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The Evolving Organization of U.S. Innovation Agencies: An Overview

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There have been four major innovation organization policy moments for the federal government, driven by the demands of politics and technology since World War II, and some experts are now recognizing a fifth. This brief highlights each of the periods, focusing on select representative agencies. It notes a fundamental divide in the design of federal science agencies, between a "connected" model prevalent in World War II, where innovation stages and actors were closely linked, and a "disconnected" postwar model, where the federal role focused on one innovation stage, basic research. Subsequent decades have seen a series of efforts in new agency design to bridge the divide. I focus here on the evolution of the federal agency role: What innovation stages does it focus on within the innovation pipeline and how does it link to other innovation actors?

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There have been four major innovation organization policy moments for the federal government, driven by the demands of politics and technology since World War II: 1) the immediate postwar period where the Cold War helped drive the formation and expansion of a plethora of science agencies; 2) the Sputnik aftermath, which sparked the formation of DARPA and NASA and scaled-up funding for science; 3) the competitiveness era "valley of death" programs of the 1980s; and recently, 4) an energy technology shift driven by energy security and climate demands. Some experts are now recognizing a fifth moment: advanced manufacturing.

In that lengthy evolution, what lessons have we learned about the design of federal innovation organizations? What are the institutional elements in the "new generation" innovation policy programs now developing or under consideration?

This policy brief highlights each period, focusing on select representative agencies. It notes a fundamental divide in the design of federal science agencies, between a "connected" model prevalent in World War II, where innovation stages and actors were closely linked, and a "disconnected" postwar model, where the federal role focused on one innovation stage, namely basic research, and lines to the industry development and implementation roles were largely erased. Subsequent decades have seen a series of efforts in new agency design to bridge the divide and restore the connections.

THE POSTWAR, DISCONNECTED, SCIENCE MODEL

The federal innovation role shifted from modest to major during World War II.[1] President Franklin Roosevelt's wartime science czar, Vannevar Bush, led a highly connected system of innovation actors, closely linking industry, government, and university research.[2] Bush and his colleagues created can be called a "connected science" approach, where technology breakthroughs at the basic science stage were closely connected to the follow-on applied stages of government-supported development, prototyping, testbeds, and production, operating under what can be called a "technology challenge" model. Not only were the stages of research linked, but the innovation actors were as well. The federal government supported all the research and development (R&D) stages, as well as the implementation stages, encouraging close connections between government, university, and industry innovation actors. After the war Bush dismantled this system and substituted an alternative, disconnected, one.[3]

When the war ended and the military was being dismantled in the expectation of world peace, Bush was able to salvage a residual level of federal science investment. In his 1945 polemic for science support, *Science, the Endless Frontier,* Bush argued that the U.S. government should fund basic research, which would deliver ongoing progress to the country in economic growth, national security, and health.[4] In other words, he proposed ending his wartime model of connected science R&D, organized around major technology challenges, in favor of making the federal role one of funding only one stage of technology advance: exploratory basic research.[5] Bush's approach became known as the "pipeline" model for science investment.[6] The federal government would load basic science into one end of an innovation pipeline in the hope that industry would pick up the early- and late-stage technology development and prototyping roles inside the pipeline, with new technology products emerging from industry at the end.

While Bush proposed to achieve research coherence under a single organization—the National Science Foundation (NSF)—a veto by President Truman delayed its formation until 1950, and in the interim science agencies multiplied.[7]

These two developments left U.S. science fragmented at the institutional level: overall science organization was split among numerous agencies, and federal investment primarily was focused on only one stage of the technological pipeline—basic research.[8] Bush thus left a legacy of two conflicting models for scientific organizational advance: the connected, technology challenge model of his World War II institutions, and the disconnected, multi-headed model focused on basic science of postwar U.S. science institutional organization.

THE SPUTNIK CHALLENGE OF 1957 AND RISE OF THE DARPA MODEL

While the civilian research agencies moved to a disconnected model, the defense agencies by 1949 found themselves in a Cold War. They could not live with the inherent inefficiency of a disconnected model, so began by the end of the 1940s to recreate the "connected" S&T model that had served them well earlier.

The Soviet launch of Sputnik in 1957 created a crisis in confidence over U.S. science leadership. Anxieties over these geopolitical developments created a political driver for science support, bringing new institutions and R&D investments. Created in 1958 by Eisenhower as a unifying force for defense R&D in light of the stove-piped military services space programs that had helped lead to America's space failure, the Defense Advanced Research Projects Agency (DARPA) became a unique entity.

DARPA was set up to address deficiencies in R&D collaboration between the military services, rather than as a counterpoint to civilian agencies. It was a particularly interesting model, very different from Vannevar Bush's approach. DARPA's aim was a "right-left" translational approach: decide the technologies required from the right side of the innovation pipeline, then nurture breakthrough science advances on the left side of the pipeline to get there.[9] DARPA embodied a return to Bush's earlier "connected science" through a "technology challenge" model. The most successful of the postwar and Cold War science and technology agencies, DARPA led the information technology revolution and a long series of other major advances.[10] As it came into its own in the 1970s and 1980s, DARPA was a counterweight to the swing toward a "pure" basic research approach.

While DARPA illustrates the connected science approach, there are also political design lessons to be drawn from this model. DARPA operated not only in the basic research space but further down the innovation pipeline in the development and prototyping spaces and often was able to hand off its technology advances to military procurement for initial product implementation—in the ideological parlance of the time, it was "picking technology winners and losers."

Although DARPA inherited the earlier "connected science" model, it added another aspect to the mix. "Great Group" innovation theory posits that innovation is no longer the output of solo inventors, but occurs at the face-to-face level in groups, and these groups follow common organizational rule sets.[11] Behind these "great groups" lies a supporting innovation ecosystem at the level of institutions, above the personal level. Both are required for innovation to occur. Unlike other R&D agencies, DARPA has operated at both the institutional and personal levels of innovation. It plays an institutional innovation support role but has consciously fostered great groups as well. Thus DARPA has been both an innovation actor and an innovation enabler.

Other DARPA characteristics enhance its ability to operate at both the institutional and personal innovation organization levels:[12]

- *Small and flexible:* DARPA consists of only 100–150 professionals; some have referred to the organization as "100 geniuses connected by a travel agent."
- *Flat:* Flat, non-hierarchical organization, with empowered program managers.
- *Innovative research model:* A challenge-based "right-left" research model.
- *Great talent:* Emphasis on selecting highly talented, entrepreneurial program managers often with both academic and industry experience who serve for a limited (3–5 year) duration.
- *No labs:* Research is carried out entirely by outside performers, with no internal research laboratory; not limited by peer review group selection processes, DARPA managers aim to select the very best research performers.
- *Acceptance of risk:* Projects focus on "high-risk/high payoff" motif, selected and evaluated on what impact they could make on achieving a demanding capability or challenge.
- *Seed and scale:* Provides initial short-term funding for seed efforts that can scale to significant funding for promising concepts, but with clear willingness to terminate non-performing projects.
- Autonomy and freedom from bureaucratic impediments: Operates outside the civil-service hiring process and standard government contracting rules, which gives it unusual access to talent, plus speed and flexibility in contracting for R&D efforts. Although largely outside the bureaucracy, it tries to maintain a lifeline back to senior Department of Defense (DoD) administrators for support on technology implementation.
- *Hybrid model:* DARPA often puts small, innovative firms and university researchers together on the same project so firms have access to breakthrough science and researchers see pathways to implementation.
- *Teams and networks:* At its best, DARPA creates and sustains highly talented teams of researchers—great groups—highly collaborative and networked around the challenge model.
- *Acceptance of failure:* At its best, DARPA pursues a high-risk model for breakthrough opportunities and is very tolerant of failure if the payoff from potential success is great enough.
- *Orientation to revolutionary breakthroughs in a connected approach:* DARPA is focused not on incremental but radical innovation. It emphasizes high-risk investment, moves from fundamental technological advances to prototyping, and then hands off the production stage to the armed services or the commercial sector.
- *A technology visioning process,* as opposed to incremental steps, occurs at the front of DARPA's research nurturing process.[13]

DARPA marked a return to Vannevar Bush's initial approach, but it was more. From an institutional innovation perspective, DARPA is a connected model, crossing the barriers between innovation stages from research to implementation, but also making an organizational link between the face-to-face group level of innovation and an innovation-enabling institution. In contrast to the civilian R&D agencies focused on the initial stage, basic research, the DoD created an innovation system that spanned the full spectrum of the innovation pipeline, supporting each stage, from research, to development, to prototype, to demonstration, to testbed, and often using its procurement power for initial product market creation. DARPA was part of a defense innovation system—it was an entrepreneurial innovator within DoD, but often relied on the military services (and in the case of IT, the private sector) for the follow-on stages to foster implementation.

THE 1970–1990 COMPETITIVENESS PERIOD

Vannevar Bush's basic research pipeline model institutionalized a disconnect between research and later-stage development over most of the U.S. innovation system, making the handoff to commercialization very difficult compared to his wartime approach. The creation of DARPA furthered a shift in the defense innovation sector away from this model and expanded beyond defense in the late 1980s. As the United States entered a period of heightened economic competitiveness over technology advance with Japan and Germany, concerns grew that although the United States was originating the leading innovations, it was limited, due to this disconnect, (or "valley of death") in its ability to commercialize them.[14] Five new institutional models were adopted in this period to bridge the gap:

1. *The Bayh-Dole Act,* passed in 1980, shifted ownership of federally-funded research results to the universities where the research was executed, pushing both universities and their researchers further down the innovation pipeline toward technology development and company creation.[15]
2. *The Manufacturing Extension Partnership (MEP)* was authorized in1988, and aimed to bring the latest manufacturing technologies and processes to small manufacturers.[16]
3. *The Small Business Innovation Research (SBIR)* program offered competitive R&D grant funding to small and start-up companies, administered through the Small Business Administration.[17]
4. *The Advanced Technology Program (ATP)* was formed in 1988 by the National Institute of Standards and Technology (NIST) to fund a broad base of high-risk, high-reward R&D undertaken by industry.[18]
5. *Sematech:* A collaboration between the U.S. government and the U.S. semiconductor industry, also tied to semiconductor equipment makers, which worked systematically to improve chip manufacturing processes.[19] DARPA matched industry Sematech funding until 1996.

ARPA-E: THE NEW-GENERATION ENERGY INNOVATION INSTITUTION

The Department of Energy's (DoE) efforts to bring on energy innovation traditionally focused on the front end of the innovation pipeline—on the R&D side.[20] Its major research program, the Office of Science, for the most part has followed a basic research model. Programs on the back end—technology demonstration, testing, commercialization and deployment—were attempted by DoE in areas such as synthetic fuels during the Carter administration, but failed after the collapse in oil prices in the early Reagan era. DoE has been very reluctant to reinitiate such programs and is limited by political ideology that discourages a governmental role in later stage innovation in non-defense areas.[21] While the Department of Defense operates at all stages of the innovation pipeline from research through initial market creation, DoE halts at the prototype stage. It is an incomplete innovation system, disconnected from later innovation implementation stages. The challenge in the 2000s of energy security and climate change greatly complicated DoE's mission of launching new energy technologies and created a further problem in the energy area that DoE is not fully prepared to handle, that of "technology launch."[22]

Although a breakthrough-oriented R&D agency, the Advanced Research Projects Agency-Energy (ARPA-E) is a conscious attempt to move much further down the development pipeline to resolve this problem.[23] ARPA-E was recommended in a 2006 National Academy report and received initial funding in 2009.[24] It was consciously designed by the U.S. Congress to apply the DARPA model to the new energy technology sector. ARPA-E's roughly $US 200 million in annual funding makes it about the size of a single DARPA program office. It has emphasized speed—rapidly moving research breakthroughs into technologies through a process it labels "Envision, Engage, Evaluate, Establish, Execute."

ARPA-E has incorporated the well-known elements in the DARPA rule set cited earlier, but is not a simple clone of DARPA. Because of its difficult task in launching technology into the complex, established legacy sector of energy, ARPA-E has taken new steps to assist in moving its technology to implementation, commercialization, and deployment:

- ARPA-E program directors *consider the implementation process* for technologies they are evaluating; before they fund a project they evaluate the technology stand-up process and how it might evolve.
- *"In-reach" within DoE:* ARPA-E has worked to build ties with applied programs in DoE so these agencies can be ready to pick up ARPA-E projects and move them into the applied, later-stage development programs they run.
- *Building ties to DoD for testbeds and initial markets:* Although DoE does limited work beyond the prototype stage, DoD works at all the innovation stages and has major procurement programs and energy efficiency needs. It is a logical implementation partner for ARPA-E.
- *Commercialization team:* Unique among R&D agencies, ARPA-E has assembled a separate staff team ("technology-to-market advisors") working full time to promote implementation

and commercial advances for ARPA-E technologies.

- *"Halo effect":* ARPA-E is consciously taking advantage of its "halo effect" where venture and commercial firms move toward commercialization of the technologies that are selected by ARPA-E as promising.
- *Connecting to the industry "stage gate" process:* The stage gate process is used by most major companies in some form in the management of their R&D; ARPA-E works with its researchers to get their technologies into a format and condition to survive in the industry stage gate process.
- *Consortia encouragement:* ARPA-E is building an additional industry connection step between the firms and academics that it works with and the industries they must land in—consortia promotion.

To summarize, ARPA-E has not only worked to replicate elements at DARPA, but it has attempted to build new elements into its innovation rule set as it confronts the unique features of the established energy sector where its technologies must land. Particularly interesting are the approaches it is applying in the implementation and deployment process for its technology advances, moving much further down the development pipeline than traditional R&D agencies.

A NEW INNOVATION MODEL FOR ADVANCED MANUFACTURING?

Manufacturing remains a critical element of the U.S. economy, contributing $1.7 trillion to the $15 trillion economy and employing 12 million.[25] However, the United States is no longer the leader in manufacturing and lost some 30 percent of its manufacturing jobs from 2000 to 2010, symptomatic of a larger sectoral decline.

Since World War II, the U.S. economy has been organized around leading the world in technology advance. The operating assumption was that it would innovate and translate those innovations into products. By *innovating here and producing here*, it would realize the full range of economic gains from innovation at all the stages, from R&D, to demonstration and testbeds, to initial market creation, to production at scale, and to the follow-on life cycle of the product.

With the advent of a global economy, the "innovate here/produce here" model no longer holds. In some industrial sectors, firms can now sever R&D and design from production. Codeable IT-based specifications for goods that tie to software-controlled production equipment have enabled this "distributed" manufacturing.[26] Where manufacturing once had to be integrated and quite vertical, firms using the distributed model can *innovate here and produce there*.

However, there appear to be many sectors where this distributed model does not work, that still require a close connection between research, design, and production. Among the examples are capital goods, aerospace products, energy equipment, and complex pharmaceuticals. Here, the production infrastructure provides constant feedback to the research, design, and development (RD&D) infrastructure. Product innovation—incremental advance—is most efficient when tied to a close understanding and linkage to manufacturing processes. However, if RD&D and production are tightly linked, the innovation stages may have to follow production offshore. *Produce there and innovate there* may be even more disruptive than "innovate here/produce there." These twin developments bring the foundations of our innovation-based economic success into question.

The conclusion of a series of significant manufacturing studies that there are critical links between innovation and production that could affect U.S. innovation as well as production capacity, has driven a new focus on advanced manufacturing.[27] If the United States is to compete with other manufacturing powers, it must significantly increase manufacturing efficiency and productivity. This calls for a new kind of manufacturing with major technology and related process innovations.

Are there new innovation institutional elements to this challenge? The Advanced Manufacturing Partnership (AMP), made up of twelve leading firms and six research universities named by the President Obama, proposed a new model, a "National Network of Manufacturing Institutes" (NNMIs).[28] The first of these institutes has now been awarded and three more are proposed.[29]

The manufacturing institutes are to be organized around a particular strand of advanced manufacturing. The institute based in Youngstown, Ohio, for example, is to focus on "additive manufacturing" (3D printing). Other strands proposed by AMP included advanced materials, "smart" manufacturing, advanced robotics, energy-efficient production, and nanofabrication. The institutes will be consortia between large and small producers, area universities, and community colleges, with state and regional support matched by the federal government. They will combine collaborative research around the advanced manufacturing technology and collaborative staffing between the participants; serve as training centers to develop a workforce fluent in the new technology; and nurture advanced manufacturing enabling technologies through research, development, prototyping, and testbeds.[30] In short, they are to be a return to "connected" innovation, incorporating post-research stages previously outside the federal purview and tying the innovation actors together in a way not previously undertaken in the federal government outside the defense sector.

CONCLUSION

The saga of U.S. innovation organization since World War II spans four and possibly now five periods. It moves from the advent of the post-World War II basic research, "disconnected science" model sponsored by Vannevar Bush that characterized the group of R&D agencies formed or operating at the end of the war. This was followed by a period when the defense R&D agencies, faced with Cold War realities, needed to recreate the "connected" R&D model of World War II. This reached a height in the Sputnik period when DARPA was founded. Then, in the height of its tech advantage competition with Japan and Germany (1970–1990), the United States returned to the connected model in a series of new civilian research programs as well.

With the advent of the energy security and climate challenge, a new, more connected model was created within the Department of Energy, often a bastion of the disconnected model, through ARPA-E. Finally, the most recent innovation organization development—the National Network of Manufacturing Institutes proposed to deal with the advanced manufacturing challenges the U.S. faces—marks a return to the connected approach, in an almost 180-degree shift from Vannevar Bush's post-war plan for U.S. R&D organization.

It is not that basic research is not important; it remains key to U.S. strength in breakthrough innovation. However, the story of the recent decades of innovation organization is to complement that foundational approach with additional institutional elements that reach much further down the innovation pipeline to development and later innovation stages. The new-model innovation organizations discussed here deserve ongoing scrutiny and pragmatic evaluation of their performance to refine these models.

Endnotes

1. Federally-funded applied research was undertaken prior to World War II at, for example, the U.S. Coast Survey, U.S. Geological Survey, Department of Agriculture, Naval Research Laboratory and the National Advisory Committee on Aeronautics, but at a fraction of wartime and Cold War funding levels. See, generally, Bruce L. R. Smith, *American Science Policy Since World War II (*Washington, DC: Brookings, 1990), 16–35.
2. The term refers to economist Richard Nelson's portrayal of the network of R&D and related innovation institutions and support mechanisms, including those in industry, government agencies, and universities, that make up an innovation ecosystem. Richard R. Nelson, *National Systems of Innovation* (New York: Oxford, 1993), 3–21, 505–23.
3. The opening sections of this article draw on the author's detailed discussions of these developments in William B. Bonvillian, "The Connected Science Model for Innovation: The DARPA Model," *Twenty-First Century Innovation Systems for the United States and Japan* (Washington, DC: National Academies Press, 2009), 206–35; and William B. Bonvillian, "The Problem of Political Design in Federal Innovation Organization," chapter 15 in *The Science of Science Policy* (Menlo Park, CA.: Stanford, 2011).
4. Vannevar Bush, *Science, the Endless Frontier* (Washington, DC: U.S. Government Printing Office, 1945), http://www.nsf.gov/od/lpa/nsf50/vbush1945.htm. See also G. Pascal Zachary, *Endless Frontier: Vannevar Bush, Engineer of the American Century* (Cambridge, MA: MIT, 1999); George Mazuzan, "The National Science Foundation: A Brief History," NSF 88-16, July 15, 1994, 1–25, http://www.nsf.gov/pubs/stis1994/nsf8816/nsf8816.txt; William A. Blanpied, "Inventing U.S. Science Policy," *Physics Today* 51, No. 2 (1998): 34–40.
5. The pipeline model for basic research was first institutionalized at the Office of Naval Research. Harvey M. Sapolsky, Science and the Navy: *The History of the Office of Naval Research* (Princeton University Press, 1990), 9–81. It provided the foundational model for exploratory, basic research that evolved at the National Science Foundation, and certainly influenced the National Institutes of Health and the Department of Energy's Office of Science.
6. It is well understood that innovation does not necessarily occur in an orderly series of sequential pipeline stages (Branscomb and Auerswald call it a "Darwinian sea"), but the analogy is widely used and does roughly capture the stages that must be completed for technology implementation and so is used here. See Part I of Lewis Branscomb and Phillip Auerswald, "Between Invention and Innovation: An Analysis of Funding for Early-State Technology Development," NIST GCR 02-841, November 2002, http://www.atp.nist.gov/eao/gcr02-841/contents.htm.
7. Blanpied, "Inventing U.S. Science Policy;" Mazuzan, "NSF: A Brief History."
8. The problems with this model are explored in Donald E. Stokes, *Pasteur's Quadrant: Basic Science and Technological Innovation* (Washington, DC: Brookings, 1997).
9. This discussion is drawn from Bonvillian, "The Connected Science Model."
10. Mitchell Waldrop, *The Dream Machine: J.C.R. Licklider and the Revolution that Made Computing Personal* (New York: Viking, 2001), chaps. 2, 5–7, 9. On other innovations, see Vernon W. Ruttan, I*s War Necessary for Economic Growth: Military Procurement and Technology Development* (New York: Oxford, 2006); Richard Van Atta, "Fifty Years of Innovation and Discovery," in *DARPA: Fifty Years of Bridging the Gap* (Washington, DC: DARPA, 2008), http://www.darpa.mil/Docs/Intro_-_Van_Atta_200807180920581.pdf.
11. Warren Bennis and Patricia Ward Biederman, *Organizing Genius* (New York: Basic Books, 1997), 1–30, 196–218.
12. This list is drawn from "DARPA: Bridging the Gap, Powered by Ideas," (Feb. 2005) and "DARPA Over The Years," (Oct. 27, 2003). For a more detailed evaluation of DARPA's rule set, see William B. Bonvillian and Richard Van Atta, "ARPA-E and DARPA: Applying the DARPA Model to Energy Innovation," *Journal of Technology Transfer* (Oct. 2011).

13. Tammy L. Carleton, "The Value of Vision in Technological Innovation" [DARPA case study] PhD diss., Department of Mechanical Engineering, Stanford University, 62–116, http://purl.stanford.edu/mk388mb2729.
14. Kent Hughes, *Building the Next American Century: The Past and Future of American Economic Competitiveness* (Washington, DC and Baltimore, MD: Woodrow Wilson Center and Johns Hopkins, 2004).
15. 35 U.S.C § 200-212.
16. See http://www.mep.nist.gov/about-mep/legislative-history.htm for the legislative history of MEP.
17. The SBIR program has been criticized for funding too many "SBIR mills" that live off repeated awards instead of technology commercialization, and for less rigorous selection standards than the research it is, in effect, taxing for its funding. However, a series of more recent National Research Council reviews of agency programs support the program's role. See for example, NRC, *An Assessment of the SBIR Program* (Washington, DC: National Academies Press 2008), viii, 54–90, http://www.nap.edu/openbook.php?record_id=11989&page=R1; testimony of Charles W. Wessner before the Senate Committee on Small Business and Entrepreneurship on the SBIR program, Feb. 17, 2011, http://www7.nationalacademies.org/ocga/testimony/SBIR_Program.asp.
18. Section 3012 of the America Creating Opportunities to Meaningfully Promote Excellence in Technology, Education, and Sciences (COMPETES) Act, Pub. L. 110-69, 110th Cong., 1st Sess. (August 9, 2007), repealed the Advanced Technology Program (ATP) and reformed it as the Technology Investment Program (TIP). Funding for ATP/TIP was halted by Congress in 2011.
19. Larry D. Browning and Judy C. Shetler, *Sematech: Saving the U.S. Semiconductor Industry* (College Station: Texas A&M, 2000); Leslie Berlin, *The Man Behind the Microchip: Robert Noyce and the Invention of Silicon Valley* (New York: Oxford, 2005). Robert D. Hof, "Lessons from Sematech,"*MIT Technology Review* (July 25, 2011), http://www.technologyreview.com/news/424786/lessons-from-sematech/.
20. See discussion in John Alic, Daniel Sarewtiz, Charles Weiss, and William Bonvillian, "A New Strategy for Energy Innovation," *Nature* (July 2010).
21. John M. Deutch, "What Should the Government Do to Encourage Technical Change in the Energy Sector?" MIT Joint Program on the Science and Policy of Global Change Report No. 120, May 2005, http://web.mit.edu/globalchange/www/MITJPSPGC_Rpt120.pdf.
22. See discussion of the issues raised in this section in Charles Weiss and William B. Bonvillian, *Structuring an Energy Technology Revolution* (Cambridge, MA: MIT, 2009) 2, 28–36,151–161, 167–71.
23. This section draws on a more detailed discussion in Bonvillian and Van Atta, "ARPA-E and DARPA: Applying the DARPA Model." See more detailed references therein.
24. National Academy of Sciences, Rising Above the Gathering Storm (Washington, DC: National Academies Press, 2007), 152–58.
25. Discussion in this section is drawn from William B. Bonvillian, "Reinventing American Manufacturing: The Role of Innovation," *Innovations* 7 (summer 2013), 97–125. Statistics are from the Bureau of Labor Statistics, "Industries at a Glance, Manufacturing: NACIS 31-33, Workforce Statistics," http://www.bls.gov/iag/tgs/iag31-33.htm#iag31-33emp1.f.P.
26. Suzanne Berger, *How We Compete: What Companies Around the World Are Doing to Make It in Today's Global Economy* (New York: Doubleday Currency, 2005), 251–77.
27. PCAST, "Capturing Domestic Competitive Advantage in Advanced Manufacturing," Report of the Advanced Manufacturing Partnership, July 2012, 9, http://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast_amp_steering_committee_report_final_july_17_2012.pdf; MIT, "Report of the MIT Taskforce on Innovation and Production, Preview of the Production in the Innovation Economy Report (PIE)," February 22, 2013, http://web.mit.edu/press/images/documents/pie-report.pdf. See also ITIF, "Worse than the Great Depression," March 2012, http://www2.itif.org/2012-american-manufacturing-decline.pdf.
28. PCAST, "Capturing Domestic Competitive Advantage," 18–24. NNMI was not the only AMP recommendation. AMP made a series of innovation recommendations, from an enhanced advanced manufacturing R&D effort around eleven candidate advanced technologies and processes to improved workforce training and engineering education in advanced production, emphasizing that a series of related steps were required.
29. White House press release, May 9, 2013, http://1.usa.gov/YLbjOZ. The proposed new institutes are to focus on digital ("smart") manufacturing and lightweight and new metals fabrication, both led by DoD, and new power electronics, to be led by DoE.
30. PCAST, "Capturing Domestic Competitive Advantage," 21–24. See also ITIF, "Why America Needs a National Network for Manufacturing Innovation" (December 2012), http://www2.itif.org/2012-national-network-manufacturing-innovation.pdf; "Comments on the Design of the National Network for Manufacturing Innovation (NNMI)," April 2013, MIT Washington Office website, http://dc.mit.edu/resources-links

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