BACK TO THE BATTLE

FOR

BUNKER HILL

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FOREWORD

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"Behind their earthworks and flimsy fences the rebels watched and waited; men faint with hunger and fatigue, dirty farmers in floppy felt hats and homespuns, fingering their muskets nervously, feeling instinctively for spare cartridges, anxiety and disbelief welling up in their dry throats as the finest infantry in the world moved closer and closer, threatening to engulf them... Just behind the firing line, officers crouched low and moved swiftly back and forth, passing the word to shoot low, to wait for the order to fire,...to wait until they could see the whites of their eyes. And the red tide moved slowly nearer, near enough now so the defenders could distinguish faces beneath the tall pointed helmets, make out rows of shining buttons and belt buckles. Now and again there was a strong moment of silence — the big guns had stopped firing, for fear of hitting their own men — broken only by the steady, dull thump of marching feet, the swish of long grass as two thousand men pushed through it,...

"...The British were only two hundred feet away, then one hundred, now fifty, when a row of dull musket barrels leveled along the stone wall, a nasal New England voice twanged, and the wall disappeared in a sheet of flame and oily black smoke. The blast of fire tore apart the leading ranks of Fusiliers, and as the rows behind closed up, they were shattered by the violent hail of bullets. Officers fell, men spun around and dropped headlong into the shallow water, and the column stopped, recoiled, then came on again, the King's Own Regiment shoving through the broken Fusiliers, clambering over the dead and wounded only to be met with that withering fire from the wall. Officers' voices shouted hoarsely through the din, ordering the men forward, but with each advance the men in the lead simply melted away, falling grotesquely and piling up the awful carnage on the narrow beach until there was nothing to do but turn back.

"...something entirely intangible and perhaps not even recognizable at the time, had occurred... Men who were not fighters by trade or inclination had stood side by side behind their earthworks and their fences, and had waited calmly while some of the most formidable fighters in the world advanced against them in ordered ranks. They had not run from artillery fire, they had stood up to the wild terror of a bayonet charge, and they had broken only when their ammunition gave out and they could fight no more. A few months earlier the odds against the success of any American military effort would have been overwhelming; the regular army was an object of dread, not to be tested. Now Americans had met it face to face, and like a fragment of darkness suddenly exposed to the light, it could be seen for what it was — an army that commanded great respect, but one composed of men no taller or stronger than any others. By demonstrating that some rather ordinary American farmers had stood against this formidable enemy, the battle of June 17 proved, as nothing else could, that others might accomplish the same thing. Had they failed, it is just conceivable that the rebellion might have spluttered out."

"The Battle for Bunker Hill"
Richard M. Ketchum
Doubleday and Company, Inc.
New York - 1962

INTRODUCTION

In the Ketchum quote presented in the Foreward, it was clear that the British, arrogant with success, failed because they refused to change their time-tested, traditional approaches to meet new circumstances even though they had been warned, first with a thousand of fifteen hundred men killed *"without sighting more than one or two of the hidden enemy"* in Braddock's defeat of 1755, and warned again — at Concord and Lexington. The upstart colonists did not fight *"fairly"* by traditional standards.

It is now 1988, and the United States is again in battle — this time for its economic, social and perhaps even its political independence. Battles for technological superiority are ones for survival, and America's upstart foreign competitors are not fighting trade battles *"fairly."* It is time for Americans to re-visit Bunker Hill to re-learn the lessons they taught the British. The competitiveness warnings have been sounded.

Competitiveness has become the watchword of the '80s, but it has too many meanings to be a galvanizer. To some, competitiveness means better paying jobs for themselves and their children; to others it means a better educated workforce; to some it means generating greater profits; for others it is only the most recent political buzzword; but to most it means nothing as long as they have the ability to purchase what they want, when they want.

The ways that have been suggested to achieve the *"competitive edge"* range from expanding free trade concepts to adopting protectionist legislation; from expanding legislation to encourage small business development and venture capitalism to establishing tax incentives for modernizing *"smokestack industries;"* and from expanding high-tech development to reducing the value of the dollar to encourage production and export of low- and medium-tech manufactured goods.

Two articles that appeared next to each other recently on the business section front page of a regional newspaper illustrate the dilemma. Both attempted to address competitiveness. One suggested growing blueberries as an alternative crop and the other promoted streamlining a high-tech process. It is understandable that the public is confused about what *"competitiveness"* means because it means everything — and nothing. Here, competitiveness is defined simply as making a product or providing a service better than one's competitors.

Most of the profusion of books, magazines and newspaper articles on competitiveness present a litany of facts and numbers as they project the ultimate demise of the United States economy. Few furnish any specific suggestions about how to solve the problems. Stating a problem without voicing a possible solution is like yelling *"Fire!"* without pointing to the exits.

Most of these authors assert that increased productivity, enhanced levels of private savings, and increased exports of goods and services will help resolve the problem. But how can this be done? They almost all agree that science and technology are the most competitive tools the United States has to ensure continued international leadership, but few provide any directions about how to use these tools. This is akin to telling a wanderer on a foggy night that the destination he seeks lies due north without telling him which way is north. Even a compass cannot help the United States unless it first knows where it is now, where it wants to be, and what means it has to get there.

One reason those who have staked America's future on science and technology have supplied so few specific solutions is that they are not science practitioners. They are unfamiliar with the scientific community, its procedures, and what motivates many research scientists.

Scientists generally are committed strongly to the belief that what they do is for the ultimate good of all humanity. The scientific creative process is intense and all-consuming, but it also is disrupted easily by outside factors. The scientific community often is called a community of minds and spirits — one in which emotional support and encouragement for often immense mental effort comes exclusively from the participant's peers. The members of this community are productive and creative, at least in part as a result of the support and recognition that comes to them as individuals through the free and informal flow of information between them.

To make suggestions about how to harness the creative energies of science for economic development without understanding what motivates the individuals to achieve is to endanger the productivity of the community.

Most Americans know where they want to go. They want continuing or improved lifestyles for themselves and their children. They also know — sometimes in the form of a vague, nagging uneasiness — that this is in jeopardy. What they want to know now is where the country is and how it can get to where they want it to be in the future?

As a nation, the United States must be competitive in making and selling goods and services not only to have sufficient wealth to support basic research, but also in order to create jobs and maintain the American standard of living, which includes both the country's social programs and its military strength. Therefore, it is not a question of which is sacrificed, but rather of how the United States can compete more effectively to maintain what it has for all Americans.

There are more than 1,000 Federal research and development facilities contributing in some form to technological advancement in the United States. They comprise a sixth of the total research and development expenditures in the U.S. and employ a fifth of the country's scientists. It has also been reported that during the 1980's the U.S. invested $1.5 trillion in federal and industrial R&D.

This infrastructure, equipment, and scientific expertise represent a massive investment or *"hidden wealth."* A common belief is that these laboratories, merely by existing, benefit the taxpayers through knowledge development. Since enactment of the Federal Technology Transfer Act of 1986, an increasingly strong argument can be made for their contribution to industrial commercialization.

Some of the Federal laboratories recognize that a national competitiveness problem exists. On the whole, however, the Federal sector is still sending its troops up the hill marching abreast.

The premise of this paper is that policy makers, citizens, scientists, business leaders and others have not been made aware of the more complete manner in which these facilities can and should directly benefit the taxpayers. Too often they are not recognized as *"wealth"* available for direct access and use for industrial benefit. Americans have come

to accept a traditional role for Federal laboratories and have mentally compartmentalized that role. Our purpose is to challenge that compartmentalization. If we are to maintain our world position and standard of living, it is time to re-think the availability of all of America's resources — its hidden wealth.

The September 1988 report of the Council on Competitiveness, *"Picking Up the Pace,"* indicates that, *"The primary challenge for policy makers is to develop a new policy framework appropriate for today's competitive environment."* The report identified the urgent need for government action in multiple policy areas, with recommendations to correct deficiencies in several general areas: weak fiscal and trade policy which it holds responsible for our large budget deficits; misplaced Federal priorities; inconsistent incentives; outdated regulatory barriers that inhibit the rapid commercialization of technology; an inadequate research infrastructure; and narrowly focused research and development efforts. All of these either directly or indirectly impact on the rapid commercialization of new and subsequent-generation technology. But simply following these recommendations will not solve our problems. We need more specific actions for the more effective use of Federal research and development resources in order to compete in the global economy.

This paper attempts to build on the Council's effort by showing how the United States can use its Federal research and development resources more effectively to compete in the new global economy. The authors believe many of their recommendations can and should be carried out on a trial basis in one or more demonstration projects. Because of the system's complexity, it is not proposed that present policies be overturned without a trial.

RECOMMENDATIONS

The recommendations presented are based on the conclusion that the problem facing the United States in science and technology competitiveness has less to do with basic scientific research than with the application of basic research to the production of durable, simply-designed, and easily-made high-tech goods. They are based further on the belief that if means are not found to overcome this problem, the United States will have insufficient wealth to continue its support of basic scientific research.

Management is the fundamental difficulty the United States has in converting basic research to the production of such goods. Therefore, the focus must be on improving management — improving management in both the public and private sectors.

That the U.S. is successful in basic research is demonstrated by the number of its Nobel Laureates (51.6% of all those awarded in the sciences between 1950 and 1987), by the leadership roles its scientists play in virtually every major scientific society, by the more than 30,000 research scientists who visit the United States annually to receive advanced training in its laboratories, by the number of articles (more than 60% of the total) that U.S. scientists publish in virtually every major international journal, and by the number of new fields and areas of science developed in American laboratories.

The United States must continue its dominance and leadership in basic research because it is the source for the pipeline leading to new products. To do this, the nation must have sufficient wealth to fund basic research. If the United States doesn't maintain a strong manufacturing base, it is reasonable to assume that funds will not be available for that research.

It also is apparent that while the United States has been successful until now in converting basic scientific discoveries into products, it has been unsuccessful in retaining leadership in several manufacturing areas once they were established.

In electronics, the United States' share of the global market has declined from 100% in 1970 to less than 5% today. By 1986, Japan had captured 65% of the world market for semiconductors to America's less than 30%. Between 1970 and 1987, the American share of these markets declined as follows:

Phonographs	90% to 1%
Color TV	90% to 10%
Machine Tools	100% to 35%
VCRs	10% to 1%

The results of foreign manufacturers' targeting specific technologies have become commonplace knowledge, e.g., how Japan captured the market for VCRs and how, despite the fact that American engineers invented the integrated circuit in the late 1950s and the United States attained early dominance of this field in the 1960s and 1970s, the Japanese attained an equal share of the market by 1983 and 65% of it by 1986, is well known.

This is just one example showing that, while the United States develops and funds the basic research for these products through taxpayer dollars, either directly or through tax credits and deductions, the payback on that investment, more and more frequently, is going to foreign manufacturers. Another indication that the United States is failing to develop knowledge into marketable products is that 46.6% of all U.S. patents in 1987 were obtained by foreign nationals. Moreover, between 1969 and 1982, the rate at which Americans patented abroad declined by 50%.

The success of America's competitors is based on their ability to make incremental improvements to process engineering, manufacturing, and marketing of subsequent generations of products faster than America.

In more than thirty years of electronic competition with the United States, the Japanese are not recognized for being first to the marketplace with any new, significantly different high-tech product. This is beginning to change — for the worse. Now, because of improved data-gathering tactics, the Japanese and other economic competitors are beating the United States to the marketplace with first-generation products. This is apparent in one of the most rapidly developing fields of science — biotechnology. For example, the United States has invested more than $100 billion in molecular biology over the last thirty years. The basic research in molecular biology served as the genesis for what we now call biotechnology. More than 60 applications for low-level containment microorganisms for use in industrial applications were submitted to the Japanese ministry last year, while only one for similar uses was submitted in the U.S. to the Environmental Protection Agency.

The United States cannot afford to continue letting this happen. Relative to science and technology and their management, many Japanese leaders are amazed the United States has done so little to overcome problems that are obvious to them and why the solutions being proposed are too often of a Populist and isolationist nature.

The recommendations here are specific, interrelated, and form a plan for changing the manner by which Federal research and development relates to industrial practices. It is recognized that the needs, applicability and mission of each Federal agency will differ as to their respective missions, but most of the recommendations are presented as generic approaches that could be modified within most government laboratories to accomplish the same goals. The authors recognize that several Federal laboratories conduct classified research projects. Obviously, security imposes a separate dimension which must be dealt with separately and which is, therefore, *not* covered in this document.

The purposes of these recommendations are:

- To place the Federal research and development sector into proper perspective in a society whose success and foundations are deeply rooted in science and technology;
- To evaluate the role of governmental science in the United States at a time of great international economic competitiveness;
- To identify approaches to science that are needed to compete in the international marketplace;

- To develop systems to optimize the use of existing science and technology resources within the government;
- To improve the coordination between government, industry, and academia of research and development resources; and
- To suggest methods of broadening the focus of Federal research and development efforts in order to enhance commercialization, e.g., streamlining of regulatory review without adversely impacting public health.

A

Develop an infrastructure capable of more effectively utilizing the national scientific genius.

The U.S. is a technologically-based society. Our past and our present are consumed largely by events that are scientific and technologically-driven. A significant portion of the Federal budget is spent on either developing or purchasing technologically sophisticated products. Yet we lack in the Executive Branch, any well-coordinated management approach, spreading across all Cabinet-level departments and independent agencies to maximize the return on taxpayer dollars relative to such spending. In addition, the Legislative Branch consists primarily of lawyers and businessmen, few of whom have a scientific background. Therefore, they must depend on an understaffed Office of Technology Assessment, the General Accounting Office, relatively few scientific staff, and a few other advisors for scientific background information to make budget decisions and provide oversight. The Judiciary Branch, which is being called on more frequently to rule on scientific matters, must depend primarily on expert witnesses as their source of scientific information. Thus, as society becomes progressively dependent on ever increasingly complex science and technology, its leaders in all branches of government have a paucity of scientific background on which to base policies and make decisions.

It is widely recognized that the United States has, among its scientific capabilities, the widest breadth of scientific talent and individual capabilities to be found anywhere in the world. This is evidenced by the number of Nobel laureates and other major awards received by American scientists as well as the continuing flow of scientific discoveries coming from the United States. The challenge, therefore, to American management is the development of methods that will properly channel these resources to meet our global competition in the area of commercial development. Accordingly, the recommendations that follow in this section are made in order to facilitate the transfer of knowledge, both among members of the scientific community and from the research laboratory to the society as a whole in order to meet its needs for economic and social advancement.

The first recommendation provides a focus for management of several coordinating activities. It attempts to provide a mechanism for ongoing consensus building across segments of our scientific society, creating a resource to be used by all branches of government, plus industry, academia, and the public. Second, it attempts to provide a focused leadership in government in order to develop a highly coordinated and integrated approach toward science and technology.

1. *Provide a strong scientific voice at the Cabinet level and within the Domestic Policy Council for coordination of scientific issues, e.g., this does not necessarily mean raising the rank of the White House Science Advisor to Cabinet level or the creation of a Department of Science and Technology. It does mean, however, expansion of the staff of the Office of Science and Technology Policy (OSTP), restructuring of OSTP to reflect the specific research and development efforts of the Federal government, creation of groups within OSTP to address the integration of science budgets across*

Federal departments, establishment of a permanent office within OSTP to address issues of national competitiveness, coordination of long-range planning across departments, and structuring of interdisciplinary R&D efforts. It is also suggested that the very important role of providing scientific advice on matters of national security be maintained, but more closely coordinated with the National Security Council as a separate and independent function apart from issues of national economic competitiveness.

The next recommendation takes advantage of our diverse national scientific establishment. America clearly possesses much of the world's best scientific talent. This recommendation is directed toward creation of a structure to access the talent of our people, to listen to it, and to focus it on the solution of practical problems. The goal of recommendation 2 is to mobilize the scientific talent of all sectors of our society to address issues of competitiveness. This recommendation calls for councils of Federal, academic, and private scientists to provide a forum for addressing such issues.

2. *Establish three advisory science councils under the direction of the Science Advisor. Each Council would meet at least annually to discuss issues, propose solutions, establish communication channels and disseminate both new scientific and administrative information.*
   a. *Council of Federal Scientists composed of all Federal laboratory directors;*
   b. *Council of University Scientists representing academic institutions; and*
   c. *Council of Business Scientists representing the industrial sector.*

These recommendations provide a structure to obtain advice from the scientific community and upon which to build consensus. In order to succeed, however, a strong coordinating focus must be developed to utilize this advice. The members of these Councils must be given an opportunity for participation in order to attain scientific consensus and ease the task of policy setting. In order to be effective, the effort must be balanced, objective and controlled. Its goal must be one of addressing scientific issues not in a vacuum, but one in which other factors such as economics, law, taxation, business development, and the environment can be taken into consideration.

The management of this effort, indeed, will be difficult. Science, like other fields, is full of those with special interests. The leadership will have to devise mechanisms to work around or within special interests and attain consensus based on scientific principles.

Recommendation 3 is developed in support of recommendation 2. Its purpose is to ensure coordination and develop advice of other non-scientific disciplines.

3. *Establish within OSTP an executive council that would meet at least monthly in order to develop agenda, coordinate activities, and convene, when required, special work groups.*

A comprehensive strategy for funding non-defense-related basic science research and development activities should be one of the primary products emerging from the efforts to coordinate these activities. The areas of research which are addressed should be

based upon national goals and the scientists from the three sectors should aid in establishing priorities.

4. *Based on the OSTP's continuing efforts and those of the Councils, establish national strategies for funding basic science research and development to include creating centers of academic excellence, demonstration projects for innovative approaches, research consortia, and other initiatives.*

All of the activities of government require a stronger coordination in order to facilitate the process of technology transfer. Accordingly, the next recommendation calls for the establishment of science advisors reporting directly to the Secretary of each department and utilized extensively by the Secretary for advice. This presence should be linked to the OSTP presence, both for providing information to OSTP from the perspective of each department and also in order that OSTP might better serve the departments of government by ensuring coordination, thereby reducing unwarranted duplication. Every department is impacted by issues that bear directly or indirectly on science and technology, such as trade policy, tax incentives, Federal property utilization, and even purchasing of technological devices. The Federal response to these should be coordinated through the network formed by these individual offices and the OSTP network.

The coordination effort will require the creation of specialty subgroups to identify research areas that either are not being addressed or are being addressed inadequately, evaluate the impact of these deficiencies on United States scientific competitiveness, and project the long-term costs and economic potential of correcting the deficiencies.

5. *Within each department create a strong science office or council to provide each departmental secretary a budget which coordinates the department's scientific activities, defines competitiveness issues, assures coordinated scientific implementation policy, monitors performance of laboratory directors, monitors scientific expenditures, and coordinates plans and programs with the Cabinet-level office.*

There is a clear need for better presentation and utilization of scientific findings. Part of the strength of the scientific infrastructure established in this country has been the peer review process of publication and public presentation. The authors, in no way, wish to change or effect the importance of that process. However, it is one aspect of our science-development activities that must be examined. If we assume that our competitors share information amongst themselves more completely than do we, thus affording them the opportunity to develop commercializable technologies more rapidly, then we have an obligation to examine that activity requiring editorial boards to be convened and a process which appends significant time onto the activity of scientific data presentation. The authors are in favor of more rather than less peer review, in general, and would envision a scientific forum which would allow peers to present questions electronically, which would in turn be shared with all users. In addition to presenting public critiques, it would also serve very importantly to generate more collaborations among researchers, between researchers and developers, and developers and the business community as well as between all of these aspects and the financial community.

Additionally, it is envisioned that the system suggested would ultimately evolve into the first national science communication system linking the Federal, academic, and industrial scientific establishments into a unified network.

6. *Develop a national electronic scientific forum through which new findings can be presented, evaluated, and critiqued more quickly and efficiently, and communication between all sectors of the scientific establishment established. (This would not replace the current method of using meetings and journals but would reduce redundancy, generate collaborations, and increase communication.)*

B

Place national priority on converting basic scientific discoveries into durable, simply designed, easily manufactured and marketable products and on modifications to create subsequent generation products.

In order to keep our strong economy, we must convert our research findings into marketable products. The Federal grants process has been responsible in large measure for the creation of our marvelous research infrastructure and could be responsible for creating a stronger applications infrastructure for tomorrow. This activity should be apart from the current research grant process and should be governed by clear criteria geared toward applied research.

1. *Increase funding of existing government granting agencies to develop programs to fund applied research grants. Applied research grants should be awarded primarily on a competitive basis for their potential to lead to new marketable products.*

The value of our research and training grants in the basic research area has been demonstrated repeatedly. As the current market place is demonstrating, the United States needs to strengthen both process design and manufacturing. It is, therefore, important to focus the same kind of attention on this area in the future as we have on basic research in the past. The Executive Branch, the Congress, and many states and other organizations have worked to support process design and manufacturing. However, without a well-funded granting process, it is doubtful that the breadth of support needed can be generated.

2. *Establish more research and training grants in process design and manufacturing. While such programs are common in basic science, there are few for the more applied aspects of science and manufacturing.*

In recent recognition of the need to focus more of our national attention on the design and manufacture of goods, the Federal government has established some centers of excellence for this purpose. The authors believe this function should be strengthened. The current valuable efforts to develop centers of excellence should be expanded and review processes to evaluate their success should be strengthened.

3. *Working with the National Academies of Science and Engineering, and the leading professional societies, increased support for centers of excellence in applied research at both public and private facilities should be reviewed. Each center should be funded on a competitive basis and reviewed annually to ensure performance.*

As the government focuses attention on application of basic research, government laboratories should be encouraged to direct resources to problems of scale-up and production. Frequently, problems of scale-up become insurmountable barriers by all but the largest of industrial firms.

4. *Focus some of the efforts of Federal laboratories on application of developed technology, including problems of scale-up from the laboratory setting to on-line production.*

There is a need to provide more opportunities to convert research information into useful products, and to establish wider recognition of the need for such a process. Recommendations 5 and 6, below, encourage the use of public facilities for use by inventors and provide the public with knowledge of important events in converting scientific findings into marketable products. Publicity associated with these programs should stimulate interest and support.

5. *Establish a national inventor-in-residence program. Funded on a competitive basis, for individuals who want to work at public or private basic and applied research centers to convert research findings into innovative products or, when applicable, the modification of existing products.*

6. *Establish a national inventors awards program. Awards would be given to those judged to have developed the most innovative and marketable products in selected scientific areas.*

It is a frustrating fact that there is no single inventory of Federal R&D capabilities, which represent approximately half of the R&D capacity in the U.S. Several firms, universities, and government agencies have recognized need for better access to facilities and better brokering between capabilities and, as a result, have developed a number of small inventory systems. The belief of the authors is that these systems simply do not go far enough. There is a need for an on-line, interactive system which lists capabilities, facilities, equipment, developed technologies, expertise, patents, software, etc., that could be used in cooperative research and development programs. Frequently the fear is voiced that maintaining such a system would be a major *"nightmare"* and that the complexity involved in collecting all the data would represent an impossible task. The effort would be time-consuming, but clearly not impossible. In fact, the work could be distributed to each facility where a standard format could be developed and continuously updated. The resource represented by the Federal laboratories could be invaluable to the nation. However, unless there is an index to its availability, it cannot be expected to be adequately used.

7. *Using a standardized format for ease of access and evaluation, develop a national inventory of Federal research and development resources, including personnel, expertise, facilities, equipment, developed technologies, patents, software, etc., that could be used in cooperative research and development programs. (Existing computer software technology permits developing such a system in an easy-to-use format.)*

The next recommendation reinforces the fact that the Federal laboratories must be made available and useful to the private sector. The Federal Technology Transfer Act currently requires an office within each major Federal laboratory for the facilitation of the transfer of technology out of the Federal laboratory. However, a new level of importance should be added which provides a more business-oriented help desk. It would not only help to broker technological needs with availability, but it would serve as a resource for getting answers to a myriad of questions.

8. *Within all major Federal laboratories (those employing 100 or more government and contractor research professionals), establish service centers that businesses may contact for help in resolving technical problems.*

There have been several efforts to develop presentations during which Federal technology can be made known to potential industrial and academic collaborators. The authors believe these activities to be valuable, but for a national effort, they are too *"hit or miss"* in approach. There is a need for a more coordinated approach that is nationally recognized and that complements the existing schedule of conferences and in no way replaces them. Along with a sufficient level of publicity and good planning, an annual event, which is widely attended, would represent a more useful approach.

9. *Convene an annual, National Science Product Fair, at which the Federal government establishes booths for each facility that has technology available for transfer; where the industrial, university, venture capital representatives can visit and discuss these technologies with the Federal representatives.*

Relative to the second set of recommendations, the authors believe that a focus on converting basic science into manufacturable and marketable products requires much more emphasis. The Federal laboratories can become more effective in this process of technology transfer. They represent hidden wealth as described in the Introduction, but their most effective use requires the development of more effective management systems.

C

Restructure the regulatory review and patenting process to reduce review time without impairing public health and safety, the environment, or the protection of intellectual property.

The need to carefully evaluate the current regulatory review process is clear. It has been described by many as a major barrier to U.S. competitiveness. The authors do not believe that the path to regulatory relief means a reduction of safety standards. To the contrary, we need to assure customers, domestic and foreign, that American products are both safe and effective. However, such a position does not mean that one cannot carefully evaluate the existing process, seeking better management approaches.

1. *Within each regulatory agency, develop a highly trained, specialized field force of regulatory review officers who participate actively with the private sector in the up-front design of research programs intended to develop new or modify existing products. The field force would ensure that all safety evaluations are built into the initial research programs. (Currently, it is only after a product or process has been developed that it is brought to the regulators, who then often determine that further testing is required. This looping process is time-consuming, unproductive, and costly. The same or greater degree of protection of the public and the environment could be achieved by shifting regulatory input to the front end of the research and development process.)*

The authors are recommending that demonstration, pilot efforts be established where a pilot program would be established concurrent with existing programs to ensure no real or perceived negative impact. There should be a full-scale evaluation of the pilot effort. The pilot effort, if successful, should be expanded to all regulatory agencies to see in which situations it can best serve a beneficial purpose. Further, it should be thoroughly discussed through a consensus mechanism, and the positive aspects of it should be fully developed.

2. *Provide management and other incentives for agencies and laboratories, particularly those in regulatory agencies, to develop demonstration projects which, under controlled conditions, test ideas to be used in the regulatory review process in order that that process might be accomplished more effectively.*

The U.S. Patent Office process, while granting patent protection, also impedes the process of commercialization as demonstrated by the three-year back-log of biotechnology products. The authors are recommending that an effort be focused on removing this barrier in a manner similar to that recommended above.

3. *Within the U.S. Patent Office, develop a force of patent review attorneys who, on request, would meet with firms and individuals attempting to develop new products or modify existing ones and provide the criteria that must be met to enhance patentability before development is attempted. (Because of the complex and rapidly evolving nature of new scientific fields and a flood of foreign patent applications, the staff of the U.S. Patent Office is overwhelmed by an*

ever-increasing workload, thereby lengthening review time and giving little time for reflection on how best to address the ever-changing nature of science and technology. Again, final review time will be decreased and the probability of success enhanced if the criteria were established at the outset rather than at the end of the process.)

The complexity of science and technology continues to increase daily. The degree of specialization required to evaluate new concepts, products, and processes is, therefore, continuously growing. As a result, the degree of specialized skills needed to review patentability of new products is continually increasing. This drive toward increased complexity in science and technology will continue to accelerate as we become a more science and technology-dependent nation. It is thus suggested that a series of steps be developed to bring these constantly changing skills into our patenting process.

4. *Establish within the U.S. Patent Office: ongoing training programs for existing employees; provide to this office training-program authority to train lawyers in science skills and scientists in legal skills, with service pay-backs to the U.S. Patent Office based upon a percent of time for which support was provided to the trainee; and establish interdepartmental exchange programs designed to expand the skills of participants, e.g., between the research laboratory staffs of the Federal government and the U.S. Patent Office staff.*

Clearly, there are major scientific issues for which there is wide-spread and learned disagreement. However, historically scientists have come together to develop consensus over major, conflicting issues. The authors believe this approach should be relied upon more completely at the national level. The current reliance upon a quasi-legal model for resolving conflicts without having first made some attempt to reach basic consensus is divisive and counter-productive. The value of this approach obviously depends upon the quality of the persons chosen who must attain consensus. There should be a national, agreed-upon strategy for choosing our best scientists to help guide this. Many of the issues confounding science policy may be complex and require different types of solutions than have historically been experienced. Accordingly, there is a need to review educational needs in law schools, business schools, and in education in general.

5. *Establish an independent industrial/public forum within the NAS or OSTP that is staffed by paid representatives of government, industrial trade organizations and public interest groups to evaluate, discuss, and when needed, convene study groups and consensus workshops to resolve generic and specialized regulatory and public safety issues in a relatively non-adversarial atmosphere. (Such issues are addressed now in an advocacy mode by highly focused interests, usually representing a single point of view. This leads to conflict between government and business, branches of government, and government and public interest groups, slowing the process and inhibiting the resolution of complex problems, perhaps even impairing public health and safety. The suggested approach is more representative of how science historically has resolved conflicts, not through a science court, but through scientific consensus, and perhaps is more appropriate than the legal model for issues relating to science and technology.) This effort should also focus on the need for scientific and technical issue training in law schools, business schools, and others consistent with recommendation 4 above.*

The authors are concerned that our administrative systems and procedures have become too inflexible and time-consuming. There is apparently a large body of opinion holding the view that we should endeavor to regulate better, without being so slow as to adversely impact American business compared to foreign competitors. Open-minded efforts to address this situation are important and efforts should be made to move toward this goal. In the same manner that successful businesses have developed mechanisms to tap good ideas of their employees, it is important for national leadership to rely on the good ideas of its people. In order to implement this recommendation, the authors believe the Federal government should rely heavily upon a panel from all sectors and major interests, including the regulated industry to devise a series of recommendations that would improve upon the existing data submission and review processes. Current data reduction technology should be utilized to improved on this process.

6. *Through a consensus mechanism, work toward the establishment of a uniform and open electronic submission and communication system across and within regulatory agencies. The closer we can approach the standardization of submission forms, inspection reports, adverse reaction reports, etc., the more expedited would be product review, regulatory action and interagency coordination. Such a system should also address the needs of communications between the Federal and state and local governments.*

The next recommendation responds to another concern about timeliness and flexibility. The use of expert panels is invaluable to the regulatory agencies and should be continued. However, the difficulty in convening sessions of panels leads to a time-consuming process with requirements to absorb massive amounts of hard-printed data. An effort calling upon national experts should be directed toward the improved availability of electronically-transmitted data summarized in a fashion that will make it more readily reviewable. Successful implementation of recommendation 6 would certainly facilitate the implementation of recommendation 7.

7. *Study the present use of expert panels for product review to determine whether they can be modified by the use of electronic networks and more modern methods of communication. Hard (printed) copies of information on individual products and processes now are duplicated, distributed and then discussed in working groups composed of scientific experts. This process could be modernized, at least in terms of information storage and distribution and possibly even lead to a multi-participant electronic forum.*

D

Expand the cooperative research and development roles of Federal laboratories.

The era of limited foci for Federal research and development capability should be ended. In laboratories in which there is either unique, or rarely provided equipment, programs should look toward 24-hour-per-day operation. It is that type of re-examination of efficiency of capabilities that will be required in order for the U.S. to be competitive. To some extent, this recommendation is tied to recommendation B.7. which calls for an inventory of Federal capabilities. As that inventory is conducted, the availability of space and equipment which can be utilized more effectively for competitive purposes must be identified. In order for the Federal facilities to be utilized as the *"hidden wealth"* they represent, availability of space and equipment must be more clearly identified. In this fashion, the *"hidden wealth"* could be utilized directly to significantly reduce the amount of start-up capital required by businesses. By this method one can reduce risk by spreading risk over a greater number of venturers without increasing total cost of development. Structures could be established in such operations to charge the businesses a fair lease rate so that any costs accrued to the government could be reimbursed back to the U.S. Treasury. In times of insufficient laboratory space at most universities, the availability of Federal space should also be explored for the inventor-in-residence programs recommended earlier.

1. *Given the fact that the Federal government's laboratory capabilities represent rare and often unique equipment and facilities, a review should be made to determine which of these facilities could be more extensively utilized to help reduce the cost of new product development.*

Many academic institutions are people rich and facilities poor, while many government facilities are facilities rich and people poor. Programs to share the wealth of each sector should be explored. In the same fashion that the Federal laboratory infrastructure should be made available for business commercialization, it should also be made available for university training. If the Federal laboratories become aligned more closely to national needs, then training opportunities at Federal facilities would assure more relevant training. Accordingly, it will be important to examine and, where needed, strengthen the training responsibilities of Federal laboratories. In addition to the academic sector, consortia for sharing resources developed also with the industrial sector to encourage sharing of personnel, equipment, and facilities.

As these needs are being studied, it will also be important to evaluate the situation regionally to assure that business development is occurring throughout the nation. This effort should be directed toward assuring equitable distribution of Federal laboratory/university/business consortia and developmental arrangements.

2. *Expand the role of Federal laboratories to include greater interaction with the academic and business research and development programs. Government facilities should also be made available for training opportunities and the Federal laboratories should take a more active role in training. Research consortia should be established to encourage the exchange of research personnel to conduct collaborative programs.*

There is clearly a need for cooperative programs with the state governments. Almost every state has developed a strengthened program in science and technology. The Federal laboratories should be encouraged to interact with these programs. Such joint programs should include the utilization of facilities and space to aid in the recruitment of new industry or for the further development of academic programs.

3. *Establish joint programs between Federal research facilities and state science and technology programs as described in the Omnibus Trade and Competitiveness Act of 1988 (P.L. 100-418).*

E

Review existing Federal research and development operations.

There should be a comprehensive review of the Federal laboratories to: (1) determine their relevance; and (2) to assure coordination amongst those laboratories where it is appropriate. Such a review might define areas where consolidation of existing facilities is reasonable and where, perhaps, some should be closed entirely. Recognizing the importance of many of these facilities to the local economies, it also will be important to define new tasks for those facilities that might be closed so that they become important to building the local economy rather than devastating it.

1. *Use external panels to examine the roles, needs, and performances of Federal laboratories to determine their relevance to technology transfer and national competitiveness. Based on the review, programs and missions should be expanded, consolidated, restructured, remain as is, or re-focused.*

In order to encourage cooperative R&D agreements, it is important to provide assurance of quality programs. Accordingly, all unclassified Federal R&D programs should benefit from external peer review of their research activities. Such an effort would not only provide better assurance of effective programs, but also would serve to disseminate information more widely with respect to these programs.

2. *Establish standardized internal and external peer review processes for Federal intramural research programs, similar to those now used to determine priorities for extramural research requests. (Various government laboratories now make use of science advisory boards or panels to one extent or another, but they generally are limited to generic program review, often carried out after the fact. This recommendation would enhance the quality and meaningfulness of Federal research by using external peer review to provide in-depth review of individual research programs before resources are allocated.*

To conduct meaningful research, the government must be able to retain its world-class scientists. These scientists need to be able to grow in an environment that supports their scientific efforts. The authors recommend the implementation of programs of peer review by scientists outside the Federal laboratory or agency in which the scientist works and, to a large extent, outside the Federal government. Such a peer review should be comprehensive, looking at the specific accomplishments of individuals in terms of quality of publications and other scientific output, as well as efforts to make this knowledge available to the general public. Means of adequately compensating the most successful scientists in the peer-review process are essential.

3. *Move more generally across government to the use of a performance review system within government research and development operations that uses external review committees to determine grades of R&D personnel. Based in part on review results, employees would be promoted, held in grade, demoted, or dismissed. For such a system to work fully and enhance the research activities of individuals to the maximum extent possible, action should be based only*

partially on the individual's administrative responsibilities. Additionally, if world-class scientific peers find that scientists are working above current grade ceilings, opportunities for exceptions must be made.

Incentives should be provided for more complete exchange of personnel. The trend for reviewing anti-trust concerns should be continued and the application of conflict-of-interest regulations should be in cases where appropriate rather than the broad, sweeping constraints that currently exist (e.g., some departments have sweeping regulations covering all personnel uniformly when those regulations may be very appropriate for certain sections and less appropriate for others).

The next recommendation follows from the need to direct more attention to science management and the relevance of science to societal needs. Classically, the character of a research laboratory is reflective of its leadership. It is important, therefore, to maintain quality laboratory leadership. Review of such leadership is as important, if not more important, than of the bench research scientist. In order to do so, however, we must first identify criteria for measurement of laboratory leadership. We recommend that a peer-review process be established, but one insulated against conflicts of interest or special-interest groups.

The following recommendation reflects the fact that, in the future, laboratory directors should be chosen, in large part, not only on their scientific credentials and capabilities, but also on their abilities to manage and transfer technology from the Federal sector to the private sector.

4. *Establish a consistent review process for all science laboratory directors based on external peer review and specific, measurable goals and accomplishments that can be monitored and documented.*

There are a number of barriers constraining complete interaction between Federal laboratories and business facilities. A scholarly effort should be undertaken to identify those barriers and to provide recommendations where possible for their removal. Areas of consideration should include such concerns as conflict-of-interest regulations, liability concerns, the manner in which retirement systems and personnel compensation policies may impede the transfer of personnel. These activities should be reviewed from a holistic perspective including interactions between industry, academia, and government.

5. *Establish an industrial/academic/government task force to identify barriers which impede interaction between government, industry, and academia.*

Just-in-time manufacturing is a concept proven amongst successful industry. In attempting to reduce the inflexibility imposed upon Federal bureaucracy, one must examine ways in which the Federal sector can take advantage of these techniques. In so doing, one quickly realizes that the procurement barriers prevent any program resembling just-in-time manufacturing because no one can predict the number of months required to procure various products. In Federal biological research, for instance, when one needs a special enzyme for a given assay, standard time for delivery is about five months. One

simply cannot predict that kind of need five months in advance on every occasion. Other items needed for efficient management may take longer. Efforts to build collaborative programs at Federal facilities are hampered by these procurement regulations. Effectively managed science simply cannot afford to delay projects for that period of time if they are to be effective.

6. *Revise Federal procurement procedures and develop a national scientific vendors computer network to evaluate and process goods and services more rapidly. (Order processing is now time-consuming and confusing because of a myriad of regulatory considerations in addition to price that must be considered. Each order generally is evaluated independently using vendor-supplied catalogs and data sheets that often are out of date. As government-funded research is the largest consumer of the listed materials, it is reasonable that a system to expedite handling orders could and should be developed.)*

Current management efforts at government laboratories appear to be quite successful in many regards. However, due to the importance of the resources represented by the Federal laboratories to the global economy, the authors recommend that more effort at reviewing the programs and the training of Federal laboratory managers be increased.

In order to encourage this type of program, the management of Federal laboratories should be provided incentives similar to those provided to the business community. Those incentives should be based upon quality of science conducted at the facility and the success of technology transfer as measured through a host of well-defined criteria.

7. *Establish significant management incentive programs to attract and retain quality science managers, ultimately establishing an elite corps of professionals in conducting, administering, financing, and transferring technology. Within reasonable limits, this group should be permanent and somewhat free from political changes and pressures. Compensation should be tied in part to performance with a percentage of the revenues generated from technology transfer and cooperative R&D programs serving as an incentive.*

As part of the evaluation process for each laboratory, the authors recommend an oversight committee composed of representatives from government, industry, academia, and the public interest to apply some of the criteria developed centrally, but also to relate in very specific terms the work of the laboratory to national needs. Gaps in the research and development programs should be identified and addressed. Such an oversight committee would utilize guidance from the OSTP central council to evaluate the program as well as develop productivity and operating cost indicators to help the efficient and effective management of the laboratory.

8. *Establish an external oversight committee composed of representatives from government, industry, academia, and consumers at each Federal laboratory. The committee would meet at least twice annually to provide focus for research activities, ensure adherence to research excellence and laboratory mission, and provide management insight to increase productivity.*

Review of productivity indicators and cost evaluations are also important as the process of technology transfer is undertaken because competitive, well-managed business can work most effectively with competitive, well-managed government. The authors believe that there should be more incentive development to assure that continuous efforts at cost effectiveness are being maintained. Incentives should be provided that provide returns to the employees and managers based on cost savings attained.

9. *Require each laboratory to develop productivity and operating cost indicators. (These would vary among laboratories depending on mission and research activities covered, but it is reasonable to assume that such indicators would promote an intensive examination of the critical factors and costs involved in operating a laboratory.) It is expected that once baselines are established, costs approximated, and bottom lines developed, future evaluations would be more quantitative than is now the case. The acceptance of indicators will be greatest when they are based in part on the input of the laboratory personnel responsible for their performance.*

10. *Mandate each laboratory director to carry out a facility-wide operating cost evaluation on a three-year rotation. The exercise should include a comprehensive evaluation of various functions to determine if the private sector under contract might be able to perform them as well or better than the government.*

11. *Because of the rapidly evolving nature of research science, require all managers to conduct ongoing task analyses. Cost savings should be calculated over a reasonable time, such as three years, and if realized, the employees should be rewarded with a percent of the cost savings based upon documentation.*

F

Develop long-term investments in Federal research and development facilities, equipment, and personnel.

The first set of needs for long-term investment in Federal research and development is a clear statement of research goals for the laboratories that is a part of a national research plan. Although many of the laboratories have their own plans, we lack a unified plan that merges the research goals of each of these labs into a national picture.

1. *Establish clear research goals for all Federal laboratories and integrate them into a focused national research plan.*

As Federal laboratories attempt to interact more completely with national needs, the annual funding cycle becomes a significant problem. It is nearly impossible to plan long-term research and long-term collaborative programs with industry or academia when one does not know from one year to the next whether programs will be financially supported.

2. *Provide Federal R&D programs with a two-year funding base keyed to progress.*

The Federal research and development infrastructure must be maintained. Failure to do so would waste the investment already established at a time when it is critically needed. This is not to say that the missions of some facilities should not be redirected and their function somewhat changed. It is important to recognize the value of the existing federal R&D infrastructure and to take advantage of its availability rather than allowing it to fall into disrepair.

3. *Adequately maintain existing Federal research and development facilities, using properly designed preventive maintenance and replacement programs. Such programs are rarely used presently. Further, before construction of new facilities, documentation in full should be required to demonstrate that existing facilities are being used to their fullest potential.*

As the Federal laboratories become more integrated with national needs, it will be important to maintain an adequate state-of-the-art equipment capability in order for programs to remain successful. At least in some areas of the biological sciences, *"shoe string"* budgets have constrained equipment purchases to the point where state-of-the-art capability is no longer a reality. To let this capability slip away is to lose an investment just before its point of pay off

4. *Require that an equipment replacement schedule be developed and maintained in every major Federal laboratory with costs built into operating budget requests.*

In order to optimize the new-found cooperative approaches for addressing the competitiveness issues before us, it is important to view economic development in regional

terms. Unbalanced growth, in a bi-coastal sense, is not going to garner support for any federal effort from middle America. That aspect should be considered when new projects are developed and federal R&D expansion considered.

5. *Establish Federal research and development facilities, when warranted and where possible, away from high-economic growth areas. This would help adjust the already unbalanced growth patterns on the nation's coasts in relation to its interior regions.*

Federal laboratories are currently facing a problem in retaining superior scientific staff. The authors of this paper have attempted to discuss the manner in which the Federal research infrastructure is of value to the United States in terms of its competitiveness needs. Unless the federal laboratories can reverse this trend, the usefulness of this already existing investment will diminish greatly.

6. *Develop incentives for science and engineering staff to remain in Federal employment thereby slowing their egress from Federal facilities.*

The following recommendation is provided in recognition of the fact that the more Federal scientists can interact with academic and private scientists, the more understanding they will have of the dynamics of cooperative programs and technology transfer. Accordingly, the authors believe it is very important to facilitate arrangements in which there will be an interchange of scientists. Federal policies restricting these interchanges should be relaxed.

7. *Establish sabbatical leave programs to continue the growth and training of Federal research scientists. Scientists should be allowed to take such sabbaticals within or outside the United States, at public or private institutions.*

Considering the fact that minorities and women are comprising an ever larger share of the work force and that, historically, these groups have been under-represented in science and engineering programs, the authors recommend that an effort be focused on scientific development of minorities and women. Indications of the short-fall in the needed science and technological areas is critical to future competitiveness and should be addressed in general as well as through this focus.

8. *Develop a minorities and female science career pipeline from the undergraduate level through the terminal degree. The program should cover all costs of education and have a pay-back provision based on years of Federal service by the grantee. Career placement at the bachelors, masters and doctoral levels would be guaranteed.*

CONCLUSION

The nation possesses the resources and has the capability to solve our competitiveness problems. The generalized problem becomes one of transferring knowledge and capability owned by our citizens into a structure that will be effective in terms of meeting our goals. It is the structure, the policies, and the attitudes that must be changed in order to provide for optimal use of a unique resource we already have available to us. The use of that resource becomes a process of technology transfer. The use of the term *"technology transfer"* is, at times, unfortunate because it carries with it a restrictive connotation. Too often it is viewed as a product or process-specific activity rather than the opening of a huge bank account from which people can draw a breadth of knowledge to enhance academic programs and increase national economic competitiveness. This concept requires a new kind of cooperation and interaction.

Currently, the structures simply do not exist that provide for this exchange and interaction. Through altering those restrictive policies, through becoming more flexible in the way we approach problems and policies, and through the very process of utilizing our national genius, we can eliminate barriers to technology transfer; barriers that bar the final manifestation of that knowledge to the benefit of our global competitiveness and economic well being.

These recommendations focus on the development of a process to utilize this national genius that clearly exist in all sectors of our society. The authors believe that, over time, we have developed rigid policies that compartmentalize activities so that it is always someone else's responsibility to take care of critical aspects of the solution to our problems. The authors are recommending an effort to step out of compartmentalized roles, to look at the problem anew, with a fresh *"bottom-up"* approach — one that listens to our collective wisdom and then structures the organizations necessary for accomplishment of objectives in a timely fashion.

There is nothing radical about this approach. It is only a common-sense approach, but it is not the way we approach our battles today. It uses more of the technique of the Minute Men at Bunker Hill where we rely on our strengths rather than the traditional, compartmentalized roles to which we have become inured. The challenge to public policy makers is to provide a structure that will allow that to happen. The challenge to the business and academic communities is to make use of it once it has happened, and the challenge to our nation is that we all work together to provide a better future for our children.