Public Outcomes:

Building A 21st Century National Innovation System that Serves the Public[1]

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There has never been, in any of our lifetimes, a moment of such opportunity as now with the Cold War over. And if we just lift up our eyes a little and begin to see what we might be able to do, we too - we in our time - could be cathedral builders. We can be a great founding generation, like the Founding Fathers. ... as important as balancing the budget may be, as important as restoring civility and law and order in the cities may be, as important as fourth-grade testing may be, or school uniforms, they aren't the grand ennobling ideas that have been at the heart of the American experience and the ideal of the City on the Hill. (Pulitzer Prize-winning biographer David McCullough in speech to Congress, March, 1997)

The following is a summary of recommendations for federal R&D the authors are making as Chapter 10 in a forthcoming book of the same title. Although IEEE-USA has not endorsed these recommendations, there is interest in gaining the reaction of PACE leaders to the proposed legislation. Much of the supporting research was done in cooperation with the IEEE R&D Policy Committee and various members of that committee have offered resource materials and suggestions. The format of the PACE conference presentation will be equally split between

- an open, audience-participation discussion of these recommendations and
- the authors' views of the major public problems that should be addressed by federal R&D.

The audience is invited to offer their interpretation of this Nation's major problems, recommend how these public problems should be prioritized, and suggest how federal R&D may be used to address these problems. The authors also invite IEEE members to comment on these recommendations at Gover's email address listed in the title. IEEE chapters and sections may use these materials for interacting with their Congressional delegations. Contact the above email address for additional supporting materials. As a minimum, it is hoped that these discussions will have the following impact on **PACE leaders**:

- sharpen their focus on the major problems faced by the public,
- stimulate their thought about how federal R&D may be used to address these problems, and
- provoke their interaction with their Congressional delegations on behalf of these issues.

[1] The recommendations offered in this paper are those of the authors and have not been endorsed by either IEEE or the employers of the authors.

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Recommendations

I. Themes of Recommendations

Focus

Federal R&D must be principally focused on solving ***public problems*** that the marketplace is failing to address. With few exceptions, programs must be supported by roadmaps that show how the R&D is linked to ***public outcomes***.

Public Outcome Driven

Federal R&D and those who perform it must be judged in terms of the ***public outcomes*** produced, not output measures such as publications, awards, patents, and how far the frontiers of science are pushed.

Experimental Environment

The overarching issues of federal R&D policy - what it should address, how to manage it, who should perform it, how to perform it, what works best, etc. - are highly complex and lack a strong theoretical foundation. (In fact, the linear, assembly-line model used by policymakers is wrong!) It is time that policymakers recognize and acknowledge the uncertainty of their work and conduct a wide array of policy experiments (we consider SEMATECH such an experiment) that are supported by ***public outcome*** metrics. In addition to making federal R&D better address public needs, such an approach to policy making could raise the public's interest in T&S policy. Of course, as in any experiment, the results must be measured and if failures aren't observed, it is likely that policies lack vision and imagination.

Prioritize Public Problems

It is time to abandon the budget-driven federal R&D system where performers of federal R&D are treated as constituents, and replace it with a ***public problem-public outcome*** driven system where ***public problems*** are prioritized and the budget is distributed to agencies according to these priorities.

II. Legislative Recommendations

A. Develop a Follow-on to the Vannevar Bush National Technology and Science[2] Strategy.

Congress and the President should develop a comprehensive National technology and science (T&S) policy that redefines government's responsibility in technology and science; states appropriate roles for federal laboratories, universities, companies, and other performers of federal R&D; and strengthens the process for selecting and prioritizing federal R&D projects. Only then can optimization of the federal laboratory system be fully addressed to maximize ***public outcome***. This action, as well as strengthening federal laboratory governance, should be undertaken prior to beginning any wholesale restructuring of federal laboratories or other institutions that perform R&D for the federal government.

We recommend that Congress and the President establish a National Technology and Science Policy Committee (NTSPC) as a joint committee of the U.S. Senate and the U.S. House of Representatives and task it to develop a post Vannevar Bush National T&S strategy. A senior member of Congress with a distinguished history in T&S policy should be appointed to chair this bipartisan effort and it should be

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[2] We use the convention technology and science (T&S) because technology usually precedes rather than follows science. George Wise, "Science and Technology", OSIRIS, 1985, pp. 229-246, explains the difference in how historians and policymakers view the relationship between science and technology. Wise recalls technology and science metaphors: T&S are a marriage of convenience, not love; T&S are mirror-image twins; etc.

co-chaired by the vice-president. The chair and co-chair should be supported by assistant-chairs representing leaders from the academic scientific community and the industrial engineering community.

B. Improve the Policy Development Process and the Funding Prioritization Process. The political process that is used to develop T&S policy does not traditionally accommodate preprogram analysis, tends to be driven by the needs of R&D performers and the vagaries of the political process rather than ***public needs***, and is not immediately responsive to emerging problems. We recommend that Congress and the President:

- strengthen the T&S policy development process and
- strengthen the process used to establish funding priorities

by complementing the political process with technology and science. That is, use T&S to develop better T&S policy.

For example, we recommend that an independent organization conduct preprogram, cost-benefit analysis of proposed federal technology and science programs and that the response of stakeholders and the public to these proposed programs be tested by use of simulation technology. The ***public outcome*** of the federal investment in R&D at federal laboratories, companies and universities would be increased as would public perception of the ***public value*** of federal R&D.

C. 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.[3] 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 models[4], 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***.

D. Make Federal Laboratories Have Higher *Public Return*

1. We recommend that Congress and the President commission the National Research Council (NRC) or an equally able body to conduct objective, data-based research on federal laboratories. This study should have the following thrusts:

a. 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 Singapore and Denmark have been particularly successful in increasing ***public return*** from their government laboratories. Some anecdotal data are favorable to Germany's government laboratory system; other data are critical of these labs.) The NRC 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:

- 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;
- 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 those innovations to companies in the host country;

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

[4] Larry Bertholf, Governance for National Laboratories, unpublished draft report, February 3, 1997.

- 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.

b. Determine if outsourcing of federal labs nontechnical operations would increase their cost-effectiveness. While some have advocated privatizing of federal laboratories, we do not support such radical surgery as an immediate measure; furthermore, we want federal laboratories to 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 NRC studies show 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.

c. Identify barriers that inhibit the mobility of personnel between federal labs, universities, and industry and identify incentives that lead to increased personnel transfer.

d. Expand the scope of the NRC evaluation of the Army's Natick laboratory 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.

e. 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.

f. Conduct case studies and synthesize existing studies of past U.S. federal lab mission and derived mission roles and identify which roles have been most cost effective and which have been least cost effective. This study 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.

g. 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.

2. 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 ***pubic outcomes*** have been accomplished, reward them when they succeed, and not bother with the in-between 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.

3. 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 both their primary mission and 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.

4. 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 primary and 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 primary and derivative missions or be reclassified as agency laboratories.

5. 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 federal 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.

6. The U.S. Constitution emphasizes that the U.S. government is to provide for the defense of this Nation's ***citizens***. We are concerned that cuts in defense could result in defense capabilities lagging U.S. foreign policy objectives that require military involvement. Therefore, we recommend that Congress and the President task a non-DoD federal laboratory of high credibility to

a. develop a model of National defense investment as a fraction of GDP that includes the cost of developing systems that:

- effectively detect, track, and deny use or destroy weapons of mass destruction (nuclear, chemical, and biological weapons);
- effectively prevent, detect and respond to international and domestic terrorism as well as sabotage of U.S. information systems and energy and communications infrastructure;
- effectively monitor borders; and
- allow for minimum-risk, peacekeeping operations such at those in place in Bosnia and

b. determine the military significance of U.S. military technology being increasingly dependent on commercial technology.

The results of this analysis must be made available to the ***American people*** so that they can fully understand the military capability they are buying with their defense investment. Evidence of Americans' need to better understand our defense capabilities is the fact that most believe that the U.S. has in place a system that can protect the U.S. from attack by ballistic missiles. Furthermore, most Americans incorrectly believe that the U.S. defense investment exceeds healthcare and education costs.

E. Make Federal R&D Performed by Universities Have Higher Public Value

1. We recommend that Congress and the President commission the National Research Council (NRC) or an equally able body to establish a second team that conducts **objective, data-based** research on U.S. research universities. This research must be **based on fact, not assertion by "experts"** and it should have the following thrusts:

a. Determine how other nations have maximized the ***public outcome*** of their universities' research and suggest ways that the U.S. could experiment with these nations' models. The NRC should determine if there is an international precedent for the following as well as other university roles and determine how well other nations' universities have served that role:

- university serves as the nucleus of a regional technopolis;
- university serves as a regional center for technology extension services;
- university serves as a hunter, gatherer, and integrator of innovation made around the world and transfers those innovations to companies in the host country;

- university serves as an R&D center in some area of technology where host Nation's companies are not effectively competing; and
- university serves as an independent, unbiased policy analysis and policy research group.

b. Conduct case studies and synthesize existing studies of past U.S. research university roles and identify which roles have been most and which have been least cost effective in promoting economic growth and other ***public outcomes***. This study should include examination of university-based engineering research centers to determine whether or not these should be further encouraged and promoted, it should compare the long-term economic return from basic research to applied engineering research, it should compare (sector-to-sector) the private and public or social return of university research that supports major industrial sectors to determine which sectors are most affected by university research, and it should identify the stage of evolution of the industrial sector where university research has the highest value.

c. Vannevar Bush argued that most of the significant progress in a scientific field is generated by a relatively small group of the most capable practitioners.[5] The NRC should conduct selected case studies of university research and quantitatively assess how well this premise holds today, and, if it does hold, recommend how this should impact the distribution of federal research funds to universities.

d. Many studies have lauded the peer review process that is often used in selection of research proposals submitted to the federal government by universities. Others see peer review as dominated by a megaresearch university oligopoly that does not welcome new members. Still others argue that the quality of university research is less important than its teaching value. The NRC should make an **objective, quantitative** analysis of the peer review process, examine the ***public outcome*** from other alternatives for distributing federal research funds, and make recommendations to Congress regarding the importance of peer review in assuring that the value of ***public outcomes*** well exceed public costs. The social cost of preparing unfunded proposals should be included in this analysis.

e. University administrators often laud the value of research in teaching. Others argue that as university research has grown, undergraduates are increasingly taught by graduate assistants and other irregular faculty, research takes precedence over teaching, the number of students in the classroom grows, and the costs of undergraduate education are increased to finance graduate school research. The NRC should make a quantitative, cost-benefit assessment of the impact of university research on the cost and quality of undergraduate education.

f. The NRC should also examine the practice of universities owning intellectual property gained through federal funding of university research and determine if this practice serves the long-term interest of the U.S. public.

g. The industrial leader, Bob Galvin, Chairman, Motorola, proposed that federally funded U.S. research should be based on science roadmaps.[6] Others have argued that all federal research should be strategic in design with an expected or potential path to ***public outcome*** identified prior to conducting the research. The NRC should assess the value of science roadmaps and strategic research for federally funded science research and, if they show promise for increasing the ***public outcome*** from university research, recommend a process to Congress and the President for how science roadmaps and assurance of strategic content could be integrated into National innovation policy.

h. In recent years corporate management of R&D has undergone many changes with industrial research groups having to constantly reinvent themselves. In the meanwhile, university research has changed relatively little with many researchers studying the same topic throughout their entire

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[5] This position of Bush was brought to the attention of the IEEE R&D Policy Committee by member Robert L. Feik.

[6] Mr. Galvin made this proposal at the IEEE Technology Policy Council Symposium, June 10-11, 1996, Washington, DC.

career in academe. John Armstrong, retired vice president of science and technology at IBM, remarked,

> *In this endeavor of institutional reinvention, the research culture that young scientists bring to industry from their universities is almost entirely useless. We spend a lot of time teaching our people how to think straight about science and technology and their relationship to industry.*[7]

NRC should examine the university research culture and identify how it can be changed to produce graduates that are better prepared to contribute in an industrial environment.

i. Federally-funded university research should not be a vehicle for making careers in engineering and science unattractive to ***U.S. citizens***. We recommend that the NRC determine the impact of Congress giving preference to federal R&D funds that support research by faculty and graduate students that are ***U.S. citizens***.

2. We recommend that Congress and the President increase expectations of ***public outcome*** from all universities that perform federal R&D and institute metrics to measure ***public outcome***. Federal agencies that fund university research must be organized and managed so that those university researchers that maximize the ratio of ***public good*** to public cost in the execution of their research are rewarded by budget growth and those that are not successful are penalized. 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 evaluation system.

3. We recommend that Congress and the President offer tax incentives for companies to form partnerships with universities for those cases where it can be shown that the potential for ***public good*** accruing from the partnership exceeds the reduction in lost tax revenue.

4. We recommend that Congress institute a program to study the relative benefits of an Internet-based or satellite-based education system where the educated are accredited in contrast to today's traditional university system where the educational institution's process is accredited and, if this system shows promise, propose roles for the federal government to play in promoting its development and use.

F Make Federal R&D Performed by Companies Have Higher Public Value

1. We recommend that Congress and the President commission the NRC or an equally able body to establish a third team that conducts **objective, data-based** research on U.S. companies. This research must be **based on fact, not assertion by "experts"** and it should have the following thrusts:

a. The federal government has instituted numerous programs to stimulate economic growth. These programs include the Small Business Innovative Research Program, the Advanced Technology Program, the Manufacturing Extension Project, CRADAs between companies and federal labs, Small Business Loans, doubling the budget of the National Science Foundation including establishment of Engineering Research Centers, and support for consortia. Some argue that these programs have been successful; others argue that they are nothing more than corporate welfare with little, if any, ***public return***. The NRC should examine these programs and determine the ***public outcome*** per unit of public cost for each program where the costs of developing and reviewing proposals are included in the public cost. (Note, 75% of the members of the Council on Competitiveness rate the overall federal role since 1985 in strengthening industrial competitiveness as neutral to negative with the federal role in trade negotiations regarded as being the most helpful to U.S. companies[3]. However, these assertions are not **data-based** and they do not assess ***public outcome*** or public cost.) In addition, the NRC should determine if there is any evidence that these federal programs have unfairly aided one U.S. company at the expense of its domestic competitors and the NRC should determine to what degree these programs have stimulated additional industry investment in R&D.

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[7] John Armstrong, "Reinventing Research at IBM", in Engines of Innovation, edited by Richard S. Rosenbloom and William J. Spencer, Harvard Business School Press.

b. Federal competitiveness support has generally been limited to U.S-owned companies that conduct a substantial part of their manufacturing in the U.S. States have simultaneously offered major financial packages valued between $50,000 to $250,000 per primary job created to attract foreign-owned firms to establish manufacturing operations in the U.S. NRC should examine job creation in the U.S. by both foreign-owned and U.S.-owned firms and quantitatively compare the ***public outcome*** from federally-funded R&D at companies to the ***public outcome*** from investments by states and recommend to Congress and the President policy priorities for federal R&D that are most likely to create high-paid jobs for U.S. citizens.

c. While it is well-recognized that U.S. companies have made dramatic improvements in their competitiveness, some studies have argued that because U.S. companies have reduced their investment in long-term, fundamental research and have made major reductions in their investment in central corporate research laboratories, a corporate competitive crises is imminent. (Note that most surveys of corporate executives reveal that they are far more concerned about their workforce than they are about a long-term research deficit.) These studies suggest that unless the federal government corrects this long-term, fundamental research deficit, the competitiveness of U.S. companies and the U.S. economy will deteriorate. The NRC should examine these apocalyptic claims to determine if they can be supported by **objective data analysis**.

d. Surveys of corporate executives consistently reveal more concern for the cost of federal regulations, tax policy, the availability of a well-educated workforce, low National savings rates (due, in large measure, to healthcare and education costs), healthcare costs, education costs, and the federal deficit than for National science and technology policy as it has been implemented over the past decade. The NRC should: (1) examine these claims to determine if they can be quantitatively defended by **objective data analysis** and, if so, propose to Congress how federal R&D can be used to address the education and the investment concerns of corporate executives and (2) compare the cumulative impact of regulations, taxes, workforce wages and workforce competence, savings rate, and the federal deficit on the cost of doing research, development, and manufacturing in the U.S. to locating these functions in foreign countries.

e. It is sometimes argued that the federal government should give preference to funding R&D at companies (in contrast to universities or federal labs) because the company can frequently use federal R&D to develop products that have a commercial market. The NRC should research this matter to determine the fraction of major commercial companies that started as an R&D supplier to the federal government, determine if this federal support disadvantaged other U.S. companies, and determine the fraction of companies that conduct federal R&D that exclusively serve the federal government and never compete in the commercial marketplace. Include in this study a listing of the 50 U.S. companies that receive the most federal R&D, list each company's investment of private R&D funds, and list each company's government and commercial sales.

f. The NRC should review analyses of the R&D tax credit (including NRC analysis), weigh the strength of the data supporting the ***public outcome*** of the credit, and assess for Congress and the President the ***public outcome*** in comparison to both the public cost of making the R&D tax credit permanent or the public cost of using tax credits as incentives for continuing education and training and personnel exchanges with universities.

g. While some have called for government to get out of the commercial technology business, others have recommended that the public would benefit from funding research on drugs and pharmaceuticals with the public owning and licensing to several competing companies the intellectual property that resulted from this publicly funded R&D. While companies would compete for market share through their manufacturing and marketing competencies, the selling price to the public would be that of a commodity product rather than a monopoly product. The NRC should assess the potential ***public outcome*** of public support for drug and pharmaceutical research and compare it to the public cost and, if the comparison is favorable to the public, make this comparison for other industry sectors where a significant fraction of the products purchased by the public are for monopoly products.

h. While U.S. manufacturing productivity has continued to increase at a competitive rate, overall productivity growth of U.S. industry has been slow because of low productivity growth in the

services sector. The NRC should assess the major U.S. service industry sectors, identify ways to increase their productivity, and recommend ways to the President and Congress for how the federal government might stimulate increased service sector productivity.

i. Proponents of federal support for commercial technology often cite Asian and European governments' support of commercial technology and make international comparisons of governments' investment in commercial technology as a fraction of nations' GDP. The NRC should compare major governments' support for commercial R&D on an industry sector-by-industry sector basis; determine the impact these governments' funding of commercial technology is having on the competitiveness of companies; propose how these comparisons should be made, e.g., on an absolute basis or as a fraction of GDP; and identify for the President and Congress those industry sectors where U.S. companies are disadvantaged by foreign government funding of companies.

j. Several companies have determined that continuing education programs in engineering and management at universities were inadequate for their needs and have established very strong education programs that they conduct and manage internally. Noteworthy among these corporate schools is Motorola University. The NRC should research the top three of these corporate universities, ascertain if the quality of their education is as good as advertised, determine their effectiveness in avoiding obsolescence of engineers, and propose to the President and Congress how these or equivalent training resources may be made available to a much larger cross-section of the U.S. workforce and, in particular, determine how these may be used to assure a well-trained, technology-based workforce for companies located in the U.S.

k. The NRC should determine on an industry sector-by-industry sector basis the need for establishing new infratechnology laboratories. (The primary output from an infratechnology laboratory is not new science or technology, but knowledge that supports the scientific and technical enterprise in that sector. Japan has created numerous infratechnology laboratories to coordinate technology development support structures. NIST laboratories are infratechnology labs.) For those sectors where infratechnology laboratories are needed, NRC should determine the willingness of companies in these sectors to cost-share with the federal government in the operation of these laboratories.[8]

2. We believe that both the quality of engineering education and its relevance to the practice of engineering could be increased by bringing industry management and practicing industrial engineers with demonstrated teaching and research, development, or management skills to universities to conduct research, develop and teach special engineering-related courses, and participate directly in specific educational projects. The result would be engineering coursework and research that were better aligned with industry needs, long-term relationships between companies and universities, and companies willing to support more research at universities. We recommend that companies willing to establish these "industrial professorships" be awarded a **tax credit** for the overhead and living cost of each "industrial professor" they support.

3. While universities and companies can benefit from "industrial professorships", both companies and universities can also benefit from temporary appointments of engineering graduate students and university faculty to company positions. The outcome would be engineering course work and university research that is better aligned with industry needs, the development of long-term relationships between participating companies and universities, companies willing to support more research at universities, and better technology transfer from universities to companies. We recommend that companies willing to establish these "industrial appointments" be awarded a **tax credit** for the overhead and living cost of each university professor and graduate student they support, provided that these are ***U.S. citizens***.

4. Because of its aging population, the increasing life span of its citizens, and the **growing economic burden of federal entitlements**, our Nation needs to encourage companies to hire older employees and keep them on the job and off the social security rolls until they reach age 70. While lifelong learning is the responsibility of each professional, with an educational half-life of only 5 years and an oversupply of

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[8] This recommendation was adapted from a similar recommendation made by Bozeman and Crow, Federal Laboratories in the National Innovation System.

engineers at salaries reflective of modest annual salary growth, many engineers are facing antiquity in their late 30s and early 40s rather than their mid 70s. We recommend:

a. companies be offered tax or other incentives to partner with local universities to institute retraining programs for engineers,

b. the federal government investigate how the internet may be better used as a retraining vehicle for engineers, and, if necessary, provide the initial seed money for a National program of continuing education for engineers, and

c. determine how the quality of learning of the retrained engineers may be certified to potential employers.

III. Non-Legislative Recommendations for Federal Agencies, Federal Laboratories, Universities and Companies

We believe that there are additional steps that do not require legislative actions that universities, agencies, federal laboratories, and companies can take to improve the ***public outcome*** of the R&D they perform for the federal government. These are summarized in the following.

A. Universities, Federal Agencies, Federal Laboratories, and Companies

1. We recommend that all institutions that receive or manage ***public funds*** sensitize each of their employees to the ***responsibilities to the public*** that entails.

2. We recommend that institutions responsible for the management and performance of federal R&D develop ***public outcome*** metrics (not to be confused with R&D process and output metrics) and that every project or program they conduct be strategically linked to ***public outcomes***.

3. We recommend that institutions that receive or manage federal R&D 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. Institutions that only want to address the physical science and engineering content of these problems are likely to be increasingly viewed as irrelevant by the public.

4. Rather than lobby Congress and the President for more funds for federal R&D and be seen as just another special interest or entitlement driven by self preservation, we recommend that institutions responsible for the management and performance of federal R&D first look for ways to increase the ***public outcome*** from federal R&D funds. Should any of the three major classes of federal R&D performers make a dramatic improvement in the public outcome of their R&D, other 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 not make federal R&D a zero sum game. If the ***public outcome*** can be increased, the federal investment will be increased.

5. 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, we recommend that federal R&D programs 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.

B. Universities

1. We recommend that Universities place more emphasis on the continuing education of the workforce, particularly by offering advanced programs to those individuals whose work requires updating due to the rapid pace of technological innovation or due to changing business practices or due to increasing quality standards. These programs should attempt to better serve the corporate student by providing education

at his or her place of employment through a combination of technology and a cadre of circuit-riding professors[9].

2. We recommend that universities begin to cooperate with one another by sharing their technological and human resources and give up their egocentric pride in each providing full experiences to their students. There are some good regional examples of such cooperation, for example, in the southeast, universities have banded together to provide courses on every high performance computing architecture while maintaining only one on their individual campus; and in the western U. S. governors have agreed to produce video courses and use combinations of their professors to teach advanced courses.

3. We recommend that universities find a way to encourage many of their professors to hold part-time employment in government or industry so that they bring a real-world perspective to their students while adding value to the other sectors. There is evidence that this experience also improves their ability to develop research proposals that are funded. This might be accomplished, for example, by a personnel exchange agreement between a company and a university. The outcome would pay other dividends; for example, professors who knew they had full-time employment could get off the proposal-writing treadmill which uselessly wastes large fractions of their time and allow them to focus on quality of performance.

4. We recommend that universities and pre-college schools disband the traditional view that summers are a time for limited curriculum offerings and that professors or teachers are on-their-own. The public has too large an investment in the infrastructure of these institutions to partially close them for such an extended period; a company's business manager, concerned with maximizing income, would never allow such a misuse of company resources.

5. We recommend that universities that wish to increase their federal funding for research and development do so by increasing their role in federal programs that emphasize applied research or development.

6. We recommend that universities bring their full complement of R&D resources to bear on National problems by forging partnerships among different physical science and engineering departments as well as with economics departments, management departments, public policy departments, and business departments.

7. We recommend that universities increase their emphasis on finding innovative ways to increase the productivity of education, to reduce the costs of education, and to help students find part-time employment to help pay for the costs of their education.

C. Federal Agencies

1. We recommend that Federal agencies 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 contradictory to an efficient use of public resources.

2. We recommend that federal agencies 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.

3. We recommend that federal agencies lead the federally funded R&D enterprise in developing systemic solutions to public problems that the market is failing to address.

D. Companies

1. We recommend that companies and entire industrial sectors continuously review their needs for a common infrastructure and retraining of their employees and that they communicate those needs to

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[9] This is meant in the sense that rural preachers or judges traveled the sparsely populated country side in the 19th century

universities and to the government on a regular basis. The example of the Automotive Industry Action Group could serve as a model for Original Equipment Manufacturers which also influences many-times their own employees by considering the needs of supplier corporations.

E. Federal Laboratories

1. We recommend that federal laboratories face up to the fact that this great Nation has little need for federal 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.

IV. Implementation Time Frame for Legislative Recommendations

The time frame over which these recommendations should be implemented is shown in Figure 1.

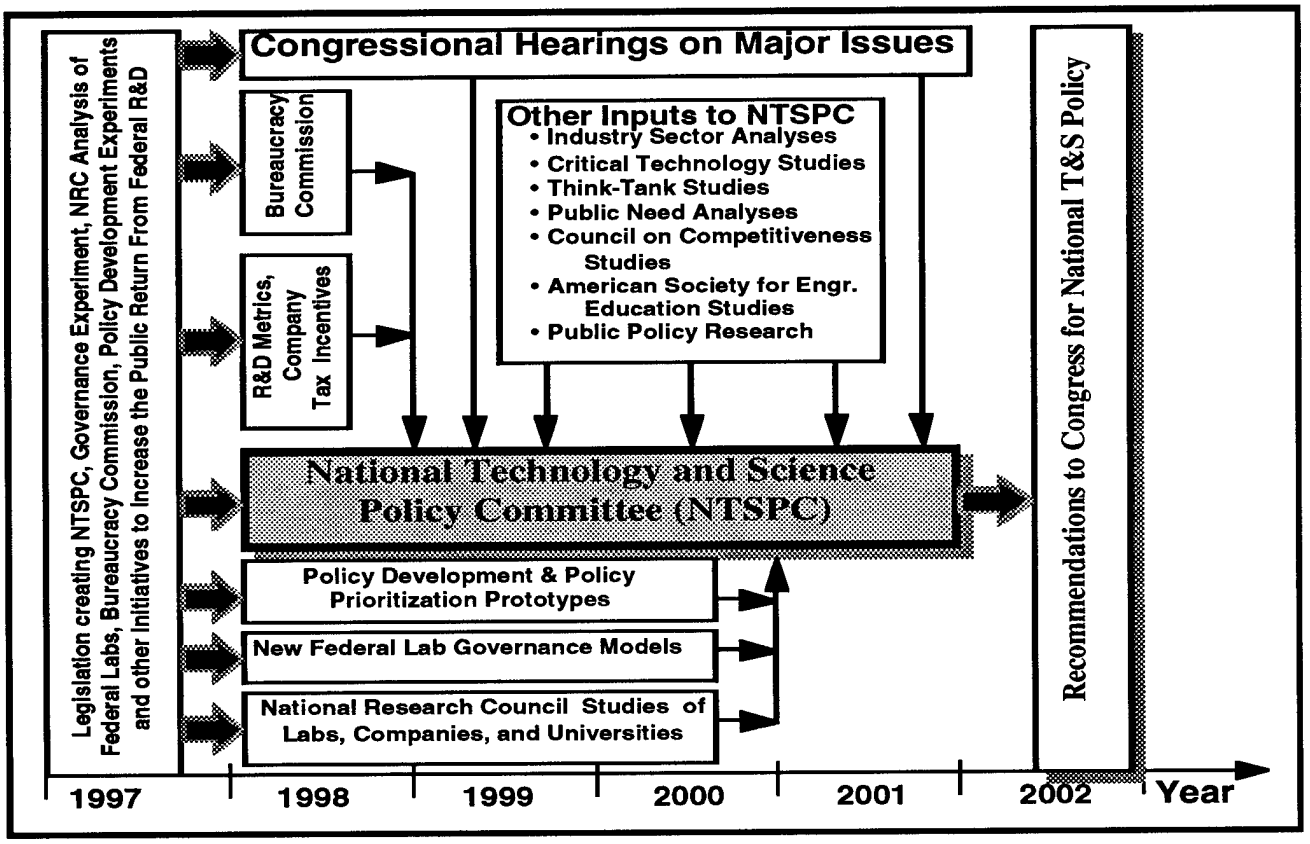

Figure 1: Time frame for execution of the preceding legislative recommendations.

In 1997 the legislation to establish a National Technology and Science Policy Committee (NTSPC) would be introduced and passed with the NTSPC starting its work in early 1998. Other improvements to university, lab, and company R&D would be immediately introduced through legislative initiatives and the impact of these improvements would be passed to the NTSPC. The Bureaucracy Commission would be established and complete their work during 1998 and its recommendations would be passed on to the President, the NTSPC, and Congress. New federal labs governance models would be started at the beginning of 1998 and allowed to run for three years. At the end of CY2000 the NTSPC would be appraised as to the results of alternative governance models. The NRC studies of federal labs, universities, and companies would take place during this same time frame and recommendations would also be delivered to Congress, the President and the NTSPC at the end of CY2000. During this time

frame Congress would also receive recommendations from a variety of other sources including those planned by the American Enterprise Institute for Public Policy Research.[10]

Between 1998 and the end of CY2000, Congress would prototype cost-benefit analyses of existing and proposed federal R&D programs and test the public's response to proposed changes to existing programs and new programs by using war-game technology. With these and additional inputs from other sources of their choosing, the NTSPC would have one year to make recommendations to Congress for a new National technology and science policy to replace the Vannevar Bush policy that has evolved since the late 1940s. The outcome of this process would help our Nation determine how our technology and science infrastructure can more effectively address 21st century problems and better accomplish ***public outcomes***.

About the Session Speaker

James Gover has a BS in electrical engineering from the University of Kentucky, a MS in electrical engineering from the University of New Mexico, and a Ph.D. in nuclear engineering from the University of New Mexico. He has been an employee of Sandia National Laboratories since 1963. He has served IEEE for over four years as a Congressional Fellow in the Office of Senator Domenici and the House Science Committee and as a Competitiveness Fellow in the Office of Senator Roth, the U.S. Department of Energy, and the U.S. Department of Commerce Technology Administration. He is currently active with the IEEE-USA R&D Policy Committee. For additional information or comments contact him at **jegover@sandia.gov** or at 505/284-3627.

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[10] The American Enterprise Institute for Public Policy Research has commissioned a series of papers exploring the implications of new theories regarding R&D and economic growth. Distinguished researchers contributing to this work include Richard Nelson, Columbia University, David Mowery, University of California, Berkeley, Roger Noll, Stanford University, Linda Cohen, University of California, Riverside, and other distinguished public policy researchers. See, for example, Einstein in Gucci Gulch: Can (Should) Science Make Its Case in Washington?, AEI Seminar, December 17, 1996. With few exceptions, e.g., Tassey, NIST, employees of federal agencies and federal laboratories are conspicuous in their absence from the community of distinguished public policy scholars.

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