The organizational ecology of science advice in America

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One way that the American government has changed in the past 50 years is through the establishment and expansion of organizations providing technical expertise for decision-making. This essay reviews the performance of current structures from the diverse vantage points of elites, bureaucracies, the general public and activist minorities, drawing on studies of the Carnegie Commission on Science, Technology and Government, and the cultural theory of Mary Douglas *et al.* The apparently mature institutional landscape may well be ripe for change.

Introduction

One of the landscapes in which scientific advisors dwell and work is called the United States of America. The Greek *oikos*, for house, fathered the siblings 'ecology' and 'economics'. Of the two, ecology implies more the web of natural forces and organisms, their competition and co-operation, and how they live off one another. Ecology has come to be closely associated with the concept of the niche, a recess or nook, or, more abstractly, the inner surface of the environment in which a species exists.

Human organizations, as much as plants and animals, have an ecology and niches. Bureaucracies, businesses, voluntary associations and other social groupings grow, reproduce, eye one another, seek energy and information, fight for dominance and fail. Such institutions confer identity on scientists and engineers as much as on other members of society.

This essay seeks to analyse the organization and dynamics of science advice in the American landscape as another might analyse the carriers of complex informational molecules that pollinate the plants in an American field. In particular, it explores how several parts of the social and political system perceive the needs of government for science and how these vary according to the characteristics or cultures of the different organizational types. It seeks to conceive the parts, and their interactions, with respect to the whole ecosystem. Let us define cultures simply as formulas for survival and science as a rigorous syntax, a system for error-correcting.

Fifteen years of experience have taught me that science advice about physical issues is surely no longer academic, if ever it was. A subject on which I have personally provided advice is climatic change. In the late 1970s it was hard to find anyone politically powerful who would listen about global warming. Now all governments negotiate at the highest level about life on a warmer earth. The communities of science and environmental alarm, which exist in symbiosis, have effectively drawn attention to the issue. Perhaps equally serious issues have not emerged or are stuck on the agenda. I have played a small part in a pertinent succession of events. Might the part have been played differently? Is there flexibility in the script?

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Carnegie Commission on Science, Technology and Government

The Carnegie Commission on Science, Technology and Government takes the greenhouse effect, and all other current scientifically rich political struggles, as occasions for generic questions about the structure and functioning of organizations and decision-making processes. The Commission is a private organization advising government, not about specific physical questions, but about how government obtains its advice on all physical questions. The Commission was established in 1988 by the Carnegie Corporation of New York, a private philanthropic foundation, to examine the health of America's public institutions with respect to the use of science and technology.

Before it completes its work during 1993, the Commission will issue more than 20 reports covering all branches of government (Appendix 1) including the President and his circle (if this is the right geometric image); the agencies of the executive branch such as the Defense and Commerce Departments and the Environmental Protection Agency; the Congress and its associated agencies in the legislative branch; and the federal courts and other facets of the judicial branch. The Commission is looking at executive and legislative functions of the 50 diverse entities which are the States of America. It is also looking at some international functions and international organizations in which the United States is a partner. How is each organization deploying science? How can procurement and deployment of science be improved? What gaps exist in the institutional mosaic? Are there organizations without science?

Working at its task, the Commission finds itself one part *perestroika*, one part management consultant, and one part psychotherapist.

Probing the need for major structural change, the Commission queries whether current structures can accommodate new pressures, functions, and growth. Have the premises of institutional action and responsibility been so drastically changed by world events (and science and technology itself) that American government must moult its organizational shell? Are far-reaching realignments needed involving the branches of government? Are power and strength located in the right places? For example, is the White House National Security Council obsolete in its current form? Is the distribution of scientific authority between the federal and state governments in need of change when economic development is at issue rather than, say, ballistic missile defense?

Management consultants typically accept the major structure and improve on it incrementally. The Commission is interested in incremental change through increased efficiency and competence. Such improvements are usually based on quantitative indicators about budgets, workloads, personnel, and various aspects of performance. They are eased by clear and effective mission statements and processes of co-ordination and evaluation. Thus, a typical question is how can the lines between foreign and domestic policy be bridged throughout the government on an issue such as AIDS? How can the numerous activities for environmental research that all agencies must undertake to fulfil their missions be made more effective? What bolstering of the judiciary can help clear the mass of cases that clog the courts owing to the complexity of litigation involving subjects such as toxicology and epidemiology?

A psychotherapist may sympathetically enable a patient to disclose failures and face a hostile environment. The Commission is concerned that government grows isolated and has difficulty obtaining constructive assistance. Qualitative aspects of organizational change and development come into play. The Commission asks government, 'How are you doing? What would you like to be different?' The simple process of eliciting views in a friendly way can be helpful. This is the case for the agencies that support Congressional decision-making, such as the Congressional Research Service (CRS). The CRS does its job well but suffers from occasional undernourishment and neglect. Normally, no one takes an interest unless the patient is sick, and so the Commission is health promotion and preventive medicine as well as surgery and disease control.

Growth of science in American government

The American government has changed impressively since the mid-century in relation to science and technology. By 1990 the federal government directly employed 112 000 scientists and 111 000 engineers full-time. The US government is probably the largest employer of scientists and engineers in the world. They pervade all functions: environmental protection, weather forecasting, space exploration, warfare, health care, agricultural production and so on. Although the distribution has shifted among fields, the total number of scientists and engineers in government has grown steadily. Scientific services provided by government began in the 19th century with geological surveys and standard weights and measures. They have now become too numerous to list.

Rich and powerful institutions have been established not only for provision of immediate services to citizens but for support of research as well. The 1950s, a nutritious decade for research institutions, saw the emergence of the National Science Foundation and the Defense Advanced Research Projects Agency, which fund research, and the National Institutes of Health, which both perform research and contract for it outside, especially in universities. National and federally-funded laboratories have grown to cover work in fields from arthritis to inertial navigation.

Institutions for provision of high-level science advice have been established and expanded. Propelled by Sputnik, the President appointed a personal Science Advisor on 7 November 1957, and the Office of Science and Technology followed shortly as a fluctuating feature of the Executive Office of the President. The President appoints about 60 scientists and engineers to key positions in the Executive Branch whom the Senate must confirm. The jobs include surgeon general, chair of the Nuclear Regulatory Commission, and director of defense research and engineering.

Almost all executive agencies have cadres of senior technical professionals employed full-time to perform analyses and oversee operational and research programmes. In addition, many agencies have advisory committees consisting of scientists and engineers working in universities and industry who comment on government policies, programmes and plans.

Feeding and watching the executive branch, and pursuing its own ends, the Congress has, meanwhile, developed its institutional arrangements for science and technology. In the 1950s and 1960s it set up standing committees of its members to oversee science and in the 1970s vastly enlarged the number of specialists employed by the committees. It welcomed to its halls enterprising Congressional Science and Technology Fellows who came to the capital from universities and industry for a year or two of flexible service. To handle efforts that require more sustained attention than members and their staffs are able to give, the Congressional Office of Technology Assessment (OTA) was established in 1972. The professional staff of the OTA now performs about 30 major studies each year in response to requests from the Congress.

The National Academy of Sciences (NAS), a private organization with a Congressional charter, conducts several hundred studies yearly for the government. The NAS spawned the National Academy of Engineering in 1964 and the Institute of Medicine in 1970, recognizing the diverse fields in which it was consulting. They jointly govern the National Research Council (NRC), the main operating arm of the Academies. NRC study committees yearly enplane more than 7000 leading scientists and engineers in uncompensated, part-time assistance to the government. Additional enormous amounts of expert advice are proffered to the government without any government request by industrial associations, public interest groups and individuals.

In short, both supply and demand for science for the government have multiplied. Since the middle part of the century the US government has increasingly institutionalized and systematized the means by which it obtains its advice. As in any ecosystem, some of the government's efforts to control its environment have been successful, but the environment is dynamic and those who love order and stability are always subject to challenges, old and new.

Defining the problem

The US appears to have a rather mature organizational ecology for science advice. Then what is the problem? A conventional way to measure failure and success is by indicators of inputs, process and outcomes.

Among the inputs to decision-making is sound and ample information—'straight facts'. When decisions were taken about acid rain or export controls for high-technology products, was relevant evidence available and marshalled? The Carnegie Commission perhaps begins with a bias that sometimes such demand for information needs to be stimulated.

Sometimes the process appears to be the problem. Many emphasize government's laborious procedures and observe that government is not smart or fast enough. Even when facts are at hand the parties to a decision remain forever in chancery. Some worry about the excessive complexity of the development, authorization, and appropriation of the federal budget, including that applied to science. Others worry about openness to criticism and participation. For example, several normally influential scientists were resentful that they were not consulted during the formation of the Strategic Defense Initiative.

Numbers of good and bad outcomes are useful indicators when outcomes can be identified and counted. Some US policies and programmes strongly associated with scientific and technical matters have emerged as clear-cut failures. Among the most prominent, in my view, are the space shuttle, manned space flight, and the support for technologically and environmentally retrograde, dirty fossil fuels, particularly coal.

An alternative way to define the problem is to ask 'Are the experts getting better at what they do?' Is the average study by the NRC or OTA 'better' by some measure in the 1990s than in the 1970s? More broadly, is learning taking place so that society solves new problems more rapidly than it solved similar ones earlier? The increasingly steep rates of innovation and the fast adoption of new technologies, such as personal computers, suggest that society has become more efficient as a learning system during the past 200 years. Organized research and development would seem to be a main factor in the progress. Yet, reviews of self-conscious attempts at social innovation, sometimes labelled the 'policy sciences', have been critical.

The difficulty in settling on the problem inevitably reflects that, for all its shared values, the scientific and technical community is not a single animal when it comes to science for policy. President Carter sought to elicit a coherent technical viewpoint from the US government in the Global 2000 study and learned that the government did not share a 'global model'.[1] Within government, scientists in the departments of energy and environment, for example, are not inclined to agree on assumptions, methods or interpretations of results. Occasionally there are massive efforts, such as the Intergovernmental Panel on Climate Change, to obtain agreement of all world science on a particular issue, in this case global warming. The centre barely holds: there is always a distribution of views. The script of science, of the world (the book of nature, Goethe called it), is always sufficiently open to allow individuals and organizations to read it differently, and every sector of society has its own qualified expert readers. The non-governmental activist organization, Greenpeace, now has its own research division. It is willing to bicker about statistics and equations with the industry-supported American Petroleum Institute or the government.

Thus, 'the problem' of government and science exists both as a problem of public administration and as a problem of science itself. However, this should not suggest that two views encapsulate the question.

Cultural theory of science advice

At least four basic points of view about the relations of science, technology and government appear to recur. These points of view correspond to four essential biases or ways of life identified in the 'cultural theory' developed by Mary Douglas, Michael Thompson, Aaron Wildavsky, and colleagues. Douglas *et al.* locate the biases in a conceptual space formed by two axes they label 'group' and 'grid'. 'Group' runs from the individual to the collective, and 'grid' from participation (creating one's own grid or rules) to management (accepting that the grid or rules already exist). The axes define four ideal types or cultural biases that are helpful heuristic devices, even if they may rarely appear in pure form in actual social interaction (Figure 1). The cultural biases, and the solutions they imply, are sometimes complementary and sometimes contradictory. Importantly, they cannot exist without one another.

One cultural perspective on the problem of government and science is that there are deficiencies above all, in regard to the small number of scientists and engineers in influential positions,

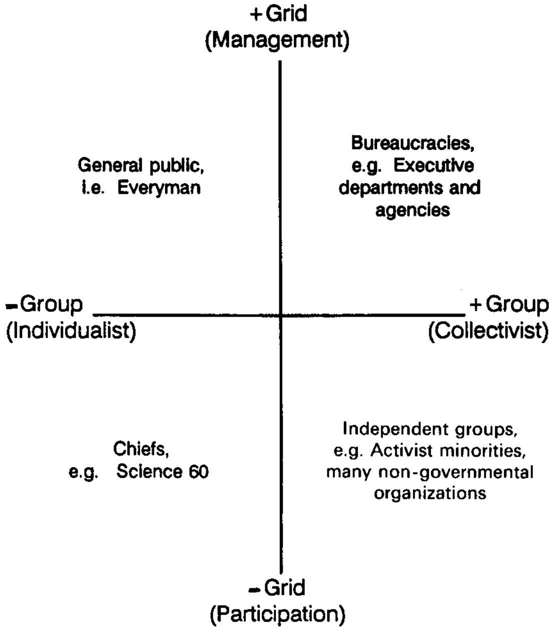

Figure 1. Cultural biases, after Mary Douglas and Michael Thompson (see bibliography).

their recruitment and retention, their freedom of action and the power they hold.

A second perspective stresses not the networks of potent individuals but the stable organizations that underpin them. In this perspective, the major problems are an inadequate capability to obtain and analyse facts, 'irrationality', an excess of pluralism, conflicts between short- and long-term goals, matching of administrative needs and resources, difficulties in planning and the co-ordination of increasingly large numbers of parties.

A third perspective comes from 'Everyman', the general public that is occasionally politically active, more often cynical and yields the taxes. It emphasizes ignorance, the lack of maturity of the science base, the sheer difficulty of issues, lack of access and attention, and the power of unpredictable forces outside the control of the system.

The fourth perspective comes from activist minorities. It is concerned with hidden agendas, the loss of independence of the science and technology community, the possible reduction of political choice in an increasingly complex society, and the technocratic implications of the increased role of expertise.

As we shall see, the four diagnoses translate to varying prescriptions for increasing or not the power and effectiveness of the White House, executive agencies, Congress, courts, and non-governmental organizations (NGOs), either for more action in the open or behind closed doors, and the different forms of consent and participation.

View of the elites

The chiefs of science and of politics tend to see the strength of their own high-level networks as the key problem. They worry about the existence of market-places where they can meet and trade. They worry about quantitative work overload; they are all moving very fast and worry that projects, programmes and deals may fail for lack of leadership. Time is especially short—the chief jokes, 'I am spreading myself thin this year—you get about a quarter of an inch.'

They worry about court politics, about who is around the table, who is in the entourage. Pioneers by temperament, they are frustrated by the slow diffusion of ideas and the way many people in the organizations below them cling to old solutions and travel only on rigid cognitive maps. They like to innovate and exist in an information-rich environment. More generally, their environment is rich, and they see resources and inputs as controllable.

The chiefs do not worry that agendas are saturated since, after all, they make the agendas. They do not worry that important issues fail to make the agenda or to receive sufficient attention once there. They like the plenitude of issues as it enables them to trade.

They do not perceive communication failures. After all, they can pick up the phone and reach anybody. They think many advisors misjudge the market. High-level business and politics (and science) are essentially oral, yet 'the system' churns out lengthy reports. In a culture where the average member of the US Congress reads only 15 minutes each day, it is obvious that the key thing is to be a member of the club, to have access, to get your message across. That message must be brief.

In this culture, recruitment to the network is a key problem. In fact the US government faces major difficulties in recruiting and retaining skilled scientists and engineers. For high government positions, it often takes one year to fill a vacant position, and the length of time that passes between when the President makes a nomination and when that person takes office averages four months. Meanwhile, there is rapid turnover, probably increasing, of political appointees. Average time in a position decreased from about three years in the 1960s to two years in the 1980s. In a system heavily based on annual budgeting, which takes at least one year to master, the ability to lead is obviously at risk.

In this perspective, a major recommendation is that the White House and the Congress should take actions to assure that the most qualified scientists and engineers in the nation are recruited to serve in the government's top technical jobs. Once recruited, the 'Science 60' should be encouraged to apply their skills to big issues, not bean counting. To improve the commerce of people and ideas, conflict of interest laws and guidelines should be clarified and reduced, salaries raised and informal communication channels fostered. The top government scientists and engineers should convene early in each administration to become acquainted and ease co-operation.

Even among mandarins there is an Emperor. The appetite of this man, the President, for science and technology must be cultivated, and the status of expertise in science and technology brought to par with that in national security, economics and other key fields of White House decision-making. Internal to a group, information is largely transmitted verbally. Ability to communicate with the headman is symbolized by physical distance. The Science Advisor to the President should thus hold not only the most senior possible position but one physically within the White House.

The elites, of course, want places where they can meet and do business with as few constraints as possible, i.e. clubs and markets. They prefer to do business privately, without rules and regulations. They worry about loss of confidentiality. They like simple network arrangements.

The Congress lacks a clubhouse in science and technology open to all its members. Thus, a logical recommendation of the Carnegie Commission is that the Congress should establish one, a continuing Congressional Science and Technology Study Conference. Such a Conference would provide a focal point for discussions and provision of information for all members and committees of Congress concerned with science and technology.

The Governors of the 50 States similarly lack a place to discuss and do business in science and technology. Thus, the Commission urges the Governors to open a Science and Technology Compact of the States to exchange experiences, form flexible partnerships, and enhance interaction with the Federal government in science and technology on level grounds.

Internationally, there is also no good clubhouse or marketplace for high-level interactions in science and technology. The United Nations Educational, Scientific and Cultural Organization (UNESCO) is not exclusive enough. The Organization for Economic Co-operation and Development (OECD) could play the role for the science-rich nations, but its name indicates where its torus lies. A promising strategy is to cultivate the capability of such international non-governmental scientific organizations as the International Council of Scientific Unions to correspond to the high level political and economic clubs. A potentially powerful network is the science advisors to the heads of government of the so-called G-7 nations who meet annually for an economic summit. At the regional level, groups such as the Academia Europaea and African Academy of Sciences can help meet the same function. Generally, leaders of national organizations such as the National Research Council and Office of Technology Assessment need to comunicate effectively with leaders of counterpart organizations abroad.

View of the bureaucracies

The great fear of generals is that their orders will not be received or followed. Their power and effectiveness rely on stable, hierarchical organizations that can adhere to plans. For convenience, we will use 'bureaucracy' to embrace these organizations.

The bureaucratic view is typically that formal responsibilities and relationships are insufficiently clear and need adjustment. Standard processes for dealing with issues are lacking. Bureaucracies do not readily accept the risks of decisions that their leaders may thrust upon them and thus tend always to seek more information to aid in imminent decisions and to justify those already made. In science and technology, bureaucracies perceive a main problem to be lack of adequate capability to obtain and analyse facts. They like to spread risk and thus are often absorbed in co-ordination. Convinced of their own procedural rationality, they perceive a general problem of irrationality. They labour hard to produce detailed reports and then are disappointed by lack of interest in the results. They are frustrated by decentralized organizations such as the US Congress, where, for example, over 100 autonomous committees deal with issues of national security.

Better matched resources and tighter management are preferred solutions. Vulnerable to challenge by their bosses and the general public, bureaucracies protect themselves with evaluation. Bureaucracies are proud of their patience and deliberate style. The bureaucrat murmurs, 'Maybe I'm lucky to be going so slowly, because I may be going in the wrong direction.'

At the top of the US government, this cultural bias leads to the view that the charters of several White House units, including the Office of Science and Technology Policy, the National Security Council, the Council on Environmental Quality and the Cabinet councils, should be revisited and the relations among the units explored for ways of bringing greater coherence to policy-making in fields such as economic performance and environment and energy.

The bureaucracies acutely experience that the great problems of the day no longer map neatly onto either academic disciplines or cabinet departments. Examples abound.

A characteristic problem is mathematics and science education for children in primary and secondary schools. Neither the Department of Education nor the National Science Foundation has had a clear mandate in this area. A close, strong and dynamic relationship is needed. The Carnegie Commission proposed a formal inter-agency treaty to overcome the barriers to horizontal communication that characterize such hierarchical organizations.

A second example is regulation of food and drugs, safety and health, and environment. To improve decision-making in these fields, a co-ordinating mechanism is needed at a high level in the federal government to achieve better informed and more consistent decisions. The ultimate challenge would be to rank all risks by common criteria and set priorities based on the total ranking.

The conduct of international relations provides a third example. Modern science rarely accompanies the silk hats and striped pants of diplomats, even though the stuff of international relations is often now a 'greenhouse' gas or the AIDS virus. The State Department must take actions at all levels to enhance its scientific competence; conversely, the numerous agencies with missions in technical fields such as health and energy must strengthen their international operations, and all must mesh their assets, goals and priorities.

In commercial technology development and diffusion, the American government feels a gap in its body. The US government has fostered technology development mostly through its defense department, but that approach appears dated. Most technologies of importance to the military have a dual use in the civilian economy and indeed now often originate there. The overlap of objectives for technologies evokes a Commission recommendation for a National Advanced Research Projects Agency created from the present Defense Advanced Research Projects Agency (DARPA). Alternatively, the National Academies have proposed that DARPA remain and a new Civilian Technologies Corporation be created to provide a reliable and durable focus to promote innovation. Analytic guidance would come from the new Critical Technologies Institute attached to the White House and funded by the National Science Foundation. These additions might fill the emptiness the United States feels when it sees the Japanese Ministry of Trade and Industry (MITI).

While the executive and legislative branches of government have increasingly armed themselves with facts and figures over the past decades, the courts have remained largely at the mercy of whatever the lawyers for the plaintiff and defendant lay before them. Judges already form a tightly knit fraternity. However, the Carnegie Commission has concluded that the judiciary, particularly at the Federal level, might benefit from the establishment of a resource centre for science and technology. It would assist individual judges in obtaining information and knowledge helpful for decision-making in cases apt to benefit from expertise in science and technology. It could, for example, help judges arrive at distinctions about when a person is qualified to testify as an expert in science and technology. The resource centre might also collect and provide information about science and technology issues in the courts. Anticipating trends

trends and planning for the future have generally not been characteristics or even concerns of the court system, which is built around the exercise of personal judgements of the peer group of judges. In short, the courts suffer a deficiency of bureaucracy.

Because they endure to bear consequences, bureaucracies worry about conflicts between near and far goals. Elected officials may say 'NIMTO' (Not In My Term of Office), but government agencies exist in perpetuity. Few institutions focus effectively on challenges to the nation and the roles its scientists and engineers may play that extend beyond the needs of the next several years. To address this shortcoming, the Commission proposes the establishment of a National Forum on Long-Range Science and Technology Goals. Its purpose would be to foster discussion on objectives and priorities for future decades and generations, which would provide a sound long-term context for near-term decisions and planning. The Forum would point out the dangers of fluctuation and the merit of steady application.

View of the general public

A repeated response to the work of the Carnegie Commission is 'You are rearranging the deck chairs on the Titanic.' Organization charts, boxes and arrows, and shelves full of studies miss the point. From the perspective of many in the general public, the paramount factors are the sheer difficulty of issues and mobilization for social change. Moreover, logic will not help much. In fact, science overstates its claims to knowledge. The public has noticed that science is never ready. At key moments, it so often seems that the science base is immature, absent or irrelevant.

The general public continues to ask alternately how sharp is the foresight of science and do not we know enough now for practical purposes. While it is easy for experts to bash government, others call for experts to be modest. Certainly the experts have a list of right and helpful predictions—expenditions to Antarctica verified losses of stratospheric ozone—but, the game is not only about prediction, although prediction is the ultimate test of science. Expert advice helps to structure problems, identify sensitivities, legitimate solutions and so forth.

However, it must be remembered that science is quite provisional. The proportion of assessments and predictions that prove sound is probably lower than many scientists believe.

In the 1930s the US President appointed a committee of distinguished scientists and engineers to report on areas of technology that would be important to the United States in the next several decades. They made a detailed report, pointing out the importance of plant breeding, synthetic gasoline and rubber, and more efficient electrical machinery.

Most interesting is what the experts missed. They missed antibiotics—Fleming's work on penicillin had been done, but its importance was unrecognized. They missed nuclear energy, which was to explode just a few years later. They missed radar, rockets, space exploration, and the jet engine aircraft. They missed transistors, solid-state electronics, computers, biotechnology and lasers. Looking back, physicist Charles Townes concluded, 'In fact, if you were to ask what were the exciting things that happened over the next several decades, they missed all of them, every one.'[2]

Examining scientists' statements which history has treated unkindly is both amusing and deeply indicative of the problems of science in its advisory role (Table 1). The experts can be blind not only to what is hidden around corners, but also to what looms over them, as was *L'Encyclopedie* on population growth and Olson on demand for personal computers (see Table 1). Another lesson is that science can fail on issues of greatest sensitivity, such as racial and gender attributes and sexuality.

What is the prescription in a world where the scientific cadre of Mao Zedong reported to Mao that if an apple is placed inside a pumpkin, the apple will grow as big as the pumpkin? One alternative is fatalism. Why worry about eventualities that cannot be foreseen, rarely come or are just a particular darkness in the night? The system will churn along regardless and anyway policy is an exercise of pulling on disconnected levers, even if the scientists were to get it right, which they probably will not. If we ignore the future, maybe it will go away.

Still, the individual must reserve a veto. The motto is that of Herman Melville's scrivener, Bartleby, who responded to opportunities and orders alike: 'I choose not to.'

Table 1 Expert advice

304 AD	Lactantius, Tutor to the son of the Emperor Constantine 'Can there be a place on earth where things are upside down, where the trees grow downwards, and the rain, hail, and snow fall upward? (It is a) mad idea that the earth is round . . .
1756	*L'Encyclopedie* (D. Diderot *et al.*, eds.) entry on 'Population' 'The population is constant in size and will remain so right up to the end of mankind.'
1762	Jean-Jacques Rousseau 'One half of the children die before their eighth year. This is nature's law; why try to contradict it.'
1835	Thomas Tredgold, British railroad engineer 'Any general system of converging passengers that would go at a velocity exceeding ten miles an hour is extremely improbable.'
1836	Francois Arago, French scientist and politician 'Transport by railroad car would result in the emasculation of our troops and would deprive them of the option of the great marches which have played such an important role in the triumph of our armies.'
1842	Sir George Bidell Airy, Astronomer Royal of Britain Estimating for the Chancellor of the Exchequer the value of the 'analytical engine' (the first computer) invented by Charles Babbage: 'worthless.'
1850	Professor Erasmus Wilson, Oxford 'When the Paris Exhibition closes, electric light will close with it and no more will be heard of it.'
1892	Camille Flammarion, French astronomer 'The present inhabitation of Mars by a race superior to ours is very probable.'
	Lord Kelvin
1895	'Heavier than air flying machines are impossible.'
1897	'Radio has no future.'
1900	'X-rays are a hoax.'
1909	Scientific American 'The automobile has practically reached the limit of its development.'
	Robert Millikan, winner of 1923 Nobel Prize in physics
1923	'There is no likelihood man will ever tap the power of the atom.'
1929	'The energy available through the disintegration of radioactive or any other atoms may perhaps be sufficient to keep the corner peanut and popcorn man going in our large towns for a long time, but that is all.'
1939	David Sarnoff, founder of Radio Corporation of America 'It is probable that television drama of high caliber and produced by first-rate artists will materially raise the level of dramatic taste of the nation.'
1943	Thomas J. Watson, Chairman, IBM Corporation 'I think there is a world market for about 5 computers.'
1956	Richard Van der Riet Woolley, British Astronomy Royal 'Space travel is utter bilge.'
1956	John von Neumann, mathematician 'A few decades hence, energy may be free, just like the unmetered air.'
1959	Managing Director, International Monetary Fund 'In all likelihood, world inflation is over.'
1977	Ken Olson, President of Digital Equipment Corporation (DEC) 'There is no reason for any individual to have a computer in their home.'

Everyman shows his wariness of institutions. His democratic revolution fights the bosses, and his dissolution of empires and large nations defeats imperial organizations. People appeal to courts and the decisions of peers rather than experts.

This cultural bias occasionally shifts to the active political voice. Ombudsmen are hired to champion Everyman before institutions, and Everyman calls a talk show on radio or TV when he has been steamrollered. Synchronized calls can block a pay raise for members of Congress or create the Presidential candidacy of Ross Perot. Each system must allow in its decision-making process for what Vaclac Havel called 'the power of the powerless.'[3]

View of the independents

The fourth view, coming primarily from organized, activist groups, perceives the problem as one of hidden agendas that distort outcomes. There is a preponderance of positive feedback at high levels in organizations whether in government or industry. Deference obscures important points for debate. It is difficult to maintain an 'opposition' with a voice that is heard. The problem is that dissidents are marginalized and quashed. No turbulence is allowed in the system.

From this perspective it is a major issue that the US research community has itself become much less independent of the federal government. When the 'modern' science advisory system began to develop in the 1940s and 1950s few academic or industrial scientists were heavily reliant on government for grants or contracts. Now, most researchers are *de facto* employees of the federal government. Much 'science advice to government' consists of scientists telling government how government should give money to scientists. There is fear that the 'Republic of Science' has been corrupted.

Rather than renewing the membership of the clubs of the rich and powerful by adding more scientists and engineers, or bringing order and secure lines of authority to the bureaucracies, here the concern is with the power afforded to those who control technical information. Activists fear the technocratic implications of the increased role of expertise and the possibilities of manipulation inherent in technological advances. They worry about the possible reduction of political choice in an increasingly complex society, particularly by closed bureaucratic processes or insider traders in the corridors of power. They desire to keep questions open longer and are unimpressed by the deals and decisions that are indicators of success for leaders and bureaucracies.

The prescription is to strengthen the role of critical, pesky, independent groups. In fact, such groups have proliferated recently. According to 'Independent Sector', an organization that assists and monitors non-governmental organizations (NGOs) in the United States, their number grows yearly by over 5000, despite high mortality. The total 'scientific and technical' cohort of NGOs in the United States might be four to five thousand. They range from the American Association for the Advancement of Science to Computer Professionals for Social Responsibility and Scientists and Engineers for Secure Energy.

Independence is usually maintained through voluntarism, relatively small scale, frugality and direct and egalitarian participation. Many NGOs function in this way, although often running the risk of losing their purity by becoming too intimate with power and riches. Loss of credibility through loss of independence is the greatest danger they face. Because they coalesce around particular concerns, many NGOs necessarily foster single-issue politics. They do not want to trade issues as the chiefs do, balance them like the bureaucrats or leave matters to fate as their passive neighbours do. In fact, they see all compromise as the reason that serious matters are not fully addressed. They are frightened that others fail to perceive urgency—the activist jokes, 'Why must you always undermine my hysteria with your logic?' The activist NGOs of the independent sector bring agility to a system that risks sclerosis and values to a system too ready to believe in its own superiority.

The affinity of most NGOs is with the Congress, which is itself relatively egalitarian and transparent compared with the executive branch of government. The laws of the land may coerce, but they coerce equally and every vote counts the same. The NGOs are happy to foster the 'ear-marking' of budgets and narrow legislation to support their particular concerns. They produce information abundantly to support them and often eagerly seek out the media to amplify their calls.

Given their fractious nature, the NGOs are usually wary even of co-ordination and co-operation. But, the challenge for them from the societal point of view is to go beyond criticism to solutions. For American science and technological NGOs, the Commission suggests that the result of their rhetoric could be a joint mission to affect policy at the national, state and local levels to improve pre-college science and mathematics education for all citizens. They should seek creative approaches, often temporary, to focus their skills and resources through networks and consortia.

Concluding Reflections

The problem of science and government is an endless dynamic. One person's problem is another's solution. Some argue that the problem is a lack of pluralism and others that the problem is an excess. Some argue that insufficient information is the problem, where others see a surfeit. Some see the problem as inattention to the long term, while others argue that the game is to take our chances now. Some want more chance for informal, off-the-record exchange, others want the same discussions recorded and broadcast. Some want permanent institutions, others only transient. In short, there are plural rationalities, though in any period one or another may be ascendant.

One solution is a 'grand coalition' bringing together all parties in a metaphorical or even actual 'round-table'. For example, to address the problem of the US role in co-operation for global economic development, which has never satisfied anyone, a new round-table might join the interests and contributions of the government, the private sector, and not-for-profit non-governmental organizations. Such efforts can succeed, but usually only briefly. In 1817 the 'Era of Good Feeling' in American politics was announced to reconcile the Republican and Federalist parties that the Founding Fathers had not expected to differ so intensely; it lasted fewer than four years. It may be impossible, as well as undesirable, to maintain a permanently peaceable kingdom where all the cultures and organizational types exist in equilibrium. However, as the diversity of the Carnegie Commission recommendations suggests, it is possible to energize all the active voices for a creative disequilibrium.

The American polity, as it pertains to science and technology, is bound to the usual and full dynamic behaviour of ecosystems. In natural systems the pattern is one of slowly increasing organization or connectedness accompanied by a gradual accumulation of capital. Stability initially increases, but the system becomes so overconnected that rapid change is triggered. Fires, storms, pests and senescence release stored capital and a new cycle begins, where the pioneers have many opportunities.

If the system of science and government in America is co-ordinated with the world economic and political system, the present era is one of creative destruction, to use Joseph Schumpeter's term, to be followed by renewal. The particularly rapid growth of non-governmental organizations during the last decade may locate America's place in the current cycle. The mature ecology, the climax forest, so to speak, should beware. The public and political questioning of science, its integrity and institutions, should not be taken lightly. The landscape will change.

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REFERENCES

1. G. O. Barney (Editor) (1980) *The Global 2000 Report to the President* (New York: Pergamon).

2. C. Townes (1991) *Cosmos Club Bulletin* Washington DC: Cosmos Club, October, p. 17.

3. V. Havel (1986) 'The power of the powerless.' In *Living in Truth* (London: Faber & Faber), pp. 36–122.

Further reading

G. R. Carroll (ed) (1988) *Ecological Models of Organizations* (Cambridge: Ballinger).

C. Cerf and V. Navasky (1984) *The Experts Speak: The Definitive Compendium of Authoritative Misinformation* (New York: Pantheon).

P. deLeon (1988) *Advice and Consent: The Development of the Policy Sciences* (New York: Russell Sage).

M. T. Douglas (1978) Cultural bias. Occasional paper 35, Royal Anthropological Institute, London. Reprinted in: *In the Active Voice* (London: Routledge and Kegan Paul).

M. T. Douglas (1986) *How Institutions Think* (Syracuse: Syracuse University Press).

Y. Ezrahi (1990) *The Descent of Icarus: Science and the Transformation of Contemporary Democracy* (Cambridge: Harvard).

A. L. George (1980) *Presidential Decisionmaking in Foreign Policy: The Effective Use of Information and Advice* (Boulder: Westview).

W. T. Golden (ed) (1991) *Worldwide Science and Technology Advice to the Highest Levels of Governments* (New York: Pergamon).

J. Habermas (1975) *Legitimation Crisis* (Boston: Beacon).

M. T. Hannan and J. Freeman (1977) The population ecology of organizations. *Am J Sociology* **82**, 929–964.

C. S. Holling (1986) The resilience of terrestrial ecosystems: local surprise and global change. In W. C. Clark and R. E. Munn (eds) *Sustainable Development of the Biosphere* (Cambridge: Cambridge University Press), pp. 292–316.

S. Jasanoff (1990) *The Fifth Branch: Science Advisers as Policymakers* (Cambridge MA: Harvard).

C. Lindblom (1990) *Inquiry and Change* (New Haven: Yale).

N. Luhmann (1982) *The Differentiation of Society* (New York: Columbia).

N. Luhmann (1990) *Die Wissenschaft der Gesellschaft* (Frankfurt: Suhrkamp).

R. MacFarquhar (1983) *The Origins of the Cultural Revolution, Vol. II.* The Great Leap Forward 1958–1960 (Oxford: Oxford University Press), p. 127.

J. G. March and J. P. Olsen (1989) *Rediscovering Institutions* (New York: Macmillan).

National Resources Committee, Subcommittee on Technology (1937) *Technological Trends and National Policy* (Washington DC: U.S. Government Printing Office).

W. Plowden (ed) (1980) *Advising the Rulers* (Oxford: Blackwell).

J. A. Schumpeter (1939) *Business Cycles: A Theoretical, Historical and Statistical Analysis of the Capitalist Process,* Vols. I and II (New York: McGraw-Hill).

M. Schwarz and M. Thompson (1990) *Divided We Stand: Redefining Politics. Technology and Social Choice* (Philadelphia: University of Pennsylvania).

H. Seidman (1970) *Politics, Position, and Power: The Dynamics of Federal Organization* (Oxford: Oxford University Press).

B. L. R. Smith (1990) *American Science Policy Since World War II* (Washington DC: Brookings).

B. L. R. Smith (1992) *The Advisers: Scientists in the Policy Process* (Washington DC: Brookings).

M. Thompson, R. Ellis and A. Wildavsky (1990). *Cultural Theory* (Boulder: Westview).

O. E. Williamson (1983) *Markets and Hierarchies: A Study in the Internal Organizations* (New York: Free Press).

J. Q. Wilson (1989) *Bureaucracy: What Government Agencies Do and Why They Do It* (New York: Basic Books).

Appendix 1
Publications of the Carnegie Commission on Science, Technology and Government

Reports and Books:

Science & Technology and the President (October 1988)

E³: Organizing for Environment, Energy, and the Economy in the Executive Branch of the U.S. Government (April 1990)

New Thinking and American Defense Technology (August 1990)

Recruitment, Retention, and Utilization of Federal Scientists and Engineers. A report to the Carnegie Commission on Science, Technology, and Government by the National Research Council (1990)

Science, Technology, and Congress: Expert Advice and the Decision-Making Process (February 1991)

Technology and Economic Performance: Organizing the Executive Branch for a Stronger National Technology Base (September 1991)

In the National Interest: The Federal Government in the Reform of K = 12 Mathematics and Science Education (September 1991)

Science, Technology, and Congress: Analysis and Advice from the Congressional Support Agencies (October 1991)

Science and Technology in U.S. International Affairs (January 1992)

Science and Technology Leadership in American Government: Ensuring the Best Presidential Appointments. Report of the National Academies of Sciences and Engineering and Institute of Medicine sponsored by the Commission (March 1992)

The Prune Book: The 60 Toughest Science and Technology Jobs in Washington, J. H. Trattner (1992) sponsored by the Commission and the Council for Excellence in Government (Lanham MD: Madison).

International Environmental Research and Assessment: Proposals for Better Organization and Decision-Making (July 1992)

Enabling the Future: Linking Science and Technology to Societal Goals (September 1992)

Science, Technology, and the States in America's Third Century (September 1992)

Partnerships for Global Development: The Clearing Horizon (December 1992)

Environmental Research and Development: Strengthening the Federal Infrastructure (December 1992)

Working with the Congress: A Practical Guide for Scientists and Engineers, William G. Wells, Jr. (1992) sponsored by the Commission and the American Association for the Advancement of Science (December 1992)

Facing Toward Governments: Nongovernmental Organization and Government's Quest for Scientific & Technical Guidance (January 1993)

Improving the Recruitment, Retention, and Utilization of Federal Scientists and Engineers. Report to the

Commission by the National Research Council (1993)

New Frontiers in Regulatory Decision Making: The Role of Science and Technology (1993)

Science and Technology in Judicial Decision Making (Spring 1993)

Science, Technology, and Congress: Organizational and Procedural Reforms (Spring 1993)

Selected Working Papers

Strengthening the policy analysis and research role and capability of the office of science and technology policy, Executive Office of the President. William G. Wells, Jr. and Mary Ellen Mogee (May 1990)

The role of NGOs in improving the employment of science and technology in environmental management. Charles W. Powers (May 1991)

The United States as a partner in scientific and technological cooperation: some perspectives from across the Atlantic. Alexander Keynan (June 1991)

A focal point for science in the courts. Denis Hauptly and Kay Knapp (October 1991)

Procedural and evidentiary mechanisms for dealing with experts in toxic tort litigation: a critique and proposal. Margaret Berger (October 1991)

The federal budget process for R&D. Willis Shapley (April 1992)

The United States and development assistance. Susan U. Raymond, Scott Tiffin, and Charles Weiss, Jr. (May 1992)

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