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The Charles H. Davis Lecture Series

Inaugural Lecture

INTRODUCTION

by

RADM Albert J. Baciocco, Jr., USN

Chief of Naval Research

THE FUTURE OF AMERICAN SCIENCE

by

DR. Philip Handler

President, National Academy of Sciences

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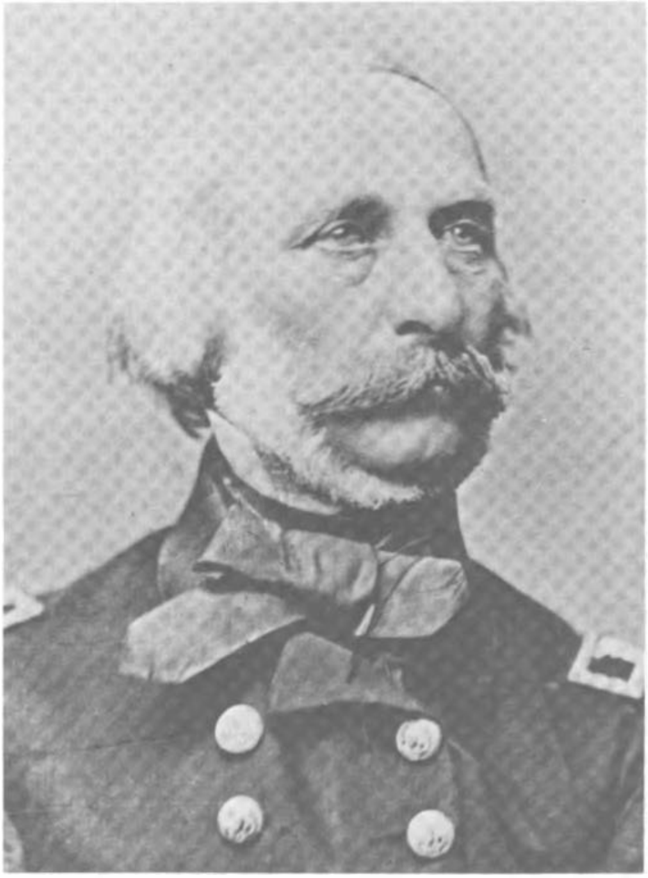
THE
CHARLES H. DAVIS
LECTURE SERIES

AT THE CLOSE of that greatest of all contests of men and machines, World War II, Theodore von Karman could say, with deep personal conviction, that ". . . scientific results cannot be used efficiently by soldiers and sailors who have no understanding of them, and scientists cannot produce results useful for warfare without an understanding of the operations." With such simple truths fresh on their minds, von Karman and his civilian and military colleagues proceeded to forge institutional links — such as the Office of Naval Research — through which they hoped to encourage and enduring partnership between the scientific and military communities. Though the intensity of the bond has fluctuated with the ebb and flow of international relations and internal affairs, the partnership has endured to produce a military capability but dimly perceived by those who established it. But, the partnership is not self-sustaining; it requires the constant vigilance of those who have not forgotten the bitter lessons of the past, the outspoken dedication of those whose vision extends beyond the next procurement cycle, and, above all, it requires open communication between the partners. It is to this latter task that the Charles H. Davis Lecture Series is dedicated.

The lecture series is named in honor of Rear Admiral Charles Henry Davis (1807-1877) whose distinguished career as a naval officer and as a scientist so epitomizes the objectives of the series, and whose clear vision of the proper role of science in human affairs rebounded to the betterment of all men. The topics and the speakers in the series are chosen by a Search Committee operating under the National Research Council of the National Academy of Sciences, and two lectures are presented each year before the students and faculty of both the U.S. Naval Postgraduate School in Monterey, California, and The Naval War College at Newport, Rhode Island. The series is sponsored by the Office of Naval Research.



REAR ADMIRAL
CHARLES H. DAVIS
(1807-1877)

CHARLES HENRY DAVIS was born January 16, 1807, in Boston, Massachusetts. His education consisted of preparation at the Boston Latin School followed by two years at Harvard University (1821-1823). In 1823, Davis was appointed midshipman and sailed (1824) on the UNITED STATES to the West Coast of South America where he transferred to the DOLPHIN for a cruise of the Pacific. Returning to Harvard he continued to work on a degree in mathematics and is listed with the graduating class of 1825.

In 1829 Davis became passed midshipman and was ordered to the ONTARIO

(1829-1832) of the Mediterranean squadron. Later, while serving aboard the VINCENNES (1833-1835), he was promoted to lieutenant. Aboard the INDEPENDENCE (1837-1841) Davis made a cruise to Russia and then to Brazil. Throughout these early years at sea Davis continued to study mathematics, astronomy and hydrology. During this period one of his superiors would write of him, "C. H. Davis is devoted to the improvement of his mind; and his country may expect much from him."

From 1842 to 1856 Davis undertook a number of special tasks and served on several commissions and boards. Notable among these was his participation in a survey of the New England coastal waters (1846-1849) during which he discovered several shoals that may have been responsible for a number of unexplained wrecks in the area. It was during this period in his career that Davis published "A Memoir upon the Geological Action of the Tidal and Other Currents of the Ocean," (1849) and "The Law of Deposit of the Flood Tide" (1852). He was also a prime mover in establishing the "America Ephemeris and Nautical Almanac" (1849), and supervising its publication at Cambridge, Massachusetts until 1855 and again from 1859 to 1862.

Promoted to Commander in 1854, Davis resumed sea duty in command of the ST. MARYS in the Pacific (1856-1859). While he was Captain of the ST. MARYS he was instrumental in securing the release of the adventurer William Walker and his followers who were beseiged at Rivas, Nicaragua.

With the outbreak of the Civil War Davis was immediately appointed to a number of important positions. He became the executive head of the new Bureau of Detail for selecting and assigning officers. He was one of three officers appointed by Secretary Gideon Welles to the Ironclad Board which passed judgment on the plans and specifications for the MONITOR and other ironclads. Promoted to Captain in November 1861, Davis participated in the development of plans for blockading the Atlantic Coast, planning the operation against Hatteras Inlet and Port Royal Channel, and the early naval strategy of the war.

During the operations against Port Royal, Davis served as captain of the fleet and chief of staff to Admiral Samuel F. Du Pont. He shares with Du Pont a great deal of the credit for the excellent plan of attack carried out on November 7, 1861. Later, as flag officer of the Mississippi Flotilla, Davis led successful engagements against the Confederate fleet which contributed to the abandonment of Fort Pillow and the surrender of Memphis. He was promoted to Commodore in July 1862, and to Rear Admiral on February 7, 1863.

In late 1862 Davis returned to Washington to head the newly established Bureau of Navigation. From this position he worked closely with such distinguished scientists as Joseph Henry and Alexander Bache to establish a "Permanent Commission" to advise the government on inventions and other scientific proposals which were being stimulated by the war. The Permanent Commission was established by the Secretary of the Navy on February 11, 1863 with Davis, Bache and Henry as members. However, Davis and his colleagues saw a wider need for cooperation between science and government and worked diligently for the establishment of the National Academy of Sciences. Their efforts were successful; President Abraham Lincoln signed a bill authorizing the establishment of the Academy on March 3, 1863.

In 1865, Admiral Davis was appointed superintendent of the Naval Observatory in Washington. In 1867 he returned to sea in command of the South Atlantic Squadron. Back in Washington in 1869 he was made a member of the Lighthouse Board and commander of the Norfolk Navy Yard. He later resumed his post as superintendent of the Naval Observatory where he served until his death on February 18, 1877.

REAR ADMIRAL A. J. Baciocco, JR., USN

INTRODUCTION TO THE CHARLES H. DAVIS LECTURE SERIES

RADM A. J. BACIOCCO, JR.
Chief, Naval Research

IN 1976 THE OFFICE OF Naval Research celebrated its Thirtieth Anniversary. One of the events commemorating the occasion was a symposium entitled "Science and the Future Navy."* A joint effort by ONR and the National Academy of Sciences, the symposium differed in one important respect from previous anniversary celebrations — the papers dealt with where we are going in science rather than where we have been. In other words, through a careful selection of speakers and topics we attempted to illuminate the technical challenges and opportunities facing the Navy and the nation in the years ahead. The reaction to the theme of the symposium and to the individual presentations was so positive that we subsequently initiated discussions with the National Academy of Sciences aimed at identifying some mechanism whereby a similar dialogue between the nation's top scientists and Navy personnel could be continued on a regular basis. These discussions ultimately resulted in the establishment of the Charles H. Davis Lecture Series, jointly supported by the Office of Naval Research and the National Academy of Sciences, and at present scheduled to be given twice each year to the students and faculty of the U.S. Naval Postgraduate School and the Naval War College.

The decision to establish the Charles H. Davis Lecture Series is a recognition that the Navy has a vital interest in the health, the innovativeness, and the aggressiveness of American science. It is a

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* "Science and the Future Navy — A Symposium," National Academy of Sciences, Washington, D.C., 1977.

recognition that only through the wise and timely utilization of the products and insights of science can the Navy continue to exercise its global responsibilities. It is a recognition that with "wise and timely" utilization comes an ever more complex and technically sophisticated Navy. And perhaps of greater importance, it is a recognition that not only must the present and future generations of naval officers and enlisted personnel be technically trained, but they must be receptive and enthusiastic in matters of science if we are to realize the operational efficiency and the leverage that science offers and that we must emphasize if we are to maintain our present position relative to the other navies of the world.

It is out of this recognition of the growing need for technically as well as operationally proficient naval personnel that we chose to name the lecture series in honor of Rear Admiral Charles H. Davis. As his friend and colleague Admiral Samuel F. Du Pont, described him, Admiral Davis was "a man of science and a practical officer, keeping the love of science subordinate to the regular duties of his profession." Born in Boston, Massachusetts, on January 16, 1807, Davis studied mathematics at Harvard and is listed with the class of 1825. With his appointment as a midshipman in 1823 he began a career that lasted until his death in 1877 as the senior Rear Admiral in the U.S. Navy.

During Admiral Davis' seventeen years at sea he held many important positions and commands. He played a significant role in developing the naval strategy of the Civil War. He participated in the successful operations against Hatteras Inlet and Port Royal Channel and commanded the Mississippi Flotilla, which successfully engaged the Confederate fleet near Fort Pillow and brought about the surrender of Memphis. But, throughout his long career Admiral Davis continued his study of mathematics, astronomy, and hydrology and wrote a number of important papers. He was appointed head of the newly created Department of Navigation in 1862, and in 1865 he became the superintendent of the Naval Observatory — a post he held until his death.

But, Admiral Davis' greatest achievement, and the one that best demonstrates his scientific statesmanship and his long view of the importance of science to the Navy and the nation, was the role he played in the establishment of the National Academy of Sciences under a congressional charter signed by President Lincoln in 1863. Working with colleagues such as Louis Agassiz, Joseph Henry, and Alexander Bache, Admiral Davis played a vital role in the negotiations that led to the creation of an institution charged with fostering the orderly development of science and its use for human welfare and with advising the federal government on matters relating to science and engineering. We believe that Admiral Davis justly deserves the honor we have bestowed on him and that his career symbolizes the objectives of this lecture series.

It is my privilege today to introduce the first lecturer in the Charles H. Davis Series. We are very fortunate to have as our first speaker a man who represents the full sweep of American science and engineering. He is a biochemist by formal training, receiving his doctorate from the University of Illinois in 1939. Much of his distinguished career was spent at the Duke University School of Medicine beginning as an instructor and finally as Chairman of the Department of Biochemistry. In 1969 he became the President of the National Academy of Sciences — a position he still holds. He has authored over 200 technical papers and several books. His honors and awards are impressive and far too numerous to recount here. It is my pleasure and honor to introduce the President of the National Academy of Sciences — Dr. Philip Handler.

DR. PHILIP HANDLER

THE FUTURE OF AMERICAN SCIENCE

DR. PHILIP HANDLER
President, National Academy of Sciences

IT IS A GREAT PLEASURE to be with you and to attempt the first Admiral Charles H. Davis Lecture. As you heard from Admiral Baciocco, Admiral Davis was both a most significant figure in the history of the Navy and a founder of the National Academy of Sciences. A splendid portrait of Admiral Davis is incorporated into a superb painting, in the Board Room of the Academy, that depicts President Lincoln signing the charter of the Academy in the company of the other founders. You are all invited to enjoy it when next you are in Washington.

It has been quite a year — the 100th anniversaries of Albert Einstein and Clerk Maxwell and the 100th anniversary of the electric light. And it has fallen my lot to participate in special ceremonies commemorating each of those events. The combination of Maxwell and Edison made for one of the most notable transition points in the history of our species — the gift of electrical power and of light to mankind — an event comparable with the beginnings of agriculture, the early refining of metals, and the invention of the printing press. Yesterday's discoveries and inventions are so easily accepted as today's commonplace, and taken for granted, that it is imperative that we seek special occasions to mark these great triumphs of the human spirit. It is that elusive, triumphal quality of the human mind that we term "creativity" that, appearing with especial force in very rare human beings, has blazed the way from the caves of our ancestors — only a moment ago, as geologic time is measured — to the rich fabric of life in the industrialized nations of the world and most particularly in this one.

That is an elitist view of history. To be sure, each human being should be enabled to live life to the fullest of his or her potential. But in a historic sense, only a handful of human beings have been privileged to leave a permanent, positive mark on the course of human events, to have affected in significant degree the quality of life for those who come after. Not all who have done so are known to us. But it would not be difficult to agree on a very small list of those whose legacy has dramatically altered the nature of our lives: Shakespeare, Galileo, Newton, Darwin, Pasteur, Maxwell, Einstein, Edison, and only a few others. The advent of the electric light and centrally generated electricity constituted what a physicist would term "a change in state" for the entire human race. Nothing could have given more dramatic evidence of that change than the fact that, when Mr. Edison died in 1931, President Hoover contemplated a proclamation that would have turned off all electric power in the United States for two minutes — but then recognized that such an action had become about as unthinkable as asking all American hearts to stop beating for two minutes.

As others have noted, Edison's greatest gift to us was "the invention of invention," the gathering and leadership of what we now recognize as the world's first industrial research laboratory, which served as prototype for those at General Electric, IBM, Bell Telephone, Du Pont, RCA, Hewlett-Packard, Eli Lilly, Westinghouse, etc., as well as Lawrence Livermore, Los Alamos, NRL, and Wright Field, that have, in our time, offered the veritable cornocupia of technology that has totally transformed the nature of daily life and vastly altered the nature of the military endeavor.

The image of Edison that has come down to us was seriously distorted, suggesting a diligent but dreamy putterer who, by trial and error, repeatedly found success. In fact, collectively, the staff on his laboratory was extremely well versed in all of the science that could then have been brought to bear on the problems that they chose to address. That trend — the marriage of the most advanced science to the development of new technologies — continues to our time; it is a primary characteristic of this era and nowhere more evident than in the development of military technology.

Only yesterday,the pace of science itself was leisurely and costs were modest. Governments required accurate geological, topographical, and navigational charts and more precise navigational procedures; they were concerned with alloys for coinage, with assays for alcohol (to be sure that the grog wasn't watered or for collection of taxes), with weights and measures for the marketplace, occassionally with agricultural yields, and always with military technology. There were wealthy patrons and even a few governmentally supported institutions for the performance of fundamental research. But there was no thought that the conduct of science, of itself, is a responsibility of a nation-state much less a purpose of society. The First World War altered that view somewhat, and industrialized nations began to develop modest arrangements for the support and the conduct of scientific research.

Modern science arose from the ashes of World War II, which for the first time witnessed in several countries full-scale mobilization of national scientific resources directed to the most critical circumstance of the moment. By integrating fundamental research, applied research, and development, the technological accomplishments were prodigious: not only rocketry, radar, jet engines, the proximity fuse, and nuclear weapons but also penicillin, atabrine, sulfonamides, fractionated blood plasma, treatment of shock and burns, and even the beginnings of peripheral nerve surgery.

When the guns were silenced, that demonstration remained alive in the minds of the world's political leadership. Uniquely, North America emerged from the war richer, stronger, and physically unharmed. The report, "Science, The Endless Frontier," produced under the chairmanship of Vannevar Bush, laid out the United States' credo with respect to science. That report called upon our government to share the faith of scientists that science and the technology that it makes possible are unqualifiedly in the public interest, that scientific knowledge, in its own right, is a good to be cultivated, legitimately to be fertilized by public funds. It asserted the deep conviction that applications of that knowledge would make a nation militarily more secure, increase the food supply, improve the public health, expand the economy, and, in diverse ways, enhance the quality of daily life. Recognizing that both the findings and the fruits of science are unpredictable, it averred that the support of science by the very best scientists in all disciplines will, in time, redound to the national interest.

Yet those who planned so well, who seemed — at the time — to be sharing a grand vision, really had a limited sense of the future. To be fair, one should note that when the Bush report was written, 35 years ago, atomic nuclei were thought to contain only neutrons and protons, the transistor was yet to be invented, plate tectonics was unknown, Sputnik was a word unknown outside of the Soviet Union, and the man on the moon was a childish fantasy. Pulsars, quasars, and black holes were yet to enter the consciousness of man. Few of us had heard of ecology; the living cell nucleus was a "black box," and no one had yet spoken of molecular biology. And so, the Bush report looked forward to a happy day when the total support of fundamental and applied research and development by the U.S. Government, including military R&D, might be as much as $50 million annually — by now, an underestimate by almost three orders of magnitude. So much for predictions!

The principal features of the American system for support of research and development emerged rapidly. Federal agencies developed competitive mechanisms for the award of research grants to individual investigators. The peer review system assured democratic accountability for the quality of the judgments thus made and, *pari passu,* the universities collectively became the primary locus for basic research. The funds so provided made possible, on campus, much of the science physical plant as well as support for faculty, graduate students, post-docs, instrumentation, supplies, and travel.

A limited number of special laboratories were created with purely scientific missions, usually centered about one or more major pieces of research equipment — an accelerator, a telescope, or oceangoing vessels, for example. In this "big science" category may also be included several of the great industrially sponsored laboratories, the National Institutes of Health at Bethesda, the NRL and a few others. Science rapidly grew more sophisticated and, hence, more expensive, so that, within two decades, federal funds became the principal support of both private and public universities that aspired to front-rank fundamental research.

Applied research and development proceeded somewhat differently. While the military services developed powerful in-house laboratories that they operate themselves, as did the AEC and the Space Agency, all came to rely on industrial laboratories for major aspects of their programs. The NIH and the USDA also grew powerful in-house capabilities but came to rely on academic laboratories for the bulk of their programs.

Support of fundamental research by the federal government now totals $3.5 billion per year. And that endeavor, in turn, serves as the essential intellectual substrate for $30 billion of federally funded applied R&D and for an effort of equal magnitude sponsored and conducted by industry in its own laboratories. Surely, I need not enumerate the fruits of that enterprise.

Our culture proved to be highly stimulating and supportive of this endeavor. Our national research enterprise has been spectacularly successful in all disciplines and was never more productive than today. And yet, not all is well with our research enterprise. That immensely productive system carries on — but in some disarray, disorder, even despair. And if we do not turn the circumstances around, the national future might well be compromised.

The fortunes of war gave to the American scientific community almost two decades of a headstart into the modern era; in the 1950's, American science was surely three quarters of the world's total. As Japan and the nations of Europe emerged from the debris of World War II, they developed scientific enterprises of their own, each in a pattern reflecting its own cultural history. In almost every country, universities again became significant instrumentalities for the conduct of scientific research. But in Germany, France, Japan, and the East European nations, powerful freestanding institutes are the principal loci for front-rank research.

In fundamental science, much the same problems are engaging the attention of the foremost practitioners of any given discipline regardless of their national homes. But I am uneasy that we are gradually losing touch with the research communities of other countries. They are beginning to develop styles of thought and methods significantly different from ours, and it behooves us to make the effort necessary to remain appraised of their trends and directions. By now, the relative role of American science on the world scene has diminished considerably. We are perhaps one third of the world total, West Europe and Japan together constitute a second third (although Japan spends disproportionately little on basic research), and the East European nations together represent a more or less equivalent third major bloc.

While the annual announcement of Nobel Prizes continues to give us chauvinistic national cheer, you should know that the European, Japanese, and Soviet research institutes have been tooling up with remarkable care, skill, and intensity. Their science grows ever more impressive and competitive, their research institutes ever more powerful. I had the privilege of visiting two research institutes in the Soviet Union a few weeks ago: the Kurchatov Institute, which is the site of their experiments with the tokamak, the instrumental arrangement whereby they hope to achieve magnetically confined fusion; and the Shemyakin Institute, devoted to general biochemistry. As a scientist I rejoiced in the remarkable facilities that these two institutes enjoy, their superb instrumentation, the abundance of technical help. Surely, I told myself, knowledge gained anywhere simply adds to the world's stock, and it matters not where it is discovered. But that was wishful thinking. Although much of science is undertaken for its own sake, it is a competitive enterprise; the rewards come to those first to learn, to understand, and to apply.

What gave me pause was the discovery that, for the first time, dozens of graduate students are working in these two institutes, engaged in their thesis research. That is a completely new development for the previously highly directed, hierarchical research institutes of the Soviet Union. They are now blending those aspects of research and education in science that have been so fruitful in our system with the organizational arrangement and facilities that they had developed earlier but that, heretofore, never rivaled ours in performance or productivity.

I had always considered their system to be bureaucracy-ridden, with a very heavy governmental hand imposed upon the management and conduct of their institutes. The reality is that each institute defends its budget request every five years, and an undifferentiated overall appropriation is given to the director and his colleagues, who are then free to utilize the resources thus made available as best they see fit for the next five years — at least, so they tell me. That strikes an American scientist as remarkably like his secret closet fantasies! Much the same approach is utilized for the applied research laboratories of the mission-oriented ministries, while their major expenditures for development are controlled in a manner more like ours. This circumstance is made all the more painful by knowledge of the fact that, while the funds available for science in other countries, particularly the Soviet Union, continue to grow in real terms, the resources available to the average American scientist have declined almost by half in the last decade. Moreover, governmental bureaucracy is exercising an ever more detailed control of the conduct of fundamental research even in the laboratories of universities, a circumstance that appears to worsen almost daily.

What is sad to note is that the bureaucratic encroachment on your research enterprise and its inadequate financial support reflect not so much an altered view of the importance of science in our national life as they do the erosion of trust, the decline of confidence in all the established institutions of our society.

Nor is that all. In small science, not dependent on major instrumental facilities, West European science is in the doldrums, largely because of the impact of inflation. However, while the political unification of Europe may be proceeding haltingly, the scientific unification of Europe proceeds apace. A decade ago every European scientist found it necessary to spend at least a year in the United States, and there was a flurry of planning of cooperative research between American and European laboratories. But today, driven by the high costs of major scientific instruments, those relationships are being replaced by a network of cooperative endeavors within Western Europe itself. And the pooled resources of Europe are comparable with ours. Increasingly, national barriers cease to confine European science. And as their sense of unity, their common strategic planning wax, the strength of their scientific relations with this country wanes. That makes particularly ironic the decline in the number of young American scientists who can arrange a meaningful experience in the European laboratory — when the benefits of such experience are now greater than ever.

American science is still at the forefront of all disciplines, and it is prodigiously productive — but patently we shall soon have to look to our laurels. As each year we devote an ever-decreasing fraction of our Gross National Product to research while other nations continue to develop their capabilities, I can too easily imagine a scenario in which we congratulate ourselves on our current crop of Nobel Prizes for *yesterday's* research while science elsewhere overtakes and surpasses ours. Much of the creative attention of our investigators has been deflected from science itself to the search for its funding and to diverse, increasingly stringent, and vastly annoying constraints imposed on the use of those funds once they have been obtained. For too many scientists much of the joy has been removed from what they should be doing and that must certainly reduce their productivity. Creativity is easily smothered by the niggling red tape in which the American research endeavor is now enmeshed. Scientists work well on their toes — not on their knees.

Support of scientific research by government meant that, inherently, it was to be subject to a tension that has characterized American society from its beginning — egalitarianism versus elitism, in this case, pressures to assure that funds appropriated in support of research are distributed geographically as widely as possible versus pressures to support only the very best of science wherever it may be. That conflict was inconsequential during the decades of expansion. However, as the fiscal pressures grow ever more severe, that tension takes on ever greater significance. But in science the best is immensely more important than the next best. If our country is to retain its place on the world scene it is imperative that we not take from the best of science to support the second and the third rate in the interest of misguided political egalitarianism.

The knowledge gained by science has been freely shared with billions of persons worldwide who have had some glimpse of the nature of matter, of electricity and electronics, of DNA and genes, of plate tectonics, of photosynthesis and brain hormones, of what we are, and where we are, and how we have constructed the man-made world. That life experience — faith that what is not now understood will be learned tomorrow — stands in contrast to centuries of mysticism, superstition, and black terror. It is easily worth all that mankind has spent on the scientific enterprise.

It is certainly equally arguable that science-based technology has eased and enriched the personal lives of billions of humans, albeit in varying degree. No end to that process is in sight. It has been the great technological triumphs — television, communication satellites, jet aircraft, computers, better weather forecasting, antibiotics, vitamins, steroids, the pill, antihypertensive agents, improved diagnostic and surgical procedures, insecticides, and herbicides — that engendered the large-scale public support of science. Our lives are pain-free and rich in experience beyond the imaginings of the past. That technology has also quickened the pace of history — for good and for ill. And it happens before our eyes.

No aspect of our affairs has been more dramatically affected by technological advance than the military — as you know better than I. But the process has just begun. As a sample, let me read to you a statement that I sent to SIGNAL magazine, a few weeks ago, at their request:

THE IMPACT OF ELECTRONIC AND COMMUNICATIONS TECHNOLOGY IN THE DECADE OF THE 1980's

The impact of electronic and communications technology on both military and civilian activities during the decade of the 1980's will be widespread and, in some areas, profound. In my opinion, the most profound impact will be on those functions and services performed by space-based systems and their associated ground terminals (i.e., surveillance, targeting, communications, navigation, earth studies, and environmental monitoring). The driving technologies behind what I see as a significant increase in the role of satellites over the next decade will be the use of scanning electron microscopy or x-ray lithography to produce submicron-scale electronics; thus achieving another plateau in volume reduction and circuit switching speeds. Also, the introduction of charge-coupled devices or magnetic bubbles promises an increase in memory storage capacity that will permit data processing both in the satellite and in the ground terminal. The space shuttle will add some economy and flexibility through the maintenance and recovery of orbiting satellites, as well as a significant increase in some space-based capabilities by permitting the construction of large antennas in space.

The full impact of these new technologies should begin to emerge during the latter half of the 1980's. The increasing use of satellites for tactical purposes and the improvement in coverage, sensitivity, and resolution will greatly enhance the satellite as a peacekeeping tool. However, the effect of this capability on existing military systems and practices is likely to be nothing short of revolutionary. The Global Positioning Satellite will provide navigational accuracy to within a few meters for any platform large enough to mount a terminal. The netting of communication systems will greatly increase the accessibility of data banks. And, the follow-on systems to Seasat-A will greatly increase our understanding of ocean processes and greatly improve global weather predictions.

The technical problems yet to be solved are largely those of architecture and data management. The growing accessibility of data bases leading to the ethical question of privacy for governments, institutions, and individuals is likely to be much more difficult to resolve.

As you well know, a set of inhibitory phenomena has begun to afflict industrial research. There is a rising sense of national concern for the decline in innovation in American industry, concern that might not find expression were it not for the extraordinary invasion of the American market by technology designed and produced outside our borders, resulting in a negative balance of payments for technology itself. The origins of that problem are multiple and complex, but I trust that they are not intractable.

The facile explanation is "taxation, regulation, and inflation." And therein does lie a considerable measure of truth. The evidence before us includes the increased fraction of all American patents registered by non-American citizens, an absolute decline in the number of American patent applications, a sharp decline in the number of publicly funded new technology-based entrepreneurial enterprises, and the negative balance of payments for technology.

The alleged effect of the heavy hand of capital gains tax on entrepreneurial investment needs no recounting here. Inflation has surely driven up the costs of the innovation process to where, in certain industries, innovation has become so expensive and risky that boards of directors find it the better part of wisdom to use available capital in other ways. It is hard to know the extent to which high interest rates have inhibited formation of new, small entrepreneurial ventures. But such ventures are to be cherished and encouraged since they have contributed disproportionately to the overall innovation process. It is both heartening and sad that numbers of our largest industrial corporations have recently begun to invest significantly in such smaller ventures, still controlled by their entrepreneurs. How this new pattern will work out remains to be seen.

The regulation problem is even more complex. Much of regulation is today concerned with considerations of safety. That pendulum may have swung too far. Too frequently actions have rested on a flimsy scientific base of understanding concerning the magnitude of risks that are to be averted, too frequently the costs to be incurred seem vastly disproportionate to the benefits sought — although none of us knows how to put a dollar value on a statistical human life. What is important in the present context is that the need to attend to the problems created by regulation divert the attention and the resources of a given firm from those more creative endeavors that might have stimulated innovation, increased productivity and profitability, and thereby generated employment while reducing our negative balance of payments.

One almost self-evident aspect of our national circumstance has received remarkably little attention. On one side we confront a potential military adversary whose government controls all aspects of their national life and deliberately invests in military preparation, including R&D, a far larger fraction of its GNP than will our country in the absence of a military emergency. The challenge to the relevant American scientific community is to assure that we compensate in quality for what we are unwilling to purchase in quantity. That, in fact, we do so is made possible by the fact that a disproportionate fraction of our most talented physical scientists and engineers are drawn into defense research because of its great intellectual challenges, its exciting technical opportunities, and its relatively generous support. At the same time, those nations that are our most successful competitors in the international marketplace for technology invest and engage in very little military R&D. Their competitive success may rest, at least in some part, on the circumstance that the German and Japanese counterparts of our brightest scientists and engineers, shielded by the American military umbrella, are designing superior consumer products for the American market; no easy solution to that dilemma is evident. As a minimum, we should surely encourage those nations to do more basic research and help fund some of our large science projects.

One great problem within which many of these concerns come into focus is the future of energy supply and use in the United States. The totality of that problem is far too complex to attempt to analyze here this evening. But a few thoughts are relevant:

However unfair, public disillusionment with revelations of unpredicted but genuine negative impacts of science-based technology has eroded public support for science and technology. Disaffection began with the obscenity of nuclear weapons and of means of biological warfare. Three Mile Island, the DC-10, Love Canal, Torrey Canyon, kepone, vinyl chloride, asbestos, assertions of the carcinogenicity of many articles of common commerce, allegations of adverse effects of innumerable pollutants of air, water, and the food supply, have all dampened public ardor for science and technology. Some of our brightest young people now believe that the unanticipated consequences of technology have *already* injected the seeds of inevitable disaster into human affairs. They look askance upon the introduction of any new technology and are fearful, therefore, of further scientific advance.

The obligation of scientists remains clear: To pursue science at its frontiers and to address society's problems, including the national defense, wherever genuinely constructive opportunity affords. Tomorrow, as yesterday, we shall be judged by our success in meeting both sets of challenges. We would be ill-advised to offer guarantees of success — we can guarantee only that those challenges will certainly not be met if we are not permitted to try.

The intellectual elite in every era has always been pessimistic. But today, concerned that "that which can be done will be done," there has arisen an antiscientific, antirationalistic trend that must give us pause. At its ugliest — or most absurd — it finds expression in gurus, tarot cards, and astrology; more importantly, an antiscientific attitude is subtly but perniciously affecting the news media, the intelligentsia, and decision-makers. It must be confronted at every opportunity. I must confess that I fret at the fact that the umbrella of the First Amendment protects publication of astrological charts in newspapers as it does the flood of pseudo-science, faddist approaches to nutrition and unfounded allegations of environmental hazards. I admit that I do not know quite what to do about that. The political safeguard of the First Amendment is too precious knowingly to erode it just because it is abused by those who publish trash for profit. Yet it is just such practices that denied to the Navy the ELF antenna (Project Seafarer) that would have permitted communication with submerged submarines without the need for a trailing antenna. In this instance, CBS' Sixty Minutes was the principal malefactor, with Dan Rather giving full play to hysterical old ladies in sneakers and to two scientists who have never really worked in this area while falsely accusing of prejudicial bias the committee of distinguished experts, convened by the Academy, that had carefully studied the matter and reported that there is no evidence of adverse biological effects of extremely low-frequency radiation. Moreover, a few weeks ago the *Saturday Review* published a most extraordinarily garbled and erroneous account of this matter, once again deliberately spreading fear by asserting high risk in the face of a complete absence of evidence to that effect. Why does the humanistically oriented press take renegade scientists to its bosom?

The public image of science and scientists has been distorted by the participation of scientists in public policy formation. Although, beneath the surface, the environmental and the consumer movements may be an expression of anomie, a cry of protest for the sense of powerlessness of the individual educated citizen, a frequent surrogate for that deep-seated complaint is an expression of concern for the safety of some product or technology — such as nuclear energy — based always on an assertion of risk first brought forward by some member of the scientific community. In protesting what they see as excessive risk, some are really urging change in the values of our society, our national life style and form of government. What we must recognize is that, whereas the *evaluation* of a risk is a genuine scientific question, the *acceptability* of a given level of risk remains a political, not a scientific, question. And when scientists fail to recognize that boundary, unspoken ideological or political beliefs becloud seemingly scientific debate.

It is imperative that those who study technological risk carefully document their conclusions and recommendations. A decade ago it may have been desirable to flag public attention to potential hazards and proceed as if each were a clear and present danger. But that can also set us off in the wrong direction. For example, by so doing, public attention has been fastened on the perhaps five percent of all cancer that is caused by the sum of radiation, man-made chemicals, and environmental pollutants, taken together. And it has done so at the expense of resources and talent that might more usefully have been utilized to address the more important mechanisms of carcinogenesis. It is time to return to the ethics and norms of science so that the political process may proceed with greater confidence. The public may wonder at why we do not already know that which appears vital to decision. But science will retain its somewhat diminished place in public esteem only if we steadfastly admit the magnitude of our uncertainties and assert the need for further research. And we shall lose that place if we dissemble or if we argue as if all necessary information and understanding were in hand. Scientists best serve public policy by living within the ethic of science, not that of politics; those who depart from the scientific ethic do disservice to the nation and to public esteem for science and, hence, to science itself. If the scientific community will not unfrock the charlatans, the public will not discern the difference and the nation and science will suffer.

An immense amount of effort has gone into analyzing the nation's energy circumstances and the alternatives that lie before us. It seems as if a major book on the subject appears each week. (The Academy's contribution, a report called *Energy in Transition — 1975 to 2010,* has just gone to the printer; it summarizes an analysis in which more than 400 experts from diverse backgrounds have participated.) But the nation is fast running out of time in which to continue the debate. It is not that we know all we need to know — we do not. But it is imperative that we contain the feckless debate concerning the magnitude of the risk of proliferation if we build breeders or engage in reprocessing, the risks involved in burning coal, the economics and feasibility of solar energy, the environmental consequences of a synthetic fuels program, and the myriad other ways that may contribute in various small degrees to the nation's energy supply. Surely this nation is not about to be denied the use of hydrocarbons, coal, as well as of nuclear power for the generation of electricity!

We are certainly agreed to the desirability of conservation, even if we have not yet agreed as to the optimal policies whereby conservation may be encouraged. But we already know that conservation itself will not be sufficient, at least not if we wish to maintain a civilization anything like that we have known and enjoyed, not if we hope to continue that economic growth that alone has provided the means for improving the circumstances of those on the bottom of the economic ladder. Nor can we indefinitely remain hostage to a set of foreign powers whose stranglehold on the American economy has deprived us of freedom in the formulation of foreign policy, truly transforming us into a helpless giant. Witness what is now happening in Tehran. It is time to recognize that this country is still blessed with many strings to its energy bow, that we still have many open options, and that we should embark on them posthaste since the penalties of serious energy shortage are far greater than those associated with any available energy technology.

Harvey Brooks of Harvard University has pointed out that the optimists among scientists continue to see scientific understanding as a worthy goal in itself. We see it as the means for expanding the planet's energy resource base, for converting nonrenewable resources into an infinite resource base for minimizing human pain and disease, and, in his phrase, as "a means of so managing affairs that the goal of an equitable harmonious world need not be denied to mankind." But the path is perilous. Success demands an endless stream of greater and lesser appropriate decisions with little forgiveness of error. The scope of human choice and freedom widens, at the same time that the possible price of error escalates.

We now live on an overpopulated, competitive, interdependent planet, characterized by a generally similar civilization in the developed world. Yet many another once powerful, prosperous, dominant civilization has disappeared. Please understand that I am concerned for a serious possibility. Few of us gathered here can readily imagine such a fate for America; we cherish the American dream and fancy our country to be exempt from such a fate. Yet to think so is to fly in face of history. We erode that dream daily by encouragement of children to think of their ethnic cultural backgrounds as more precious than their entry into the wondrous American melting pot, by publishers with reckless regard for truth if their publications will sell, by a new-found passion for a risk-free world that can never be and might not be worth having, by living beyond our energy and mineral resource means, and by withholding support from our scientific and technical community. Many nations at the apex of power were inwardly doomed when their willpower began to falter. We should be most careful about retreating from the specific challenges of our age, reluctant to turn away from the frontiers of this epoch.

As James Michener has noted, "each noteworthy civilization has grappled with the great problem of its time." For the ancient Greeks, it was the organization of society. For the Romans, the organization of empire. For the Medievalists, it was establishing their relationship to God. For the Europeans of the fifteenth and sixteenth centuries, mastery of the oceans. For the last two centuries, it has been the scientific understanding of nature and the creation of an industrial society. For tomorrow, the challenge is to continue the latter tasks; to determine how mankind can live in harmony on this globe; establish stable, permanent relationships to its finite shrinking resources as well as with infinite space; and to enable achievement of the individual potentials of human beings as we reduce the ravages of disease. To those ends we shall need all the science we can manage. If, instead, foolishly intent on a risk-free society, we succumb to a national failure of nerve, if we always heed the naysayers, then again Shakespeare will have been proved prescient. Let me remind you of his lines:

> There is a tide in the affairs of men,
> Which, taken at the flood, leads on to fortune;
> Omitted, all the voyage of their life
> Is bound in shallows and in miseries.
> On such a full sea are we now afloat,
> And we must take the current when it serves,
> Or lose our ventures. . . .

Whatever other policies we follow, we can be unabashedly optimistic concerning the prospects for continuing great discoveries in science. Indeed, a century or two hence, this time may well appear to have been the heroic age of science in most disciplines. And yet, in every discipline the principal questions remain. This extraordinarily successful enterprise repeatedly pierces the veil of ignorance to reveal some elegant, unanticipated structure or arrangement — while making evident a host of additional, more subtle questions, offering ever greater challenges and opportunities.

Our current malaise, then, stems from a few bad experiences and from the time delay in meeting the high hopes and expectations raised in the minds of those who appreciate the great power of science and the force of technology. Those expectations have taken on a new light as science has also revealed the true condition of man on earth. I see no alternative but to address vigorously the principal questions of science itself and to use our ever-widening understanding and increasingly sophisticated technology with grace and charity and wisdom.

For myself, I retain my faith that science, which has revealed the most awesome and profound beauties we have yet beheld, is also the principal tool that our civilization has developed to mitigate the condition of man.

DR. PHILIP HANDLER

President, National Academy of Sciences

A NATIVE OF New York City, Dr. Handler received his B.S. degree at age 18 from City College of New York (1936), and his doctorate from the University of Illinois three years later. Upon completion of his graduate training he immediately joined the faculty of Duke University School of Medicine where he became Chairman of the Department of Biochemistry (1939-1969) and was later (1961) appointed James B. Duke Professor of Biochemistry. In 1969 Dr. Handler was elected the 18th president of the National Academy of Sciences, and reelected for a second six-year term in 1975. He was elected to membership in the Academy in 1964.

During his 30 years of research at Duke, Dr. Handler made notable contributions to such fields as niacin and choline deficiency, intermediary metabolism, renal mechanisms and hypertension, enzymes for biological oxidations, and biochemical evolution. He is the author of over 200 articles, and co-author of the widely used textbook *Principles of Biochemistry*. Dr. Handler's work in the field of biochemistry has been recognized in the form of numerous honors, awards, decorations, and lectureships: he holds honorary degrees from 23 universities.

Dr. Handler has been active in science and public policy since 1951 when he accepted the first in a series of government advisory appointments. He served for twelve years on the National Science Board, four of these as Chairman, and was a member of the President's Science Advisory Committee under two Presidents. Most recently (October 1979), President Carter appointed Dr. Handler to membership on the "Commission for a National Agenda for the 80's."

REAR ADMIRAL ALBERT J. BACIOCCO, JR., USN

Chief of Naval Research

REAR ADMIRAL BACIOCCO, as Chief of Naval Research, Department of the Navy, reports directly to the Assistant Secretary of the Navy (Research, Engineering and Systems). He is responsible for the planning and execution of the Navy's basic research programs and for direction of all Navy activities involving patents and inventions. He exercises both direct command authority and technical direction over more than four thousand military and civilian personnel, distributed among ten subordinate commands and activities which include ONR Headquarters in Arlington, Virginia, the Naval Research Laboratory, Washington, D.C., and the Naval Ocean Research and Development Activity in Bay St. Louis, Mississippi.

Admiral Baciocco was born on March 4, 1931, in San Francisco, California, and graduated from Lowell High School in 1948. He entered the U.S. Naval Academy in 1949 and graduated in June 1953 with a Bachelor of Science degree in Naval Engineering. His early career assignments included duty in the heavy cruiser USS SAINT PAUL (CA 73), followed by instruction at Submarine School, New London, Connecticut, and duty in the diesel attack submarine USS WAHOO (SS 565). He was selected for the nuclear power program in early 1957 and, after nuclear training, served as a Division Director in the Submarine School Nuclear Department followed by tours in the nuclear attack submarines USS SCORPION (SSN 589) and USS BARB (SSN 596). He commanded USS GATO (SSN 615) from 1965 through 1969, and subsequently commanded Submarine Division FORTY-TWO, and Submarine Squadron Four. Washington assignments have included Head of the Attack Submarine Branch under the Deputy Chief of Naval Operations (Submarine Warfare), Executive Assistant and Naval Aide to the Assistant Secretary of the Navy (Financial Management) and Deputy Director, Attack Submarine Division and SSN Program Coordinator in the Office of the Chief of Naval

Operations. Admiral Baciocco was selected for Flag Rank in 1977. He was assigned as Director, Attack Submarine Division and SSN Program Coordinator and Director, Deep Submergence Systems Division and Deep Submergence Program Coordinator, where he served until appointment to his present assignment as Chief of Naval Research in July 1978.

Admiral Baciocco's awards include the Legion of Merit and two Gold Stars (in lieu of second and third award), the Meritorious Service Medal and the Naval Commendation Medal. In addition, he is authorized to wear the Navy Expeditionary Medal, China Service Medal, National Defense Service Medal with star, Korean Service Medal with star, United Nations Medal, and Korean Presidential Unit Citation.

Admiral Baciocco is married to the former Mary Jane Rivera of Coronado, California. They have four children, David Anthony, Debra Ann, Andrew Joseph, and Mary Susan.

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