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28. Major research programs have been carried out under the auspices of the Alaskan Beaufort Sea Oilspill Response Body (U.S. industry), the Canadian Offshore Oil Spill Research Association (Canadian industry), the Arctic Marine Oilspill Program (Canadian government), and the Outer Continental Shelf Environmental Assessment Program (U.S. government).
29. *Oilweek* **34** (No. 28), 16 (1983).
30. Although deep burial is a way to avoid the ice gouge problem, it creates its own particular set of difficulties in that it places the "hot" pipeline nearer to the top of the subsea permafrost. Although a detailed characterization is generally lacking, subsea permafrost is believed to be thermally rather unstable and it can occur within a few meters (7 to 10 m) of the sea floor at sites well offshore (40 km). If the interstitial ice in such permafrost were to melt, the resulting soil compaction could cause pipeline failures.
31. *Wall Street Journal* (6 December 1983), p. 3.
32. Seal Island has just (January 1984) been announced as a discovery with an estimated production of 5000 barrels per day.
33. *Oil Gas J.* (19 September 1983), p. 82.
34. G. Weller *et al.*, *Science Program for an Imaging Radar Receiving Station in Alaska* (Jet Propulsion Laboratory, California Institute of Technology, Pasadena, 1983).
35. W.F.W. would like to acknowledge the support of the Mineral Management Service of the Department of the Interior and of the Oceanic Processes Branch of NASA.

The Open Society

John R. Opel

The American Association for the Advancement of Science represents the finest tradition of American science and engineering. This tradition is based on the premise that science must be open and free, not only providing access for laymen and students to the excitement of scientific discovery, but also inviting them to explore with experts the technological choices open to a free society and to understand their consequences.

Science offers the power to find more choices and better answers, but its benefits must be earned—they are not given. Their price is the willingness to examine critically the future consequences of today's choices, to embrace the inevitability of change enthusiastically, and to trust the processes of our free and open society to guide that change. I applaud and share the optimistic note that I detect in the year 1984.

Thirty-six years ago, in 1948, George Orwell forecast the ultimate chapter in the story of the closed society: mankind's enslavement by a malevolent despot in control of an all-powerful technology. Much of our 1984 world is indeed Orwellian, being characterized by obscurantism, thought control, and forbidden knowledge. But this is not the case in the free world of the West. Here, in the decades since Orwell wrote, we have witnessed not the encroachment of a closed society but a brilliant chapter in a long history of the open society which began in ancient Athens. It is that chapter in which the open society's scientific and technological and industrial progress has blazed the way. Since 1948—through freedom, innovation, and creative energy—the countries of the West, led by the United States, have accomplished a memorable transformation by multiplying our total national output and per capita income many times over and raising up our wartime enemies into giant industrial powers and good friends. We have witnessed an explosion of science and technology increasingly devoted to the human use of human beings.

Indeed it can be said that this year 1984 is not the year of Big Brother and an enslaving closed-circuit television. Instead, it is the year of Everyman, served by a proliferating and liberating new information technology—from the calculator to the copier to the personal computer to new forms of telecommunications.

So in the year 1984 we can, and should, celebrate these triumphs of the open society. But we should also recall, as the people of Athens learned more than 2000 years ago, that those triumphs do not come automatically. The open society, unlike the closed society, has its own particular vulnerabilities, including a propensity to self-indulgence, to contention among special interest groups, and to slackenings in self-discipline. The capacity of the open society to survive and prosper depends—as a closed society does not—on the ability of free individual citizens and their chosen leaders to face facts, think, define, distinguish real problems from false problems, enter into dialogue, and come to agreement.

These are qualities of pragmatism and cooperation. All of us as citizens must use them specifically to reinvigorate three key features of our open society: its economic health and competitiveness; its capacity for self-renewal through its educational system; and its practice of the greatest possible openness in international relations. All three need strengthening and they need it now.

Economic Health and Competitiveness

Let me begin with the reinvigoration of our national economic health and international economic competitiveness. There are many signs of erosion: (i) the drop in our share of world exports from about 18 percent in 1960 to 12 percent in 1982; (ii) a loss of market share here in the United States in such products as steel, automobiles, and consumer electronics; and (iii) a trade balance that has gone from a $9 billion surplus in 1975 to two projected deficits in a row approximating $100 billion each.

We need to undertake many actions to turn these indicators around. The most immediate is to regain our fiscal sanity. In the past 30 years the United States has had exactly four balanced budgets. Our national debt today exceeds $1.5 trillion—nearly $7000 for every American alive. To pay the interest on that debt costs us today 16 percent of our federal revenues. In addition, we face an unprecedented series of future deficits of $200 to $300 billion a year. If these

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deficits persist, it will mean higher interest rates, a renewal of recession, a renewal of inflation, or all three.

To bring those budget deficits down, we have to make major and deep cuts in government spending, including specifically cuts in defense and cuts in entitlements. The President and Congress have recently made a tentative start along this road, but we have a long way to go. We should start now and not make our problem worse by waiting until after the elections.

To strengthen our economic competitiveness, we also need tax reformation that would not only contribute to a lowering of the deficits, but also encourage savings instead of consumption, help us move toward the rates of personal saving of our principal competitors, Germany and Japan, where saving rates outstrip ours by two or three to one. Personal saving, which means new and better tools and plants, has enabled these countries to outdistance us year after year in improving productivity and raising living standards. These are overriding economic imperatives. We should not divert our attention from them by looking at false problems such as at the assertion, for example, that the United States is deindustrializing and that less and less of our GNP every year comes from manufacturing. The plain fact is that over the past decade the percentage of our GNP contributed by manufacturing has not decreased. We also should not bemuse ourselves with false solutions, such as current proposals for something called a national industrial policy.

These many and varied proposals include the establishment in Washington of two new agencies. First, a powerful 1980's style Reconstruction Finance Corporation (RFC)—a bank that, in return for vague concessions from management and labor, would make cheap loans and subsidies to economically promising industries and to other industries hard hit by foreign competition. Second, a tripartite board, with representatives from government, business, and labor, that would analyze economic trends, recommend specific industries and companies deserving of federal bankrolling, and chart and pilot the future course of the American economy.

We do not need this kind of organizational remedy. It has repeatedly failed here and elsewhere in the past: the establishment of a new agency with an omniscience allegedly more effective than a market system. What we do need is pragmatism, compromise, and action on our real problems, deficits, and tax reformation. And we need them now.

Education

The strengthening of our scientific and engineering vitality is a second major national task. The signs of its weakening are clear: (i) an inadequate representation of Americans in our engineering graduate schools, where foreign students have been receiving approximately half the doctorates; (ii) thousands of vacancies in our engineering faculties, with particular gaps in computer science and electrical engineering; (iii) shortages of trained researchers in these same fields in industry, shortages that intensify demand and divert doctoral candidates from academic careers; (iv) university laboratories with obsolete equipment; (v) schools of engineering eager to equip their students for careers in exciting new fields of automated design production and quality management but unable to find resources to effect radical changes; and (vi) an erosion in high school education in the sciences and mathematics.

To help reverse these trends I believe that we should modify our tax laws to stimulate further industrial R&D and industrial gifts of equipment and research funds to universities. We should invest more of our national budget to help our engineering schools keep current with the fast pace of today's industrial engineering by modernizing university equipment and curricula, increasing funding for graduate students and young faculty members, and furthering university-industry cooperation in research.

In the past 2 years American industry has provided vital funding for new academic laboratories for research in microelectronics, magnetic information storage technology, robotics, and computer-aided design. Thousands of cooperative projects bring together small groups of researchers from university and industrial laboratories.

Yet, we must do even more, while taking care to ensure that all such projects fit the universities' requirement for publishable work that contributes significantly to basic understanding. And government must bear a cooperative responsibility in helping to fund academic research, particularly in fundamental science.

Above all, we must improve the performance of our secondary schools by reversing the long slide in SAT scores, verbal and mathematical, of our high school graduates, reversing the erosion in SAT scoring of young men and women planning to enter high school teaching, and reversing the decline in the numbers of qualified science and mathematics teachers produced in recent years by our institutions of higher education.

This job will take time. But if I had to pick any single task in education that I would put at the top of the list, this secondary education job would be the one. We have to roll up our sleeves and go to work in public school systems to insist that they heighten instruction, particularly in science and mathematics, and we have to pay what it takes to recruit well-trained people.

A quarter century ago, Sputnik shocked us into action and we reversed a similar slide in our schools. The job took cooperation all the way from neighborhood parent-teacher groups to universities to the halls of Congress. Today we need another concerted effort—sustained hard-headed analysis of the problem, and sustained citizen action to solve it.

Summary. The open society, unlike the closed society, requires constant citizen thought and action to ensure that it will continue to survive and prosper. Today in the United States we should give particular attention to three immediate problems. We should reinvigorate our national economic health and international competitiveness, particularly by reducing our unprecedented budget deficits and reforming our tax system. We must strengthen our scientific and engineering vitality, particularly in graduate engineering education and in secondary school instruction in science and mathematics. And we should work with our allies in the free industrialized world to keep our international open society as open as possible, encouraging a flow of people and information and ideas across national boundaries while instituting sensible and efficient safeguards against leakage of critical military technology to the Soviet Union.

Openness in International Relations

A third major task that I want to discuss is not confined to the United States alone, but is one we share with our friends throughout the free industrialized world: keeping this international open society as open as possible.

This openness, this flow of information and people and ideas across national boundaries, is the greatest thing we in the West have going for us. This flow feeds on itself. It creates scientific and

technological advance, and with it we have written a great record of achievement.

Yet there is a corollary. We no longer live in the world of 1948, when the United States had a virtual monopoly on advanced science and technology. At that time, we had an overwhelming preponderance in scientists and engineers who were enriched by brilliant scientists who came to us from a dozen lands because of oppression. We also had the unilateral power to control the international movement of many technologies because we alone had them.

Today foreign firms produce approximately 75 percent of all exports of high technology products in the free world. Throughout the Western world there exist in abundance dual-purpose technologies usable not only in commercial products but in weapons systems as well. NATO's defenses depend on these critical technologies developed primarily for commercial products. The Soviet Union has shown it will go to great lengths to obtain these same technologies by both legal and apparently illegal means with the intent of using them for military purposes.

Given these facts, what must we do to assure our national security? Our national leaders have enunciated their great concern over this problem. All of us have a responsibility to contribute to a constructive and effective solution. To this end, we should define the problem with great precision. For example, I believe we can in some measure shrink the scope of the problem simply by speeding up our process of military procurement.

The technologies that we are trying to protect are largely dual use. The pace between a technology's development and its appearance in a commercial product nearly always outstrips the pace between a technology's development and its appearance in a weapons system. To narrow this gap—as David Packard, a former deputy defense secretary, has urgently argued—would not only fortify our defense capability, but would also reduce demands for government interventions in West-West technology transfers.

I believe we can also narrow the problem by more effective methods of catching malefactors, those who violate our export control laws. If militarily vital technology reaches the Soviet Union because somebody breaks the law, as it frequently has, the answer is not more controls or more licensing requirements piled on the honest traders. The answer is more effective enforcement by our government and our allies.

When we come to devising licenses and controls, we should excerise all possible precision and not try to put a little fence around everything. Instead, we should put a tall fence around genuinely critical technologies.

For example, I believe we should exclude from the list of militarily critical technologies all those technologies that are not truly militarily critical and that are readily available in commerce. If the Soviet Union can get a technology from a Western source, it will do us no good to fence it into the continental United States. We should concentrate on the most effective technology-transfer mechanisms, such as turnkey factories, process equipment, and manufacturing techniques—the means of production, the know-how. We should not try to control such things as articles in technical journals, trade exhibits, and conversation at academic conferences.

Above all, we should keep our eye on the crucial need to strengthen our alliances: keep the multinational, multidirectional flow of technology going with the greatest possible freedom and force. We should work to strengthen multilateral controls within the COCOM (Coordinating Committee) organization, which is made up principally of NATO countries, and agreements with friendly countries outside COCOM and with neutrals. Such strengthening of the alliance will require dialogue, candor, trust, and a willingness to compromise.

Yet, we can undermine this by bogging down in quarrels over minute procedures; by insisting, for example, that the U.S. government—not an allied government—must license for resale a U.S. machine owned by an allied-country customer. We can also undermine the alliance by imposing roadblocks on the dissemination of technological information to foreign nationals, whether they are students, professors, scientists, or engineers in industrial laboratories.

Today foreign nationals fill half the classrooms in our graduate schools. They write half the technical articles in some of our major journals in computer-aided design, information theory, and electronics. Many of these people will make their careers here in the United States, help fill the vacancies in our engineering faculties, and help relieve the severe shortage of researchers in our industrial laboratories.

By heavy-handed restrictions on what research they can do, and what information they can have access to, we not only cut ourselves off from this source of trained manpower, but also alienate them and in some measure weaken what we most need to preserve—the technological openness of the West.

Conclusion

So there are three major problems we face: restoring our economic competitiveness; reinvigorating our science and technology; and keeping the open society of the West open while instituting effective protections of militarily critical technology. These jobs demand pragmatic thought, willingness to enter into dialogue, and concerted action. They exemplify what is demanded of us if we hope to keep this open society flourishing in the decades ahead as it has flourished in the decades preceding 1984.

If all of us do our part, we can hold out for ourselves the great hope of seeing the day when many of today's international fences will fall and technology will flow instantly and freely across all national borders. Technology will then be at the command not of an all-powerful government, but of individual citizens everywhere on earth, because the amount of technology—specifically information technology—per capita is one trenchant index of freedom.

Just ask yourself how indefinitely a society can remain scientifically and technologically competitive if it thwarts and throttles the free flow of information among its people, and specifically among its scientists. If it permits that free flow of information, how indefinitely can that totalitarian society remain totalitarian.

Nothing could help the cause of freedom more than an unlimited proliferation of computer networks and copiers and telephones and newspapers and television channels and books and journals throughout every obscurantist society on earth, including the Soviet Union.

The new technologies, I believe, are indeed freedom's best friend, and every scientist and engineer in the free world ought to be proud of his or her part in their advancement.

More than 2000 years ago in Thucydides' *History of the Peloponnesian War*, Pericles described Athens and the Athenian mind in these words: "I say that as a city we are the school of all the known world. . . . We throw open our city to the world, and never . . . exclude foreigners from any opportunity of learning or observing . . . trusting less in system and policy than to the native spirit of our citizens. . . ." Ever since, that Athenian ideal has inspired the civilizations of the West. Of course, we have problems. We always will. But they are the problems of a society that is open, not closed—the open society of Western democracy, the open society of science.

We can overwhelm those problems, as we always have. But only if, with pragmatism and cooperation, we do our part.