US at a crossroads

LEO P. KADANOFF

is at The James Franck Institute, University of Chicago, 929 East 57th Street, Chicago, Illinois 60637, USA. He is Past President of the American Physical Society.
e-mail: leop@uchicago.edu

Science once enjoyed a close and fruitful relationship with the White House and Capitol Hill — one that must now be rekindled, as a new president and Congress take office.

The United States is about to have a new president in the White House, as well as new members in Congress. Many challenges await them. Populations are rising rapidly; global climate change seems to be increasingly threatening; the cost and availability of energy have become national concerns; clean water is becoming scarce; military efforts are only partly successful. And these long-term difficulties will have to be faced in the midst of financial and economic turmoil. Science can help ease some of these problems. The modern world has been shaped by technologies that physicists helped create — electronics, telecommunications, medical imaging and nuclear power are just a few examples. Now physicists can contribute once more, by developing innovative technologies, improving education and extending mankind's understanding of nature.

However, economic and political obstacles prevent us scientists from doing our best. Our political leaders see nothing very fascinating about science. Government often sees science as just another lobby asking for money to support its own interests. Politicians face frequent elections; however, basic research in physical science may be expected to be useful only in the long run. Worse yet, hardly any organization that pays for basic research can be confident of getting a return: in competitive industries, an investor in science is likely to see the return go to its rivals; in a competitive world, a government's investment in science is likely to benefit other nations.

Recent disappointments felt by US scientists have been both caused by and reflected in the estrangement between science and the Bush administration. An early indication was that the presidential 'science advisor', an important figure in several previous administrations, was appointed late and remained far from the centre of power. More seriously, the Bush administration has been distorting the messages and reports produced by its scientists and technical people, apparently with a view to making the administration's policies look better[1].

LESSONS OF THE PAST

It wasn't always like this. Science, and physics in particular, once enjoyed a much closer and more productive relationship with decision-makers. During the Second World War, large research projects were created for the development of ballistic missiles, nuclear weapons, radar, submarine detection, code-breaking and many other military technologies, all of which required the participation and leadership of physicists. Research and development activities continued to unite physicists and government leaders in the post-war period. The ties were strengthened when Soviet–American enmity developed into the Cold War, and strengthened again when the USSR launched Sputnik in 1957. President Eisenhower then appointed James Killian, president of MIT, as the first ever Special Assistant to the President for Science and Technology (Fig. 1). Through this appointment the President gained access to good scientific advice, leading to the big boost in US spending on research, technology, weapons and education that followed Sputnik. I saw a little of this around the time of my PhD, awarded in 1960. A large proportion of my Harvard teachers had cut their teeth in weapons research for the Second World War. In turn, I was excited by my own brief foray into missile design, in which I had the opportunity to work on a problem set for me by Hans Bethe. Weapons and physics seemed to go together like love and marriage.

Well, not quite. There were already intimations of trouble. My teachers seemed to be all for Robert Oppenheimer and all against Edward Teller in the great feud over thermonuclear weapons. The Cuban missile crisis of 1962 made me feel that my own connection with ballistic missiles was not entirely harmless. I was certainly impressed during that very scary event by the nuclear-armed aircraft that were said to be sitting close-by at Logan airport. I thought that my government was overreacting. A little later, many scientists expressed very strong sentiments against the Vietnam War. Perhaps as a result, soon afterwards military spending for science began to dry up.

Although physics was moving away from an easy relationship with government, the symbiosis of physics and industry remained strong. Scientists were extensively employed in corporate laboratories and corporate management; they were even to be found on corporate boards. New technologies were being invented, developed and exploited — adding to the richness of America, its large corporations and their employees. Great laboratories of physics and related sciences were thriving under the management of AT&T, EXXON, IBM, Xerox and others. These laboratories worked in technical fields in which there was little real competition so that their companies could invest in knowledge without worrying too much that the knowledge gained would be used by someone else. In the rest of the world, the Second World War had knocked out large parts of science and high technology, leaving US industry with a field cleared of competition.

But the marriage between science and industry also began to fail. Bit by bit, monopoly positions were invaded or abandoned, globalization radically increased competition and industry became more focused on short-term gain. US corporate research in physics declined. Major laboratories either closed or significantly reduced their workforce and activities. In parallel, the number of scientists involved in corporate endeavours or on corporate boards also declined. By the 1990s, the major influence of US physical scientists, outside of academic institutions, was at an end.

In recent years, the estrangement of science from decision-makers has deepened. The political appointees in the Bush administration have actively distorted and suppressed scientific advice on an unprecedented scale[1]. The invasion of Iraq, for instance, was based on errors caused in part by the government's unwillingness to solicit proper technical advice on the meaning of the intelligence information it received. On the domestic front, energy- and environmental security deteriorated significantly because of the administration's reluctance to listen to advice from a broad range of experts.

THE GATHERING STORM

At the same time, many industrial and educational leaders became worried about the decline of industrial innovation in the physical sciences. This decline resulted in part from the closing and flight abroad of US R&D laboratories. It was feared that this decline in R&D was both a symptom and a cause of a loss of competitiveness of US industry. This fear ultimately consolidated a wide-spread sentiment that something needed to be done. About three years ago, industrial and scientific leaders including Norman Augustine, former head of Lockheed Martin, and Craig R. Barrett, the chairman of Intel, began to lobby intensively for better federal appreciation and support of science, education and technology. These leaders organized a series of meetings with officials and produced a sequence of reports. The most influential of these reports, *Rising above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future*[2], was a collective effort between the National Academy of Sciences and other organizations. It told how to reverse the rapidly deteriorating state of US innovation, science and technology. The primary solutions advocated in the report were (in order of priority): better education in schools; a ten-year doubling of support for physical sciences; support for higher education; more immigration of high-tech workers; and tax breaks for corporations doing R&D.

Initially, this approach seemed to gain traction with Congress, the White House and scientific organizations. The programme gained support among Democrats and Republicans, liberals and conservatives, the House and Senate, and the administration. Laws were passed, including the America Competes Act, which gave official approval to the programme goals. There was, however, no government follow-through. When it came to the appropriation of money for the programme, there was squabbling, the President threatened a veto, and the resulting compromise appropriation didn't provide the promised increases in funding.

HERE AND NOW

Long before the party conventions in late-summer 2008, the political spotlight had turned away from 'the gathering storm' and towards issues such as energy availability and the price of petroleum. More recently, all political dialogue has been dominated by the financial crisis. Science was occasionally mentioned by Barack Obama in his campaigning, but the word hardly appeared in John McCain's speeches. The American Association for the Advancement of Science and a large group of other organizations tried to bring science back into view by putting before the presidential candidates a list of fourteen key science-policy questions. After long and discouraging delays — possibly indicating the candidates' lack of enthusiasm for the task — extensive answers were returned[3].

The responses revealed many similarities between the programmes of the two candidates. Both explicitly rejected the present administration's weakness in scientific honesty and integrity; both were in favour of bringing better scientific and technical advice to the White House; both worried about energy availability and environmental degradation, and supported some sort of cap-and-trade system for limiting greenhouse gas emissions.

But there were also major differences. Whereas both candidates seemed to want to encourage 'innovation', Obama would do this via government programmes and a doubling of the budgets for basic science; in contrast, McCain's first target would be to show strong support for industry as a way of nurturing technology. Both candidates supported the improvement of education. Obama pledged to educate citizens; McCain aimed to train the workforce and retrain displaced workers.

Despite these answers, we should not feel too encouraged about science funding during the next four years. All we have so far are campaign statements, which most likely do not even come from the candidates themselves but from their staff. In addition, the various bailouts for the financial sector are likely to bring the government to a desperate shortage of funds.

BACK TO BASICS

For the public, energy, both availability and security, overshadows all other issues related to science and technology. In contrast, the industrial proponents of *Rising above the Gathering Storm* are mostly concerned about workforce issues. Our scientific organizations have, in addition, been concerned about the erosion of US leadership in basic research. A wise Congress and President should confront all three issues, in order. We scientists should also involve ourselves in dialogue and action on all these issues.

Priority one is to provide clean and secure sources of energy. The energy crisis is likely to be the first of a long series of resource and environmental crunches. Such difficulties are the almost-inevitable result of a world population increasing in number and in wealth, pushing against finite Earth resources. By working out how to pull the teeth from the present energy crunch, we will find ways of easing the difficulties to come.

We can limit the damage caused by energy shortages, but we can only do this by using a mix of strategies including a wise extension of fossil-fuel extraction and use, increased energy efficiency[4],

AIP EMILIO SEGRÈ VISUAL ARCHIVES

Figure 1 Happier times for science? President Dwight Eisenhower, seated centre with James Killian to his left, meets members of the Science Advisory Committee (including Glenn Seaborg, Wolfgang Panofsky, John Bardeen and Isidor Rabi) in December 1960.

and the use of nuclear power alongside solar, wind, hydro, geothermal, biomass, wave and thermonuclear energy[5,6]. Each component provides its own challenges: increased automobile efficiency requires getting people to accept energy-saving cars, perhaps through higher gasoline prices; efficiency in heating and cooling buildings requires engineering research, better architectural practice, and then the individual action of millions of people.

Nuclear power is very likely to be a part of our future. McCain, in his election campaign, promised[3] to be "…building 45 new nuclear reactors by 2030". Given the failures of government oversight in the US and some other places, it is prudent to commission reactors that are inherently safe against meltdown and the proliferation of radioactive material. Thermonuclear power might have great promise for the second half of this century, but for this to happen, stable funding over several decades is needed to provide the necessary basic research.

Solar energy is another promising option. Rapid advances in semiconductor technologies, thin films and organic semiconductors have provided significant increases in power and cost efficiency. Although the technology is not yet mature enough for full-scale deployment, the natural abundance and environmental benefits of solar energy are great inducements for pursuing further research and development. Other energy sources such as wind, geothermal and hydroelectric involve tested technologies and could each make a useful, although strongly geographically dependent, contribution. A key aspect to the integration of the multitude of energy sources is infrastructure — in particular, a smart and efficient grid that allows for the natural variability in some of the sources, and that minimizes losses in transmission. Basic research into network reliability and efficiency should form one line of further grid development.

GET THE JOB DONE

Fundamental research, applied research and technological or commercial development are each vital links in the technological 'food chain'. The major players — national, industrial and university labs — have been weakened significantly in recent decades. Many industrial labs are now mere shadows of their former selves. National labs are often unfocused or focused on out-of-date goals. Universities work on a narrower base, with decreased support from state government and industry and less funding from the military and space agencies. What should be done?

The US's great national laboratories should be recruited to be the central foci of programmes for improving energy security, through targeted research and long-term development in materials science, nanoscience, biology, transportation, architectural energy efficiency, risk analysis, economics and social science. Each laboratory should have responsibility for its own special areas of energy expertise and the mandate to develop and disseminate technical and public policy knowledge in its areas. In this way, the White House, Congress and industry will have access to a dedicated and targeted source of technical expertise in a multitude of scientific areas. Knowledge of energy technology and best practices should be garnered from and shared with the rest of the world. In this arena, as in many others, international cooperation will pay off much better than competition or national secrecy.

Industrial labs are strongest in the kinds of R&D that touch directly on applications and commercial development. To encourage and expand high-tech industrial research in the US, I recommend that the R&D tax credit should be made permanent for work done in the US, and available only to companies that do more than half of their R&D there. Basic research and teaching at universities and colleges also need strong support. We already have a good framework for national action in the America Competes Act. This act authorizes a 10-year doubling of funding for basic research in physical science, as well as qualitative improvement in scientific education. In addition, military research budgets should be expanded and redirected to help reach national scientific and technical goals. National labs and universities should cooperate on interdisciplinary teaching and research programmes that will instruct students from all over the world. Visa requirements should be rationalized to be less xenophobic and to make such programmes possible.

Even given funding and resources, no progress can be made without the directed effort of highly skilled and talented people. We in the United States need to boost the number of our first-rate scientists and engineers. In classical economics, the way to increase participation in some segment of the workforce is to pay higher wages. Because high-tech workers require a long and technically difficult education, it is also necessary for governmental policies to encourage enrolment into scientific and technical programmes by guaranteeing long-term employment. This process can be started by raising the salaries of scientists and engineers in the national laboratories and by renouncing the mass layoffs that have threatened these labs in recent years. In addition, immigration of highly skilled workers should also be encouraged by issuing visas that do not tie immigrants to particular employers.

Schools, colleges and universities each need more funding for their dual job of training and educating, to produce technical people and informed citizens. Universities should provide graduate and postdoctoral training that turns out flexible and broadly trained scientists and engineers. Involvement in small-scale and medium-scale basic research is particularly effective in this regard. Scientists should be recruited to study, evaluate and extend existing educational methods. Scientists' teaching skills should especially be directed to training the teachers who will then reach the schoolchildren. I would also suggest that the richest of the institutions and associations support school science, including universities of the class of Harvard, Stanford and Chicago and organizations such as the American Institute of Physics and the American Physical Society. They could each year devote a small percentage (perhaps 10%) of the return on their savings and endowments to the enhancement of pre-college education.

TOGETHER AGAIN

There is an urgent need to bring science more fully into the service of government and industry. Science itself can produce new technologies and new routes around seemingly intractable problems. Furthermore, many present concerns involve complex technical and scientific issues, and also require long chains of logic- and evidence-based decision-making, as does the scientific process. Scientists can plan ahead, past the next election and the next annual report. Science can also set examples for international cooperation and exchange of information, which can be particularly helpful in meeting problems of the environment and shortages of resources.

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