TESTIMONY OF PROF. MARTIN A. SCHMIDT, ACTING PROVOST, MASSACHUSETTS INSTITUTE OF TECHNOLOGY ON NOVEMBER 13, 2013 AT 2:30PM, AT THE HEARING BEFORE THE SENATE COMMITTEE ON COMMERCE, SCIENCE AND TRANSPORTATION ON THE ROLE OF MANUFACTURING COLLABORATIONS IN A 21ST CENTURY INNOVATION ECONOMY

Chairman Rockefeller, Ranking Member Thune and members of the Committee:

Thank you for inviting me today to discuss the role of manufacturing collaborations in our innovation economy. As requested, I will review key findings on that issue from MIT's just-released study on Production in the Innovation Economy – "PIE," as well as the Advanced Manufacturing Partnership – "AMP" - project. I have had the privilege to serve for three years on the faculty committee that prepared this MIT advanced manufacturing report, and have also served as the Technical Co-Lead on the university side for the Advanced Manufacturing Partnership.

Very often, the importance of a robust domestic manufacturing base is expressed in three contexts; jobs, economic and national security, and innovation.

At MIT, we have chosen over the past 3+ years to focus on the innovation question. Specifically, is a production ecosystem vital to our innovation processes, what level of production is needed, and how can we strengthen this area? This is not to say that matters of security and jobs are not very important, but on innovation we believe we have something particular to say, and further, as you know, technological innovation is the dominant factor behind economic growth and therefore jobs.

The MIT Production in the Innovation Economy (PIE) Study

MIT's manufacturing study was led by 20 members of the MIT faculty from a wide range of fields – engineering, science, economics, political science and management. It was data driven, undertaken over three years. It included interviews with over 250 manufacturing firms, small, medium and large. We conducted firm interviews in 21 states, but focused particularly on in-depth interview efforts in 4 states -- Ohio, Massachusetts, Georgia and Arizona -- which have quite different manufacturing economies and sectors. We also studied production in some 150 startup and entrepreneurial firms. We conducted interviews with an additional 78 firms in 7 other countries, and tried particularly to understand the manufacturing success of firms in Germany and China. We conducted, too, a major survey on workforce needs, sampling hundreds of manufacturing firms. Our report was recently released in book form; a second volume will come out this winter with the detailed backup chapters for the first overview volume. A preliminary summary of the MIT report can be found at: http://web.mit.edu/press/images/documents/pie-report.pdf.

Summary of Three Key Findings

We found three important developments.

1) Our manufacturing sector is thinning out - we need to find ways to strengthen the supporting "infrastructure" in our manufacturing sector.
2) There is a critical relationship between our innovation capability and our production capability.
3) We need to improve our ability to rapidly "scale up" production of new products based on advanced technologies.

I'll briefly summarize each finding, and then discuss how the Advanced Manufacturing Partnership effort ties to these findings.

1) Thinning Out:

First, our report found that the U.S. manufacturing sector was thinning out. We lost some 5.8 million manufacturing jobs – about 1/3 of all U.S. manufacturing jobs - in the decade between 2000 and 2010. There are ongoing debates about the origin of these losses from productivity gains to outsourcing. However, one fact is indisputable; there are far fewer people and places 'making things' in the US than there were in 2000. This translates to a thinning out of the production eco-system that we rely on for innovation in new products and a corresponding loss of investment in plants and equipment that position us to capture the manufacturing of these products.

But there is an underlying story here - the disappearance of the vertically integrated firm. Three decades ago our large firms housed under one organization all the skills and capabilities needed to design and manufacture their products. This was complemented by integrating complex value chains of supplier firms. However, capital markets have pushed these large firms to be far more capital efficient. This required them to thin down to their "core competencies" and to go "asset light." As a result, the role larger firms played in bringing best production practices to their industry, and forming workforce training systems for their supplier systems, declined. This means that our firms are now more "home alone" – their shared industrial infrastructure has thinned out.

In contrast, we looked at Germany - which has 20% of its workforce in manufacturing compared to our 11%, pays some 66% more in wages and benefits to its manufacturing workers compared to ours, and runs a very large trade surplus in manufactured goods (including with China), compared to our huge deficits. During the same period when the U.S. manufacturing ecosystem was thinning out, Germany worked to intensify its shared industrial infrastructure – closely connecting its small and large firms and tying them to technical institutes and a rigorous system of workforce training, with a very collaborative system. German manufacturing is a very different system from ours, but their success may hold some lessons for us.

2) The Connection Between Innovation and Production

For a time, U.S. manufacturing thought we could *distribute* manufacturing – we could innovate here and produce there. And to stay strong our major firms needed to be participating in major markets abroad.

This view is perhaps best embodied in Apple, a company that no one would dispute has an exceptional track record at delivering highly innovative new products, but is able to do this without keeping its manufacturing under one roof, let alone in the same country. We found that this separation of design from manufacturing can work for firms in a sector such as consumer electronics, where there has been tremendous standardization of the production processes and development of robust digital design environments, In addition, in the case of Apple, their huge market clout allows them to form unique partnerships with suppliers that emerging companies are not able to replicate.

But in most sectors – particularly where we are producing complex, high value goods - the study found that there were very close, critical links between innovation and initial production stages. Moving from innovation to product design can take years and is highly creative – there are critical feedback loops where the innovation is reworked as the product idea emerges. If you shift production abroad, we found that in many cases innovation capability has to follow it, or the innovation process is severely slowed down.

The Gillette company provides an example of production-innovation integration. It's is hard to imagine that a commodity product (e.g. a disposable razor) is manufactured first on a 30-acre waterfront site in downtown Boston, just two blocks from some of the most expensive office real-estate. Why is this the case? Well, in fact, razor blades turn out to be a highly complex good – they use, among other things, nanoscale diamond–like carbon coatings deposited in high vacuum (to keep the blades sharp), laser-welded materials, custom-formulated polymers for the blade suspension, and high-precision molded parts. All of this new production capability has to come together to manufacture these parts in high volume. Differences of pennies in the manufacturing costs can translate to significant profits or losses in this multi-billion dollar market. What Gillette has learned is that they must make these products in the same location where they interact with their customers and where they design the next generation products. This linkage of production to innovative design is critical to the success of Gillette. We have also seen this in a recent study we have done at MIT on advanced biomanufacturing. For example, in one sector of biomanufacturing, we found that 80% of all clinical production facilities are within 100 miles of the company's R&D center.

Innovation has been the U.S. strong suit – it's what we do best. But if important parts of innovation have to follow production, we could be affecting our innovation strength. And it is innovation that is the critical factor behind growth.

3) The Scale-Up Problem

We found that part of our problem in linking innovation and production is because we have growing difficulties in rapidly *scaling up production*.

We have many manufacturing sectors, but basically three kinds of firms – large multinationals; small and mid-size Main Street firms; and entrepreneurial, start-up firms.

Our large multinationals are global; they can cut production costs to compete by locating in lower cost and wage markets abroad, and they need to be in these markets to compete world-wide. Most of the top ten firms in revenues in the world are still U.S. firms. They face intense global competition but overall are doing well - but increasingly they produce abroad.

The majority of U.S. manufacturing is performed by some 300,000 small and mid-sized firms – what we called Main Street firms. The Main Street firms in our study had survived two tough recessions. So they had to be risk adverse, and could not finance much R&D. But we found in our 200 plus interviews that to survive they also had to be quite innovative – particularly in areas like manufacturing process and repurposing existing product lines for new markets. We found they had trouble with a particular stage – scaling up their innovations into production. With the demise of local banking in the face of national banking system models, they had real trouble obtaining financing for scale up of their innovations. Generally, the only option was to fund growth out of ongoing revenues. This slowed them down and limited their growth. In contrast, comparable competitors in Germany and China can tap external resources and are able to scale up production much more quickly. So "scale-up" is a growing issue for U.S. Main Street firms.

Scale-up is an issue, too, for our entrepreneurial and start-up firms that are commercializing innovations. We studied a group of 150 innovative firms that were able to obtain significant venture capital support. The venture support stayed in these firms beyond the 5 to 7 years we expected – it could extend 10 years or sometimes longer. But these firms faced obstacles when they reached the critical stage of product design, and asked their venture partners for funding to scale up production of their innovative new product. They were generally told that the venture firm had difficulty investing in production scale-up and were instead directed to contract manufacturers abroad or sometimes to sovereign wealth funds.

Innovation at scale is not a short-term process. Most new products cannot be replicated at near- zero marginal cost like software. Getting support for production scale-up of manufactured goods has become a significant problem for our entrepreneurs.

As an example, I'd point to a start-up firm I've had experience with: Lilliputian Systems**.** This is a firm that spun out of my lab at MIT in 2001. It was founded based upon research done at MIT under DARPA and Army support, as well as technology from Livermore Labs. Just this past winter, Lilliputian was finally able to demo their first product, which I have here. It burns a fuel (butane) in a completely safe way and generates electricity to recharge your mobile device when you are 'off the grid'. In fact, this product, when powered by a disposable fuel cartridge, will repeatedly recharge your mobile phone for 2-3 weeks, meaning that 'pound-for-pound' it has an order of magnitude more energy than the best battery you can buy. However, it hasn't been easy to get to this point. It's taken more than 10 years (a common time frame for disruptive new products using new technologies), it's required well in excess of $100M, and even today the company is working hard to identify investors to support the scale up of this fully functioning device to volume production.

Many of the challenges Lilliputian Systems faces are those that we hear over and over again. Namely: it takes a long time (especially if you need to rely on offshore production and development capacity) and domestic sources of capital for production infrastructure are hard to find (which encourages companies to seek foreign investment and to transfer production overseas).

Today, to get through this stage small U.S. firms increasingly do need to reach abroad. But remember the PIE study showed us clearly that in many industrial fields innovation and production need to be integrated. So unless we can solve this scale up problem, I worry that tomorrow's innovative industrial companies - built on the next generation of technology advances – may increasingly come from abroad.

The Connections Between the PIE Findings and AMP

The key findings of the PIE study link quite closely with the Advanced Manufacturing Partnership (AMP) project, the collaboration between industry and universities that Secretary Pritzker has described.

Re: Rebuilding the infrastructure –

AMP's July 2012 report recommended industry-university-state and local government collaborations in which the federal government would cost-share, built around "Manufacturing Institutes." These would be joint efforts to advance the development of critical new production technologies that could be transformative across multiple manufacturing sectors. They would support applied research, technology demonstrations and testbeds, and build collaborations between small and large firms and researchers. They are somewhat similar to the Fraunhofer Institutes so key to Germany's production system.

These manufacturing institutes fit with the MIT PIE recommendations on rebuilding our industrial infrastructure – they could fill a critical gap.

While the MIT PIE report found we didn't have a critical skilled workforce problem at this time, we will need new training and education if we are to shift to advanced manufacturing, If we don't have the trained talent to move into these new areas, we'll never get there. AMP recommended expanding the role of community colleges for this role. We can also apply the lessons we are learning in online education to develop new highly effective training modules for both workforce and engineer education.

Re: Linking Innovation and Production -

The network of Manufacturing Institutes, particularly through their testbed role, could also help link innovation with production.

In addition, a major step recommended by AMP is to develop collaborative industry – university–government manufacturing technology strategies. We need to look at the whole innovation system from research through production to figure out together how we can actually implement these breakthrough production technologies, along with their related processes and business models. The Manufacturing Institutes are part of these

strategies but we need to look at R&D feeding into the Institutes, and the next stages of implementation, as well.

We will need technology strategies and roadmaps to develop new production paradigms around technology advances - like digital manufacturing, additive manufacturing, mass customization, and advanced materials - to give us new efficiencies and productivity to compete with lower cost competitors.

Re: Scale-up

AMP will be looking hard in coming months at policy to fill the gap in our innovation system around the production scale-up problem.

Here again, manufacturing institutes will be an important strategy. They can help prove out the efficiency and costs of new production technologies, making it easier for smaller firms to obtain financing. But other approaches must be considered as well.

Congressional Action

I'm pleased to see that you and your colleagues are considering actions to help implement one key recommendation of the AMP report. Two of your colleagues, Senator Brown of Ohio and Senator Blunt of Missouri, have introduced legislation that would establish a Network for Manufacturing Innovation Program, built around Centers for Manufacturing Innovation much like the Institutes the AMP team envisioned. Congressman Kennedy from my own state of Massachusetts and Congressman Reed from New York have introduced a companion bill, so there is now bicameral, bipartisan momentum building behind these ideas.

Conclusion

Creating an America that will work better for ourselves, and work well for our children, will not be easy. The MIT study found that if we want to ensure that America's future is enriched by a robust manufacturing sector, as our past has been, creating better ties from our innovation system to our production system will be essential.

The Advanced Manufacturing Partnership suggested that public-private partnerships are the right model to create such ties in the U.S.-- industry, colleges and universities, and local and state governments can work together to build strong industries taking advantage of regional assets and expertise. Federal programs can support regional economic development, the sharing of best practices, and the development of capabilities essential to defense and other national needs.

With the AMP effort moving into its next phase and Congress giving serious consideration to the role of manufacturing in maintaining U.S. competitiveness, we have a real opportunity to strengthen our innovation ecosystem in ways that will help rebuild our economy.

Thank you.