Emerging Patterns in Cross-Sector Partnerships
National Lab Partnerships: What Works and What Doesn't

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EMERGING PATTERNS IN CROSS-SECTOR PARTNERSHIPS
National Lab Partnerships: What Works and What Doesn't

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Introduction

All elements of the research triad in this country—universities, federal laboratories, and industrial labs—have spent a good part of the last decade in a very changeable and changing environment. In the area of partnerships with industry there have been a lot of experiments, such as the Advanced Technology Program (ATP), the Technology Reinvestment Program (TRP), and the Department of Energy's (DOE) analog, the Technology Transfer Initiative (TTI). We now have, at least in principle, gained enough experience with cross-sector partnerships to make some observations on what works and what doesn't.

My judgments are preliminary and driven by the idiosyncrasies of my own lab. I think the general themes at Livermore are reflected in other DOE national security labs and, at least to some extent, in other federal labs. Although we share some features in common with universities and industrial labs, I think the nature of our funding sources, and the way in which we are affected by global political factors such as the Cold War, pose a somewhat special set of circumstances for our institutions.

Historical background

To understand these circumstances, it is useful to start with the context in which we entered this very different period of the 1990s.

Most of the federal labs began somewhere in the 1950s or 1960s. They were created to do a very specific project for the federal government, such as nuclear weapons, nuclear reactors, space exploration, or high-energy physics. Each lab spent the next 20 to 25 years doing that job as well as it could.
By the end of that time, several things had happened. For one thing, we had made considerable progress on the task the Federal government had asked us to do: the job was well on its way to being accomplished and not quite as much of a challenge. In addition, almost without exception, each lab had developed a very special set of technological skills. In many cases these technologies had been created in a de facto partnership with industries that grew up to meet our needs. These partnerships simultaneously helped the labs accomplish their missions and at the same time created new industries—for example, the supercomputer companies, much of precision engineering, and much of the laser and optics industry.

During the mid-'1970s the labs began to seek new ways to put their unique technologies to work. They were sought out by a variety of people in fields very different from those in which they started: in Livermore's case, energy, environment, and other "softer" fields (at least by the standards of the '50s and '60s). This expanded the range of federal agencies for which each lab did work as well as the breadth of work done by our parent agencies.

In the 1980s, Congress and the White House added a new mandate. The Stevenson-Wydler Technology Innovation Act of 1980 established the foundation for technology transfer in the Federal government. Stevenson-Wydler in effect said, "Go forth: you now have a mandate to do technology transfer with all of those technologies you have, in addition to what you are doing for other agencies."

Stevenson-Wydler allowed us to spend a half percent of our budgets on technology transfer. Personally, I never thought one-half percent of your budget represented much of a mandate, but it was construed by some as a new Lab mission.

And so we began, in addition to performing a broader range of federally funded work, to look for new ways to work with industry. As the '80s went on and we began taking on more work less related to our original core missions, the missions of the national labs became more diffuse, and technologies were more and more widely distributed throughout the federal system.

Then, around 1990, the Cold War ended. For a huge fraction of the federally supported research and development establishment, this meant that many aspects of the "mission" and "key" technologies became murky and in need of redefinition. In an attempt to clarify roles and identify areas where they could make important contributions, the mission agencies and their labs pursued a variety of experiments with different technologies and new missions.
Many of these experiments were done under the rubric of "economic competitiveness" as a new mission. They typically involved some aspects of defense conversion, and they inevitably stressed the importance of alliances among the triad of research institutions. I now want to review our experience with those cross-sector partnerships during this period. Then I will use a set of diverse examples to illustrate what has seemed to work best for us.

**DOE’s Technology Transfer Initiative**

The Department of Energy's driver for cross-sector partnerships in the early 1990s was a process—the Technology Transfer Initiative (TTI), which provided for money to be invested in CRADAs (Cooperative Research and Development Agreements) with industry. The basic model was that DOE (through a lab) would put in 50 cents; a company would put in 50 cents; and the DOE lab and the company would work together to do a dollar's worth of work on a well-defined project.

Figures 1 and 2 show Livermore's experience with these agreements as a function of year. We signed 247 CRADAs over the 5-year period from 1992 to 1997, with a total investment of $787 million. CRADAs started during the Bush Administration, with Admiral Watkins as Secretary of Energy; they reached heights of frenzy in the early years of the Clinton Administration; and then heights of "inverse frenzy" after the '94 Congressional elections.

Figure 3 shows both historical and recent funding for industrial partnerships at Livermore. Figure 3a shows the up and down growth in DOE-funded CRADAs. We have had, more recently, CRADA partnerships where the research is funded by industry, with no cost-sharing by government and these are shown in Figure 3b. (I will discuss these a little later.) We also continue to do some CRADAs which are funded out of Laboratory program dollars (where we, not DOE, choose the company), as shown in Figure 3c. Figure 3d shows work done directly for industrial sources such as the United States Enrichment Corporation and a few other industrial sources who are paying us outside the CRADA framework. So we now have industrial sponsors, not just federal sponsors. Total revenues from industry-funded CRADAs and direct sources (Figure 3b + 3d) today dwarf what the government funded under its CRADA program in 1997 (Figure 3a + 3c).
Reflections on our experience

Having gone through a variety of experiences with cross-sector partnerships, one can make a few general observations.

The first conclusion is that technology transfer can only work if you have a "real" mission. Almost all national laboratories would love to have the mission, "Our purpose is to be a reservoir of science and technology for the country." But that doesn't sell very well for very long. A compelling truth from this period is that you have to have some centrally defining reason to be in business, and transferring technology or working with industry aren't good enough reasons.

National policy is the critical mission driver for federally funded labs. One of the things that has recently helped the three DOE national security laboratories (Livermore, Los Alamos, and Sandia) is the reaffirmation and reconstitution of those laboratories' national security missions to reflect the post-Cold War context. This came about as a result of a policy shift from a national security program which relied on testing nuclear weapons to one which (a) emphasizes a science-based, non-nuclear testing methodology as the means for ensuring the safety of the nuclear weapons stockpile; and (b) gives significant priority to work against proliferation of nuclear weapons, nationally and internationally. The transition to this model has led to a redefined sense of purpose and commitment for the three national security laboratories.

Once an organization has a clear sense of purpose and mission, two positive things happen. First, you gain a strong sense of commitment from the people in the organization, and, second, you now understand which technologies matter in the context of your purpose and mission. It isn't simply "anything goes"; no longer do you have many disparate groups working on anything somebody is willing to pay for. You have a major purpose and key technologies: now you have something on which to construct industrial and academic relationships using those technologies; and things that reinforce the basic mission take on new priority. The sense of a reaffirmed purpose and the experience of these kinds of partnerships are making us much more robust laboratories.

The second major lesson we learned is that small-scale technology transfer work in the Stevenson-Wydler sense is fun and fine, but many of the intermediate-scale arrangements are simply not very sustaining. When projects are
small, you often work with exciting new companies, you can license technologies straight-forwardly, and paperwork and bureaucracy are held to a minimum.

But beyond the small-scale work, a partnership has to be big and relevant enough that the senior management pays attention to it. By this I mean that at a federal lab the overhead of regulation, rules, and procedures is so complex, and the issues around intellectual property and proprietary material are so different from the public culture, that we have to redesign our business approach to the particular situation if we are going to be successful. If we don't have a partnership important enough that we are willing to change part of the way the lab does business, it probably doesn't make sense to do it.

Let me give you some examples from both ends of the spectrum to illustrate these points.

Small scale work: some health care examples

At Livermore we have picked a few very interesting fields in which to focus our small-scale industrial interactions. One of these is health care. Some of the main technologies—lasers, computer simulation, and micro-engineering—that Livermore needs for its national security work are the technologies we are primarily using in our health care work. Although the scope of our work in this area has grown to $10 million per year, most of it is paid for by small companies and involves only a few people per task.

Recent health care projects include:

- application of advanced computer modeling techniques to improve the accuracy of cancer radiation treatment;

- use of fiber-optic-delivered pulsed laser energy to break up vascular clots (ischemic stroke);

- catheter delivery of a miniature x-ray source to treat the regrowth of artery lining following balloon angioplasty;

- improving image quality in mammography through a filmless screening unit incorporating a novel x-ray source; and

- use of high-resolution topography in osteoporosis treatment to assess fine structure of bone.
Note that many of these efforts derived from weapons technologies. The use of Monte Carlo techniques for improving accuracy of radiation treatment came out of the weapons modeling program. Digital mammography and the x-ray catheter came out of the nuclear test program. This is classic Stevenson-Wydler: technology transfer into health care. It feels good because of the applications, and I think it has a wonderful technical sense to it.

**Large-scale work: AVLIS, VNL, ASCI, and NIF**

Earlier I said that for work beyond small projects to be worth doing in the current environment, it has to be relevant enough to our mission and a big enough enterprise that we are willing to change the way we do business to make it happen. Let me give some examples of where—and why—we have changed the way the lab works to do some of these large projects. Only one of these comes from the CRADA arena, but all are major industrial partnerships.

**AVLIS**

Over the past twenty years Livermore developed a way to separate isotopes of heavy elements using lasers, one of our key technologies. The government spent over 20 years and about 1.5 billion dollars at our lab developing the process technology to separate isotopes from uranium and plutonium (see Figure 4). Several years ago, the United States Enrichment Corporation (USEC—a public corporation set up by the government to provide uranium for civilian reactors) decided to take our Atomic Vapor Laser Isotope Separation (AVLIS) technology and continue to develop it for commercial use. USEC’s goal is to deploy AVLIS technology in the early 2000s as a prime source of enriched uranium.

AVLIS is cost-competitive and timely, outperforming in principle the gaseous diffusion process and centrifuges, as well as being environmentally much more benign. We are now working toward plant-scale demonstration: USEC has overall responsibility for the enrichment plant project; Livermore for operating demonstration and design; and industry for facility design and construction. We are responsible for the R&D prototyping of the plant, but we have many Bechtel employees and Babcock and Wilcox employees working on site with us as part of a 700-person team which didn't exist at all prior to the development decision by USEC.
With the AVLIS effort we made a Lab-wide commitment to a new way of interacting with our industrial sponsor and commercial partners. Because it's a big enough and important enough project, I changed the overhead procedures and much of the way the lab does business in the USEC arena in order to make this cross-sector partnership work. This project will change the way the country—and perhaps the world—enriches uranium. It's very exciting, assuming—as USEC does—that the world will need enriched uranium at a significant level in the years after 2000.

**The Virtual National Laboratory**

Another example of a large-scale industrial relationship is the Virtual National Laboratory (VNL). We have a formal agreement with the Sandia National Laboratory and the Lawrence Berkeley National Laboratory to create a single point of contact for certain specialized commercial businesses, primarily related to microelectronics. The VNL assumes all responsibility for coordination and delivers to the customer a single reporting and interaction mechanism. Essentially, if you hire the Virtual National Lab you get a single point of contact who can direct work at all three labs, allocate resources, and make decisions. Industry is responsible for "full recovery" costs of the three laboratories to accomplish the agreed-upon tasks. VNL chooses its customers as carefully as industry chooses to engage VNL. Relevance to the core missions of the labs and consistency with lab-specialized technology are the driving concerns for VNL's selection of industry partners. Industry partners receive exclusive intellectual property (IP) rights in the field of use of their business concerns; VNL retains IP rights outside the partner's field of use.

The initial customer for this, with whom the VNL has signed a CRADA, is Intel Corporation. The total resources involved in this project are well in excess of $200 million over the next several years. The goal is to take our technologies and make quantum leaps in lithography and certain aspects of microelectronics. The dollars and scope are extensive enough to warrant spending a great deal of time and effort negotiating the arrangements among the laboratories to assure the VNL is able to do business with Intel and other subsequent microelectronics customers.

**ASCI**

A major job for the three national security laboratories now is to assure the reliability and safety of the nuclear weapons stockpile without doing nuclear testing. The ultimate integral experiment will be done on the computer, with an enormous
amount of validation using previous tests as well as a multitude of lab-scale experiments.

A fairly simple thought experiment will show that existing computers are not capable enough to do this work. Nuclear weapons were designed to be two-dimensionally symmetric, but—like humans—they age in three dimensions. This means we have to have 3-D codes for our future job, not the 2-D codes that were used to design the weapons. Consequently, you need a factor of almost a thousand in the computational speed to account for the change from two to three dimensions. In addition you need a lot more scientific process description since you can’t do the nuclear test—our estimate is a factor of about 100. Thus, you need more than a $10^5$ over all increase in capability (speed and memory) to use numerical simulation as the central tool in nuclear weapons assurance.

Figure 5 shows a sketch of computer history and what we will need in the way of computing capability to assure, from a computational point of view, the reliability and accuracy of the stockpile. The chart shows there was a big jump in computing speed in the early '50s, and then the computing power basically doubles every couple of years (Moore’s law). The CDC machines and the early Cray machines were all built for national security purposes. When personal computers (PCs) became widely available in the 1980s, they were comparable with relatively recent super computers, and many scientists began using PCs to do much of their work. When cost was factored in (10 plus millions for a supercomputer, less than ten thousand for a PC), this trend became even stronger.

Now we’re faced with the problem I identified a minute ago, the need for major leaps in computing power if we are to accomplish our stockpile assurance job. We realized that we could not rely on historical trends if we wanted to get this additional factor of a hundred thousand in computing power. So the dashed curve on the right is the jump into ASCI, the Accelerated Strategic Computing Initiative. ASCI is a 10-year, $1-billion program whose goal is to deliver multi-teraflop-scale computing capability in support of DOE’s Stockpile Stewardship and Management Program. The 3-D modeling and simulation capability that will result is key to maintaining the safety and reliability of the Nation’s nuclear deterrent without nuclear testing.
The three labs involved in ASCI have now obtained three very large computers—one made by Intel at the Sandia Lab, one made by IBM at Livermore, and one made by Silicon Graphics/Cray at Los Alamos. Once the DOE commitment to ASCI was made, the three labs moved astonishingly quickly to get things done. At Livermore we did the IBM procurement ($93 million) in under six months, from start to finish. The contract was signed on August 12, 1996, and the initial delivery was made more than 30 days ahead of schedule, on September 20, 1996. The initial IBM system has already begun significant calculations in areas important to maintaining the nuclear stockpile (see Figure 6). These include:

3-D primary stewardship issues (understanding data from past nuclear tests and predicting behavior of materials subjected to extreme conditions, all at speeds 100 times faster than the previous machine could have done);

material properties (with a goal of predicting microscopic failure properties of aging materials affecting weapon performance); and

turbulence (with over 100 million grid points requiring $10^{15}$ operations using 10,000 node/hours).

ASCI represented really accelerated strategies, not only in computing, but in procurement and DOE/Lab-industrial interactions. These are not simply procurements off the shelf. Much of the ASCI work involved close relationships with the computer manufacturers, both as part of the RFPs and on a continuing basis. The computers are being developed, both hardware and software, in partnership with the companies.

The goal, from our point of view, is to get the computing power. Presumably, the companies—IBM in Livermore's case—believe these developments will also help them achieve a very good position in their own markets. This is an area in which we both have a vested interest to get a job done and, basically, jump exponentially in computing capability.

These new super computers are also extremely parallel, and none of us—at the labs, in industry, or in academia—know how to use parallel machines very well. Consequently we have made a large university component a central element in learning how to use these computers. The DOE is investing very heavily in a competition to welcome university partners in doing simulation, not of weapons
but of other things that involve complex, multidimensional-type calculations. We want these machines to do all kinds of computing, from global climate to crash simulation.

To accomplish this the DOE has established an Academic Strategic Alliances Program as a framework for our interactions with academia on ASCI. In this fiscal year, about $8 million will be spent on this program, going to about $25 million per year in the near future. Initially, about five Strategic Alliance Centers will be established as a result of a highly peer-reviewed competition that is nearing its end right now. The money will be invested at the institutional level in the selected universities. There will also be department-level awards, and then those to individual principal investigators. From the DOE and lab’s point of view, we will get an important mission done, but we will also do an extraordinary job of making simulation a real part of science. So I think both from the scientific perspective as well as mission objective, this is a truly remarkable kind of partnership.

**National Ignition Facility (NIF)**

Livermore's other major project in the Stockpile Stewardship and Management Program is to do experimental simulation using very large lasers. We are about to break ground to build a very large laser called the National Ignition Facility, a billion dollar plus facility which is necessary for understanding and simulating high-energy density-physics in a non-testing environment. In NIF we have the same strategy of integration with industrial partners (we will spend 80 percent of the NIF capital budget in industry) and attention to university involvement as in the work I described for ASCI.

For example, Livermore has defined much of the state-of-the-art in the optics industry, especially with lasers, for the last 25 years, and NIF will push the advancement of knowledge in that field. We will also open the NIF facility to university researchers in astrophysics and plasma physics, and, as in ASCI, we and the universities will leverage each other's understanding of fundamental physical science. In so doing, we will get our job done, and superb science will be accomplished, pushing the state-of-art in both science and technology.

**Inter-lab alliances**

I thought it might be interesting to point out that besides partnerships with industry and academia, we are also partnering with other national labs in new ways. The stockpile stewardship effort and our work in nonproliferation are done through strong partnerships with the other two national security Labs. And we have
combined the three human genome centers at Livermore, Los Alamos, and the Berkeley lab, into one formally-constituted joint genome institute located away from any of our sites. The goal is to capitalize on Lab specialties and economies of scale to qualitatively accelerate the sequencing of the human genome and then apply the results for both basic and clinical purposes. This joint genome institute is not now coupled with industry but could evolve in that direction.

To be successful, these inter-lab alliances need to be strongly focused in a program area and have an effective management structure that can operate across the procedural and cultural boundaries of the participating institutions. The problems in doing this are not small. On the other hand, it must be done: letting scientists interact exclusively in their own individual modes will not work under these arrangements. A partnership is more than physical or disciplinary propinquity, and the interfaces require active and occasionally intrusive management.

**Concluding Observations**

Setting aside small-scale projects arising out of ongoing programmatic work, successful cross-sector partnerships involving the national labs with industry, universities, and other labs have to have three characteristics. First, they have to be large-scale to justify the important complexities involved. "Large-scale" means they must be important to your institution and therefore worth changing, where necessary, business procedures and human resource practices to accomplish.

Second, they have to be valuable to your mission and technology. The relationships have to be built around the technologies you want to nurture and the mission you need to accomplish.

Third, for a national laboratory, the relationships must have a major impact. In our case, if the AVLIS project works, we will change the way the country enriches uranium. If we are able to change the lithography scale, we will have changed the United States’ competitive position in the semiconductor industry; and if ASCI succeeds we will have broken through Moore’s law and made a significant impact on our ability to assure the stockpile without nuclear testing.
In summary cross-sector partnerships are most exciting when they are revolutionary, not evolutionary, and when all partners have a compelling need to succeed. The diverse set of large scale partnerships currently underway at Livermore will be a vigorous test bed for such relationships. If successful they can add a very important new element to the way important research is carried out in this country.
LLNL Cooperative Research And Development Agreements (CRADA) Activity

247 CRADA agreements provide over $787,000,000 to the technologies

$M

- 300
- 200
- 100
- 0

Calendar Years

$787M in total funding from signed CRADAs

Figure 1

Calendar Years

Cumulative growth of CRADA funds

Partner Funds

DOE/LLNL Funds

Figure 2
LLNL Industrial Partnership Activities by funding source

Fig. 3a: DOE Funded

Fig. 3b: Industrially Funded

Fig. 3c: Lab Funded

Fig. 3d: Industry non-CRADA

Figure 3
Atomic Vapor Laser Isotope Separation (AVLIS) for the US Enrichment Corporation (USEC)

AVLIS Uranium Separator Demonstration Facility

Figure 4
LLNL Computing History

Figure 5
The IBM RS/6000 system will be installed as part of DOE's ASCI Program.

512-Node RS6000 Scalable Parallel System

The staged delivery began in September 1996, leading to a three-teraflop device by the end of 1998.

Figure 6