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Federal Laboratories for the 21st Century

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Federal Laboratories for the 21st Century

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Abstract

Federal laboratories have successfully filled many roles for the *public*; however, as we enter the 21st century it is time to rethink and reevaluate how Federal laboratories can better support the public and identify new roles for this class of publicly-owned institutions. The productivity of the Federal laboratory system can be increased by making use of *public outcome* metrics, by benchmarking laboratories, by deploying innovative new governance models, by partnerships of Federal laboratories with universities and companies, and by accelerating the transition of federal laboratories and the agencies that own them into learning organizations. We must learn how government-owned laboratories in other countries serve their public. Taiwan's government laboratory, Industrial Technology Research Institute, has been particularly successful in promoting economic growth. It is time to stop operating Federal laboratories as monopoly institutions; therefore, competition between Federal laboratories must be promoted. Additionally, Federal laboratories capable of addressing emerging 21st century *public* problems must be identified and given the challenge of serving the public in innovative new ways. Increased investment in case studies of particular programs at Federal laboratories and research on the *public* utility of a system of Federal laboratories could lead to increased productivity of laboratories. Elimination of risk-averse Federal laboratory and agency bureaucracies would also have dramatic impact on the productivity of the Federal laboratory system. Appropriately used, the U.S. Federal laboratory system offers the U.S. an innovative advantage over other nations.

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² Paul Huray is a physicist and engineer. He spent five years working for the White House Office of Science and Technology Policy (OSTP) during the Reagan and Bush administrations. Between December 1985 and December 1989 he chaired the FCCSET Committee on Computer Research and Applications which developed policy leading to the creation of the Internet. He has also worked at Oak Ridge National Laboratory.

I. Executive Summary

Several organizations and studies have called for selective reorganization and restructuring of laboratories attached to particular Federal agencies. None of these studies examine the entire Federal R&D enterprise as a system and propose roles for **publicly**-owned institutions in that enterprise. Most of these offer recommendations, but say little about under what conditions government should sponsor R&D and under what conditions the **public** is best served by owning those institutions that perform its R&D. Our approach is straightforward; we have briefly examined these questions and then synthesized how Federal laboratories can better serve the **public**.

We first proposed a set of principles for the pursuit of Federal technology and science (T&S) policy. These are headed by the principle that it must be focused on **public** problems and **public** issues that the marketplace is failing to address. We then enumerate those circumstances where we believe it is to the advantage of the **public** to own the institutions that perform its research and development (R&D) and propose that when these circumstances exist, the issue of Federal laboratory - company competition is irrelevant. One of these circumstances is when it is believed to be in the **public's** interest to control the diffusion of knowledge arising from the R&D, e.g., nuclear weapons. Several other circumstances also exist. Although, not irrelevant, R&D performer competence is not the major driver of the public's choice to outsource its R&D or conduct it internally.

The Federal laboratory system is made up of 515 laboratories that annually spend about \$27 billion on research and development. These laboratories serve a wide array of purposes. Some are large multi-program laboratories; others are small, highly focused laboratories. Lack of metrics and benchmarking activities prevents determining which of these provide the highest **public return** per **public** dollar spent. Of the Federal laboratories, 39 are operated by contractors as Federally Funded Research and Development Centers (FFRDCs). These facilities spend about 25% of those Federal funds spent at Federal laboratories; the remaining 75% are spent at government-operated laboratories. Activities of FFRDCs are highly regulated by Federal law. Nevertheless, because these laboratories are generally the largest Federal laboratories, they are a target for criticism and a commission always seems to be studying them. Overlapping capabilities, lack of mission focus, and inadequate agency management are criticisms often cited in these studies and most tacitly argue for Federal laboratories to be operated as monopoly institutions.

Despite the fact that Federal laboratories have successfully filled numerous roles for the **public**, we believe that the productivity of the Federal laboratory system can be increased. We identify increased use of **public outcome** metrics, benchmarking laboratories, innovative new governance models, partnerships of Federal laboratories with universities and companies, and other changes that can lead to improved Federal laboratory performance. By emphasizing conformance to rules, today's governance system is particularly onerous and control-oriented and likely results in laboratories falling well short of their full potential to serve the public. In fact, it is our experience working in agencies and federal laboratories, that many of the inefficiencies and cultural liabilities resident in Federal laboratories are directly traceable to the governance system imposed by the agency that owns the laboratory. We advocate that several governance alternatives, including the Galvin corporatization model, be examined in experiments. Those Federal laboratories whose work is in areas where the **public** is not advantaged by owning the institution that performs its R&D should be privatized and many of the support functions at many Federal laboratories should be given consideration for privatization, if this arrangement is more cost-effective. Throughout, we argue against operation of Federal laboratories as monopolies.

The **public** value of Federal laboratories and the agencies that manage their activities can be most impacted by converting these institutions into learning organizations. To do that agencies and laboratories must increase their emphasis on leadership and examine past practices to learn from successes and failures. Agencies and laboratories may also learn from the reinvention efforts of city government. While companies represent an institutional class

that differs greatly from **public** institutions, there is much to learn from the reengineering efforts of companies responding to intense market competition and the efforts of companies to weed-out bureaucracy. Where Federal laboratories have been perhaps the most short-sighted is in their failure to learn from government-owned laboratories in other countries. We cite, in particular, the incredible success of Taiwan's Industrial Technology Research Institute in promoting economic growth in Taiwan.

We offer numerous recommendations for improving the **public value** of Federal laboratories; however, we lacked the courage to call for yet another study of laboratories. However, we do advocate identification of those laboratories capable of addressing 21st century **public** problems. Rather than a major study of Federal laboratories, we recommend increased investment in case studies of particular programs at Federal laboratories and we recommend that the **public** utility of a system of Federal laboratories be addressed in policy research. This research should be conducted by the academic public policy research community.

We propose that steps well beyond those of the National Performance Review be taken to eliminate risk-averse Federal laboratory and agency bureaucracies. We strongly advocate that all of those regulations that encourage Federal laboratories to operate as monopolies be removed and that competition between Federal laboratories for private institution and agency work be promoted by all practical means. Finally, we recommend that incentives be developed to promote partnerships between Federal laboratories, universities, and companies and that a National R&D Performer Partnership Program be established to address a wide array of **public** problems that have been long ignored. Examples include healthcare costs, regulatory costs, college costs, etc.

II. Background

A. Introduction

The United States has developed a Federal laboratory system that dwarfs that of any other Nation. Because this system was optimized for the Cold War era, it would be an incredible coincidence if it were optimized for the 21st century, an era Congressman Ehlers calls the "economic era".³ The spirit of our review is to identify ways to make this system better serve the **public** in the emerging new period characterized by entry into the 21st century.

While there have been many studies of Federal laboratories and a wide array of recommendations have been offered, these studies have generally focused on those laboratories that belong to a particular agency. Although the technical capabilities of the Department of Energy's national laboratories are often cited, this particular set of laboratories has been extensively studied, perhaps some would say, "studied to near death". Unfortunately, these studies have not looked at the entire Federal laboratory system in terms of its potential for the future, they have seemingly tacitly assumed the future to be a linear extrapolation of the past and many have become bogged down in Cold War models of Federal laboratories. To avoid that trap, we have reopened the issue of when should the **public** fund R&D and when is the **public** advantaged by owning the institution that performs its R&D. It is only in this context that it makes sense to examine Federal laboratories.

B. Principles of 21st Century Federal Technology and Science (T&S) Policy

In crafting 21st century roles and behaviors for Federal laboratories, it is necessary to first examine what role the Federal government should play in promoting science and technology in the 21st century. We do not claim to know exactly what U.S. T&S policy should be for the 21st century; however, we do believe that it must conform to the following principles. These principles place the focus on the **public**, not the technology and science or the R&D performer where it is often placed.

³ Presentation by Congressman Ehlers at Sigma Xi forum, Trends in Industrial Innovation - Industry Perspectives and Policy Implications, Washington, DC, November 20-21, 1997.

- It must preferentially address **public problems** and **public issues** that the marketplace is failing to address. If a market failure doesn't exist, government should stay out. And when a market failure exists, the priority of government should be to correct the market failure, not use the market failure as an excuse to sponsor R&D that is irrelevant to the failure.
- It must assure that all performers of Federal R&D treat the **public**, not Federal agencies, the President, or Congress, as the primary customer for federal R&D and they must stress **public outcomes**. This principle demands that R&D performers must learn to quantitatively examine everything they do in terms of its **public value**. Our Nation has a long way to go in implementing this principle.
- It must be immediately responsive to emerging and shifting **public needs** and have reliable indicators to identify what these needs might be.
- It must emerge from knowledge-intensive, disciplined, politically-pragmatic processes that emphasize **public service**.
- ◆ It must be based on roadmaps that allow politicians to understand why scientists might be moving toward science target A, as opposed to science target B.⁴
- It must raise the level of competition for monopoly (federal laboratories) and oligopoly (universities) performers of federal R&D. However, we do not regard soliciting 200 research proposals for peer review in order to make one \$200,000 research grant to be a reasonable way to promote competition.
- It must measure the **public outcome** of Federal R&D and build-in mechanisms that permit successful R&D performers, including Federal laboratories, to prosper and grow while unsuccessful R&D performers, including Federal laboratories, wither and die. Under no circumstances must a performer of Federal R&D be penalized for successfully performing its public duties.
- It must integrate basic or fundamental science with applied science and engineering to assure that all of the **public's** R&D investment contributes to **public outcomes**.
- It must increase the **public** understanding of how decisions are made, e.g., why the **public** investment in AIDS research is five times larger than the **public** investment in Alzheimer's research, and make apparent to the **public** what they are getting from their investment in R&D.
- It must be open to and encourage critical examination by academics and others that wish to conduct on-going and retrospective analyses of **public** return from Federal R&D programs.
- ◆ It must promote partnerships of universities, federal laboratories and companies to increase the probability that Federal R&D will be successful in addressing the complex, interdisciplinary problems of highest **public** interest. It must make optimum use of the core competencies of these three complementary classes of institutions by matching them with the appropriate problem categories.
- It must promote systems of governance and regulation of Federal R&D performers that lead to the most efficient performance of R&D and offer opportunities for privatization of R&D performers owned by the **public** when these R&D performers are conducting R&D under circumstances that do not advantage the **public**.

⁴ This idea has been introduced first by Mr. Bob Galvin and more recently by Dr. Michael M. Crow to attendees at the AAAS Science and Technology Conference, Washington, D.C., April 24, 1997.

Brown has concluded that there are three necessary conditions for legitimate government intervention in the market. His conditions are embodied in the above principles.

- ◆ The research must have a reasonable chance of producing benefits that outweigh its costs. These must be broad social benefits (rather than benefits just to a particular firm).
- ◆ The research would not be performed in the absence of government support.
- ◆ The Federal agency must be able to fund or perform the research efficiently.⁵

C. Intramural Performers of Federal R&D

When the Federal government decides that government-funded R&D is the best or perhaps the only way to address a **public** problem, it must decide whether the R&D should be conducted in a Federal government-owned institution (intramural), if it should be conducted in a privately-owned or state-owned institution (external), or if it should be conducted by a **partnership** of all of these institutions. Without exception, it is reasonable to favor conducting the R&D where it is most likely to provide the highest long-term **public** return per unit of public cost. (As far as we know, algorithms for making this calculation are not currently available. In fact, this is a very complex and difficult assessment, but one that should be made.) In evaluating the **public** return from university research, the educational value of the research must be included in the calculation. If analyses of **public** return per unit of **public** cost favor universities, and universities are capable of doing the work in a way timely with **public** needs, then universities should be given preference. However, the following circumstances generally favor intramural R&D conducted in a Federal laboratory over R&D performed at a university or company.

- ◆ The **public** wants to avoid distortion of the commercial market and wishes to not advantage one competing firm or university over another competing firm or university. (Industry-wide consortia also have this feature when they avoid collaboration that inhibits competition.) In selecting a single private company to perform defense R&D at the component or systems level, the Federal government advantages that company over their competitors when this R&D leads to system procurement opportunities. An alternative is to perform this R&D at a **publicly**-owned institution that makes the results available to all companies interested in bidding on a procurement contract.
- ◆ **Public** benefits may accrue from **public** ownership of intellectual property. It has been proposed, for example, that the **public** would benefit from **public** funding of pharmaceuticals research with **public** ownership of patents for product discoveries. The **public** would license manufacturing rights to multiple companies so that products would be sold at commodity rather than monopoly prices.
- ◆ **Public** benefits obtain from controlling diffusion of the new knowledge resulting from the R&D, e.g., nuclear weapons R&D. (Many defense contractors and some universities also have a culture that has made a practice of restricting diffusion of knowledge.)
- ◆ The **public** wants its investment in R&D to be Nationally appropriable and to preferentially advantage the American public.
- ◆ The **public** wants the R&D performer to have no financial or political interest in the outcome of the R&D. This is an extremely important issue that has strong implications for how Federal laboratories should be governed.
- ◆ A Federal agency needs an unbiased, competent R&D procurement advisor or R&D program manager that has no vested interest in the answer. In pursuing this activity, some Federal laboratories have partnered with companies to execute the R&D and put at risk their ability to offer unbiased systems procurement advice to their parent agency.

⁵ Kenneth M. Brown, Downsizing Science: Will the United States Pay a Price?, The AEI Press, 1998, p. 48.

- ◆ Industrial partners may be unwilling to transfer their technology to a company, but are willing to transfer it to a federal laboratory that has no potential to become a competitor. (Sandia has found that commercial semiconductor companies prefer to transfer integrated circuit designs to Sandia for radiation hardening rather than transfer the design to another commercial vendor for radiation hardening.)
- ◆ There are circumstances where neither a company nor a university have the multidisciplinary technical breadth to cost-effectively address an unmet *public* need.
- ◆ There is a need for a large, complex facility (e.g., a neutron spallation facility) which will be operated on an optimum time-efficient basis for the benefit of the most meritorious research proposals.

While these circumstances favor intramural R&D, most other circumstances favor R&D performers not owned by the Federal government or *partnerships* of all classes of R&D performers.

III. Today's Federal Laboratory System

A. Agency Distribution of Federal Labs.

The Government Accounting Office has determined that 17 Federal departments and independent agencies have 515 Federal R&D laboratories that spent a total of \$26.6 billion of an estimated \$69.4 billion that Federal agencies obligated for R&D in fiscal year 1995. DoD, DOE, HHS, and NASA labs accounted for \$23.3 billion or 88% of these funds. Some of these are flow-through funds that are spent at universities and companies. Roughly, 25% of these funds go to FFRDCs and 75% go to government-operated laboratories.

By comparison, in 1995, U.S. universities spent \$21.6 billion on research and development. Slightly over 60% of these university funds were provided by the Federal government. (In the mid-1930s, about 10% of university research funds came from Federal grants, but by 1980, the Federal government provided 68% of university R&D funds.) Over the past 15 years U.S. universities have averaged increasing their Federal R&D budget by 5.8% each year, FFRDCs have increased Federal spending by 2.8% each year, industrial laboratories have increased Federal spending by 1.4% each year, and government-operated laboratories have increased funding by 0.7% each year. Over this 15 year period, only universities experienced real growth in Federal R&D spending. Although universities have increased their Federal R&D funding by 5.8% per year, this growth rate has not been adequate to fund university cost growth which been about 6% per year. (R&D funds cover about one-third of the costs of universities.)

There is at least one Federal laboratory in every state. The state distribution of federal laboratories ranges from California with 46 federal laboratories (\$4.1 billion budget) to Delaware (\$1 million budget) and Maine (\$400k budget) with one laboratory each and Kentucky (\$2.6 million budget), Vermont (43.8 million budget), and South Dakota (\$2.2 million budget) which have two laboratories each. Agency distribution of federal laboratories and their funding is shown in Table I.⁶

Of the 515 Federal labs, 453 laboratories are government-operated and 39 have been designated as Federally Funded Research and Development Centers (FFRDCs) that are administered by either companies, nonprofit institutions, or universities and colleges. All FFRDCs that are located at facilities owned by the federal government are termed government-owned, contractor-operated (GOCO) facilities. In those instances where the GOCO contractor is a company, the intent is to deploy corporate management principles at selected labs. Those Federal laboratories that are administered by the Federal government

⁶ GAO/NRED/NSIAD-96-78R, Federal R&D Laboratories, February 29, 1996.

and staffed with employees of the U.S. government are termed government-owned, government-operated (GOGO) laboratories. In the mid 1970s Congress designated 8 of the FFRDC GOCOs managed by DOE as multi-program National laboratories to signify that these laboratories were intended to serve the Nation. Later, one additional Federal laboratory was given this distinction. Thus, National laboratories are a subset of the GOCO Federal laboratories.

Table I: The number of Federal laboratories, their Federal agency affiliation, and their FY 1995 operating budget. Note that some of these funds flow-through Federal labs and are spent supporting R&D at universities and companies.

Dept. or Agency	No of Labs	FY 1995 Budget	Dept. or Agency	No of Labs	FY 1995 Budget
USDA	185	\$733 M	Commerce	38	\$430 M
Defense	68	\$9,150 M	Education	10	\$41 M
Energy	33	\$8,081 M	Health & Human Services	19	\$1,371 M
Interior	20	\$547 M	Justice	2	\$1 M
Transportation	6	\$536 M	Treasury	1	\$1.7 M
NASA	10	\$4,833 M	EPA	11	\$348 M
Veterans Affairs	102	\$270 M	NSF	5	\$173 M
Nuclear Regulatory Comm.	1	\$16 M	Smithsonian Institution	2	\$18 M
TVA	2	\$27 M	Total	515	\$26.6B

During World War II, the Federal government established laboratories, principally at universities, to perform research and development for the war effort. Several of these eventually become Department of Defense FFRDCs: the Radiation Laboratory at the Massachusetts Institute of Technology (later reorganized as Lincoln Laboratories); the Applied Physics Laboratories in the states of Maryland and Washington, operated by Johns Hopkins University; the Center for Naval Analyses in Arlington, Virginia, operated by the University of Rochester; and the Naval Ordnance Research Laboratory at Pennsylvania State University. In 1943 the Army Air Force began supporting a rocket research division at the California Institute of Technology that was the precursor to the Jet Propulsion Laboratory, which later became an FFRDC for the National Aeronautics and Space Administration (NASA). Some of the Atomic Energy Commission (AEC) laboratories also had their roots in the war: Los Alamos Laboratory, managed by the University of California; Ames Laboratory, run by Iowa State University; and the Manhattan Engineering District's Metallurgical Laboratory (later Argonne Laboratory) at the University of Chicago. Research sites at Hanford, Washington, and Clinton, Tennessee, operated by DuPont Chemical Company and the University of Chicago, respectively, were the forerunners of Pacific Northwest and Oak Ridge National laboratories. The AEC's Lawrence Berkeley Radiation Laboratory had roots that preceded

the war, having been established in 1936 by Earnest O. Lawrence as the University of California Radiation Laboratory.⁷

Today, the technical outputs of the DOE laboratories are probably the highest in the Federal laboratory system. These laboratories have over 30,000 scientific and technical personnel. Their scientists and engineers have helped DOE research be awarded 71 Nobel prizes and 417 R&D 100 awards, including 31 in 1996, and they made up 7 of the 35 finalists for 1997 Discover Magazine awards for technological innovation. These laboratories operate over 60 scientific user facilities including the Advanced Photon Source at Argonne, the National Synchrotron Light Source at Brookhaven, the High Temperature Materials Laboratory at the Oak Ridge National Laboratory, and the Continuous Electron Beam Accelerator at the Jefferson Laboratory in Virginia. These facilities serve 15,000 users from nearly 200 universities and roughly the same number of companies.

These laboratories also support the DOE in its pursuit of its mission objectives of:

- ◆ Enhancing U.S. energy security by developing and deploying clean and affordable energy supplies, and by improving the energy efficiency of the U.S. economy;
- ◆ Ensuring a safe and reliable nuclear weapons stockpile and reducing the global nuclear danger;
- ◆ Cleaning up former nuclear weapons sites and addressing the complex challenge of disposing of nuclear waste; and
- ◆ Leveraging science and technology to advance fundamental knowledge and our country's economic competitiveness with a stronger partnership with the private sector.⁸

The enviable technical record of DOE's laboratories is often overshadowed by criticism. Brown points out,

DOE labs have been widely criticized for inefficiency, the problems stemming largely from overcontrol by Congress and the department (DOE). The labs answer to the Energy Department not only for their basic mission and their programs but also for every detail of their operation. Every nickel and every management decision must be scrupulously accounted for, and the records are subject to numerous audits. Procedures for meeting safety rules are specified in minute detail. ... Cumbersome rules for partnering with the private sector smother many good projects. On top on all this is another layer of direction and occasional micromanagement emanating from Congress.⁹

B. FFRDC Regulations.

FFRDC's business practices are highly regulated. While an FFRDC must meet some special, long-term R&D need of the Federal government, it must be sure this need ***cannot be met as effectively*** by existing GOGOs' or contractors' resources. (How one makes this assessment is seemingly left to the imagination of the assessor. Furthermore, as we showed in the previous section, there are numerous circumstances, independent of R&D performer competence, where the ***public*** is advantaged by owning the institution that performs its R&D. This regulation encourages Federal laboratories to claim uniqueness when it doesn't exist, it results in a steady stream of complaints from companies, generally defense contractors, of unfair competition from FFRDCs, it creates non-valued added jobs for agency and company lawyers, and it inhibits competition.)

⁷ Bruce C. Dale, "The Rise of Federally Funded Research and Development Centers", unpublished paper prepared April 29, 1996 for University of New Mexico History Course.

⁸ Testimony of Secretary of Energy Federico Pena to the House Science Committee, May 14, 1997.

⁹ Kenneth M. Brown, Downsizing Science: Will the United States Pay a Price?, AEI Press, 1998, p. 72.

An FFRDC has access to government's proprietary data, employees, and facilities beyond that which is typical of a government contractor. An FFRDC must conduct its business *in the public interest* with objectivity and independence and make full disclosures of its affairs to its sponsoring agency. (All FFRDCs have sponsoring agencies.) The relationship between the FFRDC and its sponsoring agency must encourage the FFRDC to maintain currency in its fields of expertise, maintain its objectivity and independence, preserve its familiarity with the needs of its sponsor, and provide a quick response capability. (The reader should note that the emphasis on public interest, objectivity and independence is in conflict with the typical contractor relationship that defines the governance of FFRDCs and encourages Federal labs to focus on their self interests - R&D funding inputs.)

An FFRDC is *prohibited from competing with any non-FFRDC concern* in response to an agency request for proposal. However, FFRDCs may provide information, qualifications, or capabilities in response to agency requests. A **consistent level of financial support** is to be maintained for each FFRDC according to the sponsoring agency's need for the FFRDC and the terms of the operating agreement.¹⁰ **Thus, the regulations and restrictions imposed on FFRDCs promote their operation as monopolies.**

C. Funding Distribution Among Federal Labs.

Those Federal laboratories with annual budgets that exceed \$100 million are listed in Table II. The largest Federal laboratories tend to be clustered around Washington, DC and the San Francisco bay area with California (\$4.1 billion), Virginia (\$4.0 billion), Maryland (\$2.9 billion), New Mexico (\$2.7 billion), and Massachusetts (\$1.0 billion) being the only states with Federal laboratory expenditures exceeding \$1 billion.

D. Advantages and Disadvantages of FFRDCs and Federal Laboratories.

a. FFRDCs. Twenty five years ago Coddington and Milliken articulated how FFRDCs were thought to advantage the *public* as well as the alleged disadvantages of FFRDCs.¹¹ Their observations, both positive and negative, are still expressed today. Public advantages include:

- ♦ Easier to attract and retain high quality staff at FFRDCs than at government operated labs.
- ♦ High objectivity and quality of R&D output.
- ♦ Freedom from conflict of interest.
- ♦ Freedom from the leaks associated with promoting new work.
- ♦ Intimate familiarity with the sponsoring agency's activities and needs.
- ♦ Good communication of R&D results.
- ♦ High degree of interdisciplinary capability, particularly in the systems area.
- ♦ Quick response to sponsor needs.

Table II: Federal laboratories that receive an annual budget over \$100 million are listed. Their agency owner and, if an FFRDC, the institution contracted for their administration, is listed following the lab's name. (LM =Lockheed Martin and BMI = Batelle Memorial Institute.)

¹⁰ Federally Funded Research and Development Centers, Paragraph, 30,748, Federal Acquisition Regulations, 35.017.

¹¹Dean C. Coddington and J. Gordon Milliken, "Future of Federal Contract Research Centers", Harvard Business Review, March-April, 1970.

	Name of Federal R&D Laboratory	Budget FY'95	State		Name of Federal R&D Laboratory	Budget FY'95	State
1	USN-Naval Air Warfare Center	\$1,398	VA	28	USAF-Lincoln Lab. (MIT)	\$275	MA
2	USN-Naval Surface Warfare Center	\$1,396	IN, MD, VA, CA	29	DOE-Knolls Atomic Power Laboratory	\$260	NY
3	DOE-Sandia National Laboratories (LM)	\$1,325	NM & CA	30	Army-Army Research Laboratory	\$253	MD
4	DOE-Los Alamos National Lab. (U of CA)	\$1,019	NM	31	DOE-Natl. Renewable Energy Lab (Midwest Res. Inst.)	\$238	CO
5	HHS-National Institutes of Health	\$991	MD	32	USAF-Development Test Center, Eglin AFB	\$228	FL
6	DOE-Lawrence Livermore National Laboratory (U of CA)	\$859	CA	33	DOE-Lawrence Berkeley National Lab. (U of California)	\$223	CA
7	NASA-Marshall Sp. Flight Ctr.	\$841	AL	34	Army-Aberdeen Proving Gnd.	\$208	MD
8	DOE-Idaho National Engineering & Environmental Center (LM)	\$802	ID	35	Army-Engineer Waterways Experiment Station	\$204	MI
9	NASA-Jet Propulsion Laboratory (Cal Tech.)	\$784	CA	36	U.S. Geological Survey-Eastern Region	\$204	VA
10	NASA-Lyndon B. Johnson Space Flight Center	\$650	TX	37	Army-Armament Research, Development, and Engr. Center	\$203	NJ
11	NASA-Goddard Space Center	\$647	MD	38	USAF-Arnold Engineering Development Center	\$202	TN
12	DOE-Oak Ridge Natl Lab. (LM)	\$545	TN	39	DOE-Morgantown Egy. Tech. Ctr.	\$202	WV
13	NASA-Ames Research Center	\$522	CA	40	DOC-NIST	\$200	MD & CO
14	DOE-Pacific Northwest National Laboratory (BMI)	\$508	WA	41	DOT-John A. Volpe National Transportation Systems Center	\$198	MA
15	USN-Naval Command, Control, & Ocean Surveillance Center	\$502	CA	42	Army-White Sands Missile Range	\$165	NM
16	NASA-John F. Kennedy Space Center	\$501	FL	43	DOE-Fermi Natl. Accel. Lab. (Universities Research)	\$164	IL
17	DOE-Argonne National Laboratory (U of Chicago)	\$473	IL	44	USAF-Wright Laboratory	\$156	OH
18	NASA Langley Res. Center	\$426	VA	45	DOT-Technical Center	\$138	NJ
19	NASA-Lewis Research Center	\$422	OH	46	USAF-Phillips Laboratory	\$128	NM
20	USN-Naval Undersea Warfare Center	\$398	RI	47	DOT-Turner-Fairbank Highway Research Center	\$126	VA
21	DoD-C³I Federal Contract Research Center (MITRE)	\$374	MA	48	DOE-Stanford Linear Accel. Center (Stanford U.)	\$124	CA
22	USN-Naval Research Laboratory	\$360	DC	49	Army-Comm., Elect. Res., Develop. and Engr. Center	\$124	NJ
23	USAF-Aerospace Corporation (Aerospace Corp.)	\$335	CA	50	DOE-Princeton Plasma Physics Lab. (Princeton U.)	\$107	NJ
24	USAF-Flight Test Center, Edward's AFB	\$330	CA	51	U.S. Geological Survey-Western Region	\$105	CA
25	DOE-Bettis Atomic Power Laboratory	\$325	PA	52	DOE-National Institute for Petroleum and Energy Res.	\$103	OK
26	DOE-Brookhaven National Laboratory (Associated U.)	\$303	NY	53	DoD-Institute for Defense Analysis (IDA)	\$101	VA
27	USN-Applied Physics Laboratory	\$289	MD	54	NSF-Ntl. Ctr. for Atmos. Res. (Univ. Corp. for Atm. Res.)	\$100	CO

Criticisms of FFRDCs recorded by Coddington and Milliken include:

- ◆ High costs relative to other types of Federal R&D performers.

- ◆ Usurp the Federal government's policy functions.
- ◆ Adverse effects on Federal in-house competence.
- ◆ Absence of the discipline to stimulate high levels of performance that accrues from intense budget competition.
- ◆ Unfair advantage in obtaining federal R&D work.
- ◆ High costs relative to other types of Federal R&D performers.
- ◆ Usurp the Federal government's policy functions.
- ◆ Adverse effects on Federal in-house competence.
- ◆ Absence of the discipline to stimulate high levels of performance that accrues from intense budget competition.
- ◆ Unfair advantage in obtaining federal R&D work.

b. Federal Laboratories. Federal laboratories are often criticized because there are so many of them. For some, 500 laboratories is simply too many. The lack of institutional research on Federal laboratories currently makes it impractical to determine whether the large, multi-program, mega labs like many of the DOE labs, deliver more **public return** per dollar spent, or whether the smallest, highly focused labs like those in the USDA, deliver more **public return** per dollar spent. (The largest of the 185 USDA labs has an annual budget of \$95 million, and less than 10% of USDA labs have an annual budget in excess of \$10 million.) Department of Energy officials made the following comments regarding the consolidation of their medium sized labs into a smaller number of large labs,

There is little obvious benefit to consolidation for its own sake. It is not clear that a few very large laboratories are more efficient than a larger number of medium-sized laboratories. To the contrary, larger laboratories often have higher overhead rates. In addition, there are high costs for moving facilities and even higher costs for reconstituting a closed laboratory if it is determined to be needed in the future.¹²

One of the expectations that Congress has for technology transfer from federal laboratories has been job creation. If job creation is a central mission of Federal laboratories, it has been questioned whether or not large technological clusters are the best way to achieve this outcome. Some have proposed that the National labs might need to reorganize into smaller units that more closely match local economic needs, even while retaining geographical proximity.¹³

While we are uncertain if large federal laboratories are more or less productive than small laboratories, because of their large budgets, large laboratories are a target for studies and criticism. The many studies of DOE's laboratories are evidence of this. The GAO recently reported that many government advisory groups have urged DOE to clarify its national laboratories' missions and improve their management. For example¹⁴:

¹² Charles B. Curtis, John P. McTague, and David W. Cheney, "Fixing the Federal Laboratory System", Issues in Science and Technology, Spring 1997, p. 55-56.

¹³ Bruce Smith and Claude Barfield, "Contributions of Research and Technical Advance to the Economy", in Technology, R&D, and the Economy, edited by Smith and Barfield, The Brookings Institution and the American Enterprise Institute, 1996.

¹⁴ Victor S. Rezendes, Director, Energy, Resources, and Science Issues, Resources, Community, and Economic Development Division, Government Accounting Office, Clearer Missions and Better Management

- In 1983, the White House Science Council Federal Laboratory Review Panel issued a report (commonly known as the Packard Report) about all federal research and development laboratories. It found that while DOE's laboratories had defined their **missions** for part of their work, most activities were fragmented and unrelated to the parent agency's policies.¹⁵
- In 1992, DOE's Secretary of Energy Advisory Board found that the broad laboratory **missions**, coupled with rapidly changing world events, had "... caused a loss of coherence and focus at the laboratories, thereby reducing their overall effectiveness in responding to their traditional **missions** as well as new national initiatives. . . .adding that DOE and its laboratories suffered the. . . .lack of a common vision as to the **missions**"16
- A 1993 report by an internal Energy Department task force on laboratories reported that their **missions** "must be updated to support DOE's new directions and to respond to new national imperatives"17
- The 1995 Galvin Task Force—the latest of these initiatives—called for a more "disciplined focus" for the national labs and also reported that the labs may be "oversized" for their **role**.¹⁸
- The Interagency Federal Laboratory Panel, chartered by presidential directive in 1994, has been examining all federal laboratories, including DOE's. The panel's March 1997 report noted that "none of the agency strategic plans, however, includes a clear and specific vision describing the **role** and nature of that agency's laboratory system—the 'end point' of reform—in sufficient detail to guide its evolution." In addition, the panel noted that "continuing micromanagement of the laboratories impedes progress, particularly at DOE. "

In most cases these studies were largely driven by the sentiments of corporate executives that tend to view federal laboratories similar to how they might view a corporate R&D laboratory. Consequently, most of these studies either emphasize that DOE's FFRDCs should stick to their mission or these FFRDCs are unaware of their mission assignment. First, Federal laboratories do not have missions; Federal agencies have missions that are designated by Congress.¹⁹ Second, FFRDCs, particularly those operated by DOE are contractors to agencies. Laboratory activities fluctuate according to the funding they receive from agencies. Furthermore, when a Federal laboratory is assigned an exclusive mission, it effectively operates as a monopoly. While there have been many studies, the recommendations of these studies are not particularly insightful about how to make the Federal laboratory system work better.

An interesting feature of the Federal laboratories is the number that are engaged in the big science areas of high energy physics research, pulsed power research or fusion research. Included are Brookhaven National Laboratory, Fermi National Accelerator Laboratory, Stanford Linear Accelerator Center, Princeton Plasma Physics Laboratory, and The Thomas Jefferson National Accelerator Facility (DOE lab in Virginia). In addition, many other laboratories,

Are Needed at the National Laboratories, testimony before, the Subcommittee on Oversight and Investigations, Committee on Commerce, House of Representatives, October 9, 1997.

¹⁵ Report of the White House Science Council, Federal Laboratory Review Panel, Office of Science and Technology Policy, May 15, 1983.

¹⁶ Secretary of Energy Advisory Board, Final Report, 1992.

¹⁷ Changes and Challenges at the Department of Energy Laboratories, Final Draft Report of the Missions of the Laboratories Priority Team, 1993.

¹⁸ Alternative Futures for the Department of Energy National Laboratories, Secretary of Energy Advisory Board, Task Force on Alternative Futures for the Department of Energy National Laboratories (Feb. 1995).

¹⁹ Charles B. Curtis, John P. McTague, and David W. Cheney, "Fixing the Federal Laboratory System", Issues in Science and Technology, Spring 1997, p. 50-51.

including Sandia, Oak Ridge, Los Alamos, Berkeley, and others have major programs in these areas. Lawrence Livermore National Laboratory is scheduled to build another big science facility, the \$1.2 billion National Ignition Facility (NIF), to help it understand how the reliability and safety of nuclear weapons secondaries are affected by aging.²⁰

E. Federal Labs Have Filled a Variety of Roles.

Federal labs have filled many R&D roles for the American public. In each case these roles were necessary to execute their derivative missions assigned by their parent Federal agencies. (In practice, agencies often prefer to have a particular laboratory focus in some specific area. In this case, the Federal laboratory may be said to have a derivative mission.) These roles include:

- ◆ Conduct R&D in traditional mission areas of government - generally areas where public needs are not being met in the marketplace, e.g., defense (DoD and DOE labs), disease research (NIH labs), energy (DOE labs), space (NASA labs), etc.
- ◆ Conduct Nationally or government appropriable R&D, e.g., nuclear weapons (DOE labs), intelligence R&D.
- ◆ Manage federal R&D programs, e.g., NIST, a DOC lab, manages the Advanced Technology Program and the Manufacturing Extension Project.
- ◆ Provide unbiased procurement advice to an agency, e.g., most DoD labs fill this role.
- ◆ Provide unbiased, third-party broker analyses for regulatory bodies, e.g., resolve technically-based regulatory issues for Nuclear Regulatory Commission (DOE labs).
- ◆ Assemble fast-response SWAT-like teams to quickly address National emergencies. (DOE's labs have provided this service for the Iowa battleship accident, acid spills in semiconductor manufacturing plants, oil well fires in Kuwait, the Three Mile Island nuclear event, etc.)
- ◆ Benchmark foreign technology. (A DOE lab has provided this service to SEMATECH and several laboratories provide this service for intelligence agencies.)
- ◆ Provide user facilities (generally large test or fabrication facilities whose costs are prohibitive for a single company or university) for universities, companies and other federal labs, e.g., practically every Federal lab operates one or more user facilities.
- ◆ Support industry-wide consortia. (DOC and DOE labs have conducted R&D for SEMATECH.)
- ◆ Conduct dual use R&D. (Practically every Federal laboratory has done this.)
- ◆ Develop technology infrastructure such as industrial measurement standards. (A DOC lab has done this for years.)
- ◆ Perform high-risk, long-term R&D that private capital shuns. (Many Federal labs would like to do this.)

IV. Increasing the Productivity of the Federal Laboratory System

A. General Recommendations.

²⁰Tom Zamora Collina, "The National Ignition Facility: Buyer Beware", Technology Review, Feb./March 1997, pp. 34-40.

The public perception of Federal laboratories seems to be that they have low productivity. In fact, neither we, the public, nor Federal laboratories have quantitative measures of how productive Federal laboratories are because Federal laboratories, like the rest of the Federal R&D community, have only offered project-specific anecdotes instead of measures of the **public return** from their work. In the short-term, it is easy to identify options that can contribute to improving the **public return** from Federal R&D conducted at Federal laboratories. In the long-term we advocate much more emphasis on developing R&D metrics. In addition to improving the actual **public return**, the public must be made aware of the services they are getting from Federal laboratories. The following identifies several areas that could lead to improved performance and increased public awareness:

- ◆ Develop a common set of metrics for **public return** from Federal R&D. Because of the lack of use of metrics, measures of the **public return** from Federal laboratory R&D have not been made. Therefore, there is no firm reference point by which labs can be gauged.
- ◆ Assess the performance of Federal laboratories by benchmarking them against industry laboratories that are thought to be among the highest R&D performers. For example, the National Research Council (NRC) has evaluated the performance of the Army's Natick Laboratory. The evaluation methods developed by the NRC could and should be applied to all Federal laboratories.
- ◆ Develop a governance system for Federal labs that makes them directly **accountable to the public**. Numerous studies including that of the Galvin Task Force have noted that onerous, hierarchically-structured governance by risk-averse Federal agencies over-responding to Congressional micromanagement have led to significant reductions in the efficiency of Federal laboratories.

The hierarchy was established to preserve a set of cherished capabilities: clear accountability, legitimate authority, established routines, division of labor, and specialization. In a world of unpredictable change, globalization, dynamic technologies, and educated employees and consumers, these capabilities will not work.²¹

- ◆ Federal laboratories must be encouraged to partner with universities, other Federal laboratories, and companies and to use these partnerships to improve the productivity of their R&D.
- ◆ Federal laboratories can increase their contact with the public by establishing a distributed system with program-specific laboratory satellites located in areas around the country most affected by the results of the particular program. Partnerships between the satellites and local universities and companies should be promoted.
- ◆ Expand the skill set of Federal laboratories beyond the physical sciences. We are moving into the information age where the relative importance of the physical sciences will be diminished. Most of the real problems faced by Americans have economic and social components that demand a broader skill set than **physicist-dominated** Federal laboratories have emphasized in the past.
- ◆ Federal laboratories must have a vision for their role in the 21st century that is not inhibited by their 20th century roles. **Federal laboratories, Federal agencies, and those that study Federal laboratories spend entirely too many resources reflecting on the past and implicitly postulating the future to be a linear extrapolation of the past. Congress spends entirely too much time worrying about "mission creep" of Federal laboratories when the real issue is how to address emerging public**

²¹ Dave Ulrich, "Organizing Around Capabilities", The Organization of the Future, The Drucker Foundation, edited by Frances Hesselbein, Marshall Goldsmith, and Richard Beckhard, 1997, p.190.

problems that are currently being ignored and identification of roles Federal laboratories might play in forging solutions.

- ◆ We must increase our understanding of how other countries have made use of their laboratories, identify ways that these countries have improved the productivity of their laboratory systems, and determine how they measure the *public return* from their laboratories.
- ◆ Federal laboratories must shift their focus from preoccupation with current capabilities, internal issues and competition between internal organizations for their share of the monopoly pie, to focus on public issues and development of a culture obsessed with serving the public.
- ◆ The quality of management within the U.S. Federal laboratory system must be improved to realize the full potential of these laboratories' technical staff for addressing 21st century problems. Numerous case studies of Federal laboratory R&D indicate that failed projects result far more often from deficiencies in the traditional management functions of vision, strategy, leadership, planning, etc., than from technical deficiencies. (A diagnosis of failed programs is discussed later in this report.)

B. Federal Laboratory Governance.

a. Agency Governance. Hammer has researched organizations for years to identify what makes them work. He concludes,

The twenty-first century organization is characterized by responsibility, autonomy, risk, and uncertainty. It may not be a gentle environment, but it is a very human one. Gone are the artificial rigidities and disciplines of the conventional corporation. In their place is a world full of the messiness, challenges, and disappointments that characterize the world of real human beings.²²

Analysis of the technological and economic explosion in Silicon Valley leads to the conclusion that this explosion has been driven by the existence of a deep talent base; an infrastructure, including venture capital, that supports entrepreneurs; and an entrepreneurial culture. The last of these is perhaps the most important. It is characterized by a can-do attitude, high tolerance for breaking the rules, risk-taking, and acceptance of failure as a learning experience.²³ Congress, the President, and other elected National officials often question why Federal laboratories haven't been a source of economic development equivalent to Silicon Valley. Why can't they fill a role similar to that of Taiwan's federal laboratory, Industrial Technology Research Institute, in Taiwan's industrial park in Hsinchu?²⁴ This park has 60,000 employees and over 200 companies. While many Federal laboratories have a deep talent base and many are located in areas that have an infrastructure that promotes economic growth, few have the cultural assets required to develop entrepreneurs. We believe that their risk-averse culture is a consequence of their agency-imposed governance system created partially in response to piece-meal, ad-hoc Congressional directives. These force the Federal laboratories and agencies to respond by hiring lots of lawyers and administrators to make sure that none of the rules are broken. This leads to tactical, strategy-averse, behavior by Federal laboratories. We do not believe that this serves public interests.

Congress and the President must face up to the fact that if they are unwilling to delegate responsibility to Federal laboratories; if they are unwilling to give Federal laboratories any autonomy; if they tolerate a risk avoidance culture or worse, encourage it by exercising

²² Michael Hammer, "The Soul of the New Organization", in The Organization of the Future, edited by Frances Hesselbein, Marshall Goldsmith, and Richard Beckhard, The Drucker Foundation, 1997, p.31.

²³ Business Week, "Silicon Valley: How It Really Works", August 25, 1997.

²⁴ John A. Mathews, "A Silicon Valley of the East: Creating Taiwan's Semiconductor Industry", California Management Review, Vol. 39, No. 4, Summer, 1997, pp. 26-54.

excessive control and pounding the nail that sticks up; and if they seek certainty of mission, work and budget, characteristic of a monopoly, they must take responsibility for building monopoly-like organizations that are irrelevant to the 21st century needs of the public.

Hesselbein notes,

Five hundred years ago, Renaissance man discovered that the world was round. Three hundred fifty years later, organization man developed the practice of management. But as this practice evolved, he forgot that the world was round, and he built a management world of squares and boxes and pyramids. His world had a special language that matched its structure: the language of command and control, of order and predict, of climb the ladder, of top and bottom, up and down. In every large organization for the next hundred years, rank equaled authority. ... And then a period of massive historic change began, of global competition and blurred boundaries, of old answers that did not fit the new realities. In all three sectors, in public, in private, and social organizations, a new cynicism grew about our basic institutions. ... some leaders in the private and voluntary sectors saw that the hierarchies of the past did not fit the present they were living or the future they envisioned, so they took people and functions out of the boxes; in doing so, they liberated the human spirit and transformed the organization.²⁵

We believe that it is time to take the Federal laboratories out of their little, ever-tightening boxes, liberate the spirit of their employees to address important emerging public problems and transform them to become passionate about and obsessed with serving the public. Those unable to make this transition should be privatized and encouraged to pursue the profit motive of private institutions. Either path - public service obsession or successful privatization - requires that the Federal laboratories be liberated from today's oppressive governance system.

Studies of the governance of selected Federal laboratories, especially the Galvin Task Force, have uncovered problems with today's system. We believe that there is little to be gained from tinkering with Federal laboratories until their governance is improved. Today's governance system:

- ◆ Encourages a stovepipe structure and isolation of R&D resources at different Federal laboratories from each other and from **the true customer, the public**. We advocate that Federal laboratories, and the National laboratories, in particular, have the freedom to work for many Federal agencies and that Federal laboratories seek opportunities to distribute their resources around the Nation.
- ◆ Promotes destructive competition between Federal laboratories, universities, and companies. We advocate partnering of these classes of institutions to address emerging **National needs** and we advocate increasing competition between Federal labs to sort out and eliminate those labs unable to address 21st century problems.
- ◆ Vests decision-making authority in large centralized agencies where science and technology knowledge is weak and motivation includes serving the political needs of the President and agency bureaucracy. We advocate that Federal laboratories have increased authority for decision-making and that Congress hold them accountable - with their survival at stake - for the decisions that they make. As Duques and Gaske point out,

For the big, market-dominant company (or any other organization), a large centralized staff is like Hamburger Helper - adding bulk but no content. ... neither

²⁵ Frances Hesselbein, "The Circular Organization", The Organization of the Future, The Drucker Foundation, edited by Frances Hesselbein, Marshall Goldsmith, and Richard Beckhard, 1997, p.81.

*size nor centralization of authority are predictors of sustained high ... performance.*²⁶

- ◆ Only permits R&D advocacy to Congress by universities and companies, institutions whose primary customer has often not been the public. We recommend that Congress make increased use of the resources of Federal laboratories in its development of National policy.
- ◆ Encourages agencies to become the customer for Federal R&D rather than the public. Thus, the focus by the Federal laboratories is often on R&D outputs rather than **public outcomes**. (In today's model, it is the responsibility of the agency to make sure that the output is converted to a public outcome.) We believe that the entire system of institutions that perform Federal R&D must become immersed in satisfying **public needs**, become obsessed with serving the public to the very best of their ability, and become focused on **public outcomes**, not R&D outputs.
- ◆ Permits Federal R&D performers to become a political arm of the President. We believe that Federal R&D performers must have at least partial isolation from short-term National political swings.
- ◆ Makes Federal labs captive to their agency owner; therefore, they are compelled to push agency missions rather than a **public agenda**, even after the utility of the agency mission has expired, and they rarely compete with Federal labs that belong to other agencies. We are disappointed that studies such as those of the Galvin Task Force and the National Academy of Sciences have encouraged monopoly behavior of Federal labs by advocating narrow, highly focused missions that exclusively belongs to a single Federal laboratory. While narrow focus is a desired feature of a corporate laboratory that is helping a company compete for monopoly control of a market niche, if Federal laboratories are to serve the public, they must have a holistic, multidisciplinary, big-picture focus and they must be required to compete with other Federal labs. Federal labs that operate in a monopoly environment are as inept as companies that operate as a monopoly.
- ◆ Constrains the competence of each Federal laboratory to be limited by agency competence, vision, and willingness to take risks. We advocate that laboratories' growth or shrinkage be entirely driven by measures of the **public outcomes** resulting from their work performed in a competitive environment. Those laboratories unable to compete should be permitted to die rather than being sustained on life-support systems. We advocate that competition between Federal labs, not a lab-closing commission, be the vehicle for identifying which labs are not useful for addressing 21st century problems.
- ◆ Promotes a mission-driven laboratory system that is not responsive to emerging new public problems until those problems become so severe that Congress creates an agency to address the issue. During an era where Congress wants to be rid of certain agencies and is unable to muster the political will to take action, it is reluctant to create a new agency for fear that it will have an infinite life. Thus, many very important National problems - crime, health care costs, optimization of regulations, cost and quality of education, shifting of wealth, aging population, etc. - are not being addressed. For example, the issue of healthcare costs has been on the table for 20 years without any action by the Federal government. We advocate that Federal laboratories have some responsibility to address emerging issues before they grow into severe problems. We believe that Washington has spent far too much time concerning itself with "mission creep" at Federal labs and, instead, should be more concerned about "problem-creep" - the emergence of public problems that are being ignored. We recommend that Congress determine an efficient and effective way, making use of the resources at Federal

²⁶ Ric Duques and Paul Gaske, "The Big Organization of the Future", in The Organization of the Future, edited by Frances Hesselbein, Marshall Goldsmith, and Richard Beckhard, The Drucker Foundation, 1997, p.38.

laboratories, to address new **public problems** without a new Federal agency having to be created.

- ◆ Inhibits creativity of labs, promotes narrow, non-systemic focus in labs, and discourages laboratories from developing strengths in the "soft sciences". The easiest part of many emerging National problems is the physical science component. Our vision is for Federal laboratories to grow into National resources that can partner with universities and companies to systematically address emerging National problems.

b. Privatization of Federal Laboratories. Several have called for privatization of the Federal laboratories. Congressman Klug on behalf of himself and other members of Congress introduced a bill calling for the establishment of a commission that would be tasked to make recommendations for the reconfiguration, corporatization, privatization, and consolidation of Department of Energy National Laboratories. This commission would deploy the following selection criteria in making these recommendations²⁷:

- ◆ Give strong consideration to the recommendations for reorganization and corporatization expressed in the Galvin Report;
- ◆ Eliminate duplication of effort by energy laboratories and reduce overhead costs as a proportion of program benefits distributed through an energy laboratory;
- ◆ Define appropriate missions for each energy laboratory, and ensure that the activities of each such laboratory are focused on its mission or missions;
- ◆ Seek to achieve cost savings for the overall budget for such laboratories;
- ◆ Consider the program costs and program distributions on a State and county basis, including real and personal property costs associated with each energy laboratory considered;
- ◆ Consider the number of participants in programs conducted through an energy laboratory and staff resources involved;
- ◆ Estimate the cost savings and increased costs that would accrue through the reconfiguration of corporatization, privatization, or consolidation of energy laboratories;
- ◆ Consider the potential of each energy laboratory to generate revenues or to offset costs;
- ◆ Consider the transfer of energy laboratories to other federal agencies;
- ◆ Consider the privatization of the energy laboratories as an alternative to closure or reconfiguration.

But why should the commission be restricted to only considering privatization of the DOE laboratories? If privatization is desirable, why not consider it as an option for all Federal laboratories?

There are several reasons that privatization might be pursued. First, some of the Federal laboratories may no longer meet the criteria for intramural research that we described previously. In this case they should either be offered an opportunity to compete for legitimate intramural research or be privatized. Second, the efficiency of some Federal laboratories might be increased by privatizing some of their non-critical support functions, e.g., security or plant maintenance. Third, any federal laboratory that is unable for whatever reason - agency governance, management philosophy of operating institution, etc. - to treat the public as their

²⁷ National Energy Laboratories Reorganization Commission, H.R. 1295, introduced in the U.S. House of Representatives, April 10, 1997.

customer should be privatized. However, as the Galvin task force concluded, few Federal laboratories are ready for privatization. We recommend that privatization be pursued in those steps illustrated in Figure 1.

Figure 1: Transition from a GOGO Laboratory to a fully privatized laboratory with three intermediate steps. In each of the above steps, the Federal laboratory is moved closer to the free market until it is finally ready for independent stature as an independent private laboratory. The overall privatization process from GOGO to privatized laboratory would probably take one decade or more. During the early stages of the privatization process, support functions of the laboratory could be spun off as privatized entities.

V. Converting Federal Agencies and Their Laboratories Into Learning Organizations

A. Introduction.

Garvin defined a learning organization as an organization skilled at creating, acquiring and transferring knowledge, and willing and capable of modifying its behavior to reflect new knowledge and insights.²⁸ Federal agencies and their laboratories do not generally satisfy these criteria. Others define learning organizations in terms of how their managers behave. For example, in learning organizations managers put aside their old ways of thinking, learn to be open with others, understand how their organizations really work, form a plan or vision everyone can agree on, and then work together to achieve that vision. (Low conformance to the requirements of the Government Performance and Results Act suggests that Federal agencies and their laboratories do not generally satisfy these criteria either.) In learning organizations, tension and conflict are present, systems thinking is everywhere, and there exists an open, risk-taking culture which facilitates learning.²⁹ (While Federal agencies and their laboratories have tension and conflict, they generally do not meet these criteria either.)

In today's turbulent times, learning is everything. Because of their pressure to change with

²⁸ D. A. Garvin, "Building a Learning Organization," *Harvard Business Review*, 71 (4), pp. 78-91.

²⁹ Fred Luthans, Michael J. Rubach, and Paul Marsnik, "Going Beyond Total Quality: The Characteristics, Techniques, and Measures of Learning Organizations," *The International Journal of Organizational Analysis*, Vol. 3, No. 1, January, 1995, pp. 24-44.

the times in order to survive, there are many lessons about learning evolving from the private sector that can be transferred to government. Hamel and Prahalad have made the following observations about companies that are particularly applicable to government.

Companies seldom miss the future because the future is unknowable, they miss the future because experience blinds them to new opportunities. Those that are most blind typically have the most power. Shouldn't authority be as much a function of foresight as of hindsight? In a world of discontinuous change, shouldn't authority rest not only on experience, but also on the capacity to learn and adapt?

As industry boundaries meld, industry specialization may be a handicap. Might the capacity to think across industry boundaries - to spot opportunities at the juncture of two or more industries; to draw relevant analogies from seemingly unrelated industries - be as valuable as deep experience on a single sector?³⁰

Senge's proposal that there are two styles of learning - adaptive learning and generative learning - is widely accepted. Adaptive learning is responding to mistakes in a classical way and taking corrective action to cope with the mistakes so that the status quo isn't disturbed. This can also be thought of as tactical learning. Most institutions, including Federal laboratories, do this reasonably well. Generative learning is a creative form of learning that results from entirely new mental models or new ways of looking at events. Generative learning anticipates and avoids mistakes and results in expanded capabilities by challenging predispositions. Generative learning tends to be strategic while adaptive learning tends to be tactical.³¹ Federal agencies and their laboratories excel at adaptive learning; they have yet to master generative learning.

B. Leadership for Learning.

Institutions are learning organizations if, and only if, they are well-led. While organizations find it easy to identify administrators and managers, leaders are difficult to find.

The dearth of leadership is apparent throughout society. No matter where we turn, we see a severe lack of faith in the leadership of our schools, religious organizations, and governments. To paraphrase a 1990 Business Week article, if Martians descended someplace in the United States and demanded that we take them to our leaders, we would have to think twice about where to take them.³²

The leadership scholar, Joseph Rost, defines leadership as,

Leadership is an influence relationship among leaders and followers who intend real changes that reflect their mutual purposes. ... First, the leadership relationship is multidirectional. ... This means that anyone can be a leader and/or follower; followers may persuade leaders and other followers as do leaders; leaders and followers may change places; and there are many different relationships that can make up the overall relationship that is leadership. ... Second, leadership as an influence relationship means that the behaviors used to persuade other people must be noncoercive. If the behaviors are coercive, the relationship becomes one of authority or power or one that is dictatorial. ... Most important, followers do not do followership, they do leadership. Both leaders and followers form one relationship that is leadership. There is no such thing as followership in the new school of leadership.³³

³⁰ Gary Hamel and C. K. Prahalad, "Competing in the New Economy: Managing Out of Bounds", Strategic Management Journal, Vol. 17, 237-242, 1996.

³¹ Peter M. Senge, The Fifth Discipline: The Art and Practice of the Learning Organization, Doubleday, 1990.

³² James F. Bolt, "Developing Three-Dimensional Leaders", in The Leader of the Future, edited by Frances Hesselbein, Marshall Goldsmith, and Richard Beckhard, The Drucker Foundation, 1996, p.163.

³³ Joseph C. Rost, Leadership for the Twenty-First Century, Praeger, 1993.

As Bertholf points out,

*Leadership is not just finding a parade and getting in front of it.*³⁴

Peter Senge, one of the world's leading experts on learning organizations, emphasizes that leaders in an organization are found at all levels in the organizational hierarchy. They don't just have to be those at the top of the hierarchy. However, perhaps the greatest casualty of a bureaucracy is its inability to permit leadership to emerge from the middle and lower ranks of the hierarchy.

We are coming to believe that leaders are those people who walk ahead, people who are genuinely committed to deep change in themselves and in their organizations. They lead through developing new skills, capabilities, and understandings. And they come from many places within an organization. ... Part of the problem in appreciating effective leadership in learning is that all of us are so used to the captain of the ship image of traditional hierarchical leaders. We are used to thinking of top managers as the key decision makers, the most visible and powerful people in the organization. Although undoubtedly some key decisions will always have to be made at the top, cultures are not changed through singular decisions, and decision-making power does not produce new learning capabilities. When executives lead as teachers, stewards, and designers, they fill roles that are much more subtle, contextual, and long term than the traditional model of the power-wielding hierarchical leader suggests.

Senge identifies three types of leaders essential to building learning organizations. Each type roughly corresponds to three different organizational positions:

- ◆ Local line leaders, individuals with significant business responsibility and bottom-line focus, who can undertake meaningful organizational experiments to test whether new learning capabilities lead to improved business results.
- ◆ Executive leaders, who provide guiding ideas, support line leaders, develop learning infrastructures, and lead by example in the gradual process of evolving the norms and behaviors of a learning cultures.
- ◆ Internal networkers, or community builders, the seed carriers of the new culture, who can move freely about the organization to find those who are predisposed to bringing about change, help out in organizational experiments, and aid in the diffusion of new learning.³⁵

KPMG has determined that their senior leaders must exhibit seven leadership attributes:

- ◆ Values: Establish and champion values.
- ◆ Vision: Have the capacity to discover vision.
- ◆ Perspective: Provide high-impact messaging.
- ◆ Strategy: Think and act strategically.
- ◆ Knowledge: Expand the knowledge base.

³⁴ Larry Bertholf, personal communication to James Gover.

³⁵ Peter M. Senge, "Leading Learning Organizations: The Bold, the Powerful, and the Invisible", in The Leader of the Future, edited by Frances Hesselbein, Marshall Goldsmith, and Richard Beckhard, The Drucker Foundation, 1996, p.163.

- ◆ People: Be a resource architect.
- ◆ Self: Know who you are.³⁶

Stephen Covey has a model that breaks the work of leaders into three major functions or activities:

- ◆ Pathfinding: The essence and power of pathfinding are found in a compelling vision and mission. It ties together your value system and vision with the needs of customers.
- ◆ Aligning: This consists of ensuring that your organizational structure, systems, and operational processes all contribute to achieving your mission and vision of meeting the needs of customers and other stakeholders.
- ◆ Empowering: A fire is ignited within people that unleashes their latent talent, ingenuity, and creativity to do whatever is necessary and consistent with the principles agreed upon to accomplish their common values, vision, and mission in serving customers and other stakeholders.

*These roles of modeling principle centered leadership - pathfinding, aligning, and empowering - represent a paradigm that is different from traditional management thinking. Leadership focuses on doing the right things; management focuses on doing things right. ... Most managers and executives operate within existing paradigms or ways of thinking, but leaders have the courage to bring those paradigms to the surface, identify the underlying assumptions and motivations, and challenge them ...*³⁷

C. Learning From Mistakes.

a. Brookings Institution Analyses. Most learning organization scholars emphasize that mistakes invariably offer more opportunities for learning than do successes. There is a growing awareness that many past U.S. government R&D programs have failed. For example, Cohen and Noll have examined retrospective cost-benefit analyses of the supersonic transport program, NASA's communications satellite program, the breeder reactor program, the photovoltaics program, the space shuttle program, and the synthetic fuels program. (The ability of public policy scholars to retrospectively analyze agency programs is handicapped by lack of publicly available agency data and a reluctance of bureaucrats to share data with a scholar that might be critical. Remarkably, most scholars are forced to invoke the freedom of information act in order to gain access to information.³⁸) Cohen and Noll concluded that only NASA's communications satellites program can be regarded as having been worth the effort. They explain that the photovoltaics program made significant progress, but was scaled back for political reasons. They concluded that the remaining four programs were unqualified failures.³⁹ Lessons learned from these programs include:

- ◆ Not a single program failure was attributed to technical deficiencies in the funding agency or the performing institution. In fact, agencies with responsibilities for fundamental R&D may be prone to pursue projects, in part, for their technical challenge, rather than their potential to produce **public outcomes**.

³⁶ James G. Brocksmith, Jr., "Passing the Baton: Preparing Tomorrow's Leaders", in The Organization of the Future, edited by Frances Hesselbein, Marshall Goldsmith, and Richard Beckhard, The Drucker Foundation, 1997, p.254-255.

³⁷ Steven R. Covey, "Three Roles of the Leader in the New Paradigm", in The Leader of the Future, edited by Frances Hesselbein, Marshall Goldsmith, and Richard Beckhard, The Drucker Foundation, 1996, p.152-153.

³⁸ Personal communication, Professor Linda Cohen, University of California, Irvine, and James Gover.

³⁹ Linda R. Cohen and Roger G. Noll, "An Assessment of R&D Commercialization Programs", in The Technology Pork Barrel, The Brookings Institution, 1991.

- Programs should only be started in technologies in which market failures in private R&D decisions are most pronounced.
- ◆ It should be determined prior to program funding that Federal R&D provides a higher ratio of **public return** to public cost than regulatory options, e.g., favorable tax treatment of private R&D.
- ◆ Relatively inexpensive exploratory work should investigate alternative technological pathways with major programs supported only when they are the preferred alternative and there is evidence they can be linked to **public outcomes**.
- Technological optimism by advocates in the executive branch and impatience among political officials lead to hasty decision making and program inflexibility.
- ◆ The fragility of the political coalitions that typically form around R&D commercialization programs lead to budgetary booms and busts.
- The time required to complete a program must be compatible with the lifetime of the salient national political issue on which the program is grounded.
- ◆ New societal problems are likely to not fit well into the organizational structure of the executive branch and Congress. This can lead to ongoing bureaucratic turf wars and lack of an institutional basis for long-term program support.
- Because the political payoff from R&D is distant and uncertain, members of Congress are likely to emphasize short-term benefits to their constituents.

b. Very High Speed Integrated Circuit Program. Scholarly assessments of the Very High Speed Integrated Circuit (VHSIC) program are skeptical of its value. VHSIC was created because advanced integrated circuits that were revolutionizing consumer electronics and telecommunications were not making their way into military systems. Rather than deal with this issue through procurement reform to adapt commercial integrated circuits to military use, military systems contractors with relatively little commercial business were funded to develop very high speed integrated circuits. Ten years and one billion dollars later very few VHSIC funded integrated circuits had made their way into military systems.⁴⁰ Furthermore, several studies have concluded that the VHSIC Program contributed little to the civilian sector.⁴¹ The principal lesson to be learned from VHSIC is that \$1 billion programs must be preceded by thorough strategic analysis and planning. Those tacit assumptions that underlie programs like VHSIC must be made visible and openly debated prior to spending great sums of the taxpayer's resources.

c. Big Science Programs. Additionally, there is concern that Federally funded projects, "big science" projects^{42,43} in particular, are too easily influenced by "pork-barrel" politics. Note that in the past "big science" projects have made up much of the Federal R&D budget. For example, the President's budget that was proposed for 1993 included \$350M for the magnetic fusion reactor, \$640M for the super collider, \$500M for synthetic fuel from coal, \$250M for the National Aerospace Plane, \$2.25B for the space station, and \$400M for the Earth

⁴⁰ John A. Alic, Lewis M. Branscomb, Harvey Brooks, Ashton B. Carter, and Gerald L. Epstein, Beyond Spinoff, Harvard Business School Press, 1992, p. 268.

⁴¹ Alok K. Chakrabarti and C. Lenard Anyanwu, "Defense R&D, Technology, and Economic Performance: A Longitudinal Analysis of the U.S. Experience", IEEE Transactions on Engineering Management, Vol. 40, No. 2, May 1993, p. 136.

⁴² G. Pascal Zachary, "Where Did Big Science Take Us?", UPSIDE, April, 1992.

⁴³ G. Pascal Zachary, "Time for the Big Science Spectacle to Fold Its Tent", UPSIDE, May, 1992.

Observation Satellite System.⁴⁴ Because these projects are so large and their closure would have so much economic impact, it is argued that "big science" projects are almost impossible to wind down even when their lack of utility is widely recognized. Again, we advocate that "big science" programs be preceded with considerable strategic analysis with more attention given to international collaboration and cost sharing.

The Government Accounting Office has recently examined "big science" projects at the Department of Energy. GAO reported to Congress⁴⁵,

DOE's success with managing big projects is not outstanding. From 1980 through 1996, DOE conducted 80 projects that it designated as "major system acquisitions" (MSAs), which are its largest and most critical projects, ranging in cost from \$100 million to billions of dollars. Many of these projects were managed directly by the laboratories. As of June 1996, 31 of the projects had been terminated prior to completion after total expenditures of over \$10 billion. Only 15 of the projects were completed, and most of them were finished behind schedule and with cost overruns. Furthermore, 3 of the 15 completed projects have yet to be used for their intended purposes. The remaining 34 projects continue, many with substantial overruns and "schedule slippage."

We believe there are four key factors underlying the cost overruns, schedule slippage, and terminations of DOE's largest projects:

- *DOE's constantly changing missions often make it difficult to maintain departmental and congressional support for these long-term, high-cost projects.*
- *The MSAs' incremental, annual funding subjects them to potential delays or terminations in each year.*
- *A flawed system of incentives does not always reward individuals and organizations for "doing the right thing" and has often rewarded contractors despite poor performance.*
- *DOE has difficulty in hiring, training, and retaining enough people with the requisite skills to provide effective oversight and/or management of contractors' operations.*

D. Learning From Successful Programs.

The reader is reminded that the public's investment in national defense has made the U.S. the world's only superpower. While in some instances the particular programs supporting national defense may not have resulted in the desired **public outcomes**, in an overall sense, the defense investment has produced the **public outcome** desired by the public.

In addition to satisfying public needs, researchers have identified numerous government funded programs that have also been commercial successes. For example, much of the early commercial success of Silicon Valley is attributed to Federal defense funding microwave electronics and aerospace.⁴⁶ Without question, U.S. agriculture policies of the 1930s to 1960s contributed to extraordinary productivity growth in that sector. SEMATECH, an effort jointly funded by DARPA and the private sector, has assisted in strengthening the U.S. semiconductor manufacturing equipment industry.⁴⁷ The U.S. satellite communications

⁴⁴Linda R. Cohen and Roger G. Noll, "Research and Development", in Setting Domestic Priorities: What Can Government Do?, edited by Henry Aaron and Charles Schultze, The Brookings Institution, 1992.

⁴⁵Victor S. Rezendes, Director, Energy, Resources, and Science Issues, Resources, Community, and Economic Development Division, Government Accounting Office, Clearer Missions and Better Management Are Needed at the National Laboratories, testimony before, the Subcommittee on Oversight and Investigations, Committee on Commerce, House of Representatives, October 9, 1997.

⁴⁶Stuart W. Leslie, "How the West Was Won: The Military and the Making of Silicon Valley," in Technological Competitiveness, edited by William Aspray, IEEE Press, 1993, p.75.

⁴⁷James E. Gover, "Analysis of U.S. Semiconductor Collaboration", IEEE Transactions on Engineering

industry, a \$4B annual industry; the global positioning system, a \$1B annual business; and Geographic Information Systems, a \$5B per year industry have all benefited from early DoD and NASA R&D investment in satellite communications.⁴⁸ And the role of the government in creating the Internet is exemplary.

The processes whereby technology is transferred from government laboratories to private companies in both the U.S. and Japan is a subject of continuing research.⁴⁹ While some newspapers have searched for failures, anecdotal evidence suggest that these efforts have been largely successful. Several examples of government funding at the Sandia National Laboratories (SNL) serve to illustrate this. For example, the \$1B per year market for vertical, laminar flow clean rooms and the \$100M per year market for diamond-tipped drill bits are a spin-off of R&D performed by Sandia. Independent research on the sum of public and private costs and private benefits of Sandia's plasma spray technology program and polycrystalline diamond drill bit technology program indicate that drill bit technology public cost-**public benefit** ratio was 1:125 and the plasma spray technology cost-benefit ratio was 1:190.⁵⁰ Sandia National Laboratories New Ventures Program facilitated the creation of 20 new commercial ventures in its first 9 months of operation.⁵¹ One example of a successful company emerging from federal laboratory technology transfer is Quartex Corporation which has used double-ended tuning fork quartz resonator force sensor technology developed at Sandia as the basis for commercialization of numerous products.⁵² Sandia has 8 times as many requests from companies for technology transfer as its budget can accommodate and Sandia's industrial partners' investment in the technology transfer process is two times that of the DOE.⁵³ Anecdotal evidence indicates a high ROI from Sandia technology transfer but no systematic measures are available to compare these results to other Federal laboratory successes. We assume that other Federal laboratories have similar success stories.

Researchers at the Haas School of Business, University of California, Berkeley, have conducted detailed case studies of five projects between firms and the Lawrence Livermore National Laboratory. The primary lesson learned from their research is that the "treasure chest model" of DOE laboratories' technology assets and the process through which these assets can assist U.S. industry is an inaccurate characterization and has led to excessive agency control of intellectual property rights, budgetary and managerial inflexibility, and caused prolonged lapses in communication between laboratory and firm personnel. Ham and Mowery explain,

DOE and its congressional overseers must recognize that extended collaboration between laboratories and private firms will be needed to modify and apply most laboratory-developed technologies. This collaboration is fraught with uncertainty. It requires intensive interaction and communication, and ideally should extend through

Management, Vol. 40, No. 2, May, 1993, pp. 104-113.

⁴⁸Randy Barrett, "Down-To-Earth Billions", Technology Transfer Business, Fall 1993, p. 13.

⁴⁹ Manabu Eto, Everett M. Rogers, Danielle Wierengo, Patrick Byrnes, and Marcel Allbritton, Technology Transfer From Government R&D Laboratories in the United States and in Japan: Focus on New Mexico, Department of Communication and Journalism, University of New Mexico, Albuquerque, New Mexico, May, 1995.

⁵⁰ Santa Falcone, Technology Transfer Impact Profiles, Interim Report #1, University of New Mexico School of Public Administration, November, 1995.

⁵¹ Leland B. Traylor, "Building Business from Technology: The Sandia Experience", presented at the Department of Energy New Business Start-Ups Conference, July 29, 1995, Albuquerque, NM, by Warren Siemens.

⁵² O. Lew Wood and Errol P. EerNisse, "Technology Transfer to the Private Sector from a Federal Laboratory", IEEE Engineering Management Review, Spring 1992, p.p. 23-28.

⁵³ Warren Siemens, Sandia National Laboratories, personal communication.

*the initial stages of large-scale manufacture of products incorporating the technology.*⁵⁴

There is much anecdotal evidence that many government R&D programs have produced valuable returns to the U.S. public. For example, there is little doubt about the economic utility of the Internet. The uncertainty is the overall value of the returns relative to the taxpayer's investment. For example, Chakrabarti and Anyanwu have concluded from their analyses of the U.S. defense R&D investment between 1955 and 1988 that despite specific successes in aerospace, there was no statistically visible evidence of overall effect from defense R&D on the economy. They did find, however, that there were indirect benefits in that defense R&D spending has promoted technological change.⁵⁵

It is clear that evaluation of past Federal R&D programs suffers from a lack of emphasis given to measuring *public return* or identifying the parameters that have high probabilities of providing that *public return*. This is an R&D management problem, not an R&D performance problem.

E. Learning From City Government.

For many years America's cities funded bloated, centralized, wasteful, rule- and regulation-driven, hierarchical bureaucracies; plush union contracts for those providing city services; speculative and overly optimistic social programs; and generally spent too much of their resources attempting to do things that cities are not competent to do. Starting in the 1980s, the federal government stopped sending the cities money to cover the cost of new mandates. By 1982 states and local governments lost almost \$1 out of every \$4 the federal government had been returning. But the mandates continued. These include mandates such as clean air regulations, welfare, and health care. In response, local taxes in many areas have risen. Between 1986 and 1991 local taxes increased 8.1% in comparison to 6.3% for state taxes and 6.1% for federal taxes.⁵⁶ In addition, cities bear much of the economic and social burden for the disappearance of meaningful low-skill jobs.

Coincidentally, electorates decided that they would bear no additional tax burden and made that known to city officials. In response to these extraordinary pressures, cities such as Philadelphia, Cleveland, Chicago, and many smaller cities have followed the lead of corporations responding to competitive pressures and have begun to reinvent their governments. Freezing or even reducing taxes, changing the work rules of unions, privatizing city services, forcing competition between public and private service providers, and generally leading their electorate to shift from a philosophy of entitlement to a philosophy of empowerment are recurring themes among those cities that are *reinventing their governments*.⁵⁷

Indianapolis requires public employees to compete against privately owned businesses to provide all city services except for police, fire, and zoning operations. Since 1992 this growing city has reduced the cost of city government by 25%, cut the city work force by one-third, and saved \$240 million in city taxes.⁵⁸ Rather than privatizing services, Somerset, Kentucky, attained efficiency by city ownership and operation of natural gas and other services. The underlying theme of successful city governments is competition versus monopoly rather than private versus public ownership. That is, publicly-owned and

⁵⁴ Rose Marie Ham and David C. Mowery, "Improving Industry-Government Cooperative R&D", Issues in Science and Technology, Summer 1995, p.p. 67-73.

⁵⁵ Alok K. Chakrabarti and C. Lenard Anyanwu, "Defense R&D, Technology, and Economic Performance: A Longitudinal Analysis of the U.S. Experience", IEEE Transactions on Engineering Management, Vol. 40, No. 2, May, 1993, pp. 136-143.

⁵⁶ Fortune, "Taxes Grow More Local", October 4, 1993, p. 24.

⁵⁷ Newsweek, "Cities, Heal Thyselves", July 5, 1993, p. 24.

⁵⁸ The Washington Post National Weekly Edition, "Indianapolis May Have Found a Way to Turn Lead Into Gold", September 29, 1997, p. 29.

operated entities that must compete to survive are more efficient than privately-owned entities that are permitted to operate as a monopoly. Note, however, the shift from a monopoly culture to a free market culture is not trivial. AT&T serves as an excellent example.

In their pioneering work studying the reinvention of government, Osborne and Gaebler identify numerous examples of cities improving government. They note that instead of being market oriented and using the market to leverage change, governments have traditionally preferred to establish programs, including R&D programs, and to use command and control tactics in the regulatory arena. The weaknesses of these responses are: they are driven by constituencies and politics, not customers and policy; they create turf which bureaucratic agencies defend at all cost; they create fragmented service delivery systems; they are not self-correcting; they rarely die; they rarely achieve the scale necessary to make a significant impact; and they use commands, not incentives.⁵⁹

Osborne and Gaebler advocate ten principles of entrepreneurial governance:

- ◆ **Catalytic** - The appropriate role of government is to serve as a catalyst for action, to steer rather than row. Top level government officials must concentrate on providing direction and leadership and empower their subordinates to concentrate on the operation of services.
- ◆ **Community-Owned** - To achieve the most effective government, the community must be empowered to assert ownership and control of government.
- ◆ **Competitive** - To be efficient, achieve quality, be responsive to customer needs, stimulate innovation, and develop pride and morale among public employees, competition (either public or private competitors) must be injected into all government services.
- ◆ **Mission-Driven** - Government organizations that turn their employees loose to pursue the organizations' missions are more efficient, effective, innovative, flexible, and have higher morale than government organizations that are driven by conformance to rules.
- ◆ **Results-Oriented** - Government must be results oriented and focused on *funding outcomes*, not funding inputs to services providers. To achieve a results-oriented government, great emphasis must be placed on measuring the quality, quantity, and cost of every service offered by government and the best governments must be benchmarked for self comparison.
- ◆ **Customer-Driven** - Government must be customer-driven; that is, it must be focused on meeting the needs of the public, not its bureaucracy.
- ◆ **Enterprising** - Government must be enterprising and devote its attention to earning revenues rather than taxing and spending revenues⁶⁰.
- ◆ **Anticipatory** - Governments must focus on anticipating problems and instituting preventive measures rather than curing problems after they occur.
- ◆ **Decentralized** - Government must be decentralized and move from hierarchy to participation and teamwork of government organizations, their management, their employees, and the electorate.
- ◆ **Market-Oriented** - Government must be market-oriented and leverage change through the market rather than through programs or command and control strategies.

⁵⁹ David Osborne and Ted Gaebler, Reinventing Government, Addison-Wesley, 1992, pp. 286-289.

⁶⁰ Somerset, Kentucky, earns over 90 percent of its budget from the sale of services it provides to the public and private sectors.

Implementation of these principles has allowed numerous local and state governments to create a new paradigm of operation and service delivery. These come into play when public organizations are confronted by crisis, generally a financial crises, and the participants - officials and constituents alike - need to overcome the crisis with leadership resources, and a common trust and vision. It may require a crisis to determine if trust, vision, resources, and leadership are to be found within the community of the publicly-funded scientific research and development community.

While many read the cover leaf of Osborne's book and thought it to be a treatise on the miracles of privatization, that interpretation is incorrect. The underlying theme is breaking up monopolies, either public or private, and introducing competition into all areas of government services. Competition sorts out and removes institutions that are stuck in command and control bureaucracies.

F. Learning From Corporate Competition.

Lessons can be learned from private companies that have restructured to better serve their customers. The behavioral changes that must occur in Federal agencies in order for them to effectively lead Federal programs that address major public problems, promote national economic development, create well-paid jobs, and avoid distorting domestic competition among companies may be addressed by examining the principles of competitive institutions. The intense pressure placed on private institutions has led them to constantly search for new ways to increase their effectiveness. There is much for government agencies to learn from this rapid evolution in corporate behavior. Secretary of Defense Cohen has explained this perspective,

Over the past decade, the American commercial sector has reorganized, restructured, and adopted revolutionary new business and management practices in order to assure its competitive edge in the rapidly changing global marketplace. Now the Department (of Defense) must adopt and adapt the lessons of the private marketplace so our armed forces can maintain their competitive edge in the rapidly changing global security market.⁶¹

Kanter has reviewed studies of competitiveness and concluded that there are four areas in which companies should concentrate to strengthen their competitiveness.⁶² These are strengthening core competencies, compressing time, making continuous improvements, and strengthening relationships.

In Tables III, IV, V, and VI government-sponsored mission R&D and basic research program practices are compared to those practices needed to promote the principles of competitiveness in U.S. companies that are marketing commercial products.

⁶¹ Simon Patrick Carr, "Secretary Cohen Establishes Task Force on Defense Reform", News release, Electronic Industries Association, May 20, 1997.

⁶² Rosabeth Moss Kanter, "How to Compete", Harvard Business Review, July-August, 1990, p. 7.

Table III: Recommended Government Behavior in Strengthening Core Competencies as an Analog to the Practices of Competitive Companies.

ISSUE	COMPETITIVE COMPANY	GOVERNMENT ANALOG
Who Identifies Core Competencies That Are Needed?	Selects core competencies based on perception of what will advantage the company in the marketplace by differentiating them from their competitors.	Federal agencies and R&D performers develop core competencies based on their perception of public needs not being met in the marketplace.
Where Is Emphasis?	Products that consumers will buy.	Technology and knowledge needed by the public that is not supplied by the market.
What is the Emphasis?	<p>Build core competencies through collection, interpretation, and diffusion of knowledge that is created around the world.</p> <p>Choose core competencies that are difficult for others to imitate.</p> <p>Build on strengths and correct weaknesses.</p> <p>Emphasize learning from others.</p> <p>Analyze the marketplace and competitors.</p>	<p>Emphasize the public utility of innovation, not just its originality or creating knowledge for its own sake. Invest in the collection, interpretation, and diffusion of knowledge that is created around the world.</p> <p>Fund R&D that is nationally appropriable.</p> <p>Make maximum use of the R&D skills of Federal labs and universities that have been developed through Federal R&D investments. Make Federal labs and publicly-funded universities accountable to the public.</p> <p>Study policies of other nations to identify those that have worked.</p> <p>Research unmet public needs and look for innovative ways that technology can help meet those needs.</p>
R&D Funding Priorities.	Market need (profit potential, market share potential, and sales potential), and the ability to compete in market.	<p>Emphasize public needs rather than R&D performer's needs or interests.</p> <p>Use economic and other measures of importance to the public and weigh investment against their chance for success and public impact.</p>
Program Metrics.	<p>Economic Metrics:</p> <p>Market Share Growth</p> <p>Increased Sales</p> <p>Increased Profits</p>	Measure public return: e.g., jobs created, quality of life, etc., rather than number of breakthroughs, publications, awards, and patents.

Table IV: Recommended Government Behavior in Strengthening Relationships as an Analog to the Practices of Competitive Companies.

ISSUE	COMPETITIVE COMPANY	GOVERNMENT ANALOG
Whose Interests Relationships Serve	Win-win relationships are established to serve the needs of all the companies that are party to the relationships.	Relationships are established to serve the needs of the American public, not the bureaucracy.
Internal Relationships	Stimulate intracorporate relationships by developing programs that reward boundary-less behavior and eliminate the need for bureaucracies.	<p>Government should encourage organizations within a company that supply government to be integrated with that companies' organizations that supply the commercial sector.</p> <p>Boundaryless behavior should be rewarded and the need for bureaucratic behavior eliminated in Federal agencies. Formal programs are required to do this.</p>
Vertical Relationships	Supportive, trusting relationships that empower suppliers to exceed company requirements.	Supportive and empowering relationships rather than adversarial and controlling relationships must be extended to those that supply government. Much of government's obsession with rules and control is designed to avoid the appearance of impropriety. It must learn to treat suppliers of technology as partners, not adversaries.
Horizontal Relationships	Establish R&D joint partnerships and industry-wide consortia where the partnerships benefits all corporate members and do not constitute anti-trust or inhibit competition.	<p>Promote cooperative relationships between government labs, universities and companies that advantage the US public.</p> <p>Remove the barriers to government labs working for multiple agencies.</p> <p>Promote joint strategic planning among agencies with similar technology needs to avoid redundant R&D activities.</p>

Table V: Recommended Government Behavior in Compressing Time as an Analog to the Practices of Competitive Companies.

ISSUE	COMPETITIVE COMPANY	GOVERNMENT ANALOG
Program Start-Up	Start programs at funding levels necessary to be competitive in international competition.	Rather than start small with low visibility and slowly build-up programs as a political consensus is being established, programs should be ramped-up according to public need.
Program Shut-Down	When a program has accomplished its goals or will not reach its goals in a way timely with market conditions, it is shut down.	Stop programs that aren't cost-effectively meeting public needs.
Establishing System Reliability	Reliability is a product of robust design.	Avoid time-consuming testing, testing, and more testing to shun the political risks of field failures, and learn to accomplish reliability through design.
Organization of R&D Institutions	Concurrent engineering principles are implemented to simultaneously do work in teams.	Discard the linear model of R&D and apply the chain-link and concurrent engineering models.
Priority of Timing	The demands of competition rarely accommodate time delays.	To achieve efficient R&D, the timing of technology development must have higher priority.
Rules and Regulations	The output and impact of programs are the focus. Flat organizations with empowered workers.	Preoccupation with low risk and making sure that all rules are followed must be discarded in favor of a preoccupation with public outcome. Hierarchical organizations with authority at the top slows decision-making and must be discarded in favor of flatter organizations.
Basic Research Timing	Formal processes are employed to reduce the time delay between discovery and industrial commercialization. Technology roadmaps are used to align the timing of basic research with the timing of public needs.	Connect basic research performers to U.S. industry to avoid first commercialization of U.S. research by foreign firms. Deploy basic research roadmaps that result in public return.
Time Compression by Empowerment	Emphasis on outcome, empowering suppliers and employees to perform, and holding them accountable when they do not.	Avoid emphasis on control through rules, orders, regulations, and paperwork that delay accomplishment of outcomes and make public outcome the focus of R&D.

It is reasonable to expect that continuous improvements, a Total Quality Management (TQM) concept invented in the U.S., implemented by Japan during the U.S. occupation, and promoted in U.S. industry by the U.S. Department of Commerce through the Malcolm Baldrige Award would be widely adopted in Federal agencies, government-owned laboratories, and universities funded by the Federal government. Despite the fact that government is willing to recognize the private sector for its successful use of Total Quality

Management, it remains difficult to institute TQM principles in government organizations. Introducing continuous improvements in government organizations must overcome the stigma that their introduction implies that something is wrong with the organization.

Table VI: Recommended Government Behavior in Making Continuous Improvement as an Analog to the Practices of Competitive Companies.

ISSUE	COMPETITIVE COMPANY	GOVERNMENT ANALOG
Self Assessment	Formal metrics are constantly used to review programs to determine which are and which are not working.	The practice of always claiming success must be discarded in favor of critical reviews to determine if public goals are being met.
When to Improve	Throughout the lifetime of a project or program including during manufacturing.	The rule-driven Federal procurement practice must be overhauled to eliminate sequential phases and rules that lead to designs frozen throughout production.
Organizational Structure	Research, development, and manufacturing are integrated to aid continuous improvement of products and processes.	The linear model of innovation (with research, development, and production activities isolated) must be abandoned in favor of the chain-link model.
Incentives for Continuous Improvement.	Employees at all levels are rewarded for introducing continuous improvements.	Government incentives must encourage continuous improvements of products procured by the Federal government. Regulatory agencies must be offered incentives to not over regulate, e.g., regulatory processes need to be reinvented so that improvements to regulated products can follow an accelerated regulatory process.
Types of Improvement Programs.	Bottoms-up improvement programs emphasize making frequent, incremental improvements to product design and manufacturing processes. Top-down improvement programs (re-engineering) look for radical improvements.	New mechanisms that permit continuous improvement programs to be implemented throughout agencies, their suppliers, and in the products and processes procured by government need to be invented.
Program Metrics	Company Metrics: Market Share Sales Profits Competitive Edge Intellectual Property	Formal public return metrics must be introduced into every Federal R&D program. Measures of technical milestones and technological or scientific breakthroughs is inadequate.

G. Learning From Corporate "Bureaucracy Busting". Osborne and Plastrik⁶³ have identified numerous ways to banish bureaucracy from government.

- ◆ Decentralize authority and push decisions down to lower levels of the hierarchy.
- ◆ Develop customer service attitudes.

⁶³ David Osborne and Peter Plastrik, Banishing Bureaucracy, Addison-Wesley, 1997.

- ◆ Use management tools such as benchmarking to improve operations.
- ◆ Utilize program reviews.
- ◆ Require periodic reauthorization of programs.
- ◆ Privatize some functions.

While these suggestions would seem to have merit, some companies have successfully implemented formal programs to stamp-out bureaucracy. Thanks to the writing of General Electric's chairman, Jack Welch, much can be learned from General Electric's efforts to remove bureaucracy and develop what is commonly termed boundaryless behavior. In fact, the U.S. Air Combat Command (ACC), the 103,000 strong military organization that controls the Nation's bombers, fighters and missiles, sent a team of personnel to GE for training in process reengineering. As a result, ACC was able to reduce the inspection time of B1-B bombers by 42%, reduce the inspection time of fighter planes by 65%, and cut the preparation time of F-15 fighter planes for combat by 50%. In addition, West Virginia's Environmental Protection Division and the city of Louisville, Kentucky, have made extensive use of GE's process reengineering technology.⁶⁴ Despite these success stories, government has only begun to tap the learning that can come from the experiences of companies like General Electric that have made inroads in cutting bureaucracy.

Welch defines boundaryless as the language, the behavior definer, the culture, and the soul of a true global enterprise. It ignores geography, borders, accents, and currencies, and unites people of all cultures.⁶⁵ It leads to an obsession for finding a better way, be its source a colleague, another GE business or another company.⁶⁶ Boundaryless behavior is achieved when customers and suppliers are participating in the entire business process, a company is taking ideas from wherever they come, employees are paying close attention to people outside the organization, and the walls between organizations are torn down.

Welch argues that to achieve boundaryless behavior a company must shed labels like engineering, marketing, hourly, salaried, etc., and discard the concept of little kingdoms called finance, engineering, manufacturing and marketing sending each other specs and memos. Instead, the company gets them all together in a room to wrestle with issues as a team. While labels are useful to institutions in deciding how to distribute salaries, they are barriers that extract a toll on productivity. GE seeks to tear down the artificial barriers and walls people build around themselves to assure status, power, and security, and to keep change away. Welch explains,

*We must resist hobbling ourselves with boundaries, labels, fiefdoms and ego- or bureaucracy-driven distinctions among us. ... It has become more obvious to us over the past few years that people will work more creatively and productively if they are trusted - empowered - and if they know for sure that what they are doing means something.*⁶⁷

Employee empowerment is expected to change the form of every organization in the twenty-first century. It will force antiquated organizational forms to adjust to both societal change and

⁶⁴ David Osborne and Peter Plastrik, "Mission Impossible", The Washington Post Magazine, May 11, 1997, pp. 6-8.

⁶⁵ Jack Welch, Global Competitiveness: America in the Eye of the Hurricane, speech at the Economic Club of Detroit, 1994.

⁶⁶ Jack Welch, 1994 Share Owners Report, 1995.

⁶⁷ Jack Welch, Work in America, speech at the Seventh Annual Awards Dinner of the Work in America Institute, 1990.

the expansion of workers' attitudes. Educated workers will reject nineteenth-century authoritarianism as they have rejected it in other aspects of their life.⁶⁸

GE has found that boundaryless behavior is impossible to embed in a bureaucratic culture steeped in tight management and control. To overcome this GE attacked vertical boundaries - hierarchical organizational layers - by eliminating layer after layer of management.

We found that with fewer layers we had wider spans of management. We weren't managing better. We were managing less, and that was better. We found that the leaders - people with a vision and a passion - soon began to stand out. And when they did, we found our own self-confidence growing to the point that we began to delegate authority further and further down into the company.⁶⁹

To reduce boundaries between customers and GE, boundaries between suppliers and GE, and boundaries between GE functions, GE is attempting to make decisions with everyone involved, including customers and suppliers.⁷⁰ Consensus-based decision making is widespread among companies that have achieved the highest success in the marketplace. GE has found horizontal boundaries between GE functions to be the most difficult to eliminate. This is because these barriers are created from insecurity.

People who spend their days working in the smog of bureaucracy have difficulty making the connection between what they do all day and whether the customer is served and the company wins or loses. Their sense of security then must come from their place in the bureaucracy and their sense of importance from owning a piece of organizational turf and defending it with jargon, channels, approvals and the other symptoms of what we call functionalitis. ... The antidote is self-confidence. Give people the chance to make a contribution to winning, let them gain the self-confidence that comes from knowing their role in it, and before long they abandon the paraphernalia of status and bureaucracy. They simply don't need it anymore.⁷¹

To tear down internal horizontal barriers, GE reduced the staff that was spending their time checking, auditing, and kibitzing those that were attempting to do work. They found that those people who were given space and trusted to make their own decisions worked harder at making sure they made good decisions. GE got rid of numerous forms, rituals, and duplication of effort, the staples of bureaucracies. But, most important, GE got rid of bureaucracy.

Bureaucracy and bureaucrats have to be ridiculed and removed. We need to cultivate a visceral hatred of **bureaucracy** ... because its unvarying agenda is the defeat of change, the muffling of communication, the waste of minds and energies. **Bureaucracies** keeps businesses balkanized and focused on themselves rather than on their customers. It distracts and disengages good minds from productive activity. It favors those who control over those who contribute.⁷²

*If we're not simple we can't be fast - and if we're not fast we can't win. ... Simplicity is an indispensable element of a leader's most important functions: projecting a vision - and demanding and **rewarding boldness, speed, and passion**. ... But just as surely*

⁶⁸ Frederick G. Harmon, "Future Present", in The Future of the Organization, edited by Frances Hesselbein, Marshall Goldsmith, and Richard Beckhard, The Drucker Foundation, 1997, p.241.

⁶⁹ Jack Welch, Managing for the Nineties, speech at Annual Share Owners Meeting, 1988.

⁷⁰ Jack Welch, The Speed and Spirit of a Boundaryless Company, speech at the Annual Share Holders Meeting, 1993.

⁷¹ Jack Welch, In Pursuit of Speed, speech at the Annual Share Holders Meeting, 1991.

⁷² Jack Welch, A Glass Half-Full: Another View of America's Prospects, speech at the North Carolina Citizens for Business and Industry, 1992.

as speed flows from simplicity, simplicity is grounded in self-confidence. ... what we must do, is to give each of our people that opportunity to dream, risk, and win and hence earn self-confidence themselves.⁷³ ... Self-confidence does not grow in someone who is just another appendage on the bureaucracy...whose authority rests on little more than a title.

GE's program to look for better ways to do work, tear down horizontal barriers, and introduce culture change is called Work Out. This program seeks to introduce the notion that ideas are to be evaluated based on their merit, not the rank of the person who came up with them. Within one year after starting Work Out, Welch was able to identify progress. We believe that Federal agencies and Federal laboratories could benefit from some of the 'bureaucracy busting' methods developed by Work Out.

I. Learning From Other Nations.

a. Introduction. Because the U.S. entered the post World War II period with a science and technology monopoly and we (both public and private entities) literally threw money for science and technology at any problem we faced, we became internally focused. While companies have responded to the global economy and competitiveness pressures by learning to look outside, Federal agencies and Federal laboratories are still living with their internally focused Cold War culture. It is shocking how little we know about public entities in other nations and how well they work. In particular, our ignorance of the role public entities play in economic development in other nations is profound. In the following we examine how a federal laboratory in Taiwan has promoted economic growth. First, we introduce cluster theory.

b. Cluster Theory. The "global village" has arrived. Telecommuters work from offices in their homes and meet with business associates around the world in fractions of a second. Communication with a co-worker across the hall differs little from communication with co-workers in Asia. World financial markets are linked throughout the world; capital is transferred at the speed of light. In this era of globalized, highly-mobile financing, multinational corporations are looking across nation state borders to find the best firms to integrate into their production and distribution chain. In the new global web of enterprise, power and wealth flow to institutions and groups that have accumulated the most valuable skills in problem-solving, problem-identification, and strategic brokering. This globalization of enterprise and economic transactions is transforming the world economy from capitalism to a post-capitalist society.⁷⁴

Competitor differentiation is increasingly arising from knowledge. Although hardware and software forms of knowledge are highly mobile, the wetware⁷⁵ state of knowledge (knowledge that can only be stored in the human brain) is only as mobile as people. Since people are relatively immobile, wetware is far less mobile than software, hardware and capital. As nation states face the dilemma of how to promote local economic development to provide jobs for their residents during a period when the mobility of hardware, software and capital offer firms great liberties in choosing where they will locate, promotion of the growth of wetware must be encouraged.

Virtual companies, fueled by entrepreneurs, are being established throughout the world as firms increasingly recognize the value of co-optition, a revolutionary game theory-based strategy that combines competition and cooperation.⁷⁶ As governments come to appreciate the futility of protectionism, barriers to international business are vanishing and firms are

⁷³Jack Welch, Soft Values for a Hard Decade: A View on Winning in the '90s.

⁷⁴ Jeffrey Alexander and Elias G. Carayannis, "The Role Of Knowledge Exchange In Trust, Co-Optition And Post-Capitalist Economics", presented at the European Institute for Advanced Studies in Management (EIASM) 1997 Conference, Leuven, Belgium, Jun 4-6, 1997.

⁷⁵ Richard R. Nelson and Paul M. Romer, "Science, Economic Growth, and Public Policy", Challenge, March-April, 1996, p. 15.

⁷⁶ Adam M. Brandenburger and Barry J. Nalebuff, Co-opetition, Doubleday, 1996.

expanding their global focus. The world's leading companies, regardless of the nation state where the company originated, are multinational, less by choice than necessity. Low-skill, low-margin multinational firms whose products and services have low wetware content are seeking the lowest wage environments around the world. High-skill, high-margin firms in the services and manufacturing sectors whose products and services have high wetware content are seeking the highest knowledge generation environments in the world.

To be competitive in the global environment, companies must have faced intense competition in their regional or domestic market.⁷⁷ This intense regional competition usually leads to certain industry sector groups geographically clustered within regions located around the world. For example, in the U.S., major semiconductor manufacturing and software clusters have emerged in the San Francisco Bay area (Silicon Valley) and in the Fort Worth-Dallas-Austin, Texas, area and miniclusters are gradually emerging in New Mexico and Oregon. Porter explains this phenomena,

*A nation's successful industries are usually linked through vertical (buyer/supplier) or horizontal (common customers, technology, channels, etc.) relationships. ... The phenomenon of industry clustering is so pervasive that it appears to be a central feature of advanced national economies. The reasons for clustering grow directly out of the determinants of national advantage and are a manifestation of their systemic character. One competitive industry helps to create another in a mutually reinforcing process.*⁷⁸

Because industrial clusters often emerge in geographically concentrated areas, people are highly mobile within individual clusters. Therefore, wetware diffuses rapidly and competition between firms within the cluster grows to a level of intensity required for survival or even dominance in the global marketplace. If a small collection of firms, a miniclust, is to develop into a major industrial cluster, specialized knowledge, especially wetware, that supports this cluster must rapidly emerge and be diffused throughout the cluster. Technology parks centered around major research universities, e.g., the Stanford Research Park centered around Stanford University, have been important sources of this knowledge and they have played important roles in its diffusion.

c. Technology Parks. Most of the world's 500 technology parks emphasize university-based research. It should be pointed out, however, that only 40 percent of the world's fastest growing companies have ever availed themselves of college and university resources. But those that did use university resources boast productivity rates 59 percent higher than their peers without such relationships, 21 percent higher projected revenues, and 23 percent more major capital investments.⁷⁹

There was a proliferation of research parks in the U.S. during the early to mid 1980s. Most of these were launched by universities with the belief that these parks were a tool to attract major companies to establish research laboratories close to the university and hopefully provide research funds to the university. However, because of downsizing, large companies have been more interested in consolidating their resources rather than relocating them. Therefore, with a few exceptions, research parks have been more of a magnet for attracting small companies and a resource for starting new companies than they have been a magnet for attracting large companies.⁸⁰

While many of the most successful U.S. research parks have been centered on universities, others have emerged spontaneously without the formal intervention of the university

⁷⁷ Michael Porter, The Competitive Advantage of Nations, The Free Press, 1990.

⁷⁸ Ibid, p. 149.

⁷⁹ Coopers & Lybrand, "Growth Companies With University Ties Have Productivity Rates Almost Two-Thirds Higher Than Peers Yet Only Four in Ten Forge These Links", Trendsetter Barometer, January 26, 1995.

⁸⁰ Nancy Croft Baker, "University Research Parks Form an Evolution of Minds", Technology Transfer Business, Fall 1996, p.13.

community. Although California, in particular, has witnessed this, local universities have, nevertheless, been important sources of the research discoveries that drove the business growth in these parks. If a region is evolving a strong technology-based industry sector with linkages between research institutions, private companies, venture capital, and skilled labor, it may not be necessary to formally establish a technology park to spur economic growth. If, however, the region has elements of the resources needed to support technology-driven business, but they are underdeveloped or inadequately linked, a technology park may be needed to coalesce economic growth.⁸¹

d. The Hsinchu Park. Whereas U.S. universities have been important early sources of the knowledge explosion that jump starts technology park centered industrial clusters, Federal laboratories have played lesser roles in the evolution of technology parks in the U.S. However, that is not the case in Asia, particularly in Taiwan's Science-Based Industrial Park in Hsinchu. Government-owned laboratories have played key roles in the development of many of Asia's technology parks. A major government research laboratory, the Industrial Technology Research Institute (ITRI), has played a critical role in the development of the Hsinchu park in Taiwan. In 1996, ITRI's budget was just slightly under \$1 billion, making it of comparable size to the largest U.S. Federal laboratories. By 2003 the Hsinchu park is projected to include 1385 acres, have 300 tenants, 80,000 employees, and sales revenues of US\$50 billion. In 1995 this park had 1,000 acres, 180 tenants, 42,000 employees, and sales revenues of US\$11.3 billion. Thus, the return on the ITRI investment is over ten to one.

A new technology park, Tainan Science Based Industrial Park, is under construction in Tainan, Taiwan. Within 15 years after its completion in year 2,000, this park is projected to have 1,625 acres, 40,000 employees, and annual sales of US\$33 billion. Japan's Tsukuba Science City has three science parks and 50 government research institutes. The latter account for 50 percent of the R&D investment made by Japan's government.⁸²

Mathews has researched the Hsinchu park. He notes,

*development at Hsinchu has been achieved as a deliberate matter of public policy. It was not a development so much as a creation. An institutional framework has been established with the conscious intention of facilitating the leveraging of advanced technologies from around the world and accelerating the uptake and mastering of these technologies by Taiwanese firms. .. what Taiwan has created is a "Silicon Valley" in Hsinchu Science-Based Industry Park, organized and administered by a public-sector agency. Make no mistake, Taiwan's semiconductor industry is a flourishing market-driven industry. It has no "nationalized" firms within it; all are privately owned and managed. It is strongly export-oriented. It has never imposed any protective tariffs on its semiconductor products. There are no government "handouts" to any of the firms. And yet its creation, its nurturing and its guidance have been entirely the product of government and public sector institutions. ... the case can be made that Taiwan's strategies apply not just to a developing country, but to any country which is attempting to keep abreast of the fast-changing technological frontier. It can be argued that **competitive advantage will pass increasingly to countries which can master the management of the diffusion of technological innovations, rather than the generation of new knowledge itself.**⁸³*

⁸¹ James R. Musbach, David Zehnder, and Jason Moody, Spontaneous Research Districts: Universities in Local Economic Development, presented at Association of University Related Research Parks Annual Conference, Monterey, CA, June, 1997.

⁸² Rustam Lalkaka, Convergence of Enterprise Support Systems: Emerging Approaches at Asia's Technology Parks & Incubators, Association of University Related Research Parks, 12th Annual Conference, Research Parks & Technology Incubators: Capitalizing on Change, June 25-28, Monterey, CA.

⁸³ John A. Mathews, "A Silicon Valley of the East: Creating Taiwan's Semiconductor Industry", California Management Review, Vol. 39, No. 4, Summer, 1997, pp. 27-28.

Many Asian parks have established special incubators that cater to students returning from their education in other countries or returning to their home country after working in technology-based companies in the United States. Another common feature of Asian parks is the heavy government involvement in funding parks and planning park activities. However, as Castells and Hall point out, the park in Hsinchu, Taiwan, was not primarily conceived as a tool for local economic development; rather, it was established by Taiwan's Ministry of Economy as a government demonstration project to foster partnerships and cooperation between government research institutes, universities, and high-technology firms.⁸⁴ Thus, Taiwan has not only capitalized on a new model of technology parks, it has emphasized the company - Federal laboratory - university (CFLU) partnership in the development of this model.

Other emerging Asian technology parks also utilize government-owned facilities. For example, the Technology Park Malaysia, started in 1996, is near five universities and eight national research institutes. Each of these thirteen universities and government-owned research institutes are expected to play a major role in the evolution of this park.

If ITRI Can Stimulate Economic Growth, Why Can't _____ Do It?

There is overwhelming evidence that ITRI has played a critical role in the development of the Hsinchu park. Rather than attempt to emulate the Hsinchu park, some Federal laboratory officials prefer to believe that cultural differences would make it impossible for a U.S. Federal laboratory to create a Hsinchu-like park. We recommend that the Federal government provide the initial funds for three Federal laboratories to emulate the Hsinchu model. Those that succeed would continue to exist; that fail would be closed. Under these conditions, the necessary cultural adjustments would be accommodated.

VI. Conclusion and Recommendations

A. Conclusions.

1. Public Issue Sensitization. Federal laboratories that receive or manage *public funds* must sensitize every one of their employees to the *responsibilities to the public* that entails.

2. Public Outcome Metrics. Federal laboratories responsible for the management and performance of federal R&D should develop *public outcome* metrics (not to be confused with R&D process and output metrics) and every project or program they conduct must be strategically linked to *public outcomes*.

3. Laboratory Breadth. Federal laboratories that receive or manage federal R&D must come to recognize that many of the major problems facing the United States are exceedingly complex and multidimensional with the dominant components being socio-economic and socio-political. Federal laboratories that only want to address the physical science and engineering content of these problems are increasingly likely to be viewed as irrelevant by the public.

4. Increase Public Outcomes. Rather than encourage Congress and the President to increase funds for Federal R&D and promote being viewed as just another special interest or entitlement driven by self preservation, Federal laboratories responsible for the management and performance of Federal R&D must first look for ways to increase the *public outcome* from their Federal R&D funds. Should any of the three major classes of federal R&D performers (Federal laboratories, companies, and universities) make a dramatic improvement in the public outcome of their R&D, other Federal R&D performers will benefit by imitation. When the public sees that it gets more in return for a \$10 billion increase in Federal R&D than it gets for a 5% or \$10 billion increase in Medicare, it will respond and pressure Congress to

⁸⁴ Manuel Castells and Peter Hall, Technopoles of the World: the making of twenty-first-century industrial complexes, Routledge, 1994, p. 100.

not make Federal R&D a zero sum game. If the **public outcome** can be increased, the federal investment will be increased.

5. Hunters and Gathers. Much of the current, inward-focused U.S. research culture was formed during a period in which the U.S. was the dominant source of innovation in the world. Rather than regard the rapid growth in new knowledge around the world as a pending apocalypse, Federal R&D laboratories must increase their emphasis on the collection of research innovation from around the world and assist in the extension and transfer of that innovation to U.S. institutions.

6. Proposal Costs. Federal agencies must explore ways to reduce the waste of human resources inherent in competitive proposal generation which often costs the integrated applicants more in time and resources than is available for award. Such artificial competition is not an efficient use of public resources.

7. Open Communications. Federal agencies must get over their paranoia regarding communication between their contractors, employees, and Federal laboratories and Congress. Agencies must come to recognize that members of Congress represent the interests of sub-sections of the public whose taxes are paying their salaries. Closed systems are in conflict with the principles of a democracy and must be abolished.

8. Think Systems. Federal agencies must lead the Federally funded R&D enterprise in developing systemic solutions to public problems that the market is failing to address.

9. Risk Taking. Federal laboratories must face up to the fact that our great Nation has little need for laboratories that are unwilling to take the risks that accompany addressing controversial issues. It has been said that people and institutions must either lead, follow, or get out of the way. For too long Federal laboratories have taken the low-risk path and followed. It is time for Federal laboratories to either increasingly fill a leadership role or be closed.

B. Recommendations

1. Improve the Governance of Federal Laboratories. We recommend that Congress and the President explore alternative models that eventually lead to improved governance of all Federal laboratories. For example, Congress should select a set of government laboratories and organize them under the corporatized or government corporation model recommended by the Galvin Task Force.⁸⁵ To make governance by a government corporation work, it will be necessary for Congress to appropriate funds to the government corporation to sustain the R&D infrastructure at that government corporation's federal laboratories and allow these laboratories to compete for the remainder of their funds from all federal agencies. We suggest that Congress and the President also consider other governance models⁸⁶, including a government-sponsored enterprise, with each being carefully studied (the relative effectiveness of the GOCO and GOGO models should also be included in this study) to identify which governance model has the highest potential for **public return**.

2. Study and Imitate Success in Other Nations. We must determine how other nations have maximized the **public value** of their government labs and suggest ways that the U.S. could utilize these nations' models. (There is anecdotal evidence that Taiwan, Singapore and Denmark have been particularly successful with their government laboratories. Some anecdotal data are favorable to Germany's government laboratory system; other data are critical of these labs.) We should determine if there is an international precedence for the following as well as other federal laboratory roles and determine how well other nations' government-owned laboratories have served that role:

⁸⁵ Secretary of Energy Advisory Board, Galvin Task Force, Alternative Futures for the Department of Energy National Laboratories, February, 1995.

⁸⁶ Larry Berthoff, Governance for National Laboratories, unpublished draft report, February 3, 1997.

- ◆ federal laboratory serves as the nucleus of a regional technopolis;
- ◆ federal laboratory serves as a regional center for technology extension services;
- ◆ federal laboratory serves as the focal point for development of technology and science roadmaps for the Nation;
- ◆ Federal laboratory benchmarks U.S. industrial technology capabilities against those of companies around the world;
- ◆ Federal laboratory serves as a hunter, gatherer, and integrator of innovation made around the world and transfers these innovations to companies in the host country (We know, for example, that ITRI has done this for Taiwan.);
- ◆ Federal laboratory serves as an R&D center in some area of technology where host Nation's companies are not effectively competing; and
- ◆ Federal laboratory serves as an independent, unbiased policy analysis and policy research group.

3. Privatization and Outsourcing. We should determine if outsourcing of Federal labs nontechnical operations would increase their cost-effectiveness. While some have advocated wholesale privatizing of Federal laboratories, we do not support such radical surgery, unless, of course, laboratories are working on problems where it is not in the public interest to own their R&D performer. Furthermore, we believe Federal laboratories must be obsessed with serving **public needs**, not private needs. However, we do believe that the costs of many of the administrative, security, plant, and maintenance functions within Federal laboratories could be reduced by outsourcing. If analysis shows outsourcing to be cost effective, we propose that Congress offer incentives, e.g., increased R&D funds to replace saved operations funds, to Federal laboratories to outsource their non-technical operations.

4. Personnel Mobility. We should identify barriers that inhibit the mobility of personnel between Federal labs, universities, and industry and identify incentives that lead to increased personnel transfer.

5. Laboratory Evaluation. We should expand the scope of the evaluation of the Army's Natick laboratory by the National Research Council to include evaluation of laboratories operated by other Federal agencies and use these evaluations to propose metrics that can be applied to all Federal laboratories.

6. 21st Century Labs. We should identify those Federal laboratories capable of addressing emerging 21st century **public needs** that require competencies in the physical sciences, system's modeling and analysis, social sciences, public policy, and economics disciplines. (Note that even a partnership requires broad minimal competencies to support communications.) These public needs include: health care costs, optimization of regulations, terrorism, guerrilla warfare, crime, education quality and costs, etc.

7. Case Studies. We should conduct case studies and synthesize existing studies of past U.S. Federal lab derived mission roles and identify which roles have been most cost effective and which have been least cost effective. These case studies should include examination of technology transfer from federal laboratories and determine if and how its **public value** could be increased and whether or not it should be further encouraged and promoted.

8. System of Labs. We should determine the utility of forming the Federal laboratories into a National system of labs. We believe that this has the potential to reduce unintended redundancy and result in the development of entire new collective competencies at Federal laboratories.

9. Bureaucracy. We recommend that Congress and the President take steps well beyond those of the National Performance Review to eliminate risk-averse agency and laboratory bureaucracies. Much of the Federal laboratory and agency bureaucracies stem from government's micromanagement of the Federal laboratory system. Conformance to this hierarchical, rule-driven, control-intensive, audit-fostering system drains much of the creative energy of Federal labs, reduces their effectiveness, and promotes proliferation of agency and laboratory bureaucracies. Government must give the Federal laboratories challenging responsibilities, hold them accountable for **public outcomes**, measure whether or not **public outcomes** have been accomplished, reward them when they succeed, and not bother with the in-between tactical details. Numerous companies, e.g., General Electric, have established formal programs to make their companies boundaryless and to stamp-out bureaucracy. We recommend that Congress establish a commission, chaired by a distinguished industrial leader of the stature of Jack Welch, GE Chairman, to determine how the experiences of those companies that have succeeded in bureaucracy elimination can be transferred to Federal agencies and Federal laboratories.

10. Outcome Expectations/Metrics. We recommend that Congress and the President increase expectations of **public outcome** from all Federal labs and institute metrics to measure **public outcome**. The Federal laboratory system must be organized and managed so that those laboratories that maximize the ratio of **public outcome** to public cost in the execution of their derivative missions are rewarded by budget growth and those that are not successful are penalized or closed. To accomplish this, government must recognize and refuse to accept anecdotal evidence of success from performers of all Federal R&D and shift to a **public outcome**, metrics-based, quantitative evaluation system.

11. Monopolies. Private monopolies are inefficient; public monopolies are inefficient. Therefore, we recommend that Congress and the President

- ◆ allow all National labs to work for all agencies to apply competencies developed in execution of their derivative missions and
- ◆ remove the administrative barriers that inhibit these labs from doing industrial contract work within the constraints of FFRDC regulations.
- ◆ Competition among federal labs for agency work will help sort out the weak performers. We propose that all of the National laboratories be either turned into National resources that serve multiple agency missions or be reclassified as agency laboratories.

12. Partnership Incentives. We recommend that Congress and the President offer tax incentives for companies to form partnerships with federal labs. Japan has improved the economic return from their federal laboratories by offering tax incentives to companies to establish partnerships with government-owned laboratories. We recommend that Congress institute this practice for those cases where it can be shown that the potential for **public outcome** accruing from the partnership exceeds the reduction in tax revenue.

13. Partnership Programs. We recommend that Congress and the President establish National R&D performer partnership initiatives to systematically research a wide array of public problems that have been ignored for far too long. These include healthcare costs, the aging population, crime, infrastructure problems, rationalization of energy and environmental concerns, the cost of regulations, low-productivity growth service industries, college costs, continuing education, K-12 education quality, etc.

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