that glass face to perfection, along with the expertise needed to hone the process, was in Asia.

In 2012, the *New York Times* wrote this of Apple's decision:

"For years, cell phone makers had avoided using glass because it required precision in cutting and grinding that was extremely difficult to achieve. Apple had already selected an American company, Corning Inc., to manufacture large panes of strengthened glass. But figuring out how to cut those panes into millions of iPhone screens required finding an empty cutting plant, hundreds of pieces of glass to use in experiments and an army of midlevel engineers. It would cost a fortune simply to prepare.

Then a bid for the work arrived from a Chinese factory. ...

"America's loss of competitive bench strength in these manufacturing technologies, and their resulting supply chains and communities of technical knowledge, is a big part of why China now captures about 26% of the advanced technology exports in the world, according to the world bank, compared to 18 percent in the U.S. That includes high-value parts for the aerospace, computer, pharmaceutical, scientific and machinery industries.

A Question of Priorities

How did other countries set the U.S. so far back on its heels?

Quite simply, actually. One, they make sure their young people, their future workforce, is highly literate in science, technology, engineering and mathematics. At the same time, their governments work as strong partners with manufacturers, providing consistent and high levels of financial backing for applied manufacturing research. And they are persistent in their efforts, without prolonged debates or whipsawing with the political winds.

Germany's Fraunhofer Society is an often cited example of other countries' commitment to these activities, and for good reason. That network of research institutes has an annual budget of 2 billion euros (about $2.27 billion) and is one-third funded by the German government and local states, with the rest of the funding coming through contract research, some of which is also for the government.

Fraunhofer has positioned Germany as a leading global provider of manufacturing technologies, which, in turn, have helped the country hold on to valuable manufacturing work, despite relatively high wages. While Germany is a much smaller country than the U.S.—with just 25% of our population—it holds a 16% share of high-tech exports, a number that is on the rise.

Leaders in U.S. manufacturing have recognized for some time that if America does not want to be further sidelined in the critical, valuable manufacturing sector—after having a taste of the consequences—the nation would need to recapture leadership in a few key technology areas.

This is critical not just for America's employers to remain competitive, but it is also a matter of national security, according to the President's Council of Advisors on Science and Technology. Security, the council noted, doesn't mean defense goods alone; it also includes "our nation's energy security, food security, heath security, cybersecurity and economic security."

Bridging the "Valley of Death"

After the Great Recession, U.S. leaders began to seriously regroup on this challenge, with a mind toward securing U.S. leadership in manufacturing for the 21st century. President Obama commissioned a number of committees and reports, and meetings were held nationwide, as the depths of America's manufacturing challenge were explored.

Although the NNMI was just one of many recommendations that came out of those sessions, it was a centerprice proposal "because it prioritized reinvestment in manufacturing research," said Steven R. Schmid, a professor of aerospace and mechanical engineering at the University of Notre Dame in South Bend, IN. Schmid served at the Advanced Manufacturing National Program Office, where he helped design the NNMI program.

America's lack of investment in manufacturing research, he told SME, is "a key area where other countries are blowing us away."

America was failing, in particular, when it came to what is designated as "technology readiness levels 4 to 7," an area also known in scientific circles as the "valley of death" along the path from converting an idea into a commercial product.

Generally speaking, readiness levels 1 to 3 are where a concept is formulated and proved out with basic scientific research. Levels 4 to 7 are when a proven idea is further developed and scaled for a manufacturing environment through what is known as "applied research." Levels 8 and beyond are when a technology is ready for prime time and produced in a production environment for sale to customers, who then use the technology to build products.

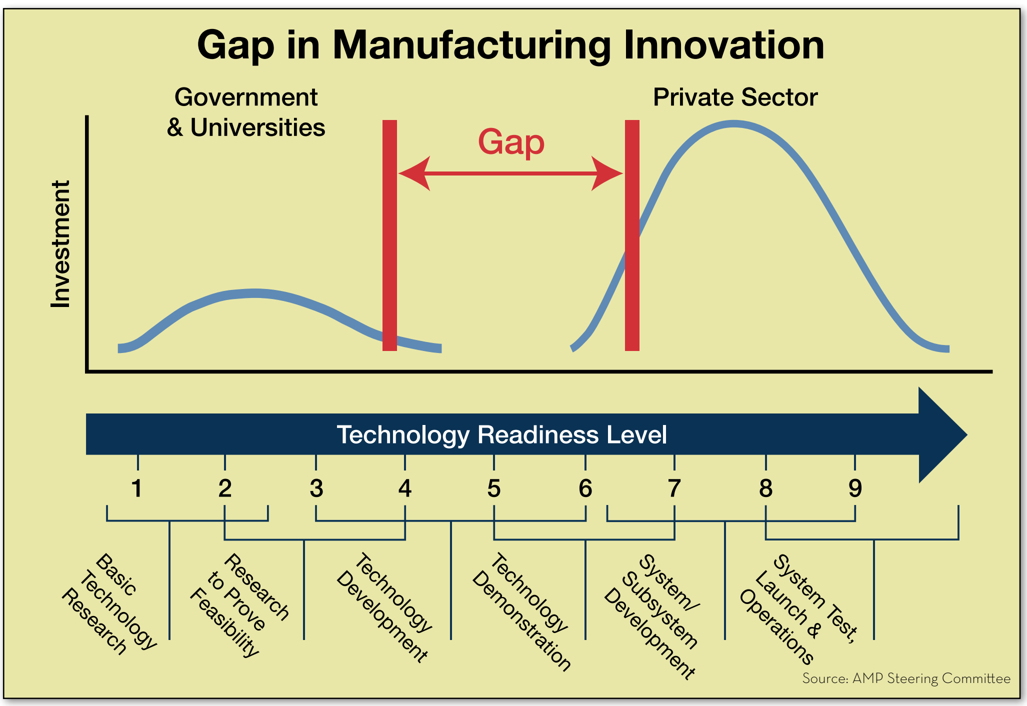
Schmid noted that the U.S. lags far behind other countries in manufacturing research investment—a stinging blow considering that foreign governments spend heavily to develop manufacturing technologies for the purpose of making products actually invented in the U.S.

For the U.S. to catch up to Germany's or Japan's level of spending in this area alone, it would have to spend $6 billion a year, according to a white paper produced by the North American Manufacturing Research Institution of SME (NAMRI/SME).

"The numbers are astounding," Schmid said.

Take Singapore, an island nation with a population and area roughly equal to Chicago, he said. Singapore alone invests more annually in applied manufacturing research than the U.S. Scaled by economy size, the U.S. would need to spend $25 billion to match Singapore's commitment. Matching South Korea's investment would require $175 billion annualy; matching China's investment would take $222 billion annually.

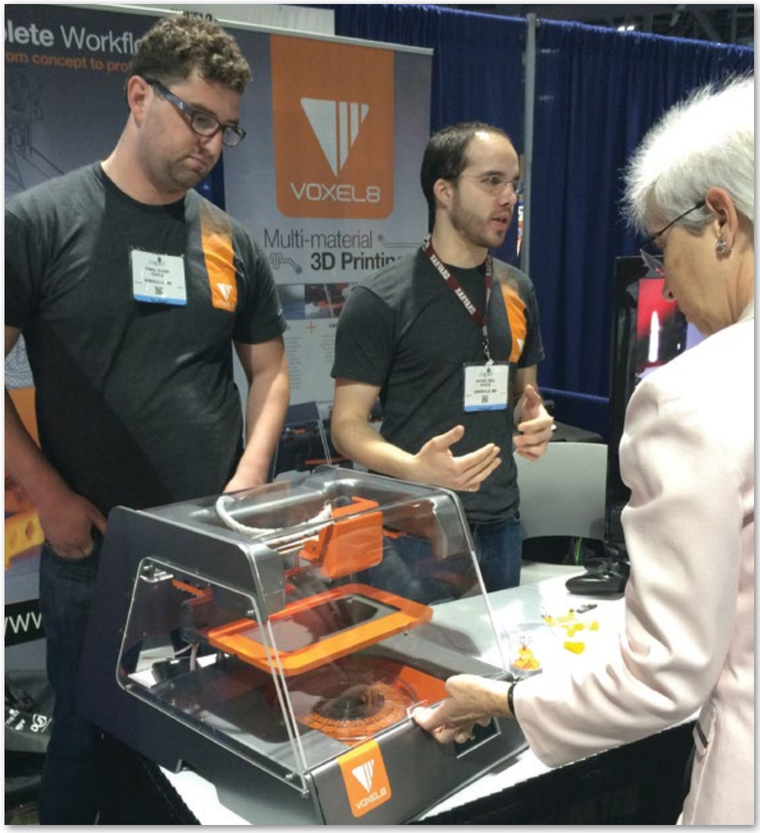
What would the U.S. be like if it spent as much as, say, Germany? "They didn't lose any manufacturing jobs since 2000—we lost 6 million," Schmid said. "And they have a higher labor rate than us."



Time, Money and Patience

Why does this so-called valley of death exist in the first place?

For one, this area of research is considered high risk. Not every proven scientific idea for a manufacturing technology is scalable for the commercial market, in terms of repeatability, quality or cost. So this is an area where shortcomings, some of them insurmountable, are often exposed, and money is inevitably lost.



Voxel8, based in Somerville, MA, is a U.S. company that is trying to get a promising new manufacturing technology off the ground. Later this year, Voxel8 will begin delivery of the world's first 3D electronics printer, which can rapidly embed 3D circuitry into a broad array of materials and holds the promise of making a wide range of future products. The printer is based on more than a decade of research into conductive inks by Prof. Jennifer A. Lewis at Harvard University, and previously, at the University of Illinois. Voxel co-founders Daniel Oliver and Michael Bell showed off the technology at RAPID 2015.

A lot of money. Converting a proven scientific idea into a commercial manufacturing technology is very, very expensive, partly because it can take a lot of time, involving many rounds of trial and error, as well as intersecting sciences. Development of these technologies can be slow, incremental and span decades.

Consider this high risk and cost with the objectives of investors, who want short-term results, or CEOs, who are under pressure to deliver them, and many companies simply find it difficult to justify—unless compelled by regulation or some other force.

Which is why governments often step in to bet on a potential payoff for their citizenry.

The development of modern solar panels, for example, has literally taken centuries, starting in the early 1800s, when the photovoltaic effect was first observed, and running right through until present times. The painstaking work of figuring out how to manufacture solar cells, which make up a panel, and honing their efficiency and making them scalable has also spanned several continents.

The U.S. Department of Energy invested millions in the solar panel industry in the 2000s. "But China matched our millions with billions," Schmid noted. And, the U.S. solar industry collapsed.

Time and time again, history has shown that it takes a phenomenal amount of time and money to develop the manufacturing technologies necessary to make a product for the masses at a high quality and affordable cost.

Remember GE's previously mentioned plan for the flat-screen TV? It shows just how expensive and risky these endeavors can be. GE ultimately decided not to invest in the concept, which led an American electrical engineer, William Ross Aiken, to try his hand at developing it. His efforts failed, and the Pennsylvania Philco Co. ended up launching a cathode-ray flat-screen TV in 1958. That, too, flopped, helping to send Philco into bankruptcy.

It wasn't until the late 1990s, nearly four decades after GE first came up with the idea, that flat-screen TVs became scalable and affordable because of improvements made in the methods of manufacturing them. Today, most flat-screen TVs are made in Taiwan, along with many spin-out technologies that depend on the underlying technology to make the TVs.

These integrated supply chains of manufacturing technology communities, and their collective knowledge, help to tell the story of why manufacturing has one of the strongest economic multipliers in the economy.

But the amount of time it takes to develop the technologies needed to manufacture materials, parts and products cannot be overstated.

Consider the lithium-ion battery, core to so many electronics today. It was first proposed by an American chemist, M.S. Whittingham, at Exxon in the 1970s. After more than two decades of development, the first commercial version was released by Sony and Asahi Kasei, a chemical company, in Japan in 1991. Today, most Li-ion batteries are made in Asia.

It took 15 years and $500 million for DuPont to develop the manufacturing process necessary to weave Kevlar, the para-aramid synthetic fiber that is stronger than steel according to

A Big Kickoff That Still Falls Short of the Competition

The National Network for Manufacturing Innovation, the new U.S. network of research and training hubs for advanced manufacturing technologies, is a substantial investment by the U.S. government, but it's one that still falls far short that of other nations.

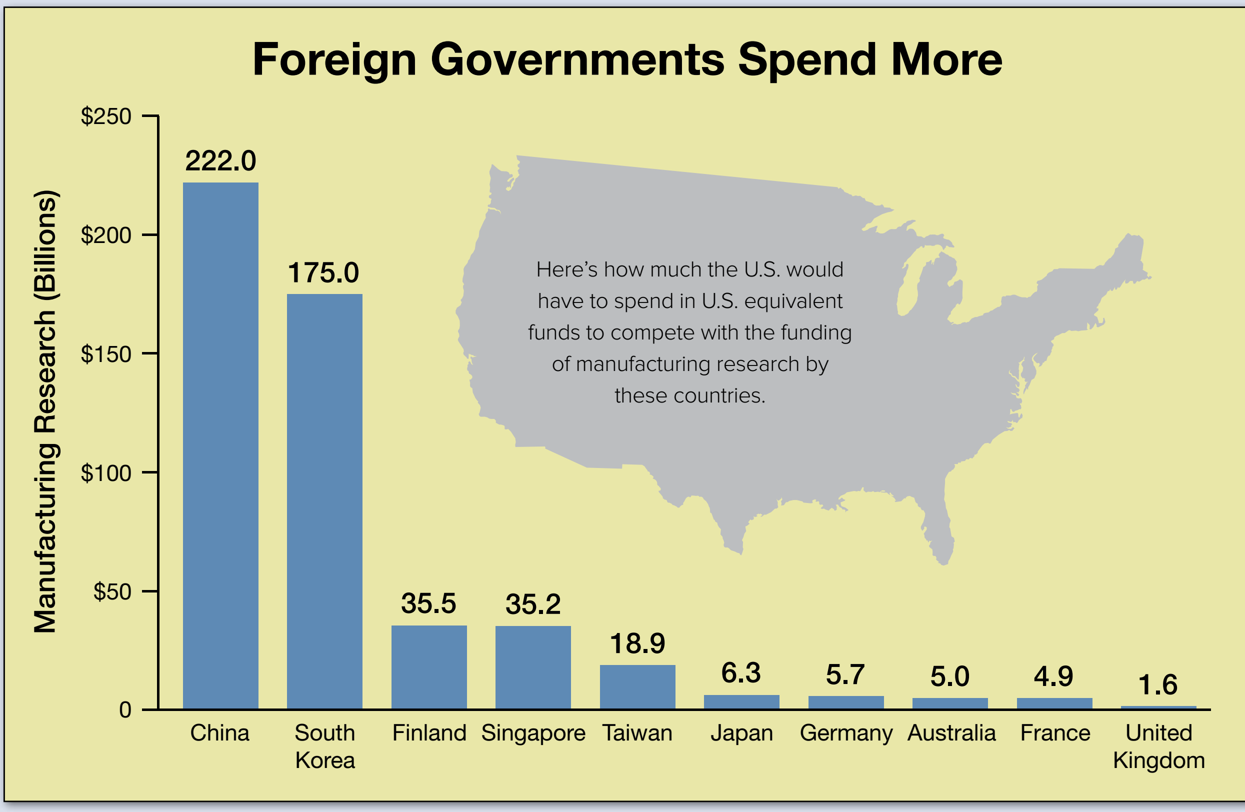
The U.S. has already dedicated $630 million to the NNMI's nine hubs that are to all be launched by the end of 2015, and it is seeking an additional $2.493 billion in its 2016 budget to support the program.

Once established, each hub will typically receive $70-$120 million in total federal funds. When combined with 1:1 mandatory co-invesment from private partners, the hubs will have a total capitalization of $140-$240 million.

The co-investment is a way to ensure that the U.S. is investing in projects for which there is a strong market interest. It also helps to ensure that companies and other private partners have skin in the game in making their projects a success. What's more, the U.S. hubs are expected to become self-sustaining within 5-7 years of launch through income-generating activities such as member fees, intellectual property licenses, contract research, and other fee-for-service activities.

"The U.S. lags behind the world in its support of manufacturing research."— The North American Manufacturing Research Institution of SME

By contrast, the German government provides about one third of the Fraunhofer Society's ongoing annual budget of 2 billion euros ($2.27 biillion). The rest of the society's funds come from contract research, including research for its government. The Fraunhofer Society is a driving force behind Germany's strength in manufacturing, despite relatively high wages.



The North American Manufacturing Research Institution of SME studied how much foreign governments invest in manufacturing research compared to the United States, and these are their findings.

Harvard's Pisano and Shih. After it was invented in 1965 by U.S. chemist Stephanie Kwolek, engineers had to determine how to produce and use the fiber in a manufacturing environment, not to mention all the research that went into determining the best weave patterns for strength and protection. Today Kevlar is used in body armor and a wide range of other products, including tires, smartphones and acoustic equipment.

Today, the technology race in 3D printing is in full force. The technology is still widely considered a young one, even though it was invented about three decades ago. It simply takes a lot of time and effort to develop technologies that can be used, repeatedly, at a compelling cost with high enough quality for a manufacturing environment.

Photo courtesy DuPont

The late chemist Stephanie Kwolek developed the first liquid crystal polymer that provided the basis for DuPont Kevlar brand fiber. It took DuPont 15 years and $500 million to develop the manufacturing process necessary to weave Kevlar, the synthetic fiber that is stronger than steel and used in body armor. DuPont has sold more than one million bullet-resistant vests made with the material.

In other countries, public-private partnerships, such as Germany's Fraunhofer, routinely step in to help develop these risky, expensive, time-consuming concepts for market. As a result, Fraunhofer now holds the foundational patent for selective laser melting, a key form of 3D printing that creates an object in a metal powder bed that is a now one of the leading forms of industrial 3D printing. Fraunhofer has also played a key role in improving the efficiency of silicon-based solar cells, among other valuable activities.

America Plays Catch Up

In its 2016 budget request, the National Institute of Standards and Technology, which is located in the U.S. Department of Commerce, mentioned some of these challenges as a rationale for seeking $150 million to fund two manufacturing hubs and coordinate the NNMI over the course of five years. That includes hiring seven full-time employees.

"U.S. inventions and innovations are commonly adopted for manufacturing in other countries who provide government support, because of the high cost and risk of development of new manufacturing processes by individual companies," the DoC budget request says.

By comparison, Germany's Fraunhofer has more than 67 institutes that employ more than 23,000 workers, or at least 300 employees at each of its hubs.

What's more, Fraunhofer has nine institutes that are physically located in the U.S., and since 1994, they have been helping U.S. researchers do applied research.

During the past decade, the Fraunhofer Center for Laser Applications, which is located near Detroit, won the Henry Ford Technology Award for the development of a laser beam welding process that improved the roof strength of the Ford F-150, America's best-selling vehicle for more than 30 years. The Fraunhofer Center for Coatings and Diamond Technologies has partnered with Michigan State University since 2003, while other Fraunhofer hubs here are partnered with the University of Maryland (software engineering), Boston University (biotechnology and photonics), the University of Delaware (biotechnology) and the University of Connecticut (energy innovation), among others.

Schmid noted that Fraunhofer is wise to make this investment, but added: "The real question is why don't we make that investment if it's so obvious to the Germans that it's a good idea?"

The Growing Manufacturing Network

By the end of 2015, America will have nine of its own manufacturing research hubs in various stages of development. In addition to workforce development projects, their mission is to invest in applied research projects in technology readiness levels 4 to 7.

America Makes, the initial pilot institute, is the furthest along and has worked through its start-up growing pains, such as intellectual property agreements with members, how to structure itself and deciding which projects to fund.

At the moment, America Makes has more than 140 members and has awarded funds to 47 projects in the area of additive manufacturing or 3D printing.

Each applied research project matches public to private

Michael F. Molnar, FSME, CMfgE, PE
Director
Advanced Manufacturing National Program Office
SME Past President

NNMI: A New Place for Advancing Manufacturing

Additive manufacturing has captured popular attention now that retailers are selling low-cost 3D printers. There is a perception that additive manufacturing simply appeared in the past two years, yet the technology has been under development for nearly 30 years—a timeline that is about average for a process or new material to mature from laboratory to production.

Additive manufacturing today is an exciting transformative technology for producing commercial products (rather than prototypes) and also for opening up new uses and markets. Moreover, for each of these transformative success stories there are a thousand other manufacturing process technologies or amazing materials struggling to cross the proverbial "valley of death."

Is there a way to bridge this gap for more technologies, and make them ready for use by manufacturers more quickly? This is exactly the purpose of the National Network for Manufacturing Innovation, or NNMI.

NNMI is a public-private partnership to create a new innovation space for U.S. manufacturers. It is where industry and academia can collaborate to solve industry-relevant problems. NNMI began as a top recommendation of the President's Council of Advisors on Science and Technology or PCAST. These senior private-sector leaders—university presidents and CEOs—aided by broad public input called for the federal government to catalyze institutes "to foster regional ecosystems in advanced manufacturing technologies."

A Focused Mission

NNMI institutes, each run by an industry-led consortium, have two main activities: applied research and workforce skills.

On research: The key is focus on bridging the "valley of death" gap; applied research to de-risk and scale-up technologies discovered from basic research at universities and national labs. Institutes provide the neutral convening ground for collaboration. The activities are still "pre-competitive"; product commercialization happens in industry so even direct competitors can collaborate on issues that no single company can solve by themselves. An important design characteristic is to have the critical mass for real impact. This is why each institute has a unique charter topic that will have national impact. These are not to be small academic centers writing papers, but significant innovation institutes with a user facility that provides value to industry.

On workforce: The key is collaboration with educational partners, including research universities and community colleges, to develop the workforce training for these emerging technologies. This addresses one of the top issues faced by manufacturers that limits growth: gaps in workforce skills in advanced manufacturing.

Institutes leverage regional and national organizations for outreach—particularly the Manufacturing Extension Partnership (MEP) network—to help build the skills necessary for establishing critical new supply chains in the U.S.

Industry collaborators can achieve grand challenges that no single company can solve by itself.

Ambitions for the Future

This dual research/workforce design was based on a year of study and public workshops with industry and academia, then validated by real-life experiential learning with pilot institutes. The first pilot institute, America Makes, was established in late 2012 with a focus of making additive manufacturing a reliable and low-cost technology for manufacturers.

Since then eight more institutes are established or underway. With broadly bipartisan Congressional authorization there are plans for a strong network plus new open topics competitions—where any topic proposed by industry can be considered for establishing an institute. The planning goal is to have a network of 45 institutes in 10 years.

So why consider being a part of NNMI? Consider joining an institute to enhance your global competitiveness, by learning and leveraging these disruptive innovations for your business. Institutes bring together the best talents and capabilities from all the partners to build the proving grounds where innovations flourish. As PCAST noted, the best means of sustaining innovation leadership is a strong and growing advanced manufacturing sector. NNMI helps you to invent here, make here and sell everywhere.

investment on a 1:1 basis and involves several companies and universities collaborating. That means if a hub receives $70 million from the government, along with a co-investment from partners, at least $140 million will be available for investment in research.

This structure is partly to ensure that the government isn't in the business of picking winners, and also that it's investing in projects for which there is a legitimate commercial interest in a valuable potential outcome.

Dean Bartles, Executive Director of the Digital Manufacturing & Design Innovation Institute in Chicago, said the fact so many important companies have signed on to participate in the initiative, putting up their own funds, "is a huge confirmation" of the NNMI concept. At DMDII, that list now includes Procter & Gamble, Lockheed Martin, Microsoft, GE, John Deere, Caterpillar, Dow Chemical, and Boeing, among others.

"These are not contracts or grants – these are truly partnerships," Bartles said. "To me, the best measurement of that is the kind of companies that are joining."

This spring in Detroit, where the new lightweighting hub—Lightweight Innovations for Tomorrow, or LIFT—is based, the leadership team was preparing to announce its first round of research awards.

Its chief technical officer, Alan I. Taub, a professor of materials science and engineering at the University of Michigan, is similar in credentials to many other manufacturing hub leaders. He earned a bachelor's degree in materials engineering from Brown University and holds a master's and Ph.D. in applied physics from Harvard University. He worked in a variety of R&D jobs at Ford Motor, Co., General Electric and General Motors before retiring in 2012 and heading to academia. He holds 26 patents, and serves on the board for a number of technology companies.

Taub told SME that the winners of LIFT's first tranche of applied research funds represent a good mix of technologies, as well as risk levels. "If these were all low risk projects, we'd just let companies do them on their own," he said. "We wanted to take some chances. That's the point."

Photo courtesy DMDII

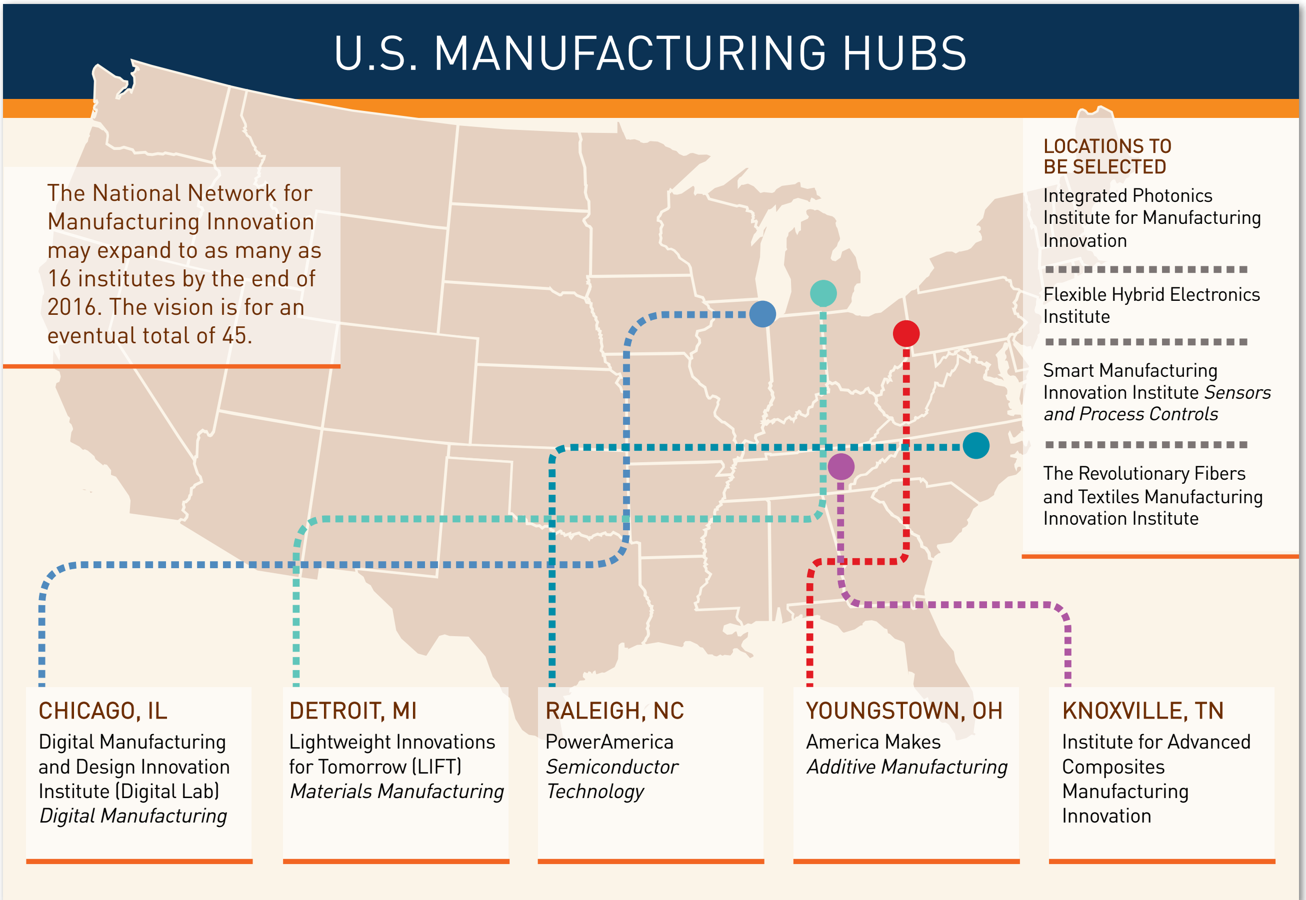
UI Labs opened its headquarters and the home of the DMDII in early May. Dean Bartles (far left), Executive Director of the DMDII and SME Vice President, and Dan Hartman (foreground), Director of Manufacturing Research & Development for the Institute, provide a tour of the hub's 24,000 square-foot manufacturing floor to community leaders, including Congressman Mike Quigley, Alderman Walter Burnett Jr., Chicago Mayor Rahm Emanuel, Illinois Governor Bruce Rauner, Senator Dick Durbin and Congresswoman Robin Kelly.

The basic business model is simple, if a bit harsh. Some of these projects will inevitably fail. But a few should succeed, and that's where the magic is supposed to happen. Ideas are to be converted into valuable intellectual property, which can then be licensed for a fee.

These fees are just one avenue of potential revenue that are designed to help make these manufacturing hubs self-sustaining within 5 to 7 years. The federal government has indicated it will not provide further assistance after that time. Other avenues of funding, similar to Fraunhofer, include fees for contract research, membership dues, and other fee-for-service activities.

The Self-Sustaining Finish Line

While the leadership of the hubs are in a breakneck race to become self-sustaining, the nature of the work they do may make



that mission difficult, if not impossible.

"We're trying to go as rapidly as we can," Morris said.

A May 2014 "progress report" on America Makes, written by a group of students at Carnegie Mellon University, which is a member of that pilot hub, found that "a consistent worry" among those involved in the hub "deals with the future funding."

Several of the executive directors of the manufacturing hubs told SME that the lack of ongoing federal funding will be a challenge, especially for hubs whose technologies are less mature in their very long development path.

"Given our competitive global economic environment," Morris said, "the U.S. is going to have to decide how to respond to continued long-term public funding by other nations in these key manufacturing technologies."

Added Schmid: "In a free-market world, manufacturing research investment is considered to be infrastructure, just like roads or airports. If we don't support our manufacturing infrastructure like these institutes, it gives other nations a competitive advantage."

Given the value that this new network could produce, Dean Bartles, the Executive Director of the digital manufacturing hub in Chicago, asked: "Why wouldn't the government want to continue funding?"

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