ditions would dwarf the most extreme claims of imbalance that we hear today.

Zuckerman foresees the elements in the debate that are now becoming clear. One is the growing recognition that what is proposed is indeed a 'supersystem' in systems engineering jargon, as C. A. Zraket pointed out in a recent paper in *Science*; that is, an aggregate of systems with hundreds or thousands of nodes interconnected over huge geographical areas and too complicated, dynamic and interactive for its performance to be understood *ab initio* no matter how much analysis is performed on it. Another is the crucial role to be played by the SALT I Anti-Ballistic Missile (ABM) Treaty. The US administration's attempt to reinterpret the treaty so as to permit testing and development of space-based ABM systems, despite the opposite intent of the treaty, justifies the fear that the treaty will be broken as the first of a sequence that could go on to ravage the Outer Space Treaty and the Limited Test Ban Treaty if nuclear explosives are to be developed for use in space.

Finally, Zuckerman raises the crucial question of whether a democracy can sustain the heavy expenditure involved for the very long time required when the outcome, in contrast to the Apollo programme for example, is so vague and uncertain. Indeed, the most striking current development is the restructuring of SDI to concentrate on short-term demonstrations of a prosaic nature at the cost of reducing the effort to develop exotic systems. The clear reason for this is to wrest maximum funding from an increasingly reluctant Congress.

Unfortunately, the European reaction to SDI receives only scant treatment. For the most part, European governments have acquiesced and public opposition to SDI is largely uninformed. It is only at this late hour that one foreign minister (Herr Genscher of West Germany) has taken a stand against the plans to erode the ABM Treaty. All of this is the essence of science advising too. Even though strategic defence stands no chance of becoming an effective country-wide shield, the effort to develop it can have profound and far-reaching political consequences. Reading Zuckerman's book might persuade some who have stood aside to enter the fray. If not, they will have benefited from a remarkable tutorial on how science serves as the seed-bed of technology, and on the Anglo-American experience in choosing what technologies to integrate into their respective social, political and military structures. □

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In the corridors of power

Daniel J. Kevles

Science, Technology, and Public Policy.

By Richard Barke. *CQ Press, 1414 22 Street NW, Washington, DC 20037:1986. Pp.245. Pbk \$10.95.*

IN THE United States today, at least 50 federal agencies deal, in one way or another, with science and technology, and technical issues have come to pervade American governmental policy. Richard Barke, a political scientist on the faculty of the University of Houston, rightly stresses that science and technology enter policy in two different ways. One is policy for science and technology — that is, policy to call forth new technologies and to advance scientific knowledge. The other is policy that uses them to achieve particular goals, for example, a clean environment. Federal science and technology policy in the former sense is a product of the Second World War, which, in its aftermath, yielded wide-ranging federal patronage of research and development (R&D) through agencies such as the National Science Foundation, the Atomic Energy Commission (most of whose functions have been taken over by the Department of Energy) and the Office of Naval Research. Currently, the richest and most powerful federal patron of R&D is the Defense Department, which accounts for about 70 per cent of federal funds spent for the purpose.

Federal policy that uses science and technology dates back well into the nineteenth century, when, for example, the management of western settlement drew in part upon geological surveys. It expanded in the twentieth century as the federal government began to exploit expert knowledge for the conservation of natural resources and the regulation of foods and drugs. What has made scientific knowledge currently so pervasive in federal policy-making is the passage in the past 20 years of laws to strengthen environmental protection, occupational health and safety, public health and medicine, and consumer protection. In 1985, 33 statutes required federal agencies to consider risk and ways to reduce it. Under the circumstances, R&D has become an instrument — in certain respects, a weapon — of policy. As regards environmental matters, for example, R&D makes regulation possible; its absence — as the Reagan administration recognized when, in its early days, it sought to cut the research budget of the Environmental Protection Agency — can undermine or destroy regulatory efforts.

Yet, despite the double significance of

science and technology in federal affairs, there is no single, overarching policy for them. (American policy for science and technology, it has been remarked, is to have no policy.) There is, rather, an array of policies that cover the multifarious technically related areas in which the federal government is engaged.

Barke argues that, for all this diversity, federal science and technology policies can be analysed with a certain degree of commonality because they are all subject to the constraints of law, knowledge, coordination and politics. He takes that analysis as his task here, while conceding that "devising a formal theory of public policy ... is analogous to the attempts of nuclear physicists to discover a grand unified theory of the four known forces of the universe" (p.153). Barke does not pretend to arrive at any conclusion about how particular technical policies — or, *a fortiori*, the aggregate of them — come to be made. But he does provide a very useful primer on the institutions, practices and problems of science and technology policy-making, and his treatment is salted with illuminating and thought-provoking insights.

Through the 1960s, the President and the federal bureaucracy held the upper hand in science and technology policy-making. The President not only enjoyed control of the budgetary agenda and centralized authority over his administration; he could also call upon a richly knowledgeable corps of technical advisors within the bureaucracy and could command the services of distinguished people outside of it, a power symbolized by the creation, in 1957, of the President's Science Advisory Committee (PSAC). Though PSAC has been transformed and demoted, the President retains the services of the bureaucracy, including the Office of Management and Budget, whose reach is immense and whose internal examiners include a number of PhDs in the sciences.

However, Congress is better equipped now than it was in the 20 years or so after the Second World War to check and balance the power of the White House. Both the House and the Senate have an extensive committee structure devoted to different aspects of science and technology, and defence R&D has become the special concern of subcommittees in the Armed Services Committees in the two houses. Congress can also turn to several omnibus support agencies, notably the Congressional Budget Office and the Office of Technology Assessment, which enjoys burgeoning Congressional confidence and which, while not really a match for the White House advisory apparatus, still provides valuable analyses and reports on diverse topics ranging from the effects of nuclear war to drug bioequivalence.

One of Barke's arresting observations concerns the considerable degree to which the courts have become involved in matters of science and technology policy. What brought the courts to prominence were the disputes, beginning in the 1960s, over the particular issue of nuclear power and the general one of environmental protection. The National Environmental Policy Act of 1969 gave citizens, interest groups and firms the right to block proposed federal actions, and, as Barke notes, helped lead to the filing before the end of the 1970s of nearly 1,200 lawsuits. Environmental measures, not to mention those addressed to occupational health

the trend bespeaks a clash over the goals of policy — whether what is to be sought is the efficient advancement of science or a geographically and institutionally more widespread scientific capability — that only politics can resolve.

Politics figures still more powerfully in policy addressed to what the physicist Alvin Weinberg has called 'trans-scientific' questions — that is, questions that go beyond the technical 'is' (or, more often, technical 'maybe') to human 'oughts'. Barke observes that "the task of risk management is necessarily political", adding, "Given the uncertainties of data and methods that plague risk analysis,

PURPOSE

SEC. 2. The purposes of this Act are: To declare a national policy which will encourage productive and enjoyable harmony between man and his environment; to promote efforts which will prevent or eliminate damage to the environment and biosphere and stimulate the health and welfare of man; to enrich the understanding of the ecological systems and natural resources important to the Nation; and to establish a Council on Environmental Quality.

Statement of intent — the opening paragraph of the National Environmental Policy Act of 1969. The Act was the stimulus for a rash of lawsuits in the following years.

and safety, consumer protection and the like, stimulated

questions about the meanings of laws, the reliability of technical evidence, and inconsistencies in government actions; so it has fallen largely upon judges to determine such questions as what levels or risks Congress implicitly designated as acceptable, or how much ambiguity in analysis was permissible [p.96].

Legislation aside, the explosion of information and the availability of new technologies has also drawn the courts into adjudicating such complex issues as the rights of the unborn and of the aged.

Yet the legislative and legal system is constrained by the limits of knowledge. Barke aptly observes: "Statutes and judges cannot successfully require what is physically impossible" (p.15). At the same time, knowledge cannot dictate science and technology policy. That is inevitably subject to considerations of customs, values, costs and interests, all of which express themselves through the political system — through politics.

Since 1945, it has been a cardinal point of American policy that the most efficient way to advance science and technology is to award R&D funds to the best scientists and engineers in the best universities. In operation, that policy has led to a concentration of federal money in certain institutions and geographical areas, with the result that the have-nots have mobilized in recent years to bypass the peer review process and obtain funds for research facilities directly through the political process. Frank Press, president of the National Academy of Sciences, has called the trend a type of "special-interest political favoritism that can only hurt the overall scientific endeavor". Perhaps, but

experts can usually be found to take opposite sides of an issue" (p.85). Then, too, the technical fact that living next to a nuclear power plant is less risky than living in cosmic-ray-rich Denver, Colorado, does not necessarily make the neighbours of the power plant any more comfortable. In one of his case-study chapters, Barke demonstrates that the administration of hazardous waste policy has made indelibly clear that scientific knowledge, however certain, cannot resolve contests of political and economic trade-offs. At the same time, growth in technical knowledge — in this case, better understanding of the ecological consequences of various waste-disposal methods — can well lead to changes in environmental requirements and creation of the political will to impose them.

To Barke's mind, proposals to improve science and technology policy-making through administrative manoeuvres (for example, creating a Department of Science), better educating the public on technical matters or removing it from politics, are not only unrealistic but also unwise. They ignore the distributive nature of power in the federal system, the absorption of different groups in the polity mainly in issues of immediate concern to themselves, and, above all, the irreducibly political nature of science and technology policy-making. The fact of the matter is that science and technology policy is no longer something special but has become a regular — if not altogether ordinary — participant in the rough and tumble of the process of governing the United States. □

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