The Future of the National Laboratories

Dan Hartley
Vice President, Laboratory Development
Sandia National Laboratories

The policy debate that has surrounded the national laboratories of the Department of Energy since the end of the Cold War has been very confusing. Initially, with the passage of the National Competitiveness Technology Transfer Act of 1989, the laboratories were encouraged to form cooperative arrangements with industry to maintain their technology base and give a boost for U.S. industrial competitiveness. But in the 104th Congress, technology transfer programs were severely constrained, and bills were introduced that would realign the laboratory system and force some laboratory closures and consolidations. The laboratories were caught between two ideological visions of their appropriate role.

But for all the rhetoric generated by this policy struggle, observers seem to agree that the DOE national laboratories are among the best scientific and engineering laboratories in world. Over decades, a succession of commissions, blue-ribbon panels, and advisory boards have independently made this point. The DOE laboratories are associated with thousands of discoveries and inventions that have proved useful in both defense and civilian applications and that have helped the United States sustain worldwide leadership in science and technology.

The national laboratories' missions continue to be important

The belief that the end of the Cold War eliminated the national laboratories' missions is a popular misconception. The national laboratories will have outlived their missions when the threats that they are best suited to address no longer pose significant national risks. But the nuclear threat, while it has diminished, is still very real; and we face new national challenges which the national laboratories are uniquely well equipped to address. Consequently, the laboratories will have vital missions for the foreseeable future.

The emerging challenge in the nuclear weapons program is how to ensure the reliability, safety, and control of a smaller nuclear weapon stockpile for the indefinite future—*without nuclear testing*. This mission demands a science base well beyond what is ordinarily required for product reliability functions in industry. In addition, the national laboratories are more involved in recent years with a broader array of security issues relating to arms control verification as well as nonproliferation of weapons of mass destruction (nuclear, biological, and chemical).

The laboratories also have an enduring mission responsibility in energy. Yes, we have abundant, cheap energy today; but the laboratories' role is strategic and holistic, involving long-term issues of energy security, efficiency of conversion, environmental effects, and critical infrastructures. The Galvin Task Force on Alternative Futures for the DOE Laboratories declared that DOE's "energy mission is of extreme importance and deserves greater attention by the national laboratories, working in collaboration with the private sector."[1] The Yergin Task Force

---

[1]Secretary of Energy Advisory Board, "Alternative Futures for the Department of Energy National Laboratories" (February 1995), p. 20.

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy under contract DE-AC04-94AL85000.

DISCLAIMER

on Strategic Energy R&D concurred and added that federal "energy-related R&D investments should serve to promote strategic goals, including *U.S. economic strength, energy security, environmental quality, and science and technology leadership*"[2] (emphasis in the original).

The national labs have a legitimate role in joint R&D

If, as the Yergin Task Force maintained, federal energy R&D investments should promote U.S. economic strength, does it follow that the national laboratories have a mission to support the economic vitality of U.S. industry? A General Accounting Office panel maintained that "a commercial technology mission for the laboratories is legitimate and important,"[3] but not as a primary mission. The Galvin Task Force also recommended that industrial competitiveness not be a primary mission of the DOE laboratories; however, it strongly supported laboratory-industry collaboration when it is derivative of DOE mission work:

> Collaborations between the national laboratories and the private sector serve the important function of providing dual benefits to the partners, but such collaborations generally should be closely aligned with core mission areas of the Department.[4]

From a DOE perspective, a key factor in selecting industrial relationships is the potential contribution of an industrial collaboration to advancing the mission-critical technologies of the laboratory. Thus, if government and industry have technology needs that coincide, collaboration may be quite appropriate, even if a partner's commercial applications have little or no relationship to DOE missions. Similarly, national laboratories will collaborate with universities at the level of the science base required for their missions, even though no "product" may be contemplated. Laboratory collaborations with industry frequently support commercial end-use applications that have no apparent utility to any particular DOE program. Rather, it is the science and technology involved in the performance of a cooperative project—and not its end use—that is the source of relevance to DOE (see Figure 1).

To illustrate, Sandia National Laboratories has collaborated with Goodyear Tire and Rubber Company for several years in a series of cooperative R&D agreements for improving design capabilities of mutual interest. Obviously, tires and nuclear weapons are very different applications. But the design technologies for each share many common requirements. For example, Sandia and Goodyear improved an engineering tool for solving structural mechanics problems common to both tire design and the design of certain weapon components. The company benefited from access to modeling and simulation codes and experimental techniques developed in the weapons program. Sandia benefited from access to 100-year's worth of proprietary data and experience on the stress behavior of composite materials. It is now applying this information to the production engineering of a weapon component.

Laboratory directors have warned for years that broad interactions with industry are essential in order to maintain the technical currency and vitality of the labs. The technology bases for government and commercial needs are rapidly converging. The laboratory system cannot

---

[2]Secretary of Energy Advisory Board, "Summary of Recommendations, Task Force on Strategic Energy Research and Development" (June 1995), p. 2.

[3]General Accounting Office, "Department of Energy: National Laboratories Need Clearer Missions and Better Management" (January 27, 1995), p. 31.

[4]Secretary of Energy Advisory Board, "Alternative Futures for the Department of Energy National Laboratories" (February 1995), p. 7.

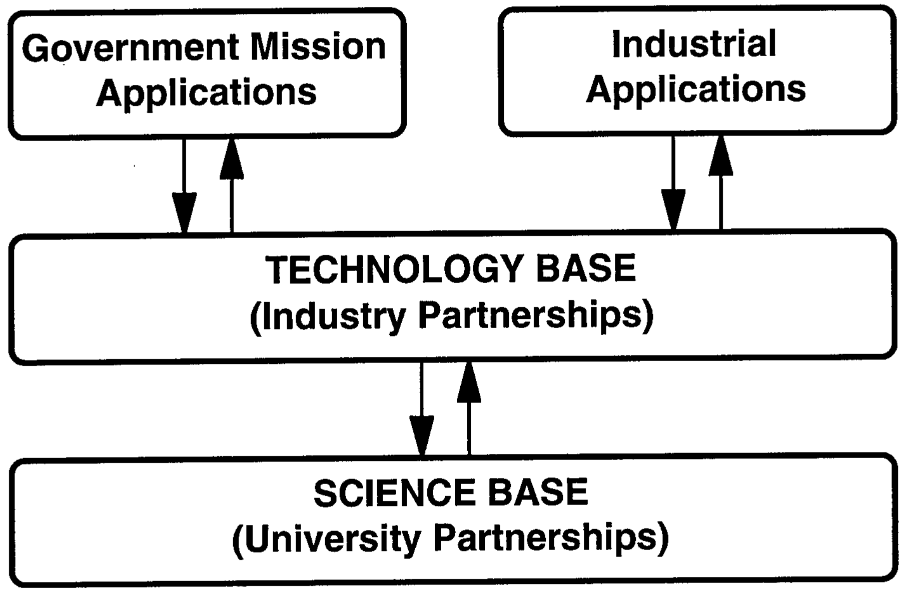

Figure 1: Laboratory partnerships strengthen the common technology and science bases.

succeed as a technological island; it must develop deep networks of collaborative relationships with industry and universities. So long as such collaborations enhance the core science and technology base, they are consistent with the emerging consensus for appropriate collaboration.

Conversely, there are compelling reasons for industry to want access to the expertise and facilities of the national laboratories. Many foreign governments deploy their national research establishments as supportive partners of their domestic industries: for example, the Fraunhofer Institutes in Germany, MITI in Japan, and other extremely aggressive and rather frightening counterparts in the emerging Asian economies. Many U.S. companies have had to shrink their internal R&D functions as part of an overall effort to drive down costs to be competitive, and they are often at a disadvantage in R&D resources with respect to their foreign competitors. Consequently, there is much greater interest among U.S. companies today in outsourcing R&D, forming research alliances, and participating in consortia. The national laboratories can play a crucial role in augmenting the R&D capabilities available to U.S. industry.

Innovation is the key

The issue most on the minds of governments of the world's powerful economies is not research per se, but innovation. It is becoming increasingly evident that innovation is more fertile at the interfaces of research and engineering than at the nuclei of those activities. Therefore, many governments are adopting strategies that bring industries, universities, and government labs into close contact. Geographical clusters of these groups have proved to be crucibles of innovation in many locations around the world. Diversity of approaches, competencies, disciplines, and thought enhances innovation.

The Fraunhofer Institutes of Germany are a leading example of this strategy in action. Fraunhofer-Gesellschaft is a network of 47 applied research institutes in 31 locations throughout Germany. The institutes are funded by federal and state (Lander) governments and industry (with industry paying a steadily increasing share) and are dedicated to helping industry apply research to the development of commercializable products and advanced manufacturing technologies. The German government suffers no ideological anguish over its very explicit intent to foster direct cooperation among governments, universities, and specific industrial sectors through Fraunhofer Institutes.

The Fraunhofer strategy is to establish partnerships among companies, local governments, and academic institutions in geographical clusters. Fraunhofers catalyze interactions between industrial firms and universities (typically their colleges of engineering), helping them collaborate in mutually beneficial ways. Fraunhofer institutes are a source of jobs for technical graduates of the universities, and many of their people ultimately migrate to industrial firms.

Fraunhofer USA is the American-based subsidiary of Fraunhofer-Gesellschaft. At present, it supports four resource centers: in Massachusetts, Michigan, Delaware, and Florida. All are partnerships involving local universities and industry, and each is affiliated with a lead laboratory of Fraunhofer-Gesellschaft. They all perform industry-driven applied research and are active in industrial and engineering education.

It is very true, of course, that these investments give Fraunhofer access to the robust research environment of the United States. Fraunhofer's leadership is quite candid about this purpose:

> "To some extent we have the impression now that we must travel to the States to see what's going on here. . . . We think the United States in the future will stay as a research powerhouse, and a lot of innovation in the world will come from the United States."[5]

But Fraunhofer's investments in the U.S. are win-win arrangements. Fraunhofer-university-industry clusters have richly benefited their communities, and local governments appear eager to attract new Fraunhofer centers. The rapid success of Fraunhofer in this country and the alacrity with which they are being embraced by local governments, are evidence that they are filling a gap that is not adequately addressed by the U.S. R&D establishment.

The national laboratories are learning and maturing

Fraunhofer's tremendous success in Germany and its recent international expansion have been noticed by U.S. observers and are grist for the debate about what role the U.S. government should play in fostering innovation. In the past few years, Congress has tried different vehicles—such as the Advanced Technology Program in the Department of Commerce, the Technology Reinvestment Project at the Defense Advanced Research Projects Agency, and the Technology Transfer Initiative in the Department of Energy—with mixed success. We have learned some lessons from our early experiences in technology transfer.

The labs have undergone a transition not unlike the "maturity continuum" model of growth described by Steven Covey.[6] The Cold War was a long period of secure *dependency* for the labs: they were fathered and fed by the federal government and grew up smart and cocky. The advent of cooperative R&D agreements was a tantalizing opportunity to demonstrate a degree of *independence*. Like over-confident adolescents, the labs felt sure their technical prowess would enable them to quickly win the world's respect.

---

[5]Hans-Jürgen Warnecke, interview in *Manufacturing News* 3, no. 7 (April 1, 1996).

[6]Steven R. Covey, *The Seven Habits of Highly Effective People* (New York: Simon and Schuster, 1989), pp. 48–52.

To their surprise, however, they found that industry's respect wasn't easily earned. The laboratories had some early failures: they hadn't fully appreciated the difficulty of transforming research into commercializable material; they didn't always listen well to their partners' needs; and they discovered that there are other smart people in the world who knew more about some things than they did. So, after learning some hard lessons, the laboratories are much more attuned now to the needs and expectations of their industrial partners. And they have also learned to appreciate what industry can teach them, and what they can take away from partnerships to enhance their own mission capabilities.

The national laboratories are now beginning to view themselves as *interdependent* with the greater national innovation enterprise. It is also encouraging to see that they are beginning to attract a sizable constituency as more and more private companies experience positive collaborations with them. In the last two years or so, the attitude of industry toward the national laboratories has turned noticeably from indifference to guarded enthusiasm.

This change of attitude can be attributed to the learning experience provided by DOE's Technology Transfer Initiative (TTI), which grew rapidly from 1991 through 1996 and was curtailed by Congress in fiscal year 1997. TTI had been challenged by some as "corporate welfare." TTI's champions, who had supported the program as a boost to America's international competitiveness, regard the program's decline as the death of lab-industry partnerships. Both groups' perceptions of the TTI program are flawed.

TTI's importance was that it created a stimulus for cultural change, both in industry and in the national laboratories: relationships were forged, visions were shared, and progress was real. Today, even with TTI a mere shadow its original funding, industry partnerships with the national laboratories are experiencing very real growth. Remarkably, industry funds-in are growing, in spite of the relatively high cost of the laboratories and the even more onerous "added factor" tacked on by some federal agencies.

Lessons from AMTEX

The American Textile Partnership (AMTEX) was one of the largest projects in DOE's Technology Transfer Initiative. AMTEX is a consortium of several DOE laboratories and the U.S. apparel manufacturing industry. The industry as a whole spends very little on R&D for manufacturing, and it has been losing market share and jobs to foreign competitors. The consortium introduced several innovations, including sensors for on-line inspection of material, energy conservation improvements, a new printing technology, and information technology systems that will help the industry become more agile.

AMTEX has suffered through the ups and downs of congressional favor and is a good case study for deriving principles for public-private partnerships. First, it is clear from the experience of AMTEX that Congress wants the federal share of joint work to be funded out of mission programs, rather than as set-asides. This ensures that the work is of value to a federal program manager and is not merely "corporate welfare." Consequently, we can expect U.S. innovation policy to continue to be tied to the mission model that has generally characterized federal R&D.

The AMTEX experience has shown the importance of developing a quantitative technology "road map" that clearly states the objectives of the project and lays out the partners' expectations and commitments. Industry must have the leadership role in drafting the road map, in consultation with the lab and university partners. The expected benefits for the partners should be defined, including rights to intellectual property. Outcomes should not be products, but processes and systems that benefit all participants.

AMTEX is just one of several consortia involving the national laboratories, research universities, and an industry sector that have appeared in recent years. Similar consortia of various sizes have performed joint R&D in specialty metals, investment casting, fuel cell technology, mesh-generation analysis, semiconductor fabrication technology, surface film-coating manufacturing technology, and other areas of common interest.

The consortium model seems to be organizationally and ideologically acceptable if leadership and majority funding are provided by industry associations or alliances. This acceptability arises from the fact that the government's role does not involve "picking winners" among an industrial sector, and the natural focus of industrial consortia is toward pre-competitive technologies. The consortium model is a good one in this sense, but it should not be the only model. Consortia are slow, subject to lengthy consensus processes, and can drift from industry-critical issues. However, if an industry is seeking a mostly funds-in arrangement with a laboratory and its needs are synergistic with a laboratory's technology base, such interactions can be extremely beneficial to both parties.

The emergence of the virtual laboratory

The national laboratories are beginning to think of themselves as a system of capabilities rather than a collection of autonomous labs. The idea has a long way to go to be fully incorporated into lab culture, but laboratory leaders see it as an important model for the future. If it can be made to work, this new way of looking at themselves should result in operational efficiencies and less redundancy among the national laboratories.

The concept also leads logically to a better model for consortia partnerships with industry, a model that is aptly called the "virtual laboratory" (see Figure 2). A system of laboratories can task its capabilities for specific programs regardless of where in the system they reside. The high-speed networks and advanced telecommunications that the laboratories have invested in are powerful tools for enabling the work of virtual laboratory teams. In a consortium, a virtual national laboratory acts as a single, coordinated entity under one leadership, rather than as a collection of federated laboratories with independent program managements. This arrangement simplifies the relationship of the laboratories with the industrial consortium.

The Extreme Ultraviolet Lithography (EUVL) Consortium is the first industry-laboratory collaboration in which the DOE labs are consciously trying to demonstrate the concept of a virtual laboratory. The program is a collaborative effort between a virtual national laboratory—consisting of elements of Sandia, Lawrence Livermore, and Lawrence Berkeley national laboratories—and an industry consortium of several U.S. semiconductor equipment manufacturers and the major U.S.-based companies that use integrated circuits (ICs) in commercial products.

The goal of the consortium is to develop the manufacturing tools and processes for a commercial production capability for ICs with features down to one-tenth micron. ICs of this scale are crucial for meeting the semiconductor industry's road-map goals in 2002; if we don't succeed by then, we may forfeit the business represented by this new generation of ICs to subsidized foreign competitors. The potential macroeconomic benefits that will accrue if U.S. manufacturers can commercialize this technology are vast, but the marginal federal investment in this consortium is

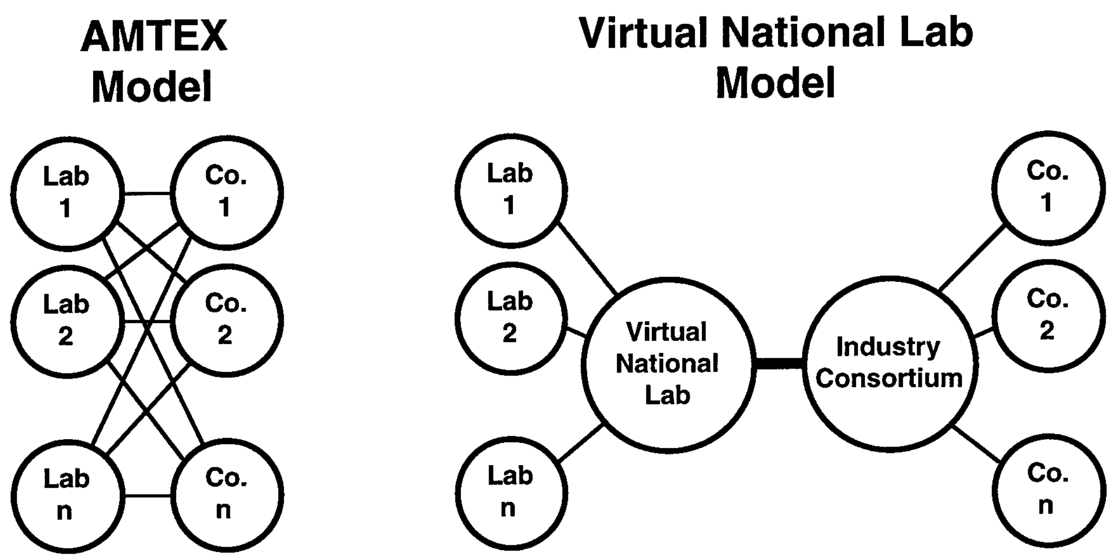

Figure 2: The virtual national laboratory model simplifies relationships with industry.

extremely modest. And at the same time, the national laboratories will strengthen their competencies in metrology, x-ray optics, precision manufacturing, laser technologies, and several other areas that are critical to DOE's missions in the long term.

National laboratories are part of the emerging U.S. innovation strategy

Although the Cold War as we knew it is over, we still face challenges that derive from the inventions and applications that characterized that confrontation: weapons of mass destruction, arms control and treaty verification, and nonproliferation of nuclear weapons and material. Other grand challenges also remain: energy, crime, health care, pollution, infrastructure deterioration, terrorism. A stable and healthy society will continue to address these challenges, while the peaceful revolutions in technology will continue: the information technology age, better transportation, housing, consumer products. All this will require innovation in an increasingly global market. Industry and universities will continue to have their vital roles, and recent successes show that the national laboratories will also provide an important bridge in the innovation spectrum.

The virtual national laboratory is a promising model for more efficient, large-scale collaborations with industry and universities. It may be a powerful tool for providing an innovation stimulus to an entire industry with very little additional public investment. Other models of cooperative R&D will also appear in the next several years, exploring new modes and levels of cooperation as suggested by research and successful experiences in other countries. A single, ultimate formula for cooperative innovation is unlikely. Several species of national laboratory partnerships are likely to co-exist and evolve through pathways that may seem unlikely from today's perspective. In particular, the globalization of innovation may make it imperative at some point in the future that U.S. national laboratories engage in international consortia.

Economic forces and mutual interests will inexorably bring industry, universities, and the U.S. national laboratories closer together. These sectors will increasingly engage in cooperative arrangements that are mutually beneficial and compatible with public policy. After years of national debate and various experiments with cooperative, cross-sector R&D, a consensus for an unofficial national innovation strategy—one that is effective, affordable, and palatable to our political-economic tradition—is starting to appear. The national laboratories will be a vital component of that strategy as it evolves.

M98000553

Report Number (14) SAND--97-2556C
CONF-971148

Publ. Date (11) 199710
Sponsor Code (18) DOE/MA, XF
UC Category (19) UC-900, DOE/ER

DOE