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Public Problems:
Still Waiting on the Marketplace for Solutions

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The following is a summary of problems of high public interest that the marketplace is unlikely to solve. We believe that many of these could and should be the focus of federal R&D programs.

Much of our literature search was done in cooperation with the IEEE R&D Policy Committee and various members of that committee have offered resource materials and suggestions. We acknowledge this committee's continued interest and encouragement.

The authors invite IEEE members and others to comment on this manuscript at Gover's email address listed in the title. IEEE chapters and sections are encouraged to use these materials for interacting with their Congressional delegations. It is hoped that these discussions will have the following impact on **IEEE section and chapter 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.

Neither IEEE nor our employers have endorsed our interpretation of the major problems faced by the American public.

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DISCLAIMER

I. Introduction

A. Background.

The United States has failed to develop bipartisan political support for a comprehensive, defensible National technology and science[1] (T&S) innovation policy that solves problems the public is worried about. Consequently, federal support for research and development is under pressure and is likely to be cut.

The stress on all federal discretionary spending, including that for R&D, is growing due to the apparent public mandate to balance the budget during a time of escalating entitlement costs. If this stress leads to a careful, thoughtful, data-based examination of all federal discretionary and entitlement spending, including spending on R&D, it can be the creative force that stimulates dramatic improvement in the ***public outcome*** from all federal programs, including federal R&D. Unfortunately for the public, careful, thoughtful, data-based examination of such matters is the work of engineers and scholars, not the work of politicians.

The Voices of Engineers Are Needed.

We strongly advocate that engineers increase their involvement in the political process. However, if engineers are to differentiate themselves from the special interest groups that solicit Congress and the President, they must offer the public, Congress, and the President higher knowledge recommendations, not self-serving mythology.[2] The opportunities are manifold because under threat of a 20% cut in federal R&D funds by the year 2002, the R&D community has unleashed a flood of rambling rhetoric, sports and war metaphors, jingoistic jargon, and apocalyptic prophecy. Candid, meaningful debate has not yet emerged.[3]

B. Expert Opinion.

We think that it is especially important that the trends described to members of the U.S. Senate by Dr. Al Narath,[4] be addressed,

> *Competition among scientific disciplines and institutions has been intensifying --- to a point where the scientific enterprise is at times seen by the public as another entitlement seeking to perpetuate itself. ... General agreement exists that continued federal support for S&T is in the public interest. But no clear consensus exists on appropriate levels of investment --- or on optimum distribution among performers.*

Dr. Charles Curtis, former Deputy Secretary, U.S. Department of Energy, addressed the issue of public support for federal R&D directly and with refreshing candor,

> *If the needs and opportunities for publicly supported science and technology are so apparent, why the budget threats? I believe the answer has two foundations. The first is the more obvious - as a nation, we need to reduce federal spending and restore fiscal discipline. The second explanation ... is that the public's trust in the institution of government, its faith in science and technology, and its perception of benefit have all eroded perceptibly since the days of Vannevar Bush.*[5]

Others note that budget pressure leads to closer program scrutiny,

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[1] Much of the time technology innovation precedes science discovery; throughout this paper we place the word technology before science. We found it to be too disconcerting to place the D before R in R&D.

[2] James Gover and Mark Peterson, "A Grass-Roots Political Role for IEEE-USA", guest editorial, IEEE Transactions on Engineering Management, August, 1996.

[3] Claude Barfield, "Gutting Federal R&D", The Journal of Commerce, November 7, 1996.

[4] Dr. Al Narath, President, Energy and Environment Sector, Lockheed Martin Corporation, testimony at Science and Technology Caucus Roundtable, U.S. Senate, February 11, 1997.

[5] Dr. Charles Curtis, former Deputy Secretary, U.S. Department of Energy, remarks at 50th Anniversary Symposium of the Associated Universities, Inc.

One outdated attitude is the belief that science is so essential to society that it deserves unquestioning support. Science is under close scrutiny, as is any activity that requires dollars and resources. Institutions that cannot respond well to such analysis will not fare well.[6]

Congressman George Brown, a long-time friend and supporter of federal R&D, remarked,

Researchers must ... do a better job of linking their work to a set of concrete National goals -- of grounding that work in the present.[7]

Joseph Coates, a futurist that advocates the importance of science and technology to the economic, social, and political future of the U.S. seldom has kind things to say about publicly funded research scientists. He recently remarked,

Most of these people are a bunch of whiny bellyachers. The academics want to keep the money flowing, and the academic universities who have a stake in all of this don't want to talk about national interests, about long-term needs, or threats to the economy. They want the money for professor x, y, or z. There's no integration, no plan, no system coming out of the science establishment.[8]

Is There an Entitlement Attitude?

Despite these observations, facing budget cuts, the best advice the U.S. R&D community, especially the academic sector, can offer Congress and the President is to advocate that federal R&D spending be doubled over the next decade. Of course, a $70 billion cut in Medicaid benefits could finance this ambitious request. Rather than utilize the scientific method to determine what the public's return is on its tax-funded R&D investment and determine what additional benefits the public might reap from additional investment in R&D, the R&D community and it's professional societies have opted for a political solution. Ironically, just as IEEE and other professional societies are lobbying Congress for more support for federal R&D, scholars are showing that additional support for university research will further aggravate the glut of MS and Ph.D. engineers in the marketplace.

Performers of public R&D must come to understand that the public is not particularly interested in how many awards public R&D performers have won, or how smart they are, or how many degrees they have. Rather, the public wants to know how well federal R&D is addressing their needs that the marketplace is ignoring.

C. Synthesis.

Many U.S. engineers and scientists have a vested interest in institutions funded by federal R&D, but more importantly, all are tax-paying citizens and, therefore, want to ensure that the ***public outcome*** accruing from taxes spent in support of R&D well exceed the public cost. We neither argue nor assume that more federal support for R&D is immediately necessary; rather, we propose that better R&D (R&D that has higher and more visible ***public outcome***) can and will eventually lead to public demand for more R&D. Like peace, Medicare, and Social Security, if the public likes it, they will soon want more of it.

The future of our Nation's T&S innovation system is highly dependent on the strategic goals of federal T&S policy. Once our Nation develops a clear vision of what these goals are going to be early in the 21st century, appropriate roles for federal agencies, states, federal laboratories, universities, and companies can be determined for implementing these goals. We recommend that Congress and the President

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[6]Sidney Perkowitz, "Moving the Goalposts", American Scientist, September/October, 1996, p. 426.

[7]Congressman George Brown, "Scientists and Engineers as Political Advocates", Technology Review, Nov./Dec., 1995.

[8] C&EN, "Projecting the Future Rationally", July 14, 1997, p. 35.

- first review the evolution of the 1940's Vannevar Bush National S&T (rather than T&S) policy,
- chart a new T&S innovation policy for the 21st century that focuses federal R&D on solving public problems that the marketplace is failing to address,
- reengineer the federal R&D system to support this new policy direction,
- maximize the ***public outcome*** of R&D performed by universities, companies, and federal laboratories by such means as facilitating the formation of strategic partnerships across all three entities, and
- commission the National Research Council (NRC) or an equivalent National body to conduct major studies related to these three performers of federal R&D to identify best partnering practices across the U.S. and abroad and to experiment with war/business gaming technology in maximizing ***public outcomes***.

II. Examples of Unmet Public Needs

A. Background.

Some may be concerned that focus on ***public needs*** not met by the marketplace automatically resigns federal R&D to addressing the leftovers. It is a fact that there is a long and growing list of ***public needs*** that are not currently being satisfied by the marketplace and these are the tough problems - the easy ones have been solved in the marketplace. In addition to those areas listed in the following, there are ***public needs*** for R&D in areas such as astronomy, anthropology, geology, deep space exploration, etc., that may not be directly linked to quality of life in the short term. In addition, there are unmet ***public needs*** in commercial technology that we address later. A problem list follows.

- First, note that we have not attempted to define how much federal R&D is required to solve these; however, we recommend that this assessment be made.
- Second, note that this is not a priority list. Congress should establish a credible prioritization process.
- Third, these are exceedingly complex problems that will likely require partnerships of companies, universities, and federal labs to attain solutions.

B. The Healthcare Cost Problem.

The cost of health care in America has risen to 14.5% of GDP, between 1.5 and 2 times that of the rest of the industrialized world. In comparison, France spends 9.9%, Germany spends 9.6%, the Netherlands spends 8%, Japan spends 7%, and Britain spends 6.9% with little noticeable disadvantage.[9] Despite the fact that Japan's population is older than the U.S. population and spends 30% of it's healthcare purchases on drugs in comparison to 8% in the U.S., Japan only spends 7% of its GDP on healthcare and its citizens live 4 years longer than Americans.[10] Comparisons of the U.S. healthcare system to those of Britain and Germany reveal that even though American hospitals are more productive in the treatment of breast cancer, lung cancer, and gallstones, they lag in treatment of diabetes and their administrative costs are much higher.[11]

Almost 20% of Americans do not have medical insurance. Furthermore, while thought to be a necessity, medical insurance actually increases the demand for healthcare services by driving a wedge between the real price and the price actually paid by the insured person. Over the past two decades, except for the recent past, healthcare costs have increased 1 percent of

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[9] The Economist, "France: A headache", March 8, 1997, p. 57.

[10] The Economist, "Japan's Sickly Drug Firms", October 19, 1996, p. 65.

[11] The Economist, "Heal Yourselves: The Economics of Health Care", November 9, 1996, p. 92.

GDP every 20 months. Healthcare costs currently account for 20% of the federal budget and 30% of states' budgets. Medicare's annual costs now exceed $200 billion and are growing at an annual rate of 11%. With today's benefit structure Medicare costs will reach $414 billion by the year 2005. A Washington Post poll showed that 52% of Americans are worried that they and their family will not be able to afford adequate medical care and that the medical benefits they receive will be reduced or eliminated.[12] Current estimates predict 2001 to be the crash date for Medicare. Public polls indicate that the public is aware of the Medicare crises but believes that it can be solved by eliminating Medicare's waste, fraud and abuse or by cutting foreign aid, believed by 64% of those polled to be the largest area of government spending. (Foreign aid actually constitutes about 1% of government spending while Social Security amounts to about 25% of government spending.[13] In 1996, Medicare waste, fraud and abuse amounted to $23 billion or 14% of Medicare's total costs.)

Health care is killing our savings.

Health care consumption is slowly eroding National savings and, as the population ages, this problem will continue to escalate. The net National savings rate has dropped from 9.1% in the 1950s to 2.7% in the early 1990s.[14] This drop is driven by the trend for the elderly to have more money and to spend more of it.[15] One reason for this drop in savings is the dramatic increase in health care spending by the elderly. Between 1984 and 1994 medical care absorbed 20% of the growth of consumption expenditures.[16]

Since 1975, personal outlays for housing and transportation services have risen by 1.5% of personal income while outlays for religious, social welfare, educational, and recreational activities have increased by 1.8% of personal income. Outlays for personal business services, including banking and brokerage fees, have increased by 2.1% of personal income. Outlays for goods - food, clothing, and gasoline - have decreased by almost 8% of personal income. Since 1975 savings have decreased from 8% of personal income to 4% of personal income. The consumption area driving the decrease in savings is medical services. **Since 1975 an additional 5.8% of personal income has gone to medical services.**[17] Thus, were it not for major increases in the productivity of goods, rapidly escalating health care costs would have dropped savings to 2.2% of personal income. Alternatively, over 70% of the productivity growth in goods - food, clothing, and gasoline - have been absorbed by increased health care costs.

It is well known that the U.S. population is aging and that the aging population is placing great stress on Medicare, Social Security, and Medicaid. There is a continuum of care that can help provide for the needs of the elderly. These range from home health care, congregate care, assisted living facilities, skilled nursing home facilities, and acute care hospitals. As the elderly move through this hierarchy of services, costs grow. For example, the total monthly cost of assisted living facilities ranges between $1,750 and $2,875; skilled nursing care averages about $4,800 per month, subacute care costs about $14,250 per month, and acute care in a

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[12] The Washington Post National Weekly Edition, "What About Us?", September 23-29, 1996, p. 9.

[13] The Washington Post National Weekly Edition, "Hands Off Social Security and Medicare", April 7, 1997, p. 35.

[14] The Economist, "Growing Old Expensively", September 7, 1996, p. 76.

[15] Lawrence Kotlikoff, John Sabelhaus, and Jagadeesh Gokhale, Understanding the Postwar Decline in US Savings: A Cohort Analysis, Brookings Papers on Economic Activity, 1996, and Steven Pearlstein (The Washington Post), "Study Pins Savings Lapse On Elderly", The Albuquerque Journal, October 5, 1996, p. C6.

[16] Competitiveness Policy Council, Running In Place: Recent Trends in US Living Standards, September, 1996, p. 18.

[17] Business Week, "Solving the Savings Riddle", November 11, 1996, p. 26.

hospital costs about $37,500 per month.[18] Because government supported programs are skewed toward the high cost end of the care spectrum, many of the elderly whose needs could be adequately met by a lower cost option, e.g., assisted living facilities, are encouraged to utilize the highest cost options of skilled nursing homes and hospital care.

Simply reducing the rate at which Medicare costs grow does not address the root cause of the healthcare cost problem. Neither does forcing small businesses to purchase health insurance for their employees. Indeed, the productivity of the entire U.S. health care system must be increased. **Regulations, both government-imposed and professionally-imposed, and government interference with the free market, have removed the economic incentives that drive productivity growth.** Many physicians-imposed regulations to withhold information on physicians' records are in conflict with a free market. Oxford Health Plans is attempting to circumvent the long-standing physicians' practice of withholding medical information from patients by surveying patients to determine their interpretation of the quality of care they received at hospitals and from physicians.[19]

Regulate or deregulate, that is the question.
The healthcare cost issue highlights the failure of government's non-systemic, piecemeal approach to addressing problems in complex systems. The federal government has been unable to make an overall investigation of the U.S. healthcare system and propose a systems-level solution that increases competition, reduces cost, and offers incentives to improve productivity.[20] Instead, it is pursuing a piecemeal[21], incremental, microscopic approach in which Congress is even beginning to specify the number of days of hospitalization each surgical procedure requires.[22] Bills introduced in 1997 include: regulations on health care plans, provisions guaranteeing health care to the estimated 10 million uninsured children, expansion of preventive care including immunizations and routine check-ups, assurance of emergency room care for those that need it, limitations on health care intervention in doctor-patient discussions, and elimination of "drive through" mastectomies.[23]

Temporary lulls in health care spending, as we are currently experiencing, stem from HMO imposed substitution of primary care physicians, statistically-based diagnostic opinions, and chemical therapeutics for medical specialists, technology-based diagnostics, and technology-based therapeutics. Cost savings are resulting from reduced income of medical specialists, not increases in delivery efficiency. Between 1994 and 1995 physicians' annual net income before taxes dropped $8,700 to $186,600 with the reduction being due to diminished income for the highest paid specialists.[24] While HMOs have been hailed as the solution to America's health care cost problem, reduction in specialists' income is largely being offset by hidden administrative costs including the amount of time that patients spend negotiating with their HMO and primary care physicians for referrals. Incredibly, primary care physicians are being rewarded by HMOs for withholding referrals to specialists. Americans are experiencing lower

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[18] Data provided by Vista Del Rio, an ARV Retirement Community located in Albuquerque, NM, administrator, Lois Jean Gover.

[19] Washington Post National Weekly Edition, "Light on Medical Care", April 14, 1997, p. 25.

[20] James Gover, "Systems Modeling: the first step in a process for solving the health care cost problem", presented at IEEE Conference, The Role of Technology in the Cost of Health Care, April 27-29, 1994, paper included in SPIE Proceedings, pp. 388-398.

[21] Elizabeth Teisberg, Michael Porter, and Gregory Brown, Innovation, Information, and Competition: A Lasting Cure for American Health Care, Working paper of the Harvard Business School, February, 1994.

[22] Joan Beck(Chicago Tribune), "Washington Taking Over Health Care Piece by Piece", The Albuquerque Journal, October 2, 1996, p. A10.

[23] The Hill, "Congress to the Rescue", April 9, 1997, p. 15.

[24] Washington Post National Weekly Edition, "Getting Into the Doctor's Pockets", September 9-15, 1996, p. 34.

quality services than they had five years ago with HMOs magnifying rather than attenuating the inefficiencies of America's mom and pop healthcare delivery system.

Productivity growth can only be driven by increased competition among service providers that leads to replacement of many of those working in the health care field with low-cost technology.[25] Some have sought to blame technology for the growth in health care costs. As Teisberg[26] has pointed out to Congress, medical technologies remain costly even when widely diffused because reimbursement to service providers for the use of technology has been based on customary charges that are largely unrelated to the cost of the technology. In today's healthcare system, technology reduces the cost of providing the healthcare service, but may not reduce the charges that are passed on to the recipient of the services. Furthermore, the demand for certain health care services could increase if there were a major decrease in the cost of this service to the consumer. In intensively competitive systems, technology innovation increases productivity, increases quality and reduces costs. In weakly competitive systems such as healthcare and education, technology innovation reduces productivity, increases quality, and increases costs. The path to productivity growth is first competition, then technology innovation. The latter occurs only because it is a necessity for surviving market competition. Productivity growth and quality of service are the result.

Every healthcare regulation that is added aggravates the root cause of all healthcare cost problems - cost escalation driven by zero productivity growth. The solution to the U.S. healthcare problem will require a combination of skills in economics, business, political science, systems modeling, and technology, particularly information technology, integrated preventive diagnostics, minimally invasive therapies, imaging technology, preventive medicine and incentives programs, and rehabilitation science and assistive technologies[27], that **forces** major changes in the healthcare delivery process.

Technology, not pills, is the cure.

Coates, Mahaffie, and Hines project that by the year 2025,

The health care debate of the late 1990s gave unexpected impetus to the automated medical center. Based on the work of Project Caduceus, there was the now-popular proliferation of shopping mall and work-site health centers. These are expert systems tied to physical equipment. Typically, the way the earliest versions worked, a person walked into the center, was greeted electronically, asked to urinate into a bottle, spit into a test tube, puncture the skin to get a blood droplet for the slide, and place each of the containers into the appropriate receptacles. While the samples were being processed, the person sat at the Caduceus and engaged in a medical dialogue. Effectively Caduceus did everything that a physician at that time did on the first two visits, including presenting alternative diagnoses, the need for further tests, and the subsequent diagnosis on the completion of the tests.[28]

The only disagreement we have with this prediction is we think that it will be unnecessary to puncture the skin.

C. The Regulatory Problem:

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[25] Joseph Bronzino and James Gover, "Medical Technology: A Solution to the Health Care Cost Problem", IEEE Engineering in Medicine and Science Magazine, June 1994.

[26] Elizabeth Olmstead Teisberg, "INNOVATION: The Key to Reducing Costs of High Quality Health Care", testimony for the U.S. House of Representatives Committee on Science, Space, and Technology Subcommittee on Technology, Environment, and Aviation, March 17, 1994.

[27] Samuel Varnado, Bryon Cloer, and Donald Wesenberg, The Role of Technology in Reducing Health Care Costs, Sandia National Laboratories Report, SAND 60-2469, November, 1996.

[28] Joseph F. Coates, John B. Mahaffie, and Andy Hines, 2025: Scenarios of U.S. and Global Security Reshaped by Science and Technology, Oakhill Press, 1997, p. 54.

Various estimates of the cost of regulations range between $500 billion and $800 billion per year. Of course, these costs are passed from companies to the consuming public. Some propose that regulations average adding $6,000 to the annual family tax burden[29]; others conservatively estimate that federal regulations in 1995 cost Americans $654 billion (47% of the federal budget) or cost the average American family $7,000 in comparison to $6,000 per family for taxes.[30] The IRS estimates that it's services costs taxpayers an additional $8.35 for every $100 collected in taxes. The compliance cost of the income tax is $157 billion with about two-thirds of these costs paid by businesses, the rest by individuals.[31]

There are many federal regulations ranging from financing issues to environmental issues that affect industry. In the absence of quantitative knowledge, these regulations are qualitatively developed by subjective means on a regulation-by-regulation basis by forging compromise between competing political forces. For example, environmental policies have been determined through political compromise between those in the environmental movement who want them to be more rigid and those in industry who want them to be relaxed.

It has been noted that regulator behavior can be influenced by the career goals of bureaucrats and this can lead to regulator capture by the interests of those regulated (this usually means less regulation) or regulator behavior can be driven by the desire of officials to expand their agency's purview or its budget (this usually means more regulation).[32] Porter explains,

> *Regulation itself is thought to result eventually in inefficient outcomes, rather than just income redistribution toward politically powerful groups, because of bargaining and other transaction costs incumbent in the process of regulatory reform. Even when an initial set of regulations is efficient, the inertia of the regulatory process will ultimately lead to inefficiencies, and the coalition building necessary for reform will occur only when these inefficiencies are extreme.*[33]

Because of the economic impact of regulations, it is extremely important that they be optimized for public and private good with great attention focused on economics. Political processes, taken alone, are unlikely to find this elusive optimum. In fact, one can cite obvious flaws that the political process introduces into the development of regulations. In some cases U.S. regulatory costs are compared to those of other nations on a regulation-by-regulation basis and differences that disadvantage U.S. industry are addressed by our political system. The converse is also practiced. For example, the fact that gasoline costs are much less in the U.S. than in Japan is sometimes used to support the argument that the U.S. should increase taxes on gasoline. The fact that corporate income taxes in the U.S. are much less than in Japan or Germany is used to justify increasing corporate income tax or not reducing capital gains tax rates. The fact that wages are less in the U.S. than in Japan or Germany is used to support increasing the minimum wage.

If U.S. companies in a particular sector are losing market share to foreign competitors, one response of government could be to offer some form of tax relief, e.g., allow an acceleration of equipment depreciation schedules or multiple deductions for R&D expenditures. The political solution can be based simply on recognition that the system isn't working as well as expected; therefore, provide regulatory relief. If that doesn't work, more regulatory relief can

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[29] Testimony of Jerry Jasinowski at Hearing on Risk Assessment and Cost Benefit Analysis, before the Committee on Science, U.S. House of Representatives, February 3, 1995, p. 3.

[30] The Economist, "Over-Regulating America: Tomorrow's Economic Argument", July 27, 1996, p. 19.

[31] Investor's Business Daily, "Hidden Costs of the Tax Code", April 14, 1997, p. A1.

[32] Roger G. Noll, "Economic Perspectives on the Politics of Regulation", in Handbook of Industrial Organization, Volume II, edited by Richard Schmalensee and Robert D. Willig, Elsevier Science Publishers, 1989.

[33] Robert H. Porter, "A Review Essay on Handbook of Industrial Organization", Journal of Economic Literature, Vol. XXIX, June 1991, p. 568.

be offered, perhaps in another area. The response of the political system to regulatory issues is analogous to the empirical control of a system in which algorithms linking output to controlled parameters aren't available. In response to political pressures, simply make a change, usually an incremental change, and see what happens. In engineering this is sometimes called, "cut and try". However, the "cut and try" method can either miss the target entirely or it can be gamed by those affected by the regulation.

Recognition that the U.S. regulatory process is in need of reform is widespread. At a CEO summit meeting hosted by Bill Gates, the keynote speaker, Vice President Gore, told executives that the U.S. must prepare for the new global economy with a new appreciation for the key role of innovation. He emphasized, however, that this doesn't mean slashing government regulations, but making regulations flexible.[34]

Think systems.
Assurance that U.S. businesses are not disadvantaged in international competition and that the U.S. is a favored site for all corporations demands a systems approach to regulatory policy development. Federal regulatory policies that affect industry must be collectively reformed so that no other nation is a more attractive site for the location of manufacturing and services facilities than the U.S. Industry will locate facilities in the U.S. only if it is comparatively advantageous. To understand the costs and advantages of regulations we must be able to fully analyze how systems are impacted by new regulations and be able to predict how those affected by a new regulation will respond.

Regulatory practices must be adjusted

- to favor the U.S. over other international alternatives when companies are choosing the location for new manufacturing and services facilities,
- to encourage industries to continue operating manufacturing facilities in the U.S., even after competition is dominated by the need to improve products and processes or the product has entered a commodity phase, and
- to favor the competitiveness of U.S. companies in international markets, regardless of where they manufacture their products.

To achieve these adjustments, the regulatory process must be reformed.

- The cost of regulations on businesses located in the U.S. and in nations that are primary competitors of the U.S. must be modeled and integrated with other cost models so that the cost of locating businesses in the U.S. can be quantitatively compared to other international alternatives.
- Restrictions must be added so that no new regulation can be passed into law until the cost of the regulation is estimated by this model; the overall economic impact is estimated; and in the event that the regulation has great public value, other areas of corporate regulatory relief identified so that National economic growth is preserved.
- We must be able to assess in advance how those affected by the regulation will react to it - will they "game" (i.e., get around) the regulation or will the regulation close the company and remove critical jobs from the economy?
- In order to avoid the "fox in the chicken house syndrome", agency-level regulatory bodies were created and tasked to only enforce regulations. Since the Atomic Energy Commission was removed because it filled both regulatory and advocacy functions, regulatory enforcement bodies have no advocacy or problem-solving role to play for

[34] USA Today, "Gates Pitches Paperless Office", May 8, 1997, p. 3B.

those being regulated. Such bodies can only err by under-enforcement; therefore, they tend to be risk-averse and over-enforce and their style is often perceived to be petulant and punitive.

By emphasizing violations rather than problems, regulation creates bitterness and adversariness. Everything must be put on the record. Businesses will not share information. A culture of resistance sets in.[35]

The U.S. regulatory process is piecemeal and Congress often changes the rules of the game in midstream. Consequently, regulations sometimes combine with other factors and have unanticipated effects, **but the *public outcome* is always the same - companies raise prices and the public pays for them.** Weaknesses in the regulatory development process often lead to regulations whose public costs exceed their public benefits. Even though regulations are based on compromise among those with a stake in the regulations, today's processes rarely lead to win-win solutions that stakeholders support. An improved process that promotes buy-in by all of those affected by regulations is needed. Cost/benefit analyses performed by "honest-brokers" with no particular stake in the regulatory debate can be combined with the war game process to introduce and test major improvements in the regulatory process.

D. The Infrastructure Problem

The U.S. infrastructure is a complex system of interdependent elements whose combined operation is vital to the security and well being of the U.S. The three primary elements of the U.S. infrastructure are telecommunications, transportation, and the power grid. With a few exceptions (Tennessee Valley Authority and Bonneville Power Administration) the telecommunications and power grid infrastructure elements are privately owned; the public has no responsibility their operation and maintenance. The transportation element is largely privately owned; an exception is highways and bridges which are publicly owned. Therefore, the public has responsibility for building and maintaining highways and bridges. However, because the U.S. infrastructure is vital to the economic security of our Nation, the public shares responsibility with the private sector for protecting the infrastructure against those that might threaten its existence.

a. Transportation Infrastructure Construction, Maintenance, and Safety. The U.S. has over 175 million passenger cars and light trucks that annually travel more than 2 billion miles over 3.9 million miles of public roads. Only 161,000 miles of these roads are part of the national highway system (NHS), but 40 percent of all highway travel, 75 percent of freight, and 80 percent of vacation travel are on the NHS. (The Interstate Highway system is part of the NHS. Interstates make up 1.2 percent of U.S. road mileage, but carry 23 percent of all traffic and 48 percent of all truck traffic.[36])

America's transportation infrastructure is congested, it is slowly deteriorating, and it is in need of repair and improvement. Traffic jams are thought to cost Americans $80 billion a year in lost time.[37] The Federal Highway Administration (FHA) has determined that 28 percent of U.S. roads are in poor to mediocre condition and 32 percent of the Nation's bridges are deficient.[38] Over 12,000 of the 42,000 annual highway deaths are believed to result from poorly designed roads, roads whose automobile capacity exceeds design limits, and roads that are inadequately maintained.[39] Highway vehicle accidents are estimated to annually cost $150 billion with about one-third of this being property damage.

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[35] Philip K. Howard, The Death of Common Sense: How Law Is Suffocating America, G. K. Hall & Co., 1994, p. 69.

[36] Keep America Moving, The Federal Highway Program and the States, 1997.

[37] Paul Krugman, Development, Geography, and Economic Theory, MIT Press, 1996.

[38] Federal Highway Administration, Conditions and Performance Report, November, 1995.

[39] Keep America Moving, How Much Funding for Highways?, 1997.

Of the $31.5 billion the federal government collects in motor fuel taxes, less than $20 billion is actually spent on maintaining and building roads and bridges. When state, local, and federal taxes on motorists are added, the total transportation tax comes to $142 billion each year. This includes $60 billion in motor fuel taxes, $23 billion in license and registration fees, $5 billion in tolls, and $55 billion in motor vehicle sales taxes, vehicle property taxes, and miscellaneous taxes levied on motorists. Of this total collected, expenditures on roads are $82 billion. These include $42 billion on capital outlays, $24 billion on maintenance and traffic services, $8.4 billion on administration and research, and $8 billion on law enforcement and safety.[40] Because of the lack of incentives for highway and bridge construction companies to invest in construction R&D, there is very little private investment in bridge and highway R&D.

The American Society of Civil Engineers (ASCE) estimates that we are underinvesting in our roads, bridges, and transit systems by $18.2 billion annually to maintain current conditions, and $42.3 billion to improve conditions and performance. ASCE calculates that driving on roads in need of repair costs American motorists $23.7 billion a year in extra vehicle repairs and operating costs.[41]

It has become increasingly difficult to set aside funds to support the testing and evaluation of new highway technologies (for example, seismic isolation and dissipation devices, high performance concrete and steel, bonding agents for pothole repairs, a heated pavement system, a high retroreflectivity traffic sign system, and a precast segmental overpass system[42]) that increase the lifetime and reduce the cost of highway maintenance. Regulatory barriers inhibit the introduction of new, proprietary technology into surface transportation systems.

A systems solution that minimizes long-term maintenance and upkeep costs is required for our highway system. The Rebuild America Coalition estimates that as much as $1.1 trillion is needed over the next 15 years to provide a minimally satisfactory public works infrastructure. Others estimate the annual aggregated construction, maintenance, and repair costs of infrastructure to be over $100 billion. About $10 billion is required per year to meet regulatory requirements for water systems. In addition to highway infrastructure needs, U .S. air traffic grows about 50% each decade.[43]

U.S. transportation systems have long:

- emphasized autonomy of the individual (Between 1980 and 1990 the percentage of people driving to work alone increased from 64 percent to almost 73 percent; the growth rate of registered vehicles was twice the population growth rate; and the growth rate of miles driven was four times the population growth rate.),

- under emphasized public transportation (Despite numerous attempts by government to promote mass transit systems, less than 3 percent of surface travel occurs on mass transit and most of that is on highways for school and bus transit. Not a single U.S. mass transit system collects user fees that cover even half of its capital and operating costs and few mass transit systems provide the suburb to suburb transportation needs of working Americans. New rail systems typically require operating subsidies between 50 percent and 90 percent of operating costs and capital subsidies of 100 percent. Mass transit transportation costs about 60 cents per passenger mile. Approximately 20 cents of this is paid by fares and 40 cents comes from government subsidies. Amtrak costs about 30 cents per passenger mile. Approximately 15 cents comes from fares and 15 cents is paid by government subsidies. [44]), and

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[40] Keep America Moving, Highway Users Fees and Taxation, 1997.

[41] Ibid.

[42] Dr. C. Michael Walton, American Society of Civil Engineers, testimony before the Subcommittee on Technology of the Committee on Science, United States House of Representatives, April 23, 1997.

[43] Data were provided by Dr. Will Kirksey, Vice-President, CERF, Washington, DC.

[44] Keep America Moving, Subsidizing Mass Transit, Amtrak and High-Speed Rail, 1997.

- maximized fuel inefficiency and air pollution. (Ridesharing, including carpooling and vanpooling, is 70 percent more fuel efficient than heavy rail or Amtrak, is 80 percent more fuel efficient than light rail and is even slightly more fuel efficient than intracity buses.)

This entire area is in need of systemic research that identifies options for the future, estimates the costs and benefits of these various options and lays out research roadmaps for realizing the preferred options.

b. Protecting the U.S. Infrastructure Against Threats. In January of 1997 a task force of The Defense Science Board (DSB) expressed concern that it is possible for an adversary to mount a structured offensive against the U.S. infrastructure, while disguising the attack. This task force issued an urgent report warning that the U.S. computer systems network is so vulnerable to malicious assaults that we may one day face "an electronic Pearl Harbor". Examples of catastrophe include: Wall Street computer screens go blank during an especially busy trading day. Automobile manufacturing lines are brought to a halt due to a programmed power outage. Air traffic control systems bring airliners in to land on a crowded Los Angeles runway where planes are taking off in the opposite direction. All of the bank accounts are emptied throughout a major city.

These are not just make believe attacks. Actual attacks have the potential for even greater consequences. In 1989 cyber thieves placed logic bombs in public telephone networks in Atlanta, Denver, and Newark. In 1995, 60,000 calling card numbers were stolen by cyber thieves. In 1994, a Russian crime ring stole $12 million by gaining access to Citibank computers. During the Gulf War a group of teenagers in the Netherlands gained access to computer files at 34 American military Internet sites and identified the exact location of U.S. troops and identified their weapons.[45]

> *Waging the domestic version of what security experts call "infowar" means applying computer viruses, hidden codes, data-destroying software programs and other electronic mechanisms that could, among other things, halt the operations of electric power grids, natural gas pipelines, railroad switching facilities and air traffic control systems. Infowarriers could also scramble the software used by bands, hospitals and emergency services, and break down telephone and other telecommunications networks.*[46]

Vamado has pointed out that there are many interdependencies between elements of the U.S. infrastructure. For example, an extended power outage could lead to computers' emergency power supplies being extended beyond their service life. Failure of the computers that control the power grid could further compound the severity of the power grid failure that initiated the computer failure. Thus failures can propagate through the infrastructure network. Varnado recommends that these infrastructure dependencies be modeled.[47]

An attack on the U.S. information infrastructure might be disguised as a series of apparently unstructured, random events that appear to be the uncoordinated work of hackers or splinter terrorists groups. Despite the difficulty in providing a specific definition of just exactly what constitutes a cyber attack, it is particularly important that the U.S. be able to detect cyber threats when they occur.[48] It is clear that we need to model the infrastructure, provide for the

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[45] Graeme Browning, "Counting Down", National Journal, April 19, 1997, p. 746.

[46] Ibid.

[47] Dr. Sam Varnado, Modeling Interdependencies in the U.S. Infrastructure, 1997 white paper provided to James Gover.

[48] Dr. Sam Varnado, Assessment of the Feasibility of Developing an Indications and Warning System to Protect Critical U.S. Infrastructures, an unpublished white paper, 1997, provided to James Gover.

early detection of infrastructure failures, and develop a consequence-based identification of critical nodes in the infrastructure network.[49]

D. Defense Spending May Be Misaligned With U.S. Foreign Policy Objectives.

a. Introduction. We are uncertain that a federal budget of 3.8% of GDP for National security (down from over 6% of GDP in one decade) and a defense R&D budget projected to decrease by 17.6% by CY2002 will support U.S. foreign policy objectives. We are particularly concerned that the U.S. defense investment, including the R&D investment, is inadequate to properly address emerging international and National threats. (For comparison, pacifist Japan spends 1.6%, Russia spends 7.4%, France spends 3.1%, Britain spends 3.1%, and China spends 5.7%. This year China increased defense spending by 12.7%.[50] Absolute comparisons for 1995 defense spending reveals that the U.S. spent $278 billion, NATO Europe spent $187 billion, Russia spent $82 billion, Japan spent $50 billion, China spent $32 billion, and non-NATO Europe spent $31 billion.[51]) Emerging threats include terrorism; international crime cartels; nuclear, chemical, and biological weapons proliferation; regional conflicts arising from multipolar distribution of regional power; the rise of China as an international economic and military power; border control; civil unrest; rising nationalism around the world; proliferation of drugs; religious and cultural conflicts; force readiness; assuring access to foreign oil; and rapid force deployment. We are also concerned that increased reliance of U.S. military systems on commercial technology could eventually lead to U.S. military systems not being technologically differentiated from those of future adversaries.

The Congressional Research Service reports,

> *Beginning in mid-1991, the United States became increasingly cautious, self-deterred, or self-restrained, reticent to use and consequently less able to threaten credibly the use of military force to support its foreign policy objectives.*[52]

The Harvard defense scholar, Huntington, points out that Desert Storm utilized a substantial part of the U.S. military capabilities - capabilities that are sure to decrease as military spending is reduced,

> *To defeat Iraq, the United States deployed in the Persian Gulf 75% of its active tactical aircraft, 42% of its modern battle tanks, 46% of its aircraft carriers, 37% of its army personnel, and 46% of its marine personnel. With significantly reduced forces in the future, the United States will be hard put to carry out one intervention, much less two, against substantial regional powers outside the Western Hemisphere.*[53]

b. Post-Cold War Landscape. While many have hoped for a peace dividend to result from the end of the Cold War, in retrospect, this was naive and a reflection of Americans' unbounded optimism for both world events and domestic issues. First, entitlement increases, especially Medicare, and budget deficit reduction have more than absorbed the post Cold War cuts in U.S. defense spending. Second, peace is not breaking out around the world. Defense scholars seem to agree that the bipolar distribution of power that prevailed during the Cold War was more stable than today's internationally unipolar, regionally multipolar

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[49] Dr. Sam Varnado, Consequence Based Rationale for an Infrastructure Assurance Program, 1997, provided to James Gover.

[50] The Economist, "The Real Cost of Japanese Defence", October 12, 1996, p. 38.

[51] The Washington Post, "Pentagon's Plan for Future Draws Heavily from Cold War Past", May 11, 1997, p. A19.

[52] Stanley R. Sloan, Foreign Affairs and National Defense Division, Congressional Research Service, The United States and the Use of Force in the Post-Cold War World: Away from Self-Deterrence?, January 6, 1997.

[53] Samuel P. Huntington, The Clash of Civilizations and the Remaking of World Order, Simon and Schuster, 1996, p. 90.

distribution of power. Should the unipolar power, the U.S., lose its will to retain its international leadership role, world military power will be entirely multipolar, it will be regionally distributed, and it will be highly unstable. If the military leadership of the U.S. is slowly diminished, we can expect increased frequency of regional conflicts such as that between Iraq and Kuwait.

Huntington explains that for the first time in history, global politics is both multipolar and multicivilizational, with cultural divisions, rather than economic, ideological, or political distinctions, framing the principal post-Cold War identity of civilizations. He argues that the hot spots in world politics are on the "fault lines" between the 7 or 8 major civilizations of the world. Since religion is the principal defining characteristic of civilizations - the most profound difference that can exist between people, Huntington concludes that fault-line wars are almost always between peoples of different religions.[54]

Russia is interpreting the eastward expansion of NATO as a threat and Russia and the Ukraine are having difficulty resolving control of Crimea and both are finding themselves involved in the conflict between Azerbaijan and Armenia. Azerbaijan claims Russia is funneling heavy arms to Armenia through Iran, and Armenia claims the Ukraine is helping Azerbaijan build up its tank forces. Azerbaijan also charges that Russia is trying to undermine its government in the hope it can influence a new one to be more amenable to Moscow.

c. Diffusion of Military Technology. While Desert Storm illustrated the technological advantages of U.S. military technology, as military technology becomes increasingly dependent on commercial technology, especially information technology, it will become easier for advanced military technology to diffuse around the world. Alvin and Heide Toffler have noted,

> *Even as politicians and the media in various nations extol the blessing of conversion of military technology to civilian uses, a far more extensive counter-process is converting civilian industries to wartime capabilities. This civilianization is the real conversion. Civilianization will soon give fearsome military capabilities to some of the smallest, poorest, and worst-governed nations on earth.*[55]

In looking to the future, some are proposing that the U.S. has the ability to strengthen its position as the unipolar power of the world. It is predicted that war fighting is in the early stage of a revolution that is based on the application of information technology - ground surveillance satellites; satellite-controlled cruise missiles; long-range, precision targeting; digital data compression for transmission and processing intelligence data; encryption and deencryption; and un-manned, supersonic aircraft - and the integration of many of these with stealth technology. It is argued that the U.S. is better positioned to develop these systems than any other country.

If the U.S. defense budget is to be reduced, personnel reduction is a necessity. Current plans call for additional reductions of 62,000 active-duty military personnel, 54,000 reserve duty military personnel, and 80,000 civilian DoD personnel. These cuts will leave the U.S. with 1.44 million active duty military personnel, the lowest troop level since 1950, just prior to the Korean war. In addition, another round of military base closures are being discussed with implementation sought for around the turn of the century.[56] In addition, the U.S. military is likely to outsource all support services that are not a direct part of war-fighting. Fighting force reductions increase reliance on information technology. Therefore, budget pressures can force the U.S. to accelerate its pursuit of the information technology defense path or alternatively,

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[54]Huntington, pp. 20-21, 254-255.

[55]Alvin and Heidi Toffler, War and Anti-War, Little, Brown and Company (1993) from a digest by Darinne Gordon and Robert Rinne, November, 1995, p. 28.

[56] The Washington Post, "Pentagon's Plan for Future Draws Heavily from Cold War Past", May 11, 1997, p. 19.

increase its reliance on nuclear weapons. Economic considerations are as likely to shape nation's selections of defense technology as their ideological preferences.

The information technology-based military revolution can greatly expand American power in the years ahead but this technology favors offense over defense. For example, the vulnerability of space-based information technology assets to nuclear weapon blasts that "pump-up" the Van Allen belts[57] could encourage a preemptive first strike against emerging potential threats.[58] Ironically, nations unable to compete in this high-tech, information-rich, conventional weapons arena may increase their reliance on terrorism and development of weapons of mass destruction - biological, chemical and nuclear weapons - to support their military operations. However, diffusion of information technology also creates new threats for U.S. security.

The Santa Fe Institute (SFI) is an aggregation of some of the most creative, interdisciplinary thinkers in the U.S., if not the world. It pulled together a group of 40 military experts, futurists, information technology experts, historians and science fiction writers to create scenarios U.S. security may face in the future. Their goal was to understand how our National security system will need to change to cope with realities of the period 2010-2015 that may result from the diffusion of information technology. They noted that there is a danger that the U.S. will be so busy fighting traditional competitors playing an old game, that it will fail to see the entire new playing field being created through the diffusion of information technology. The defense guru, Richard Perle remarked,

> *For the contingencies the United States is likely to face, a smaller, agile and more technologically advanced military would serve us best, but instead, there's been a tendency to overestimate the risk of some conflicts and exaggerate the amount of military force needed, resulting in inappropriately large heavy forces that lead to greater vulnerability, not less.*[59]

In The Santa Fe Institute's **most conservative scenario**, "Rule of Law: The Status Quo", nation states were assumed to remain the dominant actors. In this scenario it was determined that the dominant nation states face three very different kinds of threats[60]:

- **Threats from other nation states.** Examples include the total collapse of Russia, Saudi Arabia becomes the next Iran, and a Sino-Japanese alliance. Because information technology empowers smaller states and reduces the military advantage of a large population, threats could also arise from countries with advanced capabilities in information technology. Information technology also changes the nature of threats by creating new vulnerabilities and creating new domains for conflict.

- **Threats from criminal transnational organizations.** Examples include the Colombian drug cartel, Chinese triads and pirates, and terrorist organizations. It was recently reported[61] that Miami, Florida, has become a beachhead for the Russian Mafiosi as well as organized crime gangs from Jamaica, Columbia, and Italy. Russian gangs are located in 24 U.S. cities and are suspected of drug-running, prostitution, extortion, money-laundering, bank frauds, illegal arms sales - including sale of a Russian submarine complete with 62 man crew. Information technology advantages

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[57] James E. Gover and John S. Browning, Radiation-Hardening Systems Considerations: Electrical Systems and Radiation Environments, SAND86-1737.UC-2, March 1987, pp. 45-53.

[58] The Economist, "The Future of Warfare", March 8, 1997, p. 21.

[59] The Washington Post, "Pentagon's Plan for Future Draws Heavily From Cold War Past", May 11, 1997, p. A19.

[60] Katherine Fulton and Peter Schwartz, Global Business Network, Emeryville, CA, The Highlands Forum, 1996, Scenarios: Conflict in the Information Age, Santa Fe Institute, New Mexico, August 12-14, 1996.

[61] The Economist, Redfellas: Organized Crime, March 15, 1997, p. 31.

these groups over nation states by increasing their communications while hidden from physical view and by improving the effectiveness of their operations.

- **Threats from disordered people, self-organizing in new ways.** Examples include massive movements of refugees, terrorism, and weapons of mass destruction in the wrong hands. Self-organization will occur in response to increasing chaos deriving from demographic, environmental, political, and economic shifts and it will be aided by information technology.

A key objective of warfare is to disable the economy of an opponent. As computers around the world in governments, corporations, and banks become networked, the potential for direct economic intervention in nations' economies through electronics sabotage will grow. Most of these systems maintain rudimentary security systems and/or "firewalls", but even clever students have found ways to circumvent these protection devices. The global information system invites offensive and defensive national teams to threaten or even worse, make subtle changes in critical data the adversary does not recognize. Measure and counter-measure studies demand the U.S. maintain its lead in information/communications technology and recognize that it make provision for unanticipated events by burying software bombs or hardware flaws in programs, operating systems, or central processing units to be selectively activated upon command.

d. Proliferation of Weapons of Mass Destruction. Weapons of mass destruction include chemical weapons, biological weapons, and nuclear weapons. It has been reported that Russia has developed a variant of the anthrax toxin that is totally resistant to antibiotics. Russian military research laboratories are also thought to have developed three new nerve agents. In a chilling commentary, Jane's said such biological weapons in the hands of a rogue nation with a delivery system could produce a situation whereby the only reliable retribution may well be overwhelming nuclear response.[62]

Yonaspoints out,

> *As nation states, cultures, and religions around the world rally in opposition to the changing world perceived to be threatening to them, they will revitalize their old values. America will increasingly be identified as the cause of upheaval - the destroyer of the status quo - the marketer of unwelcome values. Perceived as the rich nation, the disrupter of order and the change agent, we will become the nation advocates of the status quo love to hate. The seeds of terrorism will have been planted and terrorists will have access to the fertilizer - weapons of mass destruction - needed to perfect their trade. We are not prepared for the consequences![63]*

A former UN investigator, Raymond Zilinskas, says Iraq could reassemble its germ warfare program within six months with a still-intact scientific team working with freeze-dried organisms. The 200-person workforce of Iraq's biological warfare program is intact and its 80 research and production facilities are "whole and well equipped." Zilinskas was a member of the UN team overseeing the scrapping of Iraq's weapons of mass destruction under terms of the 1991 Gulf War cease-fire. Unlike nuclear weapons whose proliferation is driven by the abailability of fissile material, it is generally thought that biological and chemical weapons would be much more easily proliferated and could be developed as "garage shop" operations. Some have argued that the only way to detect biological weapons is to look for deaths of animal species.

Aviation Week and Space Technology recently reported that Sandia Labs has developed a prototype space-based ultraviolet fluorescent laser and detector[64] system under the Energy

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[62] Jane's Land Based Air Defense, 1997-98.

[63] Gerold Yonas, "EMERGING THREATS: International Terrorism and Security Issues", presentation to Alaska World Council, Sept. 5, 1997.

[64] Aviation Week & Space Technology, "Upgrades Offer New Mission Options" August 4, 1997.

Dept.'s Caliope program. Researchers have identified biological species floating in the air at more than 11 miles. Genetic algorithms analyze returning light and so far have recognized e. coli, streptococcus and, in the lab, anthrax. The laser also has been used to look at smoke and other effluents from factories to discover what might be manufactured inside. The Caliope program is aimed at developing systems that can be fitted to satellites and UAVs.

As was pointed out in an analysis by Jane's, nuclear weapons are thought to be the most credible deterrent against the use of biological weapons. If a cache of biological weapons were attacked by a weapon using conventional explosives, the biological agents would be dispersed with some air borne. Attack by a nuclear weapon can change the chemistry of the biological agents through extreme temperatures, ionization, and nuclear transmutation.

Scholars generally agree that avoiding nuclear weapon proliferation in Asia is dependent on a strong U.S. military presence. Should U.S.-Japan relations deteriorate, a domino-like propagation of nuclear weapons in Asia is predicted.

> *Deprived of America's nuclear shield, Japan would develop its own nuclear weapons to stay even with China. South Korea which has been invaded by both Japan and China in the past would shortly follow. So might the more sophisticated South-East Asian states, whose military budgets are already growing rapidly. Pretty soon, the whole region would be nuclear and nervous.*[65],

Concern for the proliferation of weapons of mass destruction has grown, not diminished since the end of the Cold War. The Washington Post reported[66],

> *While the breakup of the Soviet Union in 1991 reduced the threat of a deliberate nuclear attack, the risk of a breakdown in the control of those nuclear weapons actually has grown since then.*

It has been reported that it takes about 15 kg of highly enriched uranium or about half that amount of plutonium to make a nuclear bomb. One kilogram of uranium or plutonium is about the size of a golf ball. Russia has stockpiled 200 tons of plutonium and 1,200 tons of highly enriched uranium. Each year about 15 tons of plutonium and 45 tons of highly enriched uranium shift from the relatively secure custody of Russia's Ministry of Defense to the less certain control of Minatom, the civilian ministry that controls Russia's nuclear industry.[67] There is concern that some of this material could be diverted to a rogue nation that would build and use a nuclear weapon for terrorist purposes. The risk of nuclear terrorism or accidents in Russia's nuclear industry is becoming greater because of the Russian Atomic Energy Ministry's plans to use excess weapons-grade plutonium as fuel at nuclear power stations. Nuclear explosive devices can be made from spent nuclear fuel and such devices can be compact enough to transport in an ordinary truck, making their detection by police or other officials very difficult. Although other Russian military officials dispute this bleak assessment, Russian Defense Minister Igor Rodionov remarked in February that Russia may soon approach a threshold beyond which its missiles and nuclear weapons systems become uncontrollable. Mr. Rodionov is now unemployed.[68]

The government of Russia is slowly losing its ability to interfere in the scenario described above. Amaud de Borchgrave has pointed out that Russia has 5,700 Mafia gangs with

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[65] The Economist, "America and Japan: Friends in Need", April 13, 1996, p. 17.

[66] Bruce G. Blair, "Whose Finger Is on The Trigger?", The Washington Post National Weekly Edition, October 7-13, 1996, p. 21.

[67] The Economist, "Costing a Bomb", January 4, 1997, pp. 30-31.

[68] Andrew Khalip, "Sacked Russia Minister Draws Gloomy Army Picture", May 29, 1997, Reuter Wire Services.

100,000 members that are supported by 3 million workers who are responsible for 35% of Russia's GDP.[69] Claire Sterling reported on the deterioration of government in Russia,

> *What we are seeing in Russia is a shared monopoly of power between politicians and crooks, and the system works to their mutual advantage. ... Russian organized crime produces nothing, invests nothing, and is not interested in developing any form of production or any means of furthering the economic welfare of the country. As soon as it makes money, it sends the money out of the country ... this country is being systematically plundered, ransacked by a criminal class working directly in hand with the political forces running the country, to the total detriment of the society it exploits. ... I think that Western authorities generally, and the United States very much in particular, bear a very grave responsibility for the extraordinary exponential growth of organized crime in Russia and its spread outside of Russia by the shortsightedness and lack of attention that has been paid to this subject.*[70]

Peter Grinenko observed,

> *In Russia, you have a whole different society. ... You have 70 years of communism; it definitely warped the way people think there. .. Peter the Great imported culture, he did not import ethics. ... there is absolutely no support for law enforcement. The people do not trust law enforcement. For it to improve will take decades. ... Pre-coup, the government kind of ran the criminals. After-coup, the criminals are kind of running the government. ... What you have got to be concerned about is that woman that works in there [at a nuclear facility] for her $12 a month and she has got three kids to feed. ... she is going to take it and she is going to figure out a way of selling it [nuclear material] to feed her kids. That is the danger.*[71]

Yonas has explained,

> *Cold War Russia is being replaced by a Russia slipping into despair, and lawlessness. I neither expected nor hoped for such an outcome from the Cold War. Our Nation's post Cold War goal was to shift the balance of terror that prevailed during the Cold War to a balance of mutual security based on a focus on protection rather than a reliance on threat of destruction. We believed we could prevail in a technology race, and we would persuade the Soviets, even if we had to do that coercively, to join us in a transition away from a military strategy based on the threat of nuclear retaliation. As it turned out, we were wildly successful compared to anything we might have hoped for, but the outcome was not what we expected. ... Now we are so worried about loose nukes and migration of Russian weapons scientists to the rogue nations, that we are expanding our efforts to help Russia with cooperative programs to destroy their nuclear weapons or greatly improve their protection of those weapons, and to work cooperatively with Russian scientists on non weapons programs. This proliferation threat stemming from the collapse of the Soviet Union is the basis of the most serious threat we face, namely the spreading of biological, chemical, and nuclear weapons throughout the world.*[72]

The first Strategic Arms Reduction Treaty (SALT I) was signed in 1991. SALT I, when fully implemented will have reduced the number of strategic warheads deployed by the U.S. and Russia to about 8,000 warheads each. START II, if ratified by Russia, would further reduce

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[69] Arnaud de Borchgrave comments in Global Organized Crime: The New Empire of Evil, Center for Strategic and International Studies, 1994, p. 106.

[70] Claire Sterling, "Containing the New Criminal Nomenklatura", in Global Organized Crime: The New Empire of Evil, Center for Strategic and International Studies, 1994, pp. 106-128.

[71] Peter Grinenko comments in Global Organized Crime: The New Empire of Evil, Center for Strategic and International Studies, 1994, p.111-114.

[72] Gerold Yonas, "EMERGING THREATS: International Terrorism and Security Issues", presentation to Alaska World Council, Sept. 5, 1997.

the number of strategic warheads to the 3,000 to 3,500 range. START III, still in the formulation stage, would reduce the number of warheads to the 2,000 to 2,500 range.[73] The Canberra Commission, former General Butler, and others have recommended total nuclear disarmament. U.S. advocates of zero nuclear weapons cite the dangers of accidental, erroneous, or unauthorized use of nuclear weapons. U.S. advocates of U.S. retention of nuclear weapons cite their value in deterring threats from nuclear, chemical, and biological weapons; note that Russia has broken their pledges to discontinue its chemical and biological weapons programs; and point out that full verification of treaty conformance is impossible (Undeclared and undetected nuclear stockpiles and production facilities are possibilities.).[74] What few are discussing is the utility of arms treaties with a nation-state that is under the control of organized crime.

In addition to the possibility of international proliferation of nuclear weapon materials, there is concern over the proliferation of ballistic missiles that could carry a nuclear, chemical or biological warhead. Britain's Lancaster University estimates that 35 non-NATO countries have ballistic missiles and that 18 non-NATO countries are capable of installing either nuclear, biological or chemical warheads on these missiles. North Korea, with financing from Iran, is thought to be developing a two-stage missile, the Taepo Dong 2, with a range between 2,500 and 4,000 miles.[75] General John Tilelli, senior U.S. military commander in Korea, told members of the Senate Armed Services Committee his top priority is adequate missile defenses to protect U.S. and South Korean forces from attack by the North. He said defenses right now are inadequate to meet the ballistic missile threat posed by Pyongyang. The U.S. has about 37,000 troops stationed in South Korea.

Russia's withdrawal from Afghanistan and its difficulties in resolving the uprising in Chechna have prompted news media around the world to speculate on the diminished capabilities of Russia's conventional military forces. **Ironically, as Russia's conventional force capabilities are reduced, they will increasing rely on their nuclear weapons as a deterrent against conventional threats Russia perceives from China, Western Europe, and former Soviet republics.**[76] Russia's reluctance to ratify the START II treaty and reduce their nuclear weapons cache to 3,500 may be evidence of this. Additionally, as the U.S. and Russia reduce their nuclear weapons stockpiles, civilian targets are likely to be selected over military targets.

e. International Leaders. Most nations' foreign policies are strongly influenced by whom they select to be their chief executive officer.

> *Two nations that have preoccupied American military and diplomatic leaders for the past half century - Russia and China - are likely to face leadership crises during the next presidential term.*[77]

Of course, China with a long standing tradition of "great man" leaders, has now experienced the loss of their leader, Deng Xiaoping, leaving many to speculate how their foreign policy will be impacted.[78] There is growing unrest in Belarus over the pro-Russian stance of their President, Alexander Lukashenko. NATO's interparliamentary organization, the North Atlantic Assembly (NAA), is freezing all ties with Belarus. According to Sen. William Roth, R-Del., who is serving currently as NAA president, Belarussian President Alexander Lukashenko's

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[73] The National Academy of Sciences, The Future of U.S. Nuclear Weapons Policy, National Academy Press, 1997.

[74] C. Paul Robinson and Kathleen C. Bailey, "To Zero or Not to Zero: A US Perspective on Nuclear Disarmament", Security Dialogue, 1997, Vol. 28(2): pp. 149-158.

[75] The Economist, "Circles of Fear", January 4, 1997, pp. 33-35.

[76] Karinne Gordon and Robert Rinne, Summary of Discussions with Professor Michael Mandelbaum, Director of American Foreign Policy, John Hopkins School of Advanced International Studies, May 1996.

[77] David S. Broder, "Echoes of 1936?", The Washington Post National Weekly Edition, October 7-13, p. 4.

[78] For a review of this and other China issues, see The Economist, A Survey of China, March 8, 1997, pp. 1-22.

policies have undermined the rule of law and the democratic legitimacy of the country's legislature.

NATO's expansion into Eastern Europe has made many Russian leaders nervous. Mr. Yeltsin's leadership is key to Russia's acceptance of NATO expansion. He has played a major role in negotiating Russia's acceptance of NATO expansion while assuring that Russia's position as a great power is respected. Senator Roth has offered Russia assurance that the eastward expansion of NATO is not a threat.

> *NATO enlargement will benefit a democratic Russia, particularly as the Alliance extends a hand of friendship and cooperation. Enlargement will provide the regional stability Russia needs to consolidate and direct its energy inward for economic and political growth. We must not allow anachronistic voices to turn NATO enlargement, and the partnership between Russia and the Alliance, into a bargaining process.*[79] *... I have told the Ukrainians that I see them as future members of NATO. I hope that they will continue to implement the reforms necessary for their inclusion in the Alliance. Their eventual membership is in America's vital interest and is a cornerstone of our vision for a post-Cold War Europe.*[80]

In order to secure Russia's approval of NATO's eastward expansion to countries previously in Russia's sphere of control, NATO has declared that it has no intention, no plan, and no reason to install or deploy nuclear weapons or to station permanently substantial combat forces on the territory of new NATO members.

F. The Crime Problem: America's crime problem is estimated to have direct and indirect annual economic costs to victims (includes quantitative estimates of the cost of pain, suffering, and lost quality of life of victims) of $450 billion. Its total social costs also include, in addition to victimization costs, judiciary system costs and the hidden costs of crime, e.g., altered behavior due to fear of crime. Violent crime accounts for $426 billion in personal costs to victims and property crime victimization costs are $24 billion per year. These estimates include white collar crime, including personal fraud, and drug crimes. When pain, suffering, and lost quality of life are included, rape has the highest victimization cost - $127 billion annually - and well exceeds the estimated annual cost of either burglary or larceny.

There are approximately 48 million crime attempts annually in the U.S. More than 16 million of these are violent crimes and attempted violent crimes (murder, rape, robbery, assault, child abuse, drunk driving, and arson). In 1990, 31,000 deaths, roughly 75 percent of the number of Americans that died in automobile accidents, resulted from crime. It is estimated that 5.5 million Americans are in need of treatment for drug abuse.[81] In 1993 research suggest that Americans spent between $49 billion and $90 billion on illegal drugs.[82]

Of particular concern in crime growth in the U.S. is the increased role of juveniles in committing crimes, especially violent crimes. In 1995 law enforcement agencies arrested 2.7 million people under age 18 - juveniles accounted for 18% of all arrests. In 1995, juveniles were involved in 32% of all robbery arrests, 23% of all weapon arrests, 15% of all murder and aggravated assault arrests, and 13% of all drug arrests. In 1995, the racial composition of the juvenile population was 80% white (includes Hispanics), 15% black, and 5% other. Roughly

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[79] Senator William V. Roth, Jr., "Toward NATO Enlargement", speech at Center for Strategic and International Studies (CSIS) conference on European security issues, Brussels, February 22, 1997.

[80] Senator William V. Roth, Jr., press release, "U.S. Congressional Delegation Visits Sevastopol, February 20, 1997.

[81] Ted R. Miller, Mark A. Cohen, and Brian Wiersema, Victim Costs and Consequences: A New Look, National Institute of Justice Research Report, February, 1996.

[82] W. Rhodes, P. Scheiman, T. Pittayathikhun, L. Collins, V. Tsarfaty, What America's Users Spend on Illegal Drugs, Report to U.S. Executive Office of the President Office of Drug Abuse Policy, 1995.

equal numbers of violent crime arrests were for white juveniles and black juveniles.[83] Over the past 25 years, the arrest rate for murder by juveniles has quadrupled and their arrest rate for rape and robbery has more than doubled. About 70% of juvenile offenders come from single parent families. Putting a child in reform school for one year costs about $50,000.[84] This is about 25 percent more than sending them to college.

Juvenile crime is further complicated by juveniles propensity to join gangs. Of 3,440 local police and sheriff's departments reporting to a DOJ sponsored survey, 54% reported youth gangs active in their jurisdictions in 1995. One-half of these departments serve localities with fewer than 25,000 residents.[85]

Solutions such as building more prisons do prevent convicted criminals from committing additional crimes against the public (while they are physically incarcerated) and offer a measure of social retribution to victims; however, imprisonment is neither cost effective, nor does it address the root causes of crime, and it often serves as a training ground for hardened criminals to further develop their core competencies. (U.S. jail population has grown from 800,000 to 1.6 million over the past decade.[86] In the early 1990s the Nation's prison population had an average annual growth rate of 7.7%. State's incarceration rates per 100,000 residents range from 90 in North Dakota to 659 in Texas. The District of Columbia has 1,444 incarcerated per 100,000 residents.[87] For every person in prison, there are between three and four individuals under supervision outside of prison - parole, probation, or community-related service.) A survey showed that 61% of Americans are concerned that crime will increase in the future and 55% are concerned that the use of illegal drugs will increase.[88]

The Rand Corporation reported,

> *Headlines about falling crime rates notwithstanding, this year there will still be one violent crime committed for every 130 U.S. citizens - a rate several times that in other industrialized democracies. Yet despite the seriousness of America's crime problem, most of the money and effort devoted to solving it are restricted to one approach - incarcerating persons who have already committed crimes. Much less attention has been paid to diverting youths who have not yet committed crimes from doing so.*[89]

Estimates suggest that three-strikes laws like California's might reduce serious crimes by about 21% at an annual economic cost of $5.5 billion. Rand analysis indicates that for another $1 billion, graduation incentives and parent training could approximately double that crime reduction. Rand's models indicated that graduation incentives that induce disadvantaged high school students to graduate could avert about 250 serious crimes per million dollars invested and has the potential to reduce crime by 15%. In comparison, California's three strikes law is projected to avert about 50 serious crimes per million dollars.[90]

Dr. Lawrence Sherman, chair of the department of criminology and criminal justice at the Unviersity of Maryland, pointed out,

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[83] Howard N. Snyder, "Juvenile Arrests in 1995", U.S. Department of Justice, Office of Justice Programs, Office of Juvenile Justice and Delinquency Prevention, Juvenile Justice Bulletin, February, 1997.

[84] Lehman Brothers, Second Annual Education Industry Conference, February 11, 1997, p. 119.

[85] John P. Moore, "Highlights of the 1995 National Youth Gang Survey", Office of Juvenile Justice and Delinquency Prevention Fact Sheet #63, April, 1997.

[86] The Economist, "Just Desserts: Prisons in America", March 15, 1997, p. 33.

[87] Darrell K. Gilliard and Allen J. Beck, "Prison and Jail Inmates at Midyear 1996", Bureau of Justice Statistics Bulletin, NCJ-162843, January, 1997.

[88] The Washington Post National Weekly Edition, "What About Us?", September 23-29, 1996, p. 9.

[89] RAND Research Brief, Diverting Children from a Life of Crime: What Are the Costs and Benefits?, May 1996, RAND Home Page.

[90] Ibid.

More effective ways of treating juvenile offenders and preventing drug abuse have been demonstrated by careful evaluation research. Teaching juvenile offenders skills like reading works better than boot camps. Making schools more firm and consistent in overall discipline works better than D.A.R.E. But these strategies lack political advocates and lose out in the competition for funding.[91]

In 1996 Congress required the Attorney General to conduct a comprehensive evaluation of the effectiveness of the over $3 billion annually spent by the Department of Justice in funding grants to state and local law enforcement and local communities in preventing crime. This analysis was conducted by a team of researchers at the University of Maryland. Their findings included:

- Substantial reductions in National rates of serious crime can only be achieved by prevention in areas of concentrated poverty where homicide rates are 20 times the National average.

- A much larger part of the National crime prevention portfolio must be invested in rigorous testing of innovative programs, in order to identify the active ingredients of locally successful programs that can be recommended for adoption in similar high-crime urban settings Nation-wide.

- Effective crime prevention in high-violence neighborhoods may require interventions in many local institutions (communities, families, schools, labor markets, place security, police, and criminal justice). The interdependency of these local institutions suggests a great need for rigorous testing of programs that simultaneously invest in multiple local institutions.

- The number and strength of available evaluations is insufficient for providing adequate guidance to the National effort to reduce serious crime. (Despite the recent emphasis at reinventing government to focus on results, most crime prevention evaluations still appear to focus on efforts. In government a dust cloud indicating high activity is far more impressive than substantive results.) This knowledge gap can only be filled by Congressional restructuring of the DOJ programs to provide adequate scientific controls for careful testing of program effectiveness. DOJ officials currently lack the authority and funding for strong evaluations of efforts to reduce serious violence.

- The strength of police effects on crime is generally moderate rather than substantial. Massive increases of police presence focused in a small number of high crime communities can have a major effect on preventing crime. It is possible that a focused crime prevention strategy could rely heavily on police presence to regain a threshold level of public order and safety. Once this threshold is reached, the effectiveness of family, community, schools, and the labor force in inhibiting crime could be substantially increased. The 1994 federal Crime Act puts a large portion of its 100,000 police where the people are, but not where the crime is.[92]

- **Measured purely by the amount of available time to reduce risk factors for crime, schools have more opportunity to accomplish that objective than any other agency of government. Succeeding at their basic job of teaching children to read, write, and compute may be the most important crime prevention practice schools can offer.**

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[91] Lawrence W. Sherman, "Crime Prevention's Bottom Line", The Wall Street Journal, August 6, 1997, p. A15.

[92] Lawrence W. Sherman, "Thinking About Crime Prevention", Chapter Two in Preventing Crime: What Works, What Doesn't, What's Promising, A report to the United States Congress, prepared for the National Institute of Justice, February, 1997.

- No program has yet shown success in tackling the unemployment rates of high crime neighborhoods. Yet of all the dimensions of neighborhood life, this one may have the most pervasive influence on crime.

- There is very little evidence that increased incarceration has reduced crime. Yet variations in how the criminal justice system treats admitted offenders can make a great deal of difference. The evidence finds encouraging support for more correctional use of drug treatment programs, rehabilitation programs in prison, and institutionalization of some juvenile offenders rather than community-based supervision.

> *The great strength of federal funding of local crime prevention is the innovative strategies it can prompt in cities like New York, Boston, and Kansas City where substantial reductions have recently occurred in homicide and youth violence. The current limitation of that funding, however, is that it does not allow the Nation to learn why some innovations work, exactly what was done, and how they can be successfully adapted in other cities. In short, the current statutory plan does not allow DOJ to provide effective guidance to the Nation about what works to prevent crime.*[93]

The bottom line of this analysis is that federal grants are being used to support programs in which many variables are being simultaneously changed, control groups are not identified and made part of the experiment design, and measurement of program effectiveness is something one does after-the-fact to a program rather than make metrics an integral part of program design and definition.

The criminal justice system is attempting to deal with 21st century crime issues with mid 20th century technology. Crime experts have identified a wide array of technology needs.

- Complete forensics quickly.
- Separate out violent criminals in a crowd.
- Implement video and audio surveillance to monitor criminal activities (e.g., pick-up conversations between criminals or between criminals and hostages).
- Detect body heat inside a building, so that police can determine where people are located.
- Lift prints on site at a crime scene.
- Create a two-way "dialog" with criminals, instead of the traditional bullhorn "monologue".
- Identify the criminal quickly by processing a verbal description or mugshot.
- Enable the officer to communicate the officer's actions to superiors in "real time", as the situation unfolds.
- Tagging and tracking vehicles.
- Sensors installed along the highway that identify stolen cars as they pass the sensors.
- Retractable barriers that can be deployed in front of fleeing vehicles.
- An electromagnetic pulse source that can disable cars by interfering with their electrical systems.
- Paint darts for marking vehicles for later interception.
- Radio transmitters attached to cars to allow for predeploying of cruisers.
- Phototechnology for a wide range of applications.
- Concealed weapons detection.
- Coordinated information systems that can give authorities comprehensive material on an individual's criminal history.
- Encryption systems that ensure that only law enforcement has access to and can operate some technologies.

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[93] Lawrence Sherman, Denise Gottfredson, Doris MacKenzie, John Eck, Peter Reuter, and Shawn Bushway, Preventing Crime: What Works, What Doesn't, What's Promising, A report to the United States Congress, prepared for the National Institute of Justice, February, 1997.

- A "smart gun" with biometrics interlocks that can only be used by the person owning the gun.[94]

We should conduct a research project that closely examines why the market is failing to provide for these needs.

Technology Can Help.

Sandia National Laboratories recently helped Belen, New Mexico, officials address their concern for rising truancy, vandalism, violence, theft, and drug and alcohol use, by introducing security systems technology concepts developed for protection of weapons facilities. Sandia first conducted a systems engineering analysis with participation by students, faculty and the community to identify unique needs and develop an **integrated systems approach**. In a letter sent to President Clinton by Belen High School Principal Ron Marquez, it was noted that vandalism was reduced by more than 75%, vehicle theft was reduced by more than 80%, and truancy was reduced by 30%. In addition, fights, previously a weekly occurrence, are down to one per month and what was once a daily false fire alarm is now a monthly incident.[95]

Hoshen of Lucent Technologies, and his colleagues[96] have shown that modern communications and information technology may be used to incarcerate prisoners electronically and reduce the need for prisons that cost $125,000 per bed to build with an additional annual cost of $25,000 per occupied bed. (Society could send prisoners to Harvard for about the same cost as incarceration. They might still be criminals, but they would be sophisticated criminals and they would know how to coordinate their wardrobes.) House arrest backed-up by a primitive (in comparison to that possible with contemporary communications technology) form of electronic monitoring has been shown to be cost-effective for the 170 cases in which it was used in Pima County Arizona.[97] George Drake of the New Mexico Corrections Department has proposed that the U.S. establish a National program for continuous electronic monitoring of criminal offenders that is a partnership between government, universities, National laboratories, and companies.[98]

There are other many other areas in the criminal justice system where technology may be introduced to reduce costs or drop the frequency of crime. It was determined by law enforcement officials from around the Nation attending the conference, Coupling Technology to National Need, held in Albuquerque in 1993, that creation of a National law enforcement technology center at a national lab that was not part of the existing federal law enforcement bureaucracy would accelerate the introduction of technology into federal, state, and local law enforcement agencies. The center envisioned by conference participants would serve to review the latest technology developments, facilitate the access and exchange of technology information, showcase specialized products and certify products for use by law enforcement officers.[99]

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[94] National Institute of Justice Report, Law Enforcement Technology for the 21st Century Conference Report, June, 1994.

[95] Kathy Kuhlmann, "Sandia Earns A+ on School Security Program Achievements in Belen", Sandia Lab News, March 14, 1997.

[96] J. Hoshen, J.D. Sennott, and M. Winkler, "Keeping Tabs on Criminals", IEEE Spectrum, February 1995, pp. 26-32. Republished in The Journal of Offender Monitoring, Vol. 8, No. 3, 1995, pp. 1-7.

[97] T. M. Forgach, "Cost Effectiveness and Use of House Arrest with Electronic Monitoring in Pima County, Arizona", Journal of Offender Monitoring, v 5, N 2, Spring, 1992, pp. 8-10.

[98] George Drake, Joseph Hoshen, and Debra Spencer, "A Proposal for Developing a Continuous Electronic Monitoring System for Criminal Offenders", an unpublished white paper.

[99] Special Technologies, "National Law Enforcement Technology Center Needed", September 15, 1993.

Politics Always Wins

One of us served as a Congressional staffer rapporteur in the public safety session at this conference. Congressional staffers carried the message from the National Need Meeting back to Washington. We have been disappointed at the inability of the federal government to act on the recommendations of meeting participants. The National Institute of Justice has indeed established an infrastructure of regional technology centers that attempts to pursue some of the conference recommendations. However, despite the best efforts of the NIJ, their programs fall well short of what is needed.

G. The Energy-Environment Problem:

a. Energy America has slowly increased its dependence on foreign sources of oil and domestic coal to meet its energy needs. The first of these sources may not be dependable, and both are more polluting than other energy alternatives. If long-range alternatives such as renewable energy sources - solar, geothermal, tidal, and biomass - and nuclear fusion are needed, it is unlikely that the marketplace will make the investment required to develop these technologies until the cost of energy dramatically increases.

Although, the jury appears to still be out on the global warming issue, the fission-based nuclear power option and renewable energy options must be reexamined from a systems perspective with much attention given to including environmental effects and inherently safe systems when comparing the costs of nuclear and fossil fuel alternatives. MacKenzie has pointed out[100],

> *In 1973 the United States imported 35% of its oil, 5% of which was from the politically volatile Middle East. In 1995, it imported 44% of its oil, with 9% coming from the Middle East. ... DOE projects that OECD countries will increase their demand for oil by 20% by 2010 ... Non-OECD nations will increase their demand for oil by more than 50% by 2010. ...International Energy Agency projects that by the year 2010, world petroleum demand will be 35% to 39% greater than in 1994 - reflecting growth of about 2% per year. ... If the upper level of ultimate reserves (2,400 billion barrels) proves to be the case, and the Middle East countries are prepared to increase their production threefold, then a 1.5% growth in oil supply could be maintained until 2010.*

Petroleum imports and trade imbalance with Japan, and more recently China are the two major factors driving the U.S. trade deficit. These accounted for $100 billion of the $175 billion 1995 trade deficit.[101] As petroleum prices increase in response to petroleum demand increasing faster than petroleum supply early in the 21st century, the U.S. trade deficit will also grow. A recent GAO study[102], however, noted that as long as the Nation's heavy dependence on oil continues, reducing imports would only force the Nation to shift to more expensive domestically produced oil. Reducing the growth in imported oil to 80% of its expected growth level would annually cost the U.S. between $50 billion and $100 billion in GDP.[103] Despite heavy public investment in energy R&D, progress in reducing the U.S. dependence on foreign oil is invisible to the public.

The public has largely forgotten the gasoline lines thought to be caused by U.S. oil companies response to the Carter administration's consideration of an import oil tax. The public shows a propensity to continue to purchase fuel-inefficient vehicles and even pay

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[100] James J. MacKenzie, "Heading Off the Permanent Oil Crisis", Issues in Science and Technology, Summer 1996, p. 50.

[101] Philip H. Abelson, "The Changing Frontiers of Science and Technology", Science, Vol 273, July 26,1996.

[102] Government Accounting Office, Evaluating U.S. Vulnerability to Oil Supply Disruptions and Options for Mitigating Their Effects, December, 1996.

[103] George Lobsenz, "GAO Challenges U.S. Policy On Reducing Oil Imports As Costly, Counterproductive", The Energy Daily, vol. 24, no. 238, December 16, 1996.

large gas-guzzler taxes imposed by the U.S. Congress. The consequences of this apparent short-sightedness may be a pending threat to our economic security.

In the U.S., nuclear power plants produce electricity at an average cost of 1.92 cents per kilowatt hour in comparison to a cost of 1.88 cents per kilowatt hour for coal.[104] Wolfe proposes that our energy future may require increased dependence on nuclear fission[105],

> *Considering the growth in energy demand and the risks associated with other energy sources, the benefit-risk ratio for nuclear power is very attractive. ... The 74 nuclear energy plants that came on line (in the U.S.) in this period (1973-1995) increased nuclear's share of electricity generation from 4% in 1973 to more than 20% today, second only to coal. ... The substitution of nuclear for fossil-fueled plants has reduced present CO^2 atmospheric emissions by more than 130 million metric tons of carbon per year, roughly 10% of total U.S. CO^2 production. Nevertheless, the United States still needs to reduce carbon production by an additional 10% to reach its goal of returning to the 1990 production level. In addition, replacement of fossil-fuel plants with nuclear power has reduced nitrogen oxide emissions to the air by over 2 million tons annually, ... and has reduced sulfur dioxide emissions by almost 5 million tons per year, half the goal for the year 2000.*

The People's Daily Overseas Edition reports that China expects nuclear power generation to increase by 400 percent - to 9,000 megawatts (9 GW) - by 2003. The report says Beijing plans to build four new nuclear power plants in its energy-starved but resource-poor coastal regions by the year 2000. China has two operating plants, one in Daya Bay in southern Guangdong province and one in Qinshan in eastern Zhejiang province, south of Shanghai. Plans call for construction of new nuclear power plants in the provinces of Shandong, Fujian, Zhejiang, Guangdong, Jiangxi, and Hunan.[106] While anti-nuclear advocates will complain about China building nuclear power plants, China is planning to build 135 GW of new electric power plants by the year 2,000 and 270 GW by the year 2010. In addition to 9GW of nuclear powered electric plants, by the year 2000, China will add 40 GW of hydroelectric power and 86 GW of coal powered electric plants.[107]

Part of the public's disaffection with nuclear power stems from:

- The $230 billion clean-up cost of the U.S. nuclear weapons complex[108] (clean-up of the Hanford, Washington site is projected to cost $49 billion over the next 75 years[109]);

- The trillion dollar cost of cleaning-up the Russian nuclear weapons complex, the high cost and loss of life stemming from the Ukrainian nuclear power accident at Chernobyl, and the tendency of nations' bureaucrats to not inform the public when there are problems with nuclear power plants. For example, the chief investigator of Japan's Power Reactor and Nuclear Fuel Development Corp. recently shocked Japan's citizens with the announcement that the state-run nuclear oversight agency deliberately destroyed photos of the country's worst atomic accident in April, 1997. In the accident at the Tokaimura processing plant, about 75 miles north of Tokyo, there was a fire, then an explosion caused by failure to extinguish the blaze properly.

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[104] Pamela Newman-Barnett, "Is Nuclear Economic? Depends On Whom You Ask", The Energy Daily, vol 24, no 240, December 18, 1996.

[105] Bertram Wolfe, "Why Environmentalists Should Promote Nuclear Energy", Issues in Science and Technology, Summer 1996, pp. 55-60.

[106] Sandia Daily News, August 7, 1997.

[107] Milton Russell, "Energy Prospects in China", in Energy and National Security in the 21st Century, edited by Patrick L. Clawson, National Defense University Press, October, 1995.

[108] The Economist, "Costing a Bomb", January 4, 1997, p. 30.

[109] The Washington Post Weekly Edition, "The Dark Side of Paradise", July 8-14, 1996, p. 6.

Several workers were exposed to radiation. Meanwhile, in the latest in a string of nuclear facility incidents over the past 18 months, a power plant at Fukushima, 125 miles north of Tokyo, recently had to be shut down because of a brief rise in radiation from exhaust gases.

- The failure of the U.S. government and the press to inform the public of all the dangers and costs associated with each energy alternative, including nuclear. The public has not been made to understand that none of the energy alternatives are a free lunch. For example, largely because of fossil fuel consumption, over the past 200 years carbon dioxide levels in the atmosphere have increased almost 30% and, if fossil fuel consumption continue to grow as projected, atmospheric carbon dioxide concentration will double in the next century.

Some of the Fellows Didn't Like Nuclear Power

While the public has been highly sensitized to the dangers of nuclear power, they are much less familiar with the public health dangers of coal consumption. When one of us served in the American Association for the Advancement of Science Congressional Fellows Program, he was particularly struck by the strength of the anti-nuclear convictions of this group of Ph.D. scientists. Despite the fact that they were highly concerned about global warming, they were unwilling to consider nuclear power as an alternative to fossil fuel consumption in order to protect against global warming.

The price that the American consumer pays for energy, particularly gasoline and other fossil fuels, does not include its environmental costs. It has been estimated that the annual environmental cost of gasoline due to air pollution is $300 billion per year, or $2.00 per gallon of gasoline consumed.[110] If Americans were to pay for all the costs of their car culture, including noise pollution and environmental restoration costs, but omitting global warming, it has been estimated that they would pay $8.00 per gallon for gasoline.[111]

In defense of this administration, Dr. John Gibbons, Assistant to the President for Science and Technology, has formed a panel of distinguished, independent experts to advise the White House on how to ensure that the United States energy program addresses the economic, environmental, and national security needs of the nation for the next century. This panel is to report its findings by October of 1997.[112]

b. Environment Apocalyptic energy and environment scenarios have so permeated the literature and the scientific community that it is very difficult to identify reality. While on the one hand the doom prophets tell us that we are choking on air pollution resulting from combustion of fossil fuels, we learn from other quarters that the U.S. is making great progress in cleaning up the air. It has been noted, for example, that total emissions of the six principal air pollutants monitored by EPA have decreased by 28 percent and lead concentration in the air has decreased by 78 percent while our population grew by 28 percent, we doubled our gross domestic product, we placed 60 percent more drivers and 80 percent more vehicles on the road, and we doubled the number of miles driven. The auto industry argues that it takes 20 of today's new cars to produce as much tailpipe pollution as one new car did 30 years ago.[113] The purists argue that we have made progress, but that much more progress is needed to clean up air pollution.

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[110] Jeffrey R. Vincent and Theodore Panayotou, "Consumption: Challenge to Sustainable Development or Distraction?", Science, April 4, 1997, p 54.

[111] J. Konheim and B. Ketcham, Costs of Roadway Transportation, Konheim and Ketcham, 1992.

[112] The White House, Office of the Press Secretary, White House Taps Panel of Experts on Energy Research and Development, March 20, 1997.

[113] Keep America Moving, Environment and Clean Air, 1997.

The environmental movement has sparked support for the notions that we are running out of resources and causing the collapse of critical ecosystems. Some argue that economic growth promotes consumption of our resource base. Sagoff[114] contradicts this point of view.

> *The idea that increasing consumption will inevitably lead to depletion and scarcity, as plausible as it may seem, is mistaken both in principle and in fact. It is based on four misconceptions:*
>
> - *We are running out of raw materials.*
> - *We are running out of food and timber.*
> - *We are running out of energy.*
> - *The North exploits the South.*
>
> *Without economic growth, which also correlates with lower fertility, the environmental and population problems of the South will only get worse. For impoverished countries facing environmental disaster, economic growth may be the only thing that is sustainable.*

Major environmental concerns surround our water resources, our air quality, our waste production, and our remediation efforts. Most of these are directly or indirectly related to energy consumption. Only 3% of the world's water is fresh water and two-thirds of all fresh water is in the form of ice. Reducing our use of surface water reduces the amount of wastes discharged into our streams and it reduces the amount of energy needed to treat wastewater. We must continue to make progress in controlling the pollutants that enter all of our surface waters. Roughly 50% of all Americans get their house water from underground sources. In addition, underground water is used for about 50% of agriculture irrigation and it accounts for about 30% of industrial water use. Although contamination of underground water often goes undetected for many years, it is increasingly being contaminated by landfills, pesticides, septic tanks and other surface activities. Depletion of ground water reserves is a growing concern, particularly in the midwestern and western states.

Although many U.S. cities have made dramatic improvements in their air quality; 40 urban areas continue to violate at least one of the U.S. ambient air quality standards. Most of air pollution arises from consumption of fossil fuels.

We Need a National Energy Strategy.

While one may recite a wide array of incremental advancements in energy technology, it is discouraging that despite an over 20 year publicly-funded R&D program in energy, our great Nation has been unable to articulate a National energy strategy that identifies the pros and cons of the issues, differentiates the roles of the private and public sectors, lays out a roadmap for energy technology development, and rationalizes energy alternatives in terms of their environmental costs. Instead, government has only offered apocalyptic prophecy that the American public has come to doubt. (This serves to illustrate the tendency for government to address the easy problems - the technical component - and leave the challenging issues - strategic analysis, planning, and management - untouched.)

There is growing evidence that the U.S. has overacted to the global warming issue. Dr. William Nierenberg, director emeritus of the Scripps Institute of Oceanography, has pointed out that appreciable effects of global warming are not likely to occur for 100 to 150 years, there is little value in corrective measure before 30 to 40 years from now, and the net effects in 100 to 150 years are likely to be a one foot increase in sea level and a 1 degree C temperature increase. He notes,

> *For now, there are no firm answers, and we should not act as if there are. Let the scientists do their work in the neutral climate of scholarly inquiry, and let Congress*

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[114] Mark Sagoff, "Do We Consume Too Much?", The Atlantic Monthly, June, 1997, pp. 80-96.

review the specifics of the U.S. global warming proposal and all its economic impacts.[115]

H. The Education Problem.

a. Introduction. In 1995 the United States spent $668 million or 9.2% of GDP on prekindergarten through post secondary educational services and content. Of this total, $318 billion was spent on K-12, $189 billion was spent on post secondary, $60 billion[116] was spent on workforce training, $45 billion was spent on the consumer market for education products, $30 billion was spent on pre K, $10 billion was spent on training programs, and $10 billion was spent on child reform. In 1992 U.S. public education expenditure per child was $11,880 and was only slightly exceeded by that of Switzerland, was almost identical to that of Japan, was approximately two times that of France, Austria, Belgium, and Denmark, and was approximately 50% higher than that spent by Sweden, Norway, and Ireland.[117] We have nearly 60 million (almost 25% of our population) full- and part-time students enrolled in courses throughout the U.S. Education employs 55% of local government workers and 45% of state workers.[118]

Despite our massive National investment in education, several concerns surround our education system. These concerns have three primary components: (a) the quality of K-12 math and science education is thought to be inadequate, (b) college costs are excessive, and (c) the U.S. has failed to design an education system that promotes and offers education from cradle to grave. As we have examined the problems of education, it has become increasingly apparent that education is far too important to the future of America to leave in the hands of an oligopoly and its attendant bureaucracy.

b. K-12 Math and Science. In 1996 international exams[119], U.S. students performed at almost exactly the international averages in both mathematics and science but were behind the scores of students from Japan, South Korea, Singapore, the Czech Republic and Hungary and roughly the same as students from England and Germany.[120] Comparisons of K-12 scores around the world demonstrate that countries with one-half the per student investment of the U.S. are matching or exceeding the examination performance of U.S. students. Singapore, the leader in both math and science scores by a considerable margin, expects children to be able to read and write in two languages and do simple arithmetic prior to entering the first year of formal schooling. In addition, parents invest in private tutoring outside of the formal classroom to ensure the success of their children in the classroom.[121] From a very early age Japanese children are taught that learning is an enjoyable part of life and that the motivation for learning is resident in the student, not the teacher.[122] Our considerable investment in education is not producing the performances many Americans expect, particularly companies that are seeking manufacturing employees.

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[115] William A Nierenberg, "Global Warming As 'Fact' Is Hot Air", Albuquerque Journal,August 4, 1997.

[116] Most reports of U.S. companies annual investment in training quote figures in the $50 billion to $60 billion range for formal training. Informal training costs, those training efforts not reported by companies, are estimated to range between $180 billion and $200 billion per year. See, for example, Information Technology Association of America, Help Wanted: The IT Workforce Gap at the Dawn of a New Century, February, 1997, p.35.

[117] Lehman Brothers, Second Annual Education Industry Conference, February 11, 1997, New York, NY.

[118] Ibid.

[119] Third International Maths and Science Study, TIMSS.

[120] For a comparative tabulation of TIMSS math and science scores by nation, see, for example, The Economist, "Who's top", March 29, 1997, p. 21.

[121] Alan Lim, Letters to the Editor, The Economist, April 19-25, 1997, p. 8.

[122] Gail Benjamin, Japanese Lessons: A Year in a Japanese School Through the Eyes of an American Anthropologist and Her Children, New York University Press, 1997.

Complexity and chaos did it.

Marshall offers an interesting interpretation of the shift in education.

It is my belief that the espoused crisis in public education is predominantly a crisis about learning and that it is fundamentally grounded in the dynamic integration of two new domains of inquiry:

1. The paradigm shift from a machine-based "clockwork" conception of the universe to a complex adaptive perspective.

2. The paradigm shift from understanding the brain as a computer to be programmed and learning as a linear process of information accumulation to understanding the brain as a dynamic, self-organizing neural network and learning as a natural, active, and messy process of pattern formulation and constructed meaning. ...

The insights of complex adaptive system theory and learning theory have fundamentally altered these (schooling and learning) metaphors and have radically reframed the discourse on learning and schooling; in place of machine-based metaphors are fluid, organic, and biological metaphors that place schooling structures in dynamic opposition to our new knowledge.[123]

There are three schools of thought regarding the K-12 math and science education issue. One group argues that the root cause of poor math and science scores is poor reading skills. Some argue that these stem from replacing phonics with word recognition as the fundamental way of teaching reading in the early grades.[124] A second group argues that the issue is strictly an inner city issue whose root cause is socioeconomic and regardless of the effort invested in education, poor math and science scores are only the symptom of a much more severe social problem. A third group argues that the K-12 problem is not just limited to inner city schools, it is also widespread in suburban and rural schools. This group also believes that poor math and science scores are not necessarily a consequence of poor reading skills, rather they argue that poor teaching skills and lack of study time are the likely culprits.

Polls show that 62% of Americans believe that our educational system will get worse instead of better.[125]

c. College Costs. Although an informal survey of Harvard graduates revealed that less than 10% could explain the phases of the moon[126], at the college level the quality of education is generally of less concern than it's cost. Lack of productivity growth, in combination with stagnation or reduction in income have resulted in education costs that an increasing fraction of America's population can no longer afford. Just as the shifting of wealth has made a college education a near necessity for personal income growth, the cost of college has made college less accessible to those in the low and middle income groups. The June, 1997, graduating undergraduate class of 1.2 million spent, on average, $150,000 of private and government funds for their education.[127] Of course, those funds provided to public colleges and universities by taxpayers are buried in order to create the illusion that public schools cost less than private schools. Most analyses indicate that private schools actually cost less when the tax bite is included in the calculus. The news media are reporting with increasing frequency that universities have been sacrificing both the cost and quality of undergraduate education to

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123 Stephanie Pace Marshall, "Creating Sustainable Learning Communities for the Twenty-First Century", in The Organization of the Future, edited by Frances Hesselbein, Marshall Goldsmith, and Richard Beckhard, The Drucker Foundation, 1997, pp. 177-188.

124 Personal communication, Mr. Charley Richardson, IEEE senior member.

125 The Washington Post National Weekly Edition, "What About Us?", September 23-29, 1996, p. 9.

126 Parade Magazine, "Have Our Schools Heard the Wake-Up Call?", January 19, 1997.

127 USA Today, "College Costs Too Much, Fails Kids", July 17, 1997, p.15A.

support research. Other reports suggest that those concerned about the cost and quality of college and university education is growing.

The Ivory Tower's Enemy List Is Large and Growing.

Much academic research is dross, churned out merely to advance an academic's career. Worse, the publish or perish syndrome which dominates academia has devalued the original purpose of higher education-that is, education itself. At too many institutions, including many of the most famous, teaching is an after-thought and done poorly. The pursuit of research has gone too far. It is time to tilt the balance back towards education.[128]

In most cases, schooling does not develop originality, delight in ambiguity, or self-expression. Rather, the thinking skill that's rewarded is figuring out the "right answer" - that is the answer held by the person in authority, the teacher. This pattern holds through university and postgraduate education, especially in a class where the professor wrote the text. ... Our way of testing and grading reinforces a pernicious pattern of short-term, superficial thinking. ... The fear-based, authority-pleasing, rule-following approach to education may have served to provide society with assembly-line workers and bureaucrats, but it does not do much to prepare people for the world as it is today.[129]

You're smart people and so you figured out many years ago that most of your courses were entirely irrelevant information. ... What you learned wasn't how-to-learn, but to recite, to get by, to work the system. School is to learning what "Cliff's Notes" is to literature. You learned to lip-sync knowledge. ... look at what the university is doing to your professors. Wonderful, bright, good-natured people are attracted to teaching at a university ... and then dissuaded from doing what attracted them to the job. No, the classroom is ultimately a distraction, an intrusion on research. ... A university was once thought of as a place for free-thinkers. Not now. The thinking is never free; it is both expensive and shackled. In the absence of free thinking, college has become vo-tech for bureaucrats. A diploma proves that you are already a card-carrying bureaucrat, that you are willing to do what you are told for years at a time. Thus, you are qualified to work for major corporations.[130]

Reform in higher education has been hampered by a near absence of strategic management, as well as by institutional traditions such as tenure that actually act as disincentives to productivity. And so the process of meaningful reform in the ivory tower grinds along at a snail's pace. Higher education will pay a price for resisting society's demands. Highly selective colleges and research universities probably can afford to ignore society's reform call. But most enrollment-dependent institutions face major revenue shortfalls and increased competition from proprietary institutions. ... The only realistic answer is growth in learning and teaching productivity, which will bring down costs and produce better prepared students. ... The time is right to challenge the worn-out and ineffectual paradigms of the ivory tower and to embrace the sometimes painful but essential process of reform. [131]

The average debt for those graduating from college at the B.S. level, excluding parental debt, is $11,000 with some carrying debts of $30,000 to $40,000.[132] During the 1980s health care prices grew 117%; the price of attending public and private colleges increased 109% and

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[128] The Economist, "Teaching Spires", August 24, 1996, p. 14.

[129] Michael J. Gelb, Thinking for a Change, Harmony Books, 1995, p. 8.

[130] Dale Dauten in graduation speech, "Conformity Class Is Over", Albuquerque Journal, May 7, 1997, p. D8.

[131] USA Today, "College Costs Too Much, Fails Kids", July 17, 1997, p.15A.

[132] The Washington Post National Weekly Edition, "You've Made the Grades, Now It's Payback Time", July 8-14, 1996, p. 20.

146% respectively.[133] In 1996 the price of tuition at state-assisted colleges and universities averaged 8.9% of annual family income in comparison to 4.5% in 1980. Of course, these figures do not include the subsidy paid through state taxes, the federal subsidies, funds drawn from endowments, and the many contributions made to universities by alumni and others. In 14 states the cost of tuition at a state-assisted college exceeds 10% of annual family income in that state. A Washington Post poll showed that 58% of Americans believe that a good college education is becoming too expensive.[134]

Marshall offers a model of education that suggests the old model of education, the Newtonian model, has outlived its utility and must be replaced with new educational models that recognize learning as a property of a complex, adaptive system.

> *By design, we constructed and operated our Newtonian schools as we understood our world, and this produced iatrogenic and learning-disabled institutions that have suppressed reflective thought, creativity, and the innate and inexhaustible human capacity for lifelong growth. ... We must transform the mechanistic paradigm of schooling into an integrated, holistic, and systemic vision of a sustainable learning community.*[135]

We note the recent interest shown by investors in the business opportunities presented by the $668 billion annual market for education. Such interest is bound to result in private competition for all sectors of education and especially for those opportunities which are being ignored by colleges and universities (such as continuing education). The competition from outside the traditional education community is likely to self correct accelerating costs and might well initiate intercollegiate competition for students based on costs.

d. Continuing Education. The ability of the U.S. to continue to attract high-value-added industries from around the world depends upon having a high quality workforce. Except for some progressive engineering schools, e.g., the University of Cincinnati pioneered cooperative engineering education, the U.S. education system has been designed to accommodate the linear model of learning - during early years one studies then eventually receives a diploma or degree which certifies the state of learning reached. The ability of educational institutions to provide this learning experience has itself been certified by an accreditation board. The graduate then marches off to the learning application phase. In many fields, engineering in particular, learning must be viewed to be a cradle-to-grave experience and must be thoroughly integrated throughout the work experience. However, educational institutions are organized to provide courses according to this linear model with the delivery schedule drawn out over a several month period. The National Academy of Science observed,

> *The United States has one of the most diversified, but poorly coordinated training enterprises in the world. ... Work-related training and continuing education are provided by a broad spectrum of private and public institutions. ... Across this vast and diverse training enterprise, there are few common standards, the quality of training is uneven, and important subsets of the nation's current and potential workforce are poorly served, particularly with regard to job-related training and continuing education within industry.*[136]

Because of the short half-life of engineers' education, continuing education for engineers has been particularly difficult to accommodate. The Competitiveness Policy Council pointed out

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[133] George Will, "Education Today: Pay More, Learn Less", The Washington Post, March 24, 1996.

[134] The Washington Post National Weekly Edition, "What About Us?", September 23-29, 1996, p. 9.

[135] Stephanie Pace Marshall, "Creating Sustainable Learning Communities for the Twenty-First Century", in The Organization of the Future, edited by Frances Hesselbein, Marshall Goldsmith, and Richard Beckhard, The Drucker Foundation, 1997, pp. 177-188.

[136] National Academy of Sciences, National Academy of Engineering, Institute of Medicine, and the National Research Council, Preparing for the 21st Century: Technology and the Nation's Future.

that the mobility of engineers means that their professional education has become a ***public good*** which individual companies are increasingly unwilling to finance.[137]

Many states, however, have recognized the need to continuously recertify professional engineers and have recently begun to require annual continuing education units for the maintenance of their certification. To date 3 of the 50 states have passed these regulations. Companies will likely respond by outsourcing the continuing education of their engineers to private or public organizations. An entrepreneurial group of educators has sensed growing opportunity for new sources of income.

e. The Future of Education. Universities have not yet taken full advantage of the productivity gains promised by information technology.

> *Governments need to raise the standards of education and skills to let their economies take full advantage of IT (information technology) and the expansion of knowledge industries. Education is one of the few sectors which has so far remained largely outside the technological revolution.*[138]

We must learn how to use technology to improve college and university education while reducing its price to the consumer. As with health care, government has been unable to address the root cause of the college cost problem. For example, it has been noted that tax breaks for families paying college tuition is bad tax policy and worse education policy and it fails to address the fundamental problem, stationary or even reduced productivity.[139]. Further federal subsidies (either research grants or tuition subsidies) are likely to increase the demand for college and, therefore, increase the cost.[140] We can expect states to increasingly look for piecemeal, non-systemic, silver-bullet solutions (tenure modification, more federal R&D funds, increased student loans, increased solicitation of contributions from alumni, tax credits for education, etc.) to the education cost escalation problem. These efforts are not systemic and only delay addressing the issue as a system.

We are living in wrenching times with one foot in the past characterized by hierarchies and bureaucracies, and one in the future characterized by teaming and collaboration. Because we're in an evolutionary period of change, these old types of organizations are not disappearing, but instead becoming smaller parts of an emerging new adapting organizational structure. The new organization consists of small internal units that have buying customers. Hewlett Packard, for example, consists of numerous small independent business units each performing a niche function. The HP structure showcases the advantages of self governing teams (small, entrepreneurial, adaptive), in contrast to the weaknesses of hierarchies exemplified by the current university system where decision-making is often paralyzed. Higher education is on the edge of a revolution as distance learning begins to take off. The inefficient bureaucracies at some of the more forward looking universities are slowly being replaced by self generating departments that allocate resources in proportion to value gained, i.e., the inefficiencies of having a $100K professor teach 5 or fewer students can no longer be tolerated.[141]

The vacuum in leadership that exists within the current university structure and universities resistance to change has greatly accelerated a trend in recent years toward company owned

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[137]Robert M. White, US Technology Policy: The Federal Government's Role, September, 1995, A paper commissioned by the Competitiveness Policy Council, p. 15.

[138] The Economist, "A Survey of the World Economy", September 28, 1996, p. 45.

[139] Lawrence E. Gladieux and Robert D. Reischauer, "Higher Tuition, More Grade Inflation", Washington Post National Weekly Edition, September 9-15, 1996, p. 26.

[140]Virginia I. Postrel, "Clinton's Education Inflation", The Washington Post National Weekly Edition, April 7, 1997, p. 21.

[141] Robert Floran, Sandia National Laboratories, personal communication to James Gover, summary of observations made at World Futures Society Meeting, July, 1997.

universities; there are now over 1,000 of these in the US with two-thirds being accredited. These, along with distance learning centers represent new competitors for the traditional university. The continued rapid growth of this phenomenon attests to the failure of the current education system to provide the private sector with graduates who can function and add value in the corporate world. We can see these trends occurring all over the United States, where the traditional large, bureaucratic university continues to be plagued by declining enrollment, while the smaller, agile and more responsive technical vocational institutes struggles to keep up with growth, as it attempts to serve the rapidly growing needs of local employers.

Outside of the U.S. the emerging model of education is the megauniversity that teaches through distance learning. These institutions rely on remote teaching methods to reach hundreds of thousands of students. Around the world eleven megauniversities annually teach up to 500,000 students each (Anadolu University in Turkey has 578,000 students and China TV University has 530,000 students.) while maintaining per student education costs ranging between 5 percent and 50 percent of the costs of universities that employ traditional methods.[142]

Lifelong education systems for home use are needed.

Coates, Mahaffie, and Hines predict the following for education in the year 2025,

Educational tools and apparatus are everywhere. Although nearly all children (96.3%) go to a public institution for schooling, the experience is hardly like what was provided in the schools of the 20th century. The in-classroom learning time has shrunk greatly, and the schools are directed at physical, social/interpersonal, and artistic development. The educational components of traditional reading, writing, and arithmetic are split 60/40 between school and home. For high school students, the shift has been even more striking to a 40/60 split. High school is primarily for interpersonal development, hands-on activities, and group activities such as teams, theater, and song.

The typical student now enters college with one year of advanced placement, and it is not unusual for extremely bright students to earn two-and-a-half years of advanced placement. The college is primarily a social acculturation institution for youth and young adults. It has also become a site for continuing education by people of all ages.

The sea change in education in the United States has been the shift from primary, secondary, and tertiary (college) education to quaternary education, that is, lifelong, individualized education. The sites of quaternary education are 50% at home, 15% at work, and 35% elsewhere.[143]

If the U.S. education system is to live up to it's responsibility to the U.S. taxpayer, three fundamental changes must be given careful consideration.

- The productivity of education must be increased through distance learning.
- The intensity of competition between education services providers must be increased throughout the education services sector.

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[142] Science, "Schools Ponder New Global Landscape", July 18, 1997, p. 311.

[143] Joseph F. Coates, John B. Mahaffie, and Andy Hines, 2025: Scenarios of U.S. and Global Security Reshaped by Science and Technology, Oakhill Press, 1997, p. 54-55.

- Accreditation emphasis must shift from the educational institution, it's educational process, and it's faculty to the educated. Only then can outcome-based education prosper.

To accomplish these, it is likely that the entire U.S. education must be privatized. It is time to acknowledge that the U.S. education oligopoly and it's accompanying bureaucracy have outlived their utility.

I. Other Low Productivity Growth Industry Sectors: In addition to the healthcare and education sectors, there are numerous major industrial sectors, e.g. construction, where there is little to no productivity growth. Much of this stagnation stems from R&D investments less than one percent of sales. We need to rank industry sectors according to their productivity growth and their potential for increased productivity and then develop programs that focus on the slow productivity growth industries with the highest improvement potential.

Unfortunately, the track record of the U.S. Congress has been weak at best in evaluating previous attempts to rectify this problem. For example, regular attempts to initiate R&D at NIST and at some of the DOE laboratories in roofing materials, building procedures, energy conservation, fire protection, heat exchangers, efficient windows, and other mundane but economically important sectors, have been met with charges of "industry welfare" by the Congress. Never mind that the marketplace is failing to provide for public needs, that foreign competition is eroding the building supply market, and that U.S. houses have inferior plumbing in comparison to those in most European homes.

The construction market is particularly susceptible to the threat of a virtual marketplace developing as the internet expands its international web. Educators have largely ignored the fact that U.S. construction suppliers are decades behind information technologists in the automotive and aerospace sectors. As the distance between construction sites and suppliers become less important and the ability of architects and builders to use information technology grows, foreign suppliers will gain equal footing to domestic suppliers. With higher quality products, the foreign suppliers will have distinct advantages.

J. The Income Distribution Problem: Stagnation or reduction in income of middle and low income wage earners is a ticking time bomb that will eventually stimulate social instability, economic class conflicts, less education, political instability, growth in crime, and eventually slow economic growth.[144] According to the Gini scale of income distribution, income inequality in the U.S. grew steadily, especially in the South and Southwest, throughout the 1980s and has surged in the early 1990s.[145] The following statistics were recently reported in Harvard Business Review,

> *In Western Europe, a male worker in the bottom 10% of the earnings distribution earns 68% of the median worker's income; in Japan, that male worker earns 61% of the median. In the United States, he earns 38% of the median. ... That so many workers in the United States fare poorly compared with their peers in other countries shows that the problem of low pay is not simply a matter of low-skilled immigrants or poorly educated minority youths. It is a problem of the overall distribution of income.*[146]

The median U.S. family income after inflation was $36,959 in 1993 in comparison to $36,893 (1993 dollars) in 1973 in spite of the fact that there was a significant increase in two income

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[144] The Economist, "Slicing the Cake", October 19, 1996, p. 82.

[145] USA Today, "Mapping Income Inequality", September 20, 1996, p. 3B.

[146] Richard B. Freeman, "Toward an Apartheid Economy?", Harvard Business Review, September-October, 1996, p. 116.

wage earners.[147] Low income wage earners are likely to experience further salary compression as welfare reform introduces even more low-skilled workers into an already overpopulated segment of the workforce. Of course, as Borjas and others have noted, the large-scale migration of less-skilled workers to the U.S. has done harm to the economic opportunities of less-skilled natives. Borjas estimates that one-third of the recent decline in the relative wages of less-educated native workers is accountable to immigration policy.[148] Note that the hourly labor costs for Americans in manufacturing is $17.20 in comparison to $31.88 for Germany and $23.66 for Japan.[149] While Japan's unemployment rate is less than that of the U.S., Germany's is over twice that of the U.S. Although salaries represent an equilibrium point between the supply of workers and the demand for workers, part of the salary stagnation of U.S. workers can be attributed to the cost of healthcare. Employer-sponsored healthcare outlays for employees has grown from 2% of wages and salaries in 1975 to about 8% today.[150] These are dollars that could have been used to increase wages.

While some have touted professional education as the solution to the income distribution problem, engineers' incomes have been stagnant for over a decade.[151] This situation makes engineering less attractive than other career options for U.S. citizens. Many U.S. graduate engineering employment needs are being met by immigrants to the U.S. who pursue an engineering education and then remain here to work.[152] Michael Teitelbaum, the esteemed demographer, recently reported,

> *There is no shortage of scientists, engineers or software professionals. If anything, there is a surplus. ... Engineers and software professionals who have lost their jobs could be easily retrained by the big high-tech companies. However, there is no incentive to do so, as long as they can easily hire from U.S.-educated foreign nationals. As one software engineer let go by a computer company reported, he and his colleagues are "disposable" rather than "recyclable."*[153]

Some suggest that the radical income distribution problem that the U.S. is experiencing is a consequence of our devotion to laissez-faire ideology. George Soros, one of the world's most prominent financiers warns that leaving social decisions to the market poses a danger to society. He notes,

> *I can assure you that all attempts at redistribution interfere with the efficiency of the market, but it does not follow that no attempt should be made. The laissez-faire argument relies on the same tacit appeal to perfection as does communism. It claims that if redistribution causes inefficiencies and distortions, the problem can be solved by eliminating redistribution - just as the communists claimed that the duplication involved in competition is wasteful and therefore we should have a centrally-planned economy. But perfection is unattainable. Wealth does accumulate in the hands of its owners, and if there is no mechanism for redistribution, the inequities can become intolerable.*[154]

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[147] Competitiveness Policy Council News Release, New Studies Find American Families Are Working Harder, But Making Less, September 12, 1996.

[148] George J. Borjas, "The New Economics of Immigration: Affluent Americans Gain; Poor Americans Lose", The Atlantic Monthly, November, 1996, pp. 72-80.

[149] The Economist, "Sliding Scales", November 2, 1996, p. 77.

[150] Business Week, "Solving the Savings Riddle", November 11, 1996, p. 26.

[151] M. F. Wolfe, "As Their 'Shelf Lives' Shrink, an NSF Study Finds Half of U.S. Engineers Working Outside Engineering", Research,Technology Management, July-August, 1996, pp. 1-5.

[152] David S. North, Soothing the Establishment: The Impact of Foreign-Born Scientists and Engineers on America, University Press of America, 1995.

[153] Michael S. Teitelbaum, "Too Many Engineers, Too Few Jobs", New York Times, March 19, 1996.

[154] George Soros, "The Capitalist Threat", The Atlantic Monthly, February, 1997, p. 52.

The Economist, apparently stung by Soros' analogy to communism, was particularly harsh in declaring that Soros was hallucinating to suggest that there is any nation where laissez-faire doctrine rules supreme. Its editors pointed out that the U.S. spends up to one-third of national income on redistribution of wealth from the rich to the poor and emphasized that economic theory suggests that governments can intervene when markets fail.[155]

K. The Aging Problem. (To be written.)

Life expectancy for US males is now 80.5 years and for US females is 83.9 years.[156]

L. The Propagation of Disease. (To be written.)

III. Federal R&D Can Solve These Problems.

A. Budget, Not Public Outcomes, Drives Policy.

In today's model of federal R&D, all of government's attention is focused on inputs or budgets, not ***public outcomes***. Consequently, the White House proposes a five year budget plan for each agency, as illustrated in Table I, and the wheels of government roll on with little attention devoted to discussing the public problems this budget is supposed to solve. At the federal level we have a budget driven strategy rather than a ***public outcome*** driven strategy that starts with public problems federal R&D must attack and solve in order to survive. **Of course, when IEEE and other professional societies request that the federal R&D budget be doubled without specifying for what purpose, they are playing to this budget driven strategy.**

When we review the projections shown in Table I we are unable to tell what problems these funds are to solve - and without defining the problems, how can budgets be assigned? For example, does the NIH budget include enough funds to solve the healthcare cost problem? Will the DoD budget prepare us to deal with emerging new military threats, or is it just an extension of the Cold War model? Is the EPA budget sufficient to clean up the environment and make rational, balanced regulatory assessments? Does the DOC budget include funds to solve the shifting of wealth problem and stimulate productivity growth in stagnant services sectors or is it little more than corporate welfare for manufacturing companies? At first glance, it appears that the federal government has not recognized education problems to be worthy of federal R&D.

It is incomprehensible that with all of the important public problems we have described that our Nation would consider cutting federal R&D, unless the public, Congress and the President have lost confidence in the U.S. publicly-funded innovation system. We believe that U.S. engineers and scientists that work for federal laboratories, universities, and companies have systems analysis and modeling skills, research skills, development skills, and a familiarity with technology that, if partnered with the skills of social scientists, the business community, economists, and political scientists, could help solve these problems. It should be clear from the previous descriptions that each of these is a systems problem that will not be responsive to piecemeal solutions.

For several years the federal government has regarded the R&D community to be just another special interest entitlement that comes to Washington for a handout. As long as R&D funds were growing, the publicly-funded R&D community was willing to prostitute themselves and play the role of the self-proclaimed sophisticated, but humble, beggar. And Congress was willing to wallow in the bed of science-advocating metaphors: the endless frontier, the engine of economic growth, etc., and sponsor undirected, non-strategic research in the sciences based on the faith that something good for the public would come of it. And it has, sometimes. However, serendipity has not yet led to solution of the myriad of problems that we have described. Yet scientists continue to lobby Congress for support for science that has little more going for it other than the fact that their peers love it.

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[155] The Economist, "Palindrome Repents", January 25, 1997, p. 18.

[156] Business Week, "Longer Life for American Men", November 11, 1997, 1996, p. 26.

Table I: American Association for the Advancement of Science[157] analysis of projected budget authority requested by the President between now and the year 2002. Budget estimates for FY 1997 and FY2002 are given in current year dollars (CY$). Note, however, that when one corrects for inflation using projections of the consumer price index (CPI), the President's projections call for a cut in federal R&D of 13.9%. Congressional projections call for even higher cuts.

Agency	FY1997 Budget CY$	FY2002 Budget CY$	% Change FY97-FY02 CY$	% Change FY97-FY02 CPI$
DoD	$37.46 B	$35.06 B	-6.4%	-17.7%
HHS	$12.92 B	$13.42 B	+3.8%	-8.7%
NIH	$12.21 B	$12.74 B	+4.4%	-8.2%
NASA	$9.32 B	$9.33 B	+0.2%	-11.9%
DOE	$6.16 B	$6.01 B	-2.5%	-14.2%
Defense	$2.81 B	$2.68 B	-4.6%	-16.1%
Non-Defense	$3.35 B	$3.33 B	-0.7%	-12.7%
NSF	$2.42 B	$2.55 B	+5.2%	-7.5%
USDA	$1.54 B	$1.49 B	-3.3%	-14.9%
DoC	$1.02 B	$1.25 B	+23.3%	+8.5%
DoI	$0.58 B	$0.61 B	+5.0%	-7.6%
DoT	$0.65 B	$0.68 B	+5.2%	-7.4%
EPA	$0.51 B	$0.62 B	+22.3%	+7.6%
Other	$1.15 B	$1.16 B	+0.9%	-11.3%
Total	$73.73 B	$72.18 B	-2.1%	-13.9%
Defense	$40.27 B	$37.73 B	-6.3%	-17.6%
Non-Defense	$33.47 B	$34.45 B	+3.0%	-9.5%

B. Leadership.

The federal government and its bureaucratic hierarchy has not exhibited the boldness, skills or imagination required to solve these problems. Government's boldness deficit exceeds its financial deficit and is illustrated by the fact that since President Nixon raised the healthcare cost issue, until President Clinton, other presidents have dodged or even denied the importance of this issue. The skills deficit is illustrated by this administration's ill-fated attempt to solve the healthcare cost problem. Something different from the traditional political process, bungling bureaucrats, and government committees of VIPs without research staff, but lots of opinions, is required to address these complex systems issues. Peter Senge points out,

> *None of today's most pressing societal issues - deterioration of our natural environment, the international arms race, erosion of the public education system, or the breakdown of the family and increasing social anomie and fragmentation - will be resolved through hierarchical authority. In all these issues, there are no simple causes, no simple fixes. There is no one villain to blame. There will be no magic pill. Significant change will require imagination, perseverance, dialogue, deep caring, and a willingness to change on the part of millions of people. ... The challenges of systemic change where hierarchy is inadequate will, I believe, push us to new views of leadership based on new principles. They will require a unique mix of different people, in different positions, who lead in different ways.*[158]

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[157] Al Teich, American Association of Science Presentation to President's Committee of Advisors on Science and Technology (PCAST), March 6, 1997.

[158] Peter M. Senge, "Leading Learning Organizations: The Bold, the Powerful, and the Invisible", The Leader of the Future, edited by Frances Hesselbein, Marshall Goldsmith, and Richard Beckhard, The Drucker Foundation, 1996, pp. 56-57.

We recommend that The President and Congress offer engineers, mathematicians and physical scientists the grand challenges we have presented; encourage them to **partner** with political scientists, economists, the business community, lawyers, and social scientists; focus oversight activities on **outcome analysis**; and **let them do their job**! The potential for solving these grand challenges is high provided that cosmopolitans that fit the leadership model of Rosabeth Moss Kanter can be found to lead these efforts.

> *Leaders must become cosmopolitans who are comfortable operating across boundaries and who can forge links between organizations. Leaders must take their ability to craft visions, inspire action, and empower others and use it to encourage people from diverse functions, disciplines, and organizations to find common cause in goals that improve the entire industry, community, country, or world and expand the pie for everyone, rather than pushing in narrow parochial interests that pit group against group, wasting resources in a scramble for shrinking slices of the pie. They must become cosmopolitans who have the vision, skills, and resources to form networks that extend beyond their home base and to bring benefits to their own group by partnering with others. ... Cosmopolitan leaders of the future must be integrators who can look beyond obvious differences among organizations, sectors, disciplines, functions, or cultures. They must be diplomats who can resolve conflicts between the different ways that organizations or communities or countries operate and who can influence people to work together, to find common cause. They must be cross-fertilizers who can bring the best from one place to another. And they must be deep thinkers who are smart enough to see new possibilities and to conceptualize them.*[159]

The U.S. nuclear power failure - no new plant ordered since 1973, nuclear power plants require up to 15 years to construct in comparison to 5 years in Japan and France, operating plants being shut down well before reaching the end of their 40 year licensed operating life, etc. - illustrate what can happen when partnerships are not established between physical scientists, engineers, lawyers, social scientists, economists and political scientists.

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[159] Rosabeth Moss Kanter, "World-Class Leaders: The Power of Partnering", The Leader of the Future, edited by Frances Hesselbein, Marshall Goldsmith, and Richard Beckhard, The Drucker Foundation, 1996, pp. 89-98.