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The Problem of Political Design in Federal Innovation Organization

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Introduction

An overlooked feature in the design of programs and institutions that support our science and technology-based innovation system is political design, as opposed to the factor generally exclusively considered, policy design. This chapter will aim to develop a framework for evaluating political design issues underlying federal innovation institutions, including from a perspective of whether the political design model is consciously structured to be supportive, as opposed to contradictory, to the policy design.

Federal science investment doesn't drive itself, of course, science is not divorced from politics despite the attraction of the ivory tower. Instead, political system demands have been the major driver for the past sixty years for science investment and new science institutions. It was the Cold War that drove growth of science agencies in the postwar period, especially defense science, the Sputnik threat that drove the 1960's science investments, and the competitive economic threat of 1980's that drove the programs of that era. Given the underlying role of political drivers in science, it should not be surprising that the question of political design requires focus.

During these prior periods of science investment advance, a series of new innovation-oriented federal government organizations was created, which offer lessons for the factors to be included in a framework for political design. Particularly illuminating are the experiences of the 1980's generation of innovation organizations designed to cross the "valley of death" between research and late stage development. A new generation of institutions is now being formed, largely to meet energy technology challenges, thus the political design issue is again timely. Innovation system institutions generally land in an intense political landscape where sound political design is important to their effectiveness. While the contending ideologies around the federal role in science and technology were largely fixed in the period after World War I,[2] the political debate in this area, particularly around the public-private partnership role many of these agencies fill, remains robust and requires program design attention.

The First Generation of Federal Innovation Agencies

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[2] David Hart, Forged Consensus (Princeton, NJ: Princeton Univ. Press, 1998) 17-29.

While the era of innovation is as old as the industrial revolution[3] the federal role in innovation didn't truly scale up until the World War II period. While innovation actors[4] were highly connected under the system administered during WW2 by Vannevar Bush, President Roosevelt's science czar, he helped dismantle this system at the end of the war, and substituted an alternative one.[5]

Bush shaped the two leading organizing entities for wartime U.S. science and technology—the National Defense Research Council (NDRC) and then the Office of Science Research and Development (OSRD). He brought nearly all defense research efforts under these two loose coordinating tents and set up flat, non-bureaucratic, interdisciplinary project teams oriented to major technology challenges, such as radar and atomic weapons, as implementing task forces. He created a "connected science" approach, where technology breakthroughs at the fundamental science stage were closely connected to the follow-on applied stages of government-supported development, prototyping and production, operating under what can be called a "technology challenge" model.

Then, immediately after the war, as the institutional elements in his connected approach were being dismantled, Bush was able to salvage a residual level of federal science investment. In his 1945 tract *The Endless Frontier*,[6] Bush argued that the U.S. government should fund basic research, which would deliver ongoing progress to the country in economic well-being, national security and health. In other words, he proposed ending his wartime model of connected science research and development, organized around major technology challenges, in favor of making the federal role one of funding only one stage of technology advance: exploratory basic research.[7] Bush's approach became known as the "pipeline" model for science investment. The federal government would dump basic science into one end of an innovation pipeline and early- and late-state technology development and prototyping would mysteriously evolve inside the pipeline, with new technology products emerging at the end. While Bush proposed to achieve research coherence under a single organizational tent through what became the National Science Foundation, authorization of NSF was delayed, and in the interim science agencies multiplied.[8] Bush's pipeline concept of federal funding focused on basic science prevailed, but his loosely centralized science model did not. The result was a new generation of highly decentralized science agencies, each largely adopting his pipeline model for the federal science role.

These twin developments left U.S. science fragmented at the institutional level in two ways: overall science organization was split among numerous science agencies, and Federal investment primarily was focused on

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[3] *See, generally*, Paul Romer, Endogenous Technological Change, Journal of Political Economy, vol. 98, (1990) 99. http://artsci.wustl.edu/~econ502/Romer.pdf

[4] The term refers to the network of R&D and related innovation institutions and support mechanisms that constitute the ecosystem Nelson and other growth economists view as a prerequisite for strong innovation capability. Richard R. Nelson, National Systems of Innovation (New York: Oxford Univ. Press 1993) 3-21, 505-523.

[5] The discussion in this section is drawn from William B. Bonvillian, "The Connected Science Model for Innovation – The DARPA Model," *21st Century Innovation Systems for the U.S. and Japan* (National Academies Press May 2009), pp, 206-235. *See also*, G. Pascal Zachary, Endless Frontier, Vannevar Bush, Engineer of the American Century (Cambridge, MA: MIT Press 1999); George Mazuzan, NSF, A Brief History (1950-1985) (Washington, DC: NSF 88-16) 1-25 http://www.nsf.gov/pubs/stis1994/nsf8816/nsf8816.txt; William A. Blanpied, inventing U.S. Science Policy, Physics Today, 51 (2) (Feb. 1998) 34-40 http://www.nsf.gov/about/history/nsf50/science_policy.jsp .

[6] Vannevar Bush, Science: The Endless Frontier (Wash., D.C.: Government Printing Office, 1945) http://www.nsf.gov/od/lpa/nsf50/vbush1945.htm

[7] The pipeline model was initially institutionalized at the Office of Naval Research. *See,* Harvey M. Sapolsky, Science and the Navy – the History of the Office of Naval Research (Princeton, NJ: Princeton Univ. Press 1990) 9-81. It provided the foundational model for exploratory, basic research that evolved at the National Science Foundation (NSF), the National Institutes of Health, and the Department of Energy's Office of Science.

[8] Bush attempted to organize postwar science under a single tent, NSF, but a veto confrontation with President Truman delayed that agency's creation by five years, and other agencies evolved in the interim. William A. Blanpied, Inventing U.S. Science Policy, *op cit,*; George Mazuzan, NSF, A Brief History (1950-1985) (NSF 88-16) 1-25 - nsf.gov website: http://www.nsf.gov/pubs/stis1994/nsf8816/nsf8816.txt

only one stage of the technological pipeline—exploratory basic research.[9] Bush thus left a legacy of two conflicting models for scientific organizational advance: the connected, challenge model of his WW2 institutions, and the basic science-focused, disconnected, multi-headed model of postwar U.S. science institutional organization.

Bush's model was a political success, drawing support from Cold War concern over American leadership in science. This network of basic research agencies enabled a growing base of American research universities, formed by the turn of the 20th century, but coming into their own under Bush's orchestration of major federal support during WW2 and expanding further during the Cold War. This was a relatively flexible model of research grant agencies and university recipients, based on competitive grant awards.

The Fixed, Large Scale Lab Model
However, another type of first generation agency emerged from the postwar period,, continuing in during the Cold War period, in parallel with the system of strengthened university research supported by a network of basic science research agencies. This brand of entity featured major in-house research and technology facilities which provided major regional employment and corresponding political involvement. These institutions were less flexible, fixed in both particular missions and particular locations, with their facilities requiring ongoing infrstructure support. This second institutional type created subsequent political intervention problems for scientific missions.

The Department of Energy's (DOE) national energy labs provide a prime example. They evolved from Los Alamos and Manhattan Project laboratories during World War II, shifted from defense control at the end of the war to the Atomic Energy Commission, and later to DOE. The DOE laboratory constellation may well employ the largest base of science PhD's in the world, some 12,000, at its seventeen labs.[10] With the end of the Cold War and a rapidly growing need for new energy technologies for energy security and climate reasons, DOE now faces the task of shifting its lab talent base from its traditional nuclear weapons role to new energy research. Yet over 5000 of its PhD's are now housed at its three historic nuclear weapons labs and only 350 at one of its smallest labs, the National Renewal Energy Lab (NREL), which is focused on energy efficiency and renewable energy. The political lock-in buttressing DOE's established labs limits the agency's flexibility in making a shift to the new energy technology challenge the country now faces.

There is a second political design problem with these types of large-scale research institutions: they tend to become exclusive clubs, isolating and crowding out other researchers working at a smaller scale in other locales. This limits the ability to place a broad base of talent in the field. Arguably, sound policy design requires a broad base of interest and talent for a range of advances. The politics of supporting major institutions with a particular research focus and an accompanying employment base – the narrow front approach - complicates sound organization on the broad front of research. Science advance requires space for both the organized focus of larger scale teams as well as a wider base of decentralized researchers working at a smaller scale – advance that is both focused and broad-based, with a range of talent on a range of tasks. The large-scale research entity, although it offers a strong political base of support can, curtail the broad front approach.

Although it was created a decade later, the National Aeronautics and Space Administration (NASA) provides a similar example. NASA evolved out of NACA, a predecessor prewar aeronautics and engineering research

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[9] The problems with this model are explored in, Donald E. Stokes, *Pasteur's Quadrant, Basic Science and Technological Innovation* (Washington, DC: Brookings Institution Press, 1997)
[10], Victor Reis. Nuclear Energy, Nuclear Weapons and Climate Change. Unpublished presentation, Washington, DC: Department of Energy, June 2008.

agency,[11] and built major research labs and mission facilities with a strong government contractor base during the space race. James Webb, the first NASA director and architect of NASA's organization, understood from his political mentors, Senators Robert Kerr and Lyndon Johnson, the earlier FDR New Deal model of building Congressional political support by creating permanent institutions anchored in regional Congressional politics.[12] A rare master of political design in science and technology, he consciously created a system of centers and contractors that would enable NASA's space mission to survive long term. The resulting regional employment and procurement contracting base provided NASA with the political support from executive branch politicians and especially from Congress that helped to sustain strong investments during the space race and thereafter. In recent years, however, the regional facilities and powerful supporting contractors have tended to lock-in NASA to ever more expensive manned-space investments, limiting the pace of its scientific and research advance.[13] As the Obama Administration attempts to restore NASA's roots as an advanced technology agency, as opposed to the largely operational agency it has become, the regional political base Webb built has reared up in opposition.[14] Similar problems have afflicted the larger scale labs (usually organized as FFRDC's – Federally-Funded R&D Centers) in the defense research establishment.

Thus, while the political support model applied in these agencies initially supported their R&D missions, the weight of their established institutional overhead, locked-in against significant modification by the political system, has in some cases curtailed these agencies' innovation flexibility in subsequent years. These are first generation examples of problems in political design that tend to undermine over time evolving agency science and technology missions. What are the political design rules that emerge from these first generation models?

Rules of Political Design:

1) <u>*Beware of Scale*</u>: The creation of excessive personnel mass in a modest number of locations can create a political design problem. While the corresponding political support this mass engenders can sustain a science agency over extended periods, it also tends over time to limit science and technology mission flexibility.
2) <u>*Don't Let Narrow Front Cancel Broad Front*</u>: A second lesson is that a narrow-front, focused advance embodied in large-scale research establishments can cancel out needed parallel broad-front science advance. Both approaches are likely to be needed, and a large-scale entity and the political power it commands by virtue of its size can cancel out a complementary broad-based advance.

The Aftermath of the Sputnik Challenge of 1957

Science investments accelerated during the crisis in confidence over U.S. science leadership created by the Soviet launch of Sputnik in 1957. These anxieties over geopolitical developments created a political driver for science support, bringing new institutions and investments. U.S. R&D investment as a percent of GDP reached a postwar height in the mid-sixties, 2% by 1964 compared to less than 1% today.[15] Both broad and narrow

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[11] Alex Roland, Model Research: The National Advisory Committee for Aeronautics 1915-1958 Volume 1 (Washington, DC: National Aeronautics and Space Administration1985); Roger Bilstein, Orders of Magnitude: A History of the NACA and NASA, 1915-1990 (Washington, DC: United States Government Printing1989).

[12] Piers Bizony, The Man Who Ran the Moon – James Webb and the Secret History of Project Apollo (New York: Thunder's Mouth Press 2006).

[13] Testimony of Norman R. Augustine on the Review of US Human Spaceflight Plans Committee, Before the Committee on Science and Technology, House of Representatives, 110th Cong., 1st Sess., Sept. 15, 2009 http://www.nasa.gov/pdf/386964main_091509-Testimony%20Augustine%20Human%20Spaceflight%20Testimony%20rev%202%20FINAL.pdf ; Report of the Advisory Committee on the Future of the U.S. Space Program (Wash., DC: NASA History Div., Dec. 1990) http://history.nasa.gov/augustine/racfup1.htm

[14] "Long Day on Capitol Hill for OSTP Director John Holdren," *FYI: The American Institute of Physics Bulletin of Science Policy News*, , No. 29, March 1, 2010.

[15] NSF, S&E Indicators (Wash., DC NSF 2008) Figure 4-17 (US R&D share of GDP 1953-2006).

front types of science institutional structures received substantial new support. NASA, as discussed above, which came to house a network of fixed, large scale labs, facilities and centers, was one of the two major new entities created in this period. While NSF had been formed after much postwar debate in 1950, it's budget tripled in one year, between fiscal years 1958 and 1959; by 1968 its budget nearly quadrupled again to $500m.[16] NSF and DOD graduate education programs grew in this period, as flexible voucher fellowships, enabling the graduate student recipient to take the award to the graduate program of his or her choice, enhancing competition between university departments and lending further funding support to the flexible network model of basic research agencies and universities. .

The second major new agency created in this period was the Defense Advanced Research Projects Agency (DARPA). DARPA was a particularly interesting model, very different from the Vannevar Bush era basic research agency. DARPA's aim was a "right-left" translational approach – decide the technologies you require from the right side of the innovation pipeline, then nurture breakthrough science advances on the left side of the pipeline to get there.[17] DARPA embodied a return to Bush's earlier World War II "connected science" through a technology "challenge" model. DARPA, perhaps the most successful of the postwar and Cold War science and technology agencies, led the information technology revolution[18] and a long series of other major advances.[19] DARPA, as it came into its own in the 70's and 80's, marked the beginning of a swing back to a more integrated science model and away from the "pure" basic research approach. While DARPA illustrates the connected science approach, there are also political design lessons to be drawn from this connected model, as discussed below.

The Competitiveness Period of the 70's and 80's

Vannevar Bush's basic research pipeline model had institutionalized a disconnect between research and later stage development over large parts of the U.S. innovation system, ensuring that the handoff to the commercialization stage would be a difficult one. Although the Office of Naval Research was the first to explore Bush's basic research model, the arrival of DARPA, as noted, marked a shift in the military away from it. That shift expanded beyond defense in the late 1980's. As the U.S. entered that period of heightened economic competitiveness over technology advance with Japan and Germany, concerns grew that although the U.S. was originating the leading innovations, it was limited, due to this pipeline disconnect, in its ability to commercialize them.[20]

During the 1980's there was also a significant ideological debate about the policy approach to address this problem. David Hart has traced the origins of this debate to the decades between the world wars.[21] He suggests that the two prevailing policy positions revived in the 1980's were between economic conservatives who wanted to limit federal economic intervention in the innovation system, and what he terms "associationists", a movement originated by Herbert Hoover when Commerce Secretary, who envisioned a collaborative, public-private partnership approach to both applied research and follow-on development.[22]

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[16] Matzuzan, *op cit*, Chapt. 3.
[17] William B. Bonvillian, The Connected Science Model, *op cit*.
[18] Mitchell Waldrop, The Dream Machine, J.C.R. Licklider and the Revolution that Made Computing Personal (Sloan Foundation Technology Series)(New York: Viking 2001) (Chapts. 2, 5-7, and 466-471).
[19] Vernon W. Ruttan, Is War Necessary for Economic Growth, Military Procurement and Technology Development (New York: Oxford Univ. Press 2006); Richard Van Atta, "Fifty Years of Innovation and Discovery", DARPA, 50 Years of Bridging the Gap (Wash., D.C: DARPA 2008) http://www.darpa.mil/Docs/Intro_-_Van_Atta_200807180920581.pdf
[20] Kent Hughes, Building the Next American Century: The Past and Future of American Economic Competitiveness (Wash., DC and Baltimore MD: Woodrow Wilson Center Press and Johns Hopkins Univ. Press 2004).
[21] David Hart, *op cit*.
[22] It is possible to push this debate even further back into American history to ideological battles between Hamilton, arguably the parent of the modern commercial American economy, and his anti-economic intervention opponents Jefferson and later Jackson. *See*, William B. Bonvillian, "The Innovation State", The American Interest (July/Aug. 2009) 78.

DARPA showed a way to resolve this ideological clash. It operated not only in the basic research space but further down the innovation pipeline in the development and prototyping spaces – in the parlance of the time, it was "picking technology winners and losers." Yet it defused this debate by tying its intervention in late stage development to the necessities of its national security mission. It offered a pragmatic solution – the value of technology advance for the national security overrode ideological concerns. In other words, it showed that an agency operating in the science-technology development continuum needs to be tethered to a mission recognized as politically significant to avoid ideological differences. Despite being tied to a security mission DARPA and DOD played a significant role in the subsequent resurgence of the U.S. economy.

As noted, he 1980's the U.S. was mired in a tough competition with Japan and Germany, which had implemented innovative models for manufacturing and appeared to be having more success in commercializing incremental technology advances than the U.S. Yet the U.S. had organized its economy in the course of World War II around a comparative innovation advantage and it's innovation system, particularly its capacity for radical or breakthrough innovation, as opposed to incremental innovation, remained world leading in the 80's and early 90's. After a multi-decade gestation period, where, as discussed, DARPA played a keystone role, the U.S. was able to move out of its confrontation over manufacturing with Japan and Germany and bring on a major innovation wave[23] – the IT revolution – in the early 90's. It was transformative: the U.S. economy created a net 22 million jobs in the 90's, or 2.2 million a year. On top of IT the U.S. also added a biotech wave. By the end of that decade leadership in those waves put the U.S. strongly ahead of competitive economies; its economy became the envy of the world. As part of its response to its 1980's competitive problems, the U.S. created the series of new innovation institutions discussed below.

The Valley of Death Organizational Models of the Late 1980's

The 1980's problem for the U.S. innovation system became known as the "valley of death" because it focused on the gap between research and late-stage development.[24] Three new institutional models[25] were adopted in this period to bridge this valley, which offer instructive illustrations of the challenges of innovation political design; each is discussed in some detail below because they are particularly relevant to the new generation of energy agencies now forming.

- The *Manufacturing Extension Partnership* (MEP) was authorized in1988,[26] based on the success of the longstanding agriculture extension program. It aimed to bring the latest manufacturing technologies

[23] Innovation wave theory is explored in, Carlota Perez, Technological Revolutions and Financial Capital (Cheltenham, UK: Edward Elgar 2002), pp. 3-46; Robert D. Atkinson (Dir., Technology and New Economy Project, PPI), The Past and Future of America's Economy – Long Waves of Innovation that Power Cycles of Growth (Cheltenham, UK: Edward Elgar 2004), pp. 3-40.

[24] Lewis Branscomb and Phillip Auerswald, Between Invention and Innovation, An Analysis of Funding for Early-State Technology Development (Wash., DC: NIST GCR 02-841 Nov. 2002), Part I – Early Stage Development <http://www.atp.nist.gov/eao/gcr02-841/contents.htm

[25] Although not an institution, as part of the same 1980's competitiveness response the Congress passed the Bayh Dole Act (35 U.S.C. 200-212) in 1980 which transferred ownership of federally-funded research from the federal government to the universities where the research was executed, giving universities a stake in its commercialization. The Act is generally viewed as a transformative success, enhancing the role of universities in what is termed here "connected" science and giving them a stake in their regional economies. See, for example, Birch Bayh, Joseph P. Allen, and Howard W. Bremer, "Universities, Inventors and the Bayh Dole Act", Life Sciences Law and Industry Report, Vol. 3, No. 24 (BNA, Dec. 18, 2009); David Roessner, Jennifer Bond, Sumiye Okubo, and Mark Planting, The Economic Impact of Licensed Commercialized Inventions Originating in University Research 1996-2007, Final Report to the Biotechnology Industry Organization (BIO Sept. 3, 2009) http://www.bio.org/ip/techtransfer/BIO_final_report_9_3_09_rev_2.pdf .

[26] See PL 100-519, Title I, Sec. 102(d) (Oct. 24, 1988); 102 Stat. 2590; 15 USC Chapt. 7, Sec. 278k (Regional Centers for the Transfer of Manufacturing Technology); 15 CFR Sec. 290.6, http://www.mep.nist.gov/about-mep/legislative-history.htm

and processes to small manufacturers around the nation, since small firms were increasingly dominating U.S. manufacturing. It aided such manufacturers by advising on the latest manufacturing advances to foster productivity gains, thus assisting them across a "valley of death" in this field. MEP formed extension centers in every state, which states cost-share, backed-up by a small Commerce Department headquarters staff charged with program evaluations and transmission of best practices to the centers. MEP's national network has a federal funding base of around $100m annually plus the approximately $200m this leverages from the state and local resources. It now consists of 59 centers employing some 1600 manufacturing specialists experienced in small manufacturing needs. For the past twenty years, the centers have worked with thousands of manufacturers, and MEP studies maintain the centers deliver some $1.44 billion in cost savings annually and $10.5 billion in increased or retained sales per year to small manufacturers.[27] While some centers are inevitably stronger than others, the overall program has received positive evaluations, and it has received solid political support and sustained stable funding from Congress.

Its political support model has worked to sustain its substantive policy design. Small manufacturers have tended to like the program because it keeps them abreast of the latest manufacturing advances in a highly competitive world economy. State governors, who cost-share the program, like it because it enables them to connect with small manufacturers, delivering appreciated technology and process advances to employers and employees to keep them competitive. While business consultants initially viewed MEP as a free rival service that might put them out of business, most found that participation in MEP generally heightened demand for their own services to introduce further productivity savings. The state MEP programs formed a trade association to compare ideas on manufacturing advances, which in turn helped to advocate for and sustain the program. Between the governors lobbying their Congressional delegations and the association providing information and further backing, there has been solid political support for the program continuation and expansion. Since this model only worked if the program quality remained high and valued by its customers, the political support model has generally promoted the substantive policy design for the program.

- The *Small Business Innovation Research* (SBIR) program is a second successful "valley of death" program model; however, the political design has not been as optimal. This program offers competitive R&D grant funding to small and start-up companies, administered through Small Business Administration (SBA) Office of Technology, which also supervises a related program, the Small Business Technology Transfer (STTR) Program. These two competitive programs aim to ensure that small, high-tech, innovative businesses are a part of the federal government's research and development efforts. Eleven federal departments participate in the SBIR program; five departments participate in the STTR program. The two programs award over $2 billion to small businesses annually. SBIR is funded through a modest "tax" (currently 2.5%) on the total research budgets of the participating federal agencies (those with extramural research budgets in excess of $100 million), which becomes a set-aside reserved for contracts or grants awarded to small firms by the participating R&D agencies.

  The SBIR program was established through the Small Business Innovation Development Act in 1982,[28] and periodically reauthorized by the Congress (in 1986, 1992, 2000, and 2004, with a reauthorization now pending). The subsequent STTR program funds joint small business and university research efforts with an additional .5% set aside. According to program founder Roland Tibbets of NSF, "SBIR was created to address a need that is still critical: to provide funding for some

[27] NIST, MEP, About MEP, http://www.mep.nist.gov/about-mep/index.htm
[28] P.L 97-219, 97th Cong., 2nd Sess. (July 22,1982), 96 Stat. 217, Report on HR 4326, 97th Cong., 1st Sess., House of Representatives, No. 97-349, pt.1; Report, 97th Cong., 2d Sess., House of Representatives, No. 97-349, pt.2-7; as amended through PL 108-447, 108th Cong., 2nd Sess. (Dec. 8, 2004).

of the best early-stage innovation ideas that, however promising, are still too high risk for private investors, including venture capital firms…. In 2005 only 18 percent of all US venture capital invested went to seed and early stage firms while 82 percent went to later stages of development that are lower risk."[29] SBIR (and STTR) aim to fill that "valley of death" support gap.

SBIR has provided initial funding for many of the most noted technology start-up firms of the past twenty-five years; few new firms consider the startup process without applying. The program is backed politically by the small business and venture capital communities. However, it has also received sustained support from a group of so-called "SBIR mills" – firms that live off repeated SBIR awards and are not particularly focused on commercializing technology, the fundamental SBIR program aim. While small firms with one-time awards have neither the motivation nor the resources to advocate to sustain the program, the mills do. While, overall, the SBIR has played an important role in helping meet the "valley of death" problem,[30] in the past much of the sustaining political support for the program has come from SBIR mills not particularly dedicated to its basic policy goal of technology commercialization. So the political support model, while strong, contradicts an overall substantive policy goal of the program. Thus, the political design is problematic: the political support system does support as strongly as it might one of the key features of the substantive program design, technology commercialization.

- The *Advanced Technology Program* (ATP, renamed and restructured in 2007 as the Technology Investment Program (TIP)),[31] is the third of the trio of "valley of death" programs from the 1980's. It was formed in 1988 in the Department of Commerce's NIST program to fund a broad base of high-risk, high- reward R&D undertaken by industry. ATP reached some $200m in annual grants during the early Clinton years, with the Administration seeking further major increases, but it was subsequently cut back by Congress to half that size, where it remains today, after nearly being shut down in 2007. Widely studied as a strong substantive model for technology innovation,[32] it has faced recurring political design problems. These issues stem from three political design problems. First, ATP was not tied to any particular science mission area, but instead was tied to a broad base of industry early stage

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[29] Roland Tibbetts, SBIR Program Manager, 1976 -1996, and program founder, National Science Foundation, Reauthorizing SBIR: The Critical Importance of SBIR and Small High Tech Firms in Stimulating and Strengthening the U.S. Economy (May 28, 2008) http://www.nsba.biz/docs/tibbetts.pdf

[30] *See* the series reports on SBIR programs at federal agencies of the National Research Council, Board on Science, Technology and Economic Policy, Committee for Capitalizing on Science, Technology and Innovation, including, An Assessment of the Small Business Innovation Research Program at the Department of Defense (Washington, DC: Nat'l Academies Press 2009) http://www.nap.edu/catalog.php?record_id=11963, An Assessment of the Small Business Innovation Research Program at the National Institutes of Health (Washington, DC: Nat'l Academies Press 2009) http://www.nap.edu/catalog.php?record_id=11964 , An Assessment of the Small Business Innovation Research Program at the National Aeronautics and Space Administration (Washington, DC: Nat'l Academies Press 2009) http://www.nap.edu/catalog.php?record_id=12441 , and An Assessment of Small Business Innovation Research Program at the Department of Energy (Washington,:DC: Nat'l Academies Press 2008) http://www.nap.edu/catalog.php?record_id=12052

[31] 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).

[32] *See*, for example, National Research Council, Board on Science, Technology and Economic Policy, Advanced Technology Program: Challenges and Opportunities (Nat'l Academies Press 1999) http://www.nap.edu/openbook.php?isbn=0309067758 ; Rosalie Ruegg and Irwin Feller, A Toolkit for Evaluating Public R&D Investment Models, Methods, and Findings from ATP's First Decade (NIST GCR 03-857 2003) http://www.atp.nist.gov/eao/gcr03-857/contents.htm ; and studies and data referenced in: NIST, Advanced Technology Program, Impacts of ATP Funding http://www.atp.nist.gov/ ; ATP Gems and Success Stories (through 2007) http://www.atp.nist.gov/gems/listgems.htm

technology support. Thus, it lacked the umbrella of support often extended by political forces to a particular mission focus, such as health (NIH) or space (NASA) or defense (DARPA). Second, it had no particular interest group battling for it. It was a highly competitive program, typically making awards at a ratio of only one out of eight or ten applicants each year,[33] thereby frustrating most of its annual applicants, who were not disposed to support the program before Congress. Those awarded R&D grants were usually small firms and startups unlikely to have resources to lobby Congress in the first place; they also knew the highly competitive award they received would almost certainly be their last. Thus, even its limited number of award winners were not likely to support the program on an ongoing basis. It was designed, therefore, without a natural political constituency. It was solely a "good government" venture, strong on substance and performance but without any political support system – it failed political design. The faulty political design, despite the substantive quality of the program, precluded it from rising to a meaningful level of funding, which has prevented it from having a significant economic effect.

In an effort to build political constituency support, the program was restructured and renamed in 2007, as noted, to allow universities and labs (in consortia with industry) to participate, and was allowed to focus not simply on a broad range of technology advances but on particular areas around important societal needs.[34] It remains to be seen whether these modifications will create a strong enough political base to sustain and expand the program from its modest funding level.

To summarize, below are three further political design lessons, in addition to those cited in the first section, from the three "valley of death" programs:

Additional Rules of Political Design:

3) *Design to Ensure a Constituency*: ensure in program design that there will be a noteworthy political interest constituency that will support the new agency before the executive and legislative branches on a continuing basis.
4) *Design to Ensure that Constituency Backs Program Quality*: Further ensure that the new program is structured so that it is in the interest of supporting political constituencies to back program quality and the substantive policy behind it, rather than shift or disrupt quality and substance.
5) *Tether the Agency to a Recognized Mission*: If a new agency will be involved in late stage development along with research, it may face an ideological debate over its role; if it is designed to be tethered to a strong, politically recognized mission area, it may be able to override ideology.

Of the three 1980's agencies discussed here, only one, MEP, achieved a political design that got both the substantive and political design criteria aligned.

New Generation Energy Innovation Institutions

There have been, as discussed above, essentially three major innovation policy moments driven by political demands since WW2: 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 with the formation of DARPA and NASA and scaled up funding for NSF and for science education, and 3) the competitiveness era "valley of death" programs of the 1980's. We may be on the verge of a fourth: an energy transformation driven by energy security and climate demands. What lessons from these earlier eras are relevant to the institutional elements in the "new generation" energy innovation policy programs now under consideration?

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[33] NIST, Advanced Technology Program, ATP Applications, Awards & Participants by State - 45 Competitions (1990-Sept. 2007)) http://www.atp.nist.gov/eao/02aap_state.htm

[34] NIST, Technology Investment Program, About TIP, Key Features http://www.nist.gov/tip/about_tip.html

Recent innovation policy has focused particularly on the new energy technology challenge, with policymakers forming new policy and technology implementation institutions to meet the triple problems of energy geopolitics, climate change and energy economic costs. These problems have been the political drivers for new energy investments in the February 2009 economic stimulus legislation (approximately $34b for energy technology implementation and $5b for energy R&D at the Department of Energy (DOE)).[35] There remains a "valley of death" problem in energy technology because of the institutional gaps designed into our energy innovation system. However, there is also a new and larger problem that U.S. innovation policy and legislation has not previously confronted: the "problem of launch" - of launching new innovations, at the implementation stage, into long-established, mature economic sectors, of which energy is a prime example.[36] In facing innovation issues in such established sectors, a gap analysis is required of the energy innovation system. While Congress and the new Administration have not yet conducted this evaluation in detail, four new programs are now being contemplated in the energy arena within DOE. Each is sketched below, along with the political design rules identified above and below that may be most relevant to each.

- *The Advanced Research Projects Agency* (*ARPA-E)* – ARPA-E was authorized in 2007 through the America COMPETES Act,[37] and received $400m in FY2010 start-up funding through the 2009 stimulus legislation (the American Reinvestment and Recovery Act). The Administration's budget calls for $300m in FY2011 funding. It is housed in DOE and reports directly to the Energy Secretary. It was based on the DARPA model as a translational research entity, bridging a gap in the energy innovation system between DOE's Office of Science, a basic research agency supporting university and lab research under a Bush basic research model, and DOE's Energy Efficiency and Renewable Energy office and other applied development and demonstration programs that primarily fund industry. It is an institutional fix aimed at the "valley of death" gap between existing DOE research and applied agencies, to expedite technologies from breakthrough research to late stage development.

  It presents the most complex political design issues among the group of new and proposed agencies. First, as a "valley of death" agency, accelerating research advances then intervening in late stage development, does it have a strong enough mission justification to survive the ideological issues that afflict entities playing this development role? The DARPA and ATP lessons on the necessity of a mission-based political design (Rule 5) appear relevant here. Ongoing bipartisan support for ARPA-E's energy mission will clearly be needed as a sustaining driver. Second, will the constituency in the energy sector it will serve – university researchers and small firms and startups - be strong enough to sustain ARPA-E as it seeks support to ramp up its initial funding? It received over 3600 applications for its broad initial R&D offering of $150m but was only able to fund 37 of these applicants.[38] Like ATP, it ran the risk of disappointing far more applicants for every one it approved, potentially jeopardizing its constituency support base at the outset. More recent ARPA-E offerings have focused on particular energy technology fields, which should narrow interest and avoid frustrating large numbers of applicants, However, this could be a continuing problem depending on the level of ongoing funding ARPA-E achieves. Recognizing it was funding only a fraction of its qualified

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[35] American Recovery and Reinvestment Act (ARRA), HR 1, P.L. 111-5, 111th Cong., !st Sess. (signed into law Feb. 17, 2009), Title IV.
[36] Charles Weiss and William B. Bonvillian, Structuring an Energy Technology Revolution (Cambridge, Mass.: MIT Press 2009) 2, 28-36,
[37] America COMPETES Act, Sec. 5012, Pub. L. 110-69, 110th Cong., 1st Sess. (August 9, 2007). *See* discussion of ARPA-E in William B. Bonvillian, "Will the Search for New Energy Technologies Require a New R&D Mission Agency?", Bridges (July 14, 2007) http://www.ostina.org/content/view.2297/721/ ; Erica R.H. Fuchs, "Cloning DARPA Successfully", Issues in Science and Technology (Fall 2009) 65-70.
[38] DOE–ARPA-E, "Bold Transformational Energy Research Projects Win $151 Million in Funding" Oct. 26, 2009 http://arpa-e.energy.gov/NewsMedia/News/tabid/83/vw/1/ItemID/20/Default.aspx

applicants, ARPA-E responded imaginatively, hosting an "ARPA-E Innovation Summit" in March 2010[39] inviting in hundreds of its promising applicants whether they received awards or not, and connecting them with venture capitalists and industrial firms. The event attracted thousands of participants, was widely appreciated by the technology sector it serves and helped build good will in its applicant pool. DARPA was able to build a loyal constituency over time that has sustained it; it's strong community of interest formed around particular areas of advance it selected for support. ARPA-E is taking steps to build such a community through its summit but may have to consider this approach of narrowing its research focus to build stronger constituency dependence and support. It may also have to build other services to applicants, such as mentoring systems of technology experts who can advise rejected applicants on how to improve their future applications. This technique was attempted by the ATP program with some success.

ARPA-E also faces the additional problem of jealous agencies within DOE, such as the energy labs and applied energy agencies, that feel threatened by its role and funding. ARPA-E, like DARPA before it, will have to make a major effort to cooperate with these potential in-house rivals, involving them in its projects, and becoming, like DARPA, their agent and supporter whenever possible. Understanding this, ARPA-E has created an advisory group of other agency representatives within DOE, trying to foster involvement and support for its programs among potential DOE rivals, portraying its program as complementary not as a funding competitor. It could also consider, as DARPA has, sharing in the cost of joint projects, enabling rival agencies to leverage their funding with ARPA-E support. ARPA-E's experience to date suggests additional political design rules for science and technology agencies:

Additional Rules of Political Design:

6) *Support Your Applicant Base Don't Dismiss It:* Grant-making agencies always run the risk of frustrating their potential support community because they must reject the bulk of their grant applications. The realities of grant-making usually make the ratio of grantees to awards far too low to appease applicants. This limits their ability to create a political support community, To counter this, the agency can create other reward systems for applicants, such as opportunities for mentoring services, or access to industry support, or as a convenor for a new research community.
7) *Coopt Intra-Agency Rivals:* Within a large agency, subagencies often compete over funding and missions. A successful subagency will attempt to integrate rival agencies and complement their missions, supporting their efforts as well as its own, including through joint-funding of common projects.

- *Energy Frontier Research Centers (EFRC's)* – These centers – forty-six are now funded - evolved after careful study over five years, through workshops and supporting major reports that engaged hundreds of the most prominent energy researchers and thinkers in the country in identifying the most promising areas of energy research. This effort was led by DOE's Office of Science, which systematically coalesced and then led this national community of energy researchers in examining basic research areas where energy advances were most needed. At the close of the effort an effective report was prepared by an advisory group that made the case for the program in clear, succinct, non-technical language, in a length (13 pages) that enabled time-challenged Congressional staff to read and digest it in twenty minutes, justifying this new program and a strong level of investment.[40] The EFRC program proposal was a model for how an agency can

[39] ARPA-E, Energy Innovation Summit Materials, March 1-3, 2010 http://arpa-e.energy.gov/ConferencesEvents/InnovationSummitMaterials.aspx
[40] DOE – Basic Energy Sciences (BES) Advisory Committee, New Science for a Secure and Sustainable Energy Future (Wash., DC: DOE-BES. Dec. 2008) http://www.sc.doe.gov/BES/reports/files/NSSSEF_rpt.pdf .

effectively stand up an new program, building careful, in depth consensus in the research support community, systematically building informed Congressional backing, and proposing a sizeable enough program to enable geographical distribution of competitive awards for centers. For FY2010, $277m in funding for centers was provided through the 2009 stimulus legislation plus further funds from appropriations, covering a wide range of research areas. The Administration budget calls for $140 million in FY2011.[41] The design appears sound – the centers will work in the basic research area so they will not face ideological challenges. They will have a university research constituency, coupled with an energy mission, to sustain them. They are relatively small in scale ($3-$5m/year per center) and authorized for five years, so they will not become protected large-scale enclaves that could isolate other researchers. The carefully organized process for forming EFRC's suggests a further rule:

Additional rule of Political Design:

8) *Build Support for the New Agency Pre-Launch:* A new program shouldn't be allowed descend like a *deus ex machina* into the political world; the creation process should be viewed as an opportunity to build a supporting constituency for the new program in the process of forming and advocating for it. This also offers a chance to create Congressional understanding and buy-in. The Energy Frontier Research Center launch process serves as a model.

- *Re-energyze* – Regaining our Energy Science and Engineering Edge (ie, Re-Energyse), is an educational effort designed to guide students and workers to pursue careers in science, engineering, and entrepreneurship related to clean energy. This proposed education initiative, which is cross disciplinary and offers study fellowships, was rushed out at the beginning of his tenure by Energy Secretary Chu, who sought funding for it in the FY10 DOE budget. When the nation began to build an IT revolution it was aided by the fact that DARPA had early-on supported a network of computer science departments within research universities. These blossomed, creating an education element to train new talent that fostered the technology advance. Secretary Chu clearly recognized the same phenomena could apply in energy – universities had disciplinary stovepipes that encompassed aspects of energy, but lacked curricula to look at energy across disciplinary perspectives and from a policy point of view. His proposed "Re-energyze" program could provide a talent base in the energy field with the foundations to deal with broad energy policy issues and interdisciplinary energy research not possible under the current disciplinary stovepipes. Universities could provide a support constituency for the program, and since it was to be a competitive program, it would be in their interest to ensure program quality.

  However, there was no effort to build up constituency support in advance of the announcement of the program through the FY10 budget. No effort was made to lay the groundwork for the program with Congressional committees, and the program was not well-defined when announced, consisting of a one-page list of ideas. Every new Administration is rushed as it comes into office, and in its the rush to get the program out the door DOE paid a price. Congress did not fund the proposal in FY10, and the Administration has resubmitted it for consideration in FY11, budgeted at $50m.[42] Congressional appropriators were unprepared to consider the concept and since science education is traditionally the territory of NSF, they were concerned about creating a duplicative new science education agency in DOE. DOE tried to accommodate this concern by offering the

[41] DOE – Office of Science, Overview – Appropriation Summary by Program, FY2009-FY2011 (2010), 10 http://www.er.doe.gov/bes/archives/budget/SC_FY2011budget_overview.pdf; DOE, Office of Science, Energy Frontier Research Centers, Tackling Our Energy Challenges, re FY2011 budget (2010) http://www.er.doe.gov/bes/EFRC/index.html .

[42] DOE, FY2011 Congressional Budget Request – Budget Highlights (Wash., DC: DOE/CF-0046, Feb. 1, 2010) 30 http://www.mbe.doe.gov/budget/11budget /Content.FY2011Highlights.pdf

proposal with an NSF element, but to no avail. Congress was also concerned that DOE had not budgeted a long-term funding stream that would enable the program to be sustained along with other new energy program elements. The political design issue DOE ran into for Re-energyze amounted to a variation of Rule 8: failure to lay the groundwork for a new program with Congress and to build in advance of launch a constituency for it can jeopardize the new idea. In general, an annual budget submission, usually held in secret by Administrations until its release by OMB, is a poor place to announce a new program: it ensures that both the potential support constituency and the Congressional Committees that will have to fund it are surprised and unprepared.

- *Innovation Hubs* – Secretary Chu, drawing on his personal experiences at Bell Labs and directing the Lawrence Berkeley Laboratory, proposed eight, larger-scale, $25 to $30m a year labs, to be housed at universities or at national labs, to sponsor research on key areas of energy research. Congress approved initial funding for three of these "hubs" In FY10, focused on solar, energy efficient building design and advanced nuclear reactors. A fourth Hub was proposed in the FY11 budget to focus on batteries and energy storage.[43] The Hubs are to aim at multidisciplinary research in areas ready to be scaled up, to speed R&D and shorten the time from discovery to technology implementation. Because of the larger scale of these efforts, compared to Energy Frontier Research Centers, for example, there is risk that this scale will lock-in political support that could limit the flexibility of future agency research directions, and that could narrow the front of research advance, crowding out a broader front. In other words, while there are large numbers of able researchers starting to engage in energy research advances, the large Hubs may capture the funding in key areas and limit support for talent outside the Hubs. This is always a risk with scaling up research efforts. These issues of institution building and corresponding research lock-in require careful attention from DOE as it stands up its initial pilot hubs, as Design Rules 1 and 2, above, suggest. It should work on designs to find ways to build these research areas in ways that allow focus on promising technology challenges that also bring in more participants on the tasks the Hubs face, not less.

The Future

What will future challenges bring for the political design for innovation organization? Ongoing efforts to bring innovation into the energy sector provide a useful future construct.

All of the Department of Energy's innovation efforts to bring on an energy transformation have been focused on the front end of the innovation pipeline – on the research and development side. Proposals on the back end – technology demonstration, commercialization and deployment - have been neglected to date by the Obama Administration. There is a further problem, as suggested above, in the energy area that none of the new innovation entities proposed to date by DOE focus on – the problem of technology launch.[44] While the "valley of death" has been the major preoccupation of science and technology policy for the past two decades, energy, as an established, complex, politically and economically powerful, technologically locked-in sector, presents an additional problem. The energy sector operates in an established political-economic-technological paradigm, and that paradigm must be altered if a new reduced carbon energy system is to prevail. Thus, even if the valley of death in energy – the gap between research and development - is surmounted, a deep problem remains. Because most new energy technologies are components in larger established systems (for example, advanced batteries are components in cars, enhanced geothermal technology must fit into existing utility systems) they must launch into these established sectors and be price competitive from the moment of launch. All of the four new agencies proposed by the Department of Energy, as discussed above, are organized around the valley of death problem; none encompass the technology launch task. As tough as crossing the valley of

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[43] DOE, FY2011 Congressional Budget Requst – Budget Highlights, *op cit,* 2.

[44] *See* discussion on the issues raised in this section in, Weiss and Bonvillian, Structuring an Energy Technology Revolution, *op cit*, 2, 28-36,151-161, 167-171.

death in energy is, reaching the point of market launch is even harder.

A network of additional innovation entities will likely be needed on the back end of the innovation process, in areas such as demonstration, financing, and technology roadmapping. For example, in financing, DOE has loan guarantee authority that it has just started to implement a half decade after it was first authorized. But loan guarantees are only relevant to some firms; most startups and small firms lack the capitalization to obtain loans, so guarantees may not solve their problems. A toolbox of financing instruments will be required if DOE wants to move technology advances from its new R&D entities into the marketplace. DOE has had diffulculty in managing commercial scale demonstrations; it will need new organizational approaches to accomplish this cimportant step. A new energy technology sector will also need testbeds, standards and technology roadmaps. Each will call for new organizational approaches. DOE has not yet undertaken the systematic analysis of gaps in the existing energy innovation system to understand which gaps need to be filled. It needs to face the innovation back end side of the challenge it faces, because innovation in a complex, established sector presents problems very different from standing up technology advances in new, unoccupied breakthrough sectors like IT or biotechnology.[45] In sum, in energy additional organizational entities will be needed to meet the challenge of innovating in an established sector. None of the new energy agencies formed to date will prove adequate unless this back end gap is filled and their efforts are fully coordinated with new programs to fill the launch support mission.

What else will the future of innovation bring? Energy is not the only established, complex sector where innovation is needed; there are at least two other crisis areas. Because there are few incentives in the current system to control costs, and little effective competition over prices, the nation is faced with out of control health care costs. The prospect of health care reforms that will expand the coverage of the existing system will make this task more difficult. Accordingly, there is a significant innovation need in health care service delivery. This innovation demand will need to focus not only on new technologies for more efficient and effective service delivery, such as the long-discussed introduction of information technologies into medicine, but also on the processes and systems for delivery of that innovation, to try to create incentives for its adaptation. As with energy, we face an established techno-economic-political paradigm that must be overcome for the introduction of efficient health care service delivery. To manage this, a careful gap analysis of that existing system and the introduction of innovation within it must be undertaken, and carefully tailored organizational fixes introduced. This is a major pending societal innovation task where political design will be a crucial element.

Similarly, manufacturing is another complex established sector ripe for innovation advances if the U.S. is to retain a presence in this economic territory. Manufacturing accounts for $1.6 trillion of U.S. GDP, directly employs 11 million, manufacturing firms account for 70% of U.S. R&D funding and 63% of science and engineering employment, and manufacturing workers are paid substantially more than service sector employees.[46] Global wealth continues to be based predominantly on trade in complex, high value, technology goods; trade in these goods dwarfs trade in services. While many economists assume the U.S. can shift to a services economy, the U.S. deficit in manufactured goods exceeded $500b in 2007, while its surplus in services trade was less than one third that number with the former was outpacing the latter. And its surplus in advanced technology goods has now turned into a deficit that exceeded $50b in 2008. In other words, U.S. strength in the global economy is being jeopardized by its declining manufacturing performance. While some argue that it can't compete in manufacturing against a low wage, low cost economy like China, Germany and Japan, high cost, high wage economies comparable to the U.S., are running major trade surpluses with China. There is movement in federal agencies to look at innovation in manufacturing, including in the Defense, Energy and Commerce Departments, through DARPA, EERE, and NIST. Two major studies are pending, at

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[45] William B. Bonvillian and Charles Weiss, "Taking Covered Wagons East," Innovations, vol 4, iss. 4 (Fall 2009).
[46] Gregory Tassey, "Rationales and mechanisms for revitalizing US manufacturing R&D strategies", Journal of Technology Transfer, Springer US, Jan. 29, 2010.

PCAST (President's Council of Advisors on Science and Technology) and at the industry-led Council on Competitiveness. Tackling innovation in this complex, established sector will likewise call for a careful gap analysis of its innovation system, which has not been carefully examined since the introduction of the Toyota production system.[47]

The future of the next generation of U.S. innovation may increasingly fall into the category of innovating in complex, established sectors, such as energy, health care delivery and manufacturing. In order to confront this existing frontier, new substantive and political designs will be required for effective innovation organization. On the political design side, one design rule already appears apparent:

Additional Rule of Political Design:

9) *Innovation in Complex, Established Sectors Requires an Innovation Gap Analysis*: Innovation occurs in complex systems of connected institutions; if innovation is to extend into the back end of the innovation pipeline, from demonstration to commercialization, a gap analysis of the strengths of innovation organizations in those areas must be undertaken, along with the traditional analysis of innovation at the front end R&D side. Since the back end is historically dominated by industry, the substantive design of such back end innovation efforts must be complemented by effective political design, which will involve careful cultivation of support from established industries that may otherwise oppose such back end intervention.

Conclusion

This chapter has briefly reviewed the history of new U.S. science and technology agencies since World War II. It has identified, a series of nine possible rules for political design embedded in the history of the political and policy issues that have afflicted new federal R&D agencies in the four key postwar periods of new innovation investments and institutions. The political design ruleset identified here is briefly summarized below:

- *First*, beware of scale; when an innovation agency reaches a large scale in a particular locality which multiplies its political support, this may limit future research and mission flexibility.
- *Second*, don't let narrow front advance cancel out the broad front; a large-scale research effort at an entity focused on a particular area of advance may crowd out and limit a broader front for science and technology advance.
- *Third*, science entities will only survive if they are designed to have a strong supporting constituency.
- *Fourth*, when designing constituency support, ensure that the selected constituency base will support a quality program consistent with the substantive program design, not divert it.
- *Fifth*, particularly if a new entity will be involved in late stage development along with research, it may face ideological challenge, so it must be tethered to a strong, politically-recognized mission area to justify its tasks.
- *Sixth*, because the number of grant applications will significantly exceed the number of grants that can be awarded, alienating the strongest potential political support community for an agency, those that it funds. An agency should offer alternative ways to build its support base, offering additional services aside from grants to its applicant pool, such as mentoring, or connections to industry or as a convenor for a research community.
- *Seventh*, to avoid intra-agency rivalry where a new arrival will inevitably be viewed as a funding competitor, the new entrant program should attempt to integrate rival entities into its

[47] Michael Dertouzos, Richard Lester, Robert Solow, Made in America: Regaining the Productive Edge (Cambridge, Mass.: MIT Press 1989); James P. Womack, Daniel T. Jones and Daniel Roos, The Machine that Changed the World (New York: Harper Collins, 1991). An exception is, Suzanne Berger, How We Compete (New York: Doubleday 2005).

deliberations and complement their missions, supporting their efforts as well as its own, to coopt the existing programs.

- *Eighth*, the launch process is key to building political support; the agency creation process should be viewed as an opportunity to build a supporting constituency for the new program in the process of forming for it, and as a chance to create Congressional understanding and buy-in. Congressional and support group launch surprise should be avoided.
- And *Ninth,* innovation in complex established economic sectors, such as energy, health care delivery and manufacturing, requires an analysis of gaps in those innovation systems, particularly of the back end of the pipeline, from demonstration to commercialization. Since industry is likely to dominate the back end in these established sectors, careful cultivation of industry support will be required for organizational interventions in this area.

Sound political design along these lines could buttress sound innovation systems. There are, of course, other political design rules; these are just some of the lessons drawn from the author's career as a political science practitioner in the science and technology field. Unfortunately, the political design issues innovation entities face has rarely received attention, yet we are on the verge of creating a new series of such institutions around the energy challenge and perhaps other areas. Unlearned lessons lead to error repetition. The lessons of scale or of narrow front advance canceling out broad front advance, for example, or of creating a new entity without a sound support base, remain unrecognized design principles and we may be facing another generation of problems in these areas with new energy entities. Recognition of a problem, of course, is the first step to its remedy. A concerted effort to examine the political support systems for science and technology agencies and their political strengths and weaknesses could be a constructive step. Possible ways to resolve these design issues so that the political design better supports the policy design require further attention from policymakers and the academic community. Otherwise political design errors will be relentlessly repeated, underminding attempts at innovation reforms. The consequences are not minor. Growth economist Richard Nelson was one of the first to recognize that innovation occurs in a system that includes a series of connected innovation institutions and program elements, public and private.[48] Creating the political design that supports the substantive policy design on the public side of that institutional network offers a significant enhancement to our innovation system.

[48] Richard R. Nelson, National Systems of Innovation (Oxford, UK and New York: Oxford Univ. Press 1993) 3-21, 505-523