Reports Outline Challenges to U.S. Manufacturing Innovation
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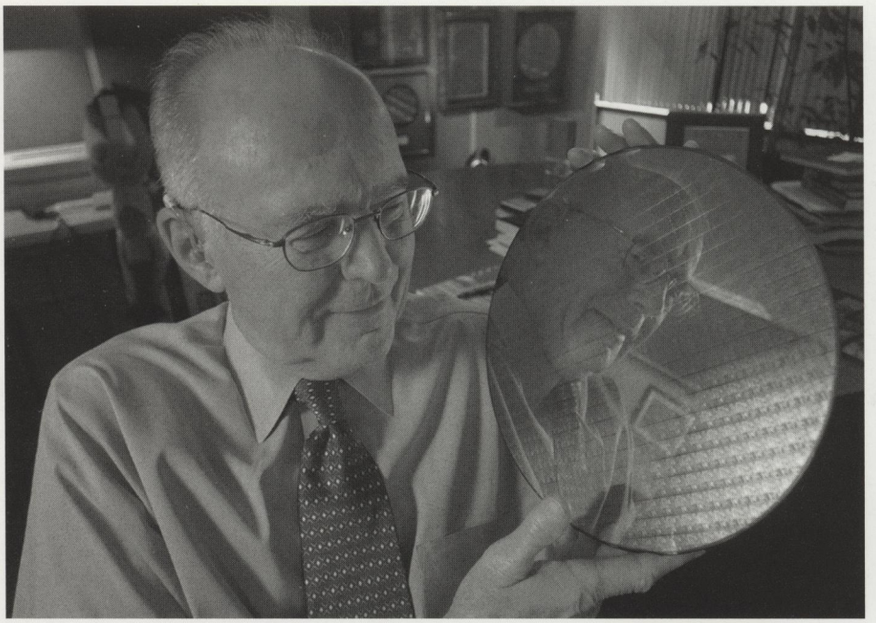

Intel Corp. co-founder Gordon Moore holds up a silicon wafer at Intel headquarters in Santa Clara, CA, during celebrations of the 40th anniversary of Moore's Law on March 9, 2005. Moore saw that the number of components on an integrated circuit had doubled every year and figured that rate would continue for a decade as transistors were made smaller. (AP Photo/Paul Sakuma)

Fe Institute and a mathematics professor at Oxford University best known for his exploits beating the roulette system in Las Vegas in the late 1970s, and Quan Bui of St. John's College in Santa Fe, chose to study six methods for predicting future advances in technology:

- Moore's law is probably the best known. Advanced by Intel co-founder Gordon Moore, the law asserts that the number of components in integrated circuit chips will double every 18 months. The early success of the predictions led analysts to expand it beyond the information technology industry to assert that any technology will improve exponentially, with the exponent depending on the technology itself.
- Wright's law stemmed from the observation by aeronautical engineer Theodore Wright that the cost of airplanes fell as the total number manufactured increased. Specifically, the cost fell in proportion to the inverse of the production raised to a particular power. As in the case of Moore's law, Wright's formula has been expanded to cover the cost-production ratio of technological products generally.
- The lagged Wright law is simply a version of Wright's law in which the results lag those predicted by the law by a year.
- Goddard's law, proposed in 1982, asserts that technological progress is driven entirely by economics of scale; as the scale of production increases, the cost per unit falls.
- The Sinclair, Klepper, and Cohen hypothesis, advanced in 2000, combines Wright's and Goddard's laws, suggesting that costs fall as a result of both the amount and the rate of production.
- The Nordhaus approach, advanced in 2009 by Yale University economist William Nordhaus, combines Moore's and Wright's laws, predicting that costs depend on both time and the amount of production.

From Aluminum to Beer

To analyze the value of the various laws, the team applied them to 62 different industry sectors, ranging from aluminum to beer and from aircraft to solar cells, a pursuit that required significant information gathering. "There are lots of proposals out there," Trancik says. "But the data to test the hypotheses is hard to come by." The team gathered data on the chosen sectors from government reports, market research publications, and similar sources that covered the years 1936 to 2009. The analysis took the form of hindcasting—using data from specific years to forecast costs in later years and comparing the forecasts with the actual results.

Surprisingly, the analysis revealed that most of the methods are quite similar in their performance. Goddard's law was less effective than the others in forecasting short-term performance, while the Sinclair, Klepper, and Cohen model's predictions falter over the longer term. Wright's and Moore's laws slightly outperformed the other four, with Wright just squeaking by as the winner.

The team cautions that the analysis doesn't cover technologies that didn't make it into the database because they failed to last long enough in the market. Nevertheless, the results support a conclusion applicable to a wide variety of technology industries. "Our analysis reveals that decreasing costs and increasing production are closely related," the researchers report. "The historical data shows a strong tendency, across different types of technologies, toward constant exponential growth rates."

To add credibility to the research, the team applied their understanding of predictions to forecasting the cost of electricity for residential-scale photovoltaic solar systems. The conclusions: An expected cost of 6 cents per kilowatt-hour in 2020, falling to 2 cents per kWh by 2030. Those figures compare with the current cost of 5 cents per kWh for coal-fired electricity, the cheapest method currently available.

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Reports Outline Challenges to U.S. Manufacturing Innovation

The recent performance of the U.S. manufacturing sector is impressive by

many economic metrics. The U.S. Bureau of Economic Analysis (BEA) reports that U.S. manufacturers generated $1.84 trillion in value-added revenue in 2011, a number that would make the U.S. manufacturing sector the world's tenth-largest economy in terms of gross domestic product (GDP). Productivity in manufacturing has also been on a steady increase, with output growing by some 55 percent over the 20-year span ending in 2011. Moreover, the BEA estimates that between 1998 and 2011 manufacturing productivity (excluding computers) grew at an average annual rate of 3.5 percent; the service sector grew by just 1.4 percent annually over the same time period.

Nevertheless, the U.S. manufacturing sector faces many challenges, as two recent reports outline. The ninth edition of *Facts About Modern Manufacturing*, released in December 2012 by the National Association of Manufacturers, the Manufacturers Alliance for Productivity and Innovation, and the Manufacturing Institute, focuses on what U.S. manufacturers view as their current and future competitiveness challenges. The *Report of the MIT Task Force on Innovation and Production*, a preview of which was released in February 2013, asked how production capabilities in the United States and abroad contribute to sustaining innovation and realizing its benefits in America. Taken together, the two reports give a good overview of the challenges and opportunities facing the U.S. manufacturing sector in the coming decade.

The *Facts* report is a compilation of 65 charts with analysis. The charts present a wide array of economic data for the U.S. manufacturing sector, with the analysis highlighting the importance of manufacturing to the U.S. and global economies. The data map the role of manufacturing in six key areas, including economic growth, innovation, employment and compensation, environment and quality of life, trade and investment, and competitiveness. The MIT report is the output of the 21-member Production in the Innovation Economy (PIE) commission. Employing in-depth interviews, the PIE researchers questioned representatives from 255 companies, of which 178 were located in the U.S., in order to find out what innovations firms had attempted to commercialize in the last five years, as well as to determine whether capital, skilled workers, suppliers, or expertise had been difficult to obtain. Those questioned included 30 major multinational manufacturers (10 of these in the *Fortune 100*), 150 firms that grew out of patents created in MIT laboratories and licensed by the MIT Technology Licensing Office between 1997 and 2008, 96 small- and middle-sized U.S. manufacturers, and a selection of foreign, mostly German (32) and Chinese (36). (Some companies appeared in more than one of these categories.)

Both *Facts* and the MIT report recognize two major challenges to U.S. manufacturing innovation: first, a deficiency in manufacturing engineers with undergraduate-level training and technically skilled employees, now and in the future; and second, increasing global competencies in advanced manufacturing innovation, which will undermine the longstanding U.S. dominance.

In addressing this first challenge, the *Facts* report notes that the manufacturing sector is being affected by the aging of the U.S. workforce; the median age of the manufacturing workforce in 2011 was 44.1 years, up from 40.5 years in 2000. And young people are not pursuing manufacturing fields in the numbers needed to replace those retiring. In 2008, the report says, only 4.4 percent of first university degrees in the United States were granted in engineering fields, as compared to other developed economies, such as Japan, with 17.1 percent, and Germany, with 12.4 percent. The gap is even larger in developing economies; approximately 31 percent of China's university graduates earn engineering or related degrees, and 25 percent of those in South Korea. The *Facts* report warns that if the U.S. does not bridge this human capital gap, the country risks losing competiveness in both disruptive and incremental product innovation.

The MIT task force found that manufacturers are already having difficulty filling employment vacancies, with 20 percent of firms experiencing long-term vacancies (over three months). This deficiency is affecting about 5 percent of core production jobs. Other major skills gap issues uncovered by the PIE commission include vacancies due to particular skills not being available in a particular region, jobs requiring advanced mathematics skills going unfilled, and vacancies persisting in small companies that have few connections to other companies in their area or to local schools.

The *Facts* report finds ample evidence that the United States no longer enjoys unquestioned global dominance in manufacturing innovation. One indication is an accelerating shift in annual patent awards. In 2011, 48 percent of all U.S. utility patents were awarded to U.S.-based inventors; in 1980, that number topped 60 percent. Other countries are also accelerating their spending on innovation; aggregate R&D spending for the 10 largest and fastest-growing economies for which reliable data exist reached 55 percent of the U.S. spending level in 2009, up from 19 percent in 1999. The *Facts* report notes that a "modestly stronger" federal allocation of funding for basic research in the physical sciences will primarily benefit the capital goods industries, a segment in which the United States remains globally competitive.

In its preliminary report, the MIT task force found that the tendency to shift the commercialization of technologies abroad presents a real danger to U.S. leadership in innovation. As more U.S. companies go abroad for manufacturing, the preliminary report says, their capacity for initiating further rounds of innovation will decline. Such a decline is a result of lost learning opportunities. Firms gain much knowledge in the progression from prototype and demonstration through the iterative stages of commercialization, such as when manufacturing engineers come back with their problems to the design engineers seeking better resolutions.

The biggest innovation challenge, according to PIE researchers, is filling the holes in the U.S. industrial ecosystem, what they characterize as "market failures." These gaps reflect an absence of complementary capabilities that

NewsBriefs

March 4—President Barack Obama nominates Ernest Moniz to succeed Steven Chu as Secretary of Energy. Moniz, a physicist by training, is the director of the MIT Energy Initiative; he served as Under Secretary of Energy during the Clinton administration. During confirmation hearings in April, Moniz argued that the Department of Energy should focus on research and development to push down the cost of low-carbon technologies. This is in contrast, some argue, to the previous program of investing in clean-tech companies. Moniz also stated that the United States is "underinvesting by a factor of three" in energy research. According to the Energy Innovation Tracker, the entire US government spent about $5 billion on energy research in 2012, compared to the Department of Defense's $72 billion R&D budget. The Senate Energy and Natural Resources Committee voted to confirm Moniz's nomination on April 18. The nomination is now under consideration by the full Senate.

MARCH 5—Researchers Jonathan Band and Jonathan Gerafi release a report on the role of non-US–owned firms in IP-intensive industries on infojustice.org. Intended to question assumptions that U.S. firms dominate international markets in these industries, "Foreign Ownership of Firms in IP-Intensive Industries" finds that many of these fields are in fact dominated by corporations based outside the United States. In 2011 and 2012, the authors find, foreign companies were awarded more US patents than US-based companies, and seven of the top ten patent recipients were non-US companies. "There is absolutely nothing sinister about foreign ownership of firms in IP-intensive industries," the authors argue. "This is to be expected in a globalized economy with multinational corporations and complex cross-border supply chains." The real point, Band and Gerafi say, is that US policy makers must reexamine the assumptions underlying protectionist IP policies and recognize that the beneficiaries of such policies are not necessarily US firms.

MARCH 28—Google announces its Open Patent Non-Assertion (OPN) Pledge, promising "not to sue any user distributor or developer of open-source software on specified patents, unless first attacked." Initially, the company said, the pledge will apply to 10 patents associated with its MapReduce, a programming model for handling large data sets. More patents will be added over time. In the announcement, on its Open Source Blog, the company expressed the hope that its OPN Pledge will become an industry model. While some commentators dismissed the action as merely symbolic, others saw it as a strong first step.

MARCH 29—Officials at Spaceport America confirm that the spaceport's 2-mile-long runway will be extended another 2,000 feet to accommodate Virgin Galactic's spacecraft. Spaceport America, which is located in southern New Mexico, is the world's first terminal constructed for commercial space travel. The extension is necessary to ensure safety, a spaceport spokesman said. It will cost $7 million and take six to eight months to design. Virgin Galactic now has more than 500 ticket holders, including celebrities, scientists, and space buffs, although its first flight is at least a year away. The $200,000 ticket reserves a seat on a 2.5-hour flight with 5 minutes of weightlessness.

MARCH 31—Roadrunner, once the world's fastest supercomputer, is decommissioned to make way for new technologies. Although the $121 million collection of processors is still among the 25 fastest supercomputers in the world, new machines are smaller, faster, and cheaper to operate. The supercomputer, which was constructed from commercially available parts by IBM and Los Alamos National Laboratory, became the first computer to break the petaflop barrier, processing a quadrillion computations a second. It has since been used for a diverse array of projects, including modeling viruses and visualizing energy flow in nuclear weapons. Researchers will have a month to experiment with Roadrunner's operating systems before the machine is dismantled.

APRIL 1—The Industrial Research Institute announces its 2013 IRI Medal winners. The organization will present the prestigious award to two influential researchers, Robert S. Langer and George M. Whitesides. Dr. Langer, who is the David H. Koch Institute Professor at MIT, is a widely recognized researcher in bioscience, recognized for bringing numerous drugs and drug delivery systems to the market; he was a 2012 recipient of the National Medal of Technology and Innovation. Dr. Whitesides, the Woodford L. and Ann A. Flowers University Professor at Harvard University, is being honored for his work in a range of fields, from nuclear magnetic resonance to organometallic chemistry and nanotechnology, which has had significant impact on a range of technology fields. The Medals will be presented at IRI's Diamond Jubilee Awards Dinner, to be held May 22 in Washington, DC.

American firms can draw on to supplement their own resources when they seek to develop product ideas. On a related note, the decline in U.S. utility patent awards in 2011 reported in the *Facts* publication may be related to the loss of university research support in emerging industries. Interorganizational ties between business, academia, and other key institutions that connect research in its earliest stages to production in its final phases are vital to manufacturing innovation. To combat these gaps, the task force argues that it is crucial for firms developing new products to locate in a diverse industrial ecosystem that offers complementary resources, such as employee training, opportunities for collaborative research, and financing mechanisms.

There has been a litany of reports and commentary about the critical role of U.S. manufacturing in the American economy. These two recent additions focus on both the business and public policy challenges to the manufacturing sector, as well as to the business services sectors that are dependent on manufacturing's success. How American leadership in both the private and public

sectors addresses these challenges will largely determine the future importance of the United States in the global economy.

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West Virginia Program Nurtures Academia/ Industry Relationships

Higher education and private industry have struggled to overcome divergent research priorities and objectives, but shrinking R&D budgets and a need for innovation have sparked new overtures for collaborations. An award-winning West Virginia initiative has taken up the challenge of improving communication between higher education researchers and business representatives by building trust and identifying needs for both sectors.

Europe is ahead in encouraging cooperation between the private sector and universities. Markus Perkmann, research fellow at the Imperial College Business School in London, and Ammon Salter, research director of the UK Innovation Research Centre and EU Commissioner for Research, Innovation and Science, wrote about the trend in a recent issue of Canada's *Financial Post*. "Rather than merely licensing inventions, another often underappreciated opportunity for firms is to get help from universities during the whole life cycle of their innovation projects," Perkmann and Salter wrote. "For example, in the United Kingdom, businesses already spend more than 20 times more on university collaboration than on licensing technology from universities . . . businesses that don't work with universities may be missing opportunities of significant proportions."

In West Virginia where higher education is feeling the pinch of reduced federal research dollars and the work force remains hungry for new industry jobs, collaborations are developing at the very starting point of innovation: where both sectors learn what each other has to offer. Linking Innovation Industry and Commercialization (LIINC) was started at West Virginia University in 2012 to accelerate commercialization of university-originated research and jumpstart collaborative projects by bringing researchers and business people together at informal events designed to nurture relationships.

Most LIINC events include brief presentations, poster sessions, and light refreshments, but in every case, the evening concludes with one-on-one discussions that often lead to productive activity. Separate events have been held for bioscience and biomedical technologies, security and intelligence, energy and the environment, and life sciences and natural resources research.

LIINC had its roots in a 2011 report, "West Virginia Blueprint for Technology-Based Economic Development," prepared by the Battelle Institute's Technology Partnership Practice and an economic development organization called TechConnectWV. In addition to identifying a need to "act boldly and quickly" to grow research, technology transfer, and commercialization, the report noted that West Virginia trails the national average in securing industry support for university-based R&D. According to the report, "From 2002 to 2009, an average of 3.3% of total R&D expenditures at West Virginia colleges and universities came from industry compared with 5.4% in the United States."

The Blueprint suggested that universities should aim to match the national average by 2020. That recommendation sparked the LIINC program. According to Lindsay Emery, the business development manager in charge of LIINC, "WVU had a record of research performance, a technology transfer office and a business incubator but no mechanism to actively connect faculty and students to the private sector. We needed to bring the University's talent base to the attention of industry partners." LIINC, which attracted funding from the Pittsburgh-based Claude Worthington Benedum Foundation and strong support from WVU STEM deans, was designed to provide that connection.

The Benedum Foundation provided $132,000 to support LIINC. "The Benedum Foundation has been supporting the growth of technology-based economic development in both West Virginia and Southwest Pennsylvania for several years," explained Mary Hunt, senior program manager at the Foundation. "LIINC is a program that enables the many players in the technology-based economy to come together and explore new opportunities. Matching researchers with existing businesses to examine relationships that result in new business and jobs is the seed planted and nurtured through LIINC."

The logistics were daunting, but perhaps not as difficult as countering the skepticism of veteran faculty researchers—a traditional cultural barrier that has long thwarted significant collaboration with private industry at the university. "We had to approach it on a very basic level," Emery explained. "Our challenge was to convince faculty that once they reach outside their laboratory bubble, opportunities open up to have their work make an impact by improving society; making products more economical; or attracting more quality young people to careers in science all without cost to them." By contrast, Emery said, the private industry response to the initiative was "it's about time."

After more than a year of coaxing faculty members, pursuing private industry leads, and hosting 14 receptions, dinners, and presentations, LIINC has managed to entice 272 representatives from 194 companies to interact with 408 faculty members and 55 students. An impressive array of companies have sent representatives to LIINC events. Pfizer, IBM, Northrop Grumman, Mylan Pharmaceuticals, and Eli Lilly, among others, have joined smaller regional companies and even federal agencies in dipping their toes in the WVU research waters. David DeVallance, assistant professor in the Division of Forestry and Natural Resources at WVU, has been working with a private company as a result of his participation in LIINC. "Through LIINC, I have been able to meet local industry that is interested in