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GOVERNMENTAL SUPPORT OF ADVANCED CIVILIAN TECHNOLOGY—POWER REACTORS
AND THE SUPERSONIC TRANSPORT

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If present budgeting plans obtain, the Federal Government is committed to spend well over \$5 billion during the next decade on developing reactors for civilian electrical power and supersonic transport aircraft for civilian passengers. Even in a trillion dollar G.N.P. economy, this is a lot of money and these programs warrant a hard look for that reason alone. Public discussion of the power reactor program has been quite limited. The considerable controversy surrounding the continuation of the SST has been motivated to a large degree by fears of the aircraft's effects on the environment. It does not appear to have been generally recognized that these two programs may herald a significant de facto revision in the institutional structure within which a considerable portion of American industry operates.*

This paper will develop and discuss the following characteristics of these two programs. First, they represent an almost unprecedented extent and kind of governmental subsidy for the development of products for production and sale by private companies through the market to the general public. Second, in no sense can it be argued that there is a pressing "need" for these new departures. Rather, these programs were pushed to attention at the Federal policy making level as technological opportunities that

*For one instance in which this point is recognized see: Albert Karr, "Subsidy, Regulation, and Uncle Sugar," The Wall Street Journal, October 12, 1970, p. 12.

"should" be exploited. Further, the early advocacy of these programs came largely from within Government, not from outside. Thus the genesis, as well as the nature, of these programs warrants a hard look for precedent. Third, the arguments for the programs were and are that industry would not undertake them rapidly or intensively enough without massive Governmental aid. Yet very little in the way of detailed persuasive analysis was, or is being, presented as to why the conservative attitudes of private industry were counter to the public interest. Fourth, what we believe to be the implicit rationale for the programs poses basic issues regarding the "standard ways of doing things" in these industries. Only the blind cannot foresee that after the particular programs in question are completed there will be a next generation of programs posing virtually the identical policy issues. More important, there will be projects in other technological fields presented as candidates for this kind of subsidy. The basic issues posed by these programs involve the whole institutional structure of industrial R and D, including who proposes, who decides, and who funds and takes the risks.

**The New Departure: Federal Subsidy for Development of New Products
for Production and Sale by Private Industry to the General Public**

The programs of the Federal Government play a vast and vital role in the research and development activities of the United States. In 1969, of a total national R and D spending of roughly \$26 billion, approximately \$17 billion were Federal funds. The purposes of the public R and D programs were numerous and diverse, but for the most part can be placed in two

categories.* The first is the development of new technology for the public sector. The dominant programs here, of course, are defense related, but the Government also undertakes or supports R and D to improve the ability of public agencies to protect the public health, guard against dangerous drugs and medicines, support construction of public facilities like airports and roads, improve air safety, etc. In all of these cases the Government is charged with performing a particular function and the R and D is undertaken to permit it to perform more efficiently. The second purpose is to advance basic knowledge or knowledge of highly diverse interest or use. Here the basic research support programs of the NSF and NIH are clear examples. Recently, of course, NASA has been a dramatic new departure in Government sponsorship of a scientific and technological venture both for the intrinsic interest of the adventure, and because of the belief that diffuse and widespread benefits will be an important by-product.

Governmental spending for both of these purposes has traditions that go back far into American history. The Constitutional responsibility for setting and maintaining standards for weights and measures soon led to a small research effort in the Treasury Department. The army arsenals performed "R and D" on a variety of weapons. Coast and Inland surveys and explorations early were undertaken and financed to enable the army and the navy to protect the country better, and because it was believed that the knowledge would be of widespread interest and utility to the citizens.

But by and large the Federal Government has steered shy of supporting or undertaking R and D aimed specifically at improving a particular class

*For a more detailed discussion see Richard Nelson, M. J. Peck, E. D. Kalachek, Technology, Economic Growth, and Public Policy, Brookings, 1967, Chapter 8.

of products or services whose normal channel of distribution is through the market. Where this has been done, the product in question has had strong claims to being a merit good, the quality of which "ought" to be improved or cost reduced (like those connected with better health), or a large fraction of the society was concerned with production of the product (as the early rationale for public support of agricultural research), or the product was closely linked with defense (as aviation). There also are a few examples of public R and D support for specific industries (like coal) that were believed to be "in distress". But by and large in all of these cases public funds tended to go into research and exploratory development, with commercial development being left to private initiative.

The pre-1960 public support of research relevant to civil aviation is directly relevant. In 1915 the National Advisory Committee on Aeronautics (NACA) was created to spur the development of American aviation. During its heyday during the 1920's and 1930's, NACA pioneered in the development and operation of R and D facilities for general use (wind tunnels, for example), in information collection and dissemination, and in basic research and exploratory development. It undertook major work on aircraft streamlining, design of engine parts, properties of fuels, and structural aspects of aircraft design, and it built and tested a variety of experimental hardware. But NACA did not directly support the development of particular commercial airplanes. Indeed, the idea that such a role should be assumed by the Federal Government was explicitly rejected in the late 1940's when Congress refused to approve bills that would have appropriated Federal funds to finance the construction of a jet transport prototype in spite of claims that private industry could not hope to raise the sums required and that U.S.

leadership in commercial aviation would be surrendered to the British, whose government was supporting prototype programs, unless such aid was forthcoming.*

Until recently the programs of Atomic Energy Commission in support of civilian power reactors were similar in spirit to the NACA support of aircraft technology.** The amended Atomic Energy Act of 1954 established a more or less explicit division of responsibility between the AEC and private enterprise, with the Government's role being limited to support of research, the building of experimental reactors, the operation of facilities for testing, information dissemination, etc. That private companies operated many of the AEC laboratories and facilities, and that these clearly were and are viewed as places where private companies and personnel could "learn" and gain experience, departs from the NACA experience. But private enterprise clearly was left the job of bringing the technology into practice on its own initiative.

During the late 1950's and throughout the 1960's, the Atomic Energy Commission gradually increased the extent of its involvement in the development of civilian nuclear power, both in terms of detailed planning and subsidy of development, and in terms of admonishing industry to do more than it seemed to want to do. Similarly, during this period the Federal program in support of supersonic transport technology evolved from a traditional

*e.g., see "Costs and Jets," editorial, American Aviation, June 1, 1948, p. 1; and "U.S. Airlines to Buy British?" Aviation Week, August 29, 1949, pp. 31-32.

**For a discussion see Philip Mullenbach, Civilian Nuclear Power: Economic Issues and Policy Formation, Twentieth Century Fund, 1963.

NACA type of effort to one of planning and financing final product development and admonishing the industry to try harder. These represent major new departures in the Government's role in R and D on products produced by private companies and distributed through the market.

The Genesis: Technology Opportunity Push from Inside the Government

The obvious question is what triggered the significant new departures. Both conventional wisdom and relatively careful research would suggest that major new Governmental policies usually stem from perception of a pressing problem, or pressure from a politically potent external interest group, or both. But for these programs this does not seem to have been the case.

In most of the more recent studies of policy making (more generally decision making in large organizations), new policy departures or major policy modifications have been described as usually coming about as a result of perceived problems with the status quo ante. While it sometimes is not fully clear what comprises a "problem," the use of the word suggests something different than simply a perceived opportunity to do better. What is interesting about the two cases in question is that they do not fit this mold. There was no pressing problem or need to call forth the escalation of public policy in civilian power reactors or civil aviation. Rather the programs evolved as they did largely on the grounds that an opportunity existed that was perceived as not being exploited fast or hard enough.

Up until just recently the electric power industry of the United States certainly was not high on the list of those whose performance was widely perceived as "unsatisfactory". John Kendrick's study of Productivity

Trends in the United States shows a long-run rate of productivity growth in electric power more than three times the national average. Relatedly the price of electric power has fallen significantly over the years and the rise in consumption has been very rapid. Concern about growing scarcity of conventional fuels goes back at least as far as Jevons in the late 19th century and such concern clearly was and is a prime factor in arguments for rapid development of nuclear power. But from the earliest analyses of nuclear power studies generally have reached relatively sanguine conclusions regarding short run energy supply adequacy, and have given no cause for alarm even for the long run. In their monumental study published in 1960, Schurr and Netchert projected that coal reserves were ample in quantity and kind to meet the demands at least to the end of the century without rising costs.* They also projected sufficiency of natural gas reserves for the medium run future. They saw petroleum reserves as more problematical, but for the purposes of generation of electricity, coal can be substituted for petroleum without difficulty. The 1966 study of Energy R and D and National Progress, which was undertaken with the express purpose of identifying sources of concern, reached the conclusion that significant shortages of conventional fuels, or sharply rising costs of extraction, were not likely in this century.**

Progress in civil aviation has been, of course, even more spectacular than in electric power. Successive generations of new aircraft have made travel vastly faster and more comfortable, and prices of air travel (even not counting the great quality improvements) have until recently fallen

*Sam Schurr and Bruce Netchert, Energy in the American Economy, Johns Hopkins, 1960.

**Energy R and D and National Progress, U.S. Government Printing Office, 1964.

relative to the average. Indeed, at least one recent study has concluded that the development of new aircraft perhaps has proceeded at too fast a rate, with CAB rate control authority precluding effective price competition by older planes to counter the speed advantages of the new, thus providing an artificially profitable market for new high performance aircraft.* Certainly the "problems" with respect to air transport, as they have increasingly been perceived during the 1960's and 1970's, involve air space crowding and safety, growing congestion to and from and at the airports, and noise; problems not of a sort resolvable by a supersonic transport.

The statement that there was no perceived problem, at least in the short and medium run, to which nuclear reactors and supersonic transports represented a possible solution is a bit too strong. There was and still is a felt "need" to do something (preferably on the cheap) for the less developed countries and, in the early days, nuclear power seemed such a possibility. U.S. development of the supersonic transport was influenced powerfully by a perceived "need" not to let other countries get ahead of us in civil aviation; relatedly, there was concern about the balance of payments consequences if this occurred. But (as we shall discuss later) the case for the programs on these grounds scarcely is powerful, and the major arguments were posed in terms of "opportunities that ought to be seized."

Just as recent models of the policy process place limited weight on "opportunity push", most views of governmental policy processes generally ascribe policy changes to outside demands. While increasingly attention is being paid to the fact that governmental agencies and civil servants have

*William A. Jordan, Airline Regulation in America: Effects and Imperfections, especially Chapter 3, "Rivalry Through Service Quality." The Johns Hopkins Press, Baltimore (in press).

wills of their own, for the most part this influence is viewed as conservative. In the power reactor and supersonic cases, not only were the departures apparently attempts to push opportunities rather than meet difficulties; the pushing seems largely to have come from within government rather than from the outside.

Advocacy of the electrical equipment producers and the private utilities was an important factor behind the "freeing up" of nuclear information and R and D from the tight control of the AEC manifested in the AEC "industry participation" program of 1951.* The 1954 amendment to the Atomic Energy Act explicitly established Governmental commitment to basic research, and exploratory development of civilian atomic power was in part at least responsive to industry and utility demands. But, according to Mullenbach, the equipment suppliers, and the U.S. Chamber of Commerce, certainly cannot be counted among the early enthusiasts for the growing Federal activism as it evolved. Neither the private utilities. Indeed the private utilities tended strongly to resist the building of Governmental reactors on sizeable scale, fearing that this might strengthen the tendency for nuclear power to go "public." While there was less resistance on the part of the utilities to governmental subsidy of private construction and ownership of large experimental plants, in the early days this seems to have been more in the spirit of "if you insist that we build, you will have to share the costs" than of active advocacy. Of course, as the equipment suppliers gradually invested in their nuclear design and production capabilities they have grown increasingly enthusiastic about governmental programs to subsidize the procurement of nuclear power.

*For a good history see Mullenbach.

But the early thrust appears to have come largely from within the AEC and the Joint Committee on Atomic Energy. The major noted advocacy speeches during the late 1950's and early 1960's were by Commissioners and Congressmen. They seem to have been the active force behind the gradual escalation of subsidy from assistance in studying the projects (in the mid 1950's) to paying a share of the capital costs (1960) to subsidizing reactor design costs. The most recent development is the proposed governmental commitment to the achievement of an economic breeder reactor by the 1980's involving explicitly AEC detailed planning, subsidation, and monitoring of large demonstration plants for designs that are at least close to produceable and saleable.

Similarly the SST program seems to have been more the result of pushing from within government than pressure from the outside. The program appears to have bubbled up as the result of a coalition between NACA (by the NASA) people who had been researching aspects of supersonic flight in the traditional NACA context, and people at the Federal Aviation Administration (FAA). The early attitude of the airlines appears to have been that an SST was inevitable but support for governmental subsidy of development was, at best, guarded. The manufacturers, naturally, were willing to proceed with development of an SST under governmental funds, but the idea does not seem to have been theirs.

The early conception of the program involved an unprecedented element of direct governmental assistance in the development of a commercial aircraft, but it was not argued at that time that Federal funding would have to play a very major role. As with atomic energy, as the sixties progressed the extent of governmental involvement and subsidy escalated. The key events seem to have been the demise of the B-70, which, it had been hoped, would provide

considerable spillover assistance to the development of a commercial SST, the British-French agreement to proceed with the Concorde, and the growing awareness on the part of SST advocates that the manufacturer would not proceed unless the subsidy was increased substantially.* The Governmental commitment has grown from a \$12 million feasibility study in 1961, to notions of Governmental cost sharing of up to 50% of development costs through prototypes, to the present level of 90% cost coverage by the Government, and the recent implicit commitment to carry the development through the post-prototype stages if industry is reluctant.

The Lack of a Persuasive Explicit Rationale

That these programs are major new departures for Government involvement in R and D, that they represent attempts to seize "opportunities" rather than reactions to "problems", and that the initiative came largely from within the Government, are not, of course, reasons for condemnation. Many students of Governmental R and D policies, including one of the authors, have called for significant expansions in the Governmental role. That Governmental policies usually tend to be responsive to problems and not opportunities is a reason for concern; such a bias in the policy-considering trigger is bound to be non-optimal.

By and large the traditional Federal R and D programs can be and have

*In this connection, see Testimony of Elwood Quesada, Former Administrator, Federal Aviation Agency, in "Economic Analysis and Efficiency of Government," Hearings Before the Subcommittee on Economy in Government, Joint Economic Committee, 91st Congress, 2nd Session, part 4, Supersonic Transport Development, pp. 925-927.

been justified on the grounds that the decentralized market mechanism would not generate the right kind of R and D. This is likely to be the case where the public sector has preempted the market, as in defense and the postal service. For basic research support, the argument is that benefits are not reflected adequately or at all in private profit opportunities. In the early days of agricultural research support, the argument was that farmers were "too small" to do R and D, and that there were many important problems where seed and equipment suppliers had no financial interest. There was also a pervasive feeling, in contrast to the ideology with respect to manufacturing, that agricultural advances should be a public good.

The reasons advanced for Federal support of prototype construction of a nuclear power reactor and an SST have not been of these sorts. Instead, it has been argued that the traditional public programs--undertaking or financing basic research, building and testing experimental hardware, providing research and testing facilities--are not sufficient by themselves to motivate private industry to undertake advanced development soon enough or intensively enough to achieve technological success in the near future. The magnitude of the funds required, the length of the development period, and the risks involved are held to transcend the capabilities of existing capital markets and firms.

Very large financial requirements and a long lead time, combined with considerable uncertainty about returns and costs, are indeed possible reasons why some kind of public action (though not likely subsidy) might be in order, if these were associated with a very high expected rate of return. The elasticity of capital supply to firms, their time horizons, and their ability to spread risks, certainly can be stretched so far that profitable ventures cannot be seized without some Federal action. Having admitted this, however,

we should not underestimate the ability of capital markets and firms today to undertake ventures of bold size and risk, and a long time horizon. IBM is reported to have risked \$5 billion in the early 1960's to develop the System/360 family of computers. This sum is somewhat higher than the total estimated cost of the SST program through delivery of the first aircraft. It was raised at a time when IBM's sales, total assets, and net worth were not significantly larger than those of Boeing Aircraft today, to say nothing of the combined assets of Boeing and General Electric, the two prime contractors on the SST project. Furthermore, many companies have shown a willingness to support R and D on projects where it was anticipated that returns would be quite distant and uncertain. Even in the late 1920's, the electrical companies were undertaking R and D on television, and Dupont was investigating high polymers.

The key reason why American industry has been unwilling to invest in R and D on power reactors and on the SST of a magnitude and kind that the advocates think appropriate is that the expected rate of return is very low, much below that of other uses of funds and resources. Cost-benefit studies by program advocates show this, even under what many outsiders regard as rigged assumptions. Were this not believed, both in the Government and outside, much more consideration would have been given to Governmental assistance and risk sharing, rather than to one form or another of subsidy.

The argument that public funds should be provided has rested largely on the case that the private financial benefits understate the true benefits to society, or that the private financial costs overstate the real costs, or both. In the controversy over the SST, for example, factors such as the program's impact on the balance of payments, its effect on employment in the

aerospace and related industries, and, to a lesser degree, technological spillovers alleged to be of value to the military have been advanced in support of Federal prototype funding.* Yet underlying these claims is a belief that the most important externality is the assurance that the program's continuation gives of continued U.S. dominance in the World commercial aircraft industry. Commercial dominance is equated with technological superiority, and it is claimed that failure to exploit the technology embodied in the SST at the earliest possible moment will mean a loss of technological leadership, which in turn will mean an irreversible loss of commercial position.

Such thinking apparently has its roots in the experience of the aircraft industry in the production of military hardware. In the past twenty-five years the American aircraft industry has grown prosperous by producing military designs which offer often marginal improvements in performance over existing designs at substantially greater cost. In military aviation sometimes (but certainly not always) even a marginal technological advantage is the difference between life and death. Yet to apply such a development strategy to a commercial product is to invite commercial disaster. As Phillips states: "While it is undoubtedly true that particular aircraft have been added to the fleets [of the airlines] because of non-cost aspects of performance and because of the influence of new equipment on passenger demand, the record over the years is strong in suggesting that, absent favorable cost behavior, none or only few of any new type of aircraft is demanded."**

*Albert Karr, "Clash Over the SST," The Wall Street Journal, September 23, 1970, p. 1.

**Almarin Phillips, Technological Change and the Market for Commercial Aircraft (draft), pp. 138-139.

That the United States has dominated the commercial aircraft market in the postwar period is undeniable. Recent estimates reveal that over 80 percent of the World's commercial airline fleet was built in this country.* Phillips' research makes it clear, however, that this dominant commercial position rests not so much upon the general technical superiority of U.S.-built commercial aircraft but instead upon the good record of the American manufacturers in deciding when to embody what technological advances into commercial products. This record undoubtedly has been aided by the fact that in each case, the decision to produce a commercial design has been made by a private company risking its own funds. There is no doubt, for example, that if Congress had been willing to appropriate the necessary funds in 1948, the U.S. and not the British could have been the first to introduce jet transports into commercial service. It is clear from a study of the designs then being proposed, however, that the early U.S. jet transports would have been no more commercially viable than was the Comet I or Comet II. And how much would it have aided the reputation of the American commercial aircraft industry had it, and not the British, been the one to discover the catastrophic effects on pressurized aircraft of metal fatigue?

In contrast to the U.S. experience, the record of the British aircraft industry in the postwar period has been relatively dismal. The British government has been prepared to cover up to 50 percent of the costs of launching civil aircraft designs and to assure a base market for these designs by requiring British flag carriers to purchase the resulting product, regardless

*Statement of James M. Beggs, Undersecretary of Transportation, "Economic Analysis and Efficiency of Government," op. cit., p. 962.

of operating costs.* As a result the British have rung up a string of technological successes that, by and large, have been commercial failures. Even the massive infusion of Governmental aid has not served to maintain the health of the British aircraft industry, and, with few exceptions, the aircraft produced have not made a favorable contribution to Britain's balance of payments.**

While proceeding under forced draft from original idea to finished product under the notion that a new technology must either be seized or lost certainly does not contribute to, and may even hinder, the attainment of a commercially successful product, it is nonetheless possible that such an accelerated program may serve to allow society to reap any benefits associated with the attainment of a particular technology sooner rather than later in time. In the cases of both atomic energy and the supersonic transport, it is apparent that the technology would be very valuable to have around, if it were developed to anything close to its potential. In the hearings, speeches, and dialogues the word "inevitable" has been used regarding both of these technologies. In the cost benefit studies of the breeder reactor program a considerable amount was made of the fact that, given the large and rapidly growing market for electric power, hastening the day that we have breeder reactors that are superior economically to existing technologies, will enable us to start our benefit flow earlier, and enhance the total benefits we shall reap. In the SST studies, although to a lesser extent, and more

*Robert E. Baldwin, Nontariff Distortions of International Trade. Brookings, 1970, p. 119. This latter commitment alone was costing the British government an estimated \$80 million in subsidy to British European Airways in 1968.

**The relatively poor commercial performance of the Caravelle, an aircraft ordered in prototype form by the French government in 1953 and which first flew in 1955, is yet another example of the point being made. The Caravelle anticipated the technology later embodied in the BAC 111 and DC-9 by almost ten years, yet this in itself was not enough to guarantee a market for the aircraft.

connected with the concern about the expansion of a particular competition technology--the Concorde--, the same kinds of arguments for hastening the inevitable are made, implicitly or explicitly.

However the very fact that these technologies, as they approach their potential, will be valuable (and this is what makes them "inevitable") means that one cannot compare the achievement of the technology under the proposed program to accelerate development against the null alternative that it never will be developed. Yet this is done in all of the cost benefit studies we have seen. The very attractiveness of the technologies and their potential profitability almost assure that even under the existing regime of private and public institutions, they will ultimately be developed. The key question is timing and scheduling of effort, and overall R and D strategy.

Common sense, history, and detailed analysis all tell us that there is a time-cost trade off.* Public subsidy or more direct programs can buy us time, but we pay for speed. The costs of hastened development must be weighed against the benefits of gaining an attractive technology sooner. While the formal cost benefit studies stress the benefits of faster achievement, they either ignore or deny that we could achieve the same results more cheaply if we didn't hurry so much. But this is really the issue.

Why are the costs and risks too great in these programs for private enterprise to bear? Because at the targeted pace of development one cannot proceed sequentially and in small bites. The technological advances that we have achieved in many industrial and product fields, largely through private

*For a discussion see Frederick M. Scherer, "Government Research and Development Programs," in Robert Drofman (ed.), Measuring the Benefits of Government Expenditures, Brookings, 1965.

efforts, have been truly spectacular. But the progress has been sequential, and efforts to achieve major advances in technology, like the first jet transports, and the recent jumbo jets, have been paced over time, with the major product development efforts waiting until components were available, until research findings had clarified many of the dark places, and until the final expensive surge looked relatively certain and the returns high.

A case can be made that this strategy of R and D implies that the long run "profits" from the early exploratory and experimental work may tend to diffuse away from the market grasp of private business firms; hence, some kind of governmental programs may be needed to assure that this part of the process is as intensively undertaken as the long run promise of the technology warrants.* And such programs were in fact being undertaken by NACA for aviation, and by the AEC in the field of power reactors, before the recent thrust to greater haste.

The rationale for the current programs totally neglects that the problem is one of time-cost trade off. Why such special haste on these programs? If these, why not others? We have not seen good answers to these questions; indeed they do not appear to have been asked. How much is it worth to get these technologies faster (not how much is it worth to get the technologies at all)? How much is it costing us to speed up their achievement (not how much is their development likely to cost under the proposed program)? What will be the technological spillovers, balance of payments effects, and employment effects of having these projects now rather than in the future and how

*See Nelson, Peck and Kalachek, Chapter 9.

do these spillover effects compare with those associated with programs that will not be undertaken due to our haste in these projects?* We think that if these questions were posed and valid answers obtained, few reasonable men would advocate the SST or the nuclear power reactor programs as they are presently constituted.

There are two deeper issues which we want to explore in the following section. One is the implication of these programs for institutional structure. The other involves concern about the way the nation looks at technology.

Questions of Institutional Structure and the Role of Science and Technology

If past experience be a guide, the conscious national decision to achieve very high rates of technical progress in a particular field is tantamount to a decision that traditional decentralized modes of R and D organization, decision making, and risk taking, be superseded by a much more concentrated and centralized structure. The Manhattan Project to develop the atomic bomb, during World War II, probably was our first national experience with extreme forced feeding of technological progress, and the project involved and required not only large amounts of resources but also a quite elaborate control and monitoring network. During the post War era, and particularly since the mid 1950's, the same kind of time urgency has marked much of military R and D. Increasingly the military R and D program has been concentrated in a few large and ambitious projects, each one under (at least attempted)

*For a recognition of the relevance of these questions see: "The SST Decision," editorial, The Wall Street Journal, September 28, 1970, p. 14.

tight control from the center and the overall "program" under increasingly tight central monitoring. Project Apollo, of course, is another example of this R and D style associated with an emphasis on speed or technology stretching with little concern with the cost, and with detailed central planning.

The presently proposed reactor program and the SST represent the transference of the R and D style of the Manhattan Project, post 1950 military R and D, and the programs under NASA, to two new areas, with the objective of achieving faster progress. In these fields it is clear that the traditional division of labor and responsibility now is or soon will become obsolete, unless there is a radical reversal of policy. The Federal government increasingly is adopting the role of deciding in detail the R and D projects that will be undertaken, paying the bill and taking the risks, and being generally responsible for the kinds of products and processes that evolve.

This clearly is so, and has received political sanction, in the civil reactor field. This is not to say that the AEC finances or undertakes all of the work, although it does for a large share of it. But the AEC does monitor private effort and seeks to influence it, as well as directly controlling the publicly supported programs. In the breeder reactor program the AEC finally has gone to the length of specifying an overall development plan in some detail, stating what the private sector should be doing as well as the public. We think it goes without saying that, unless some radical rethinking occurs, this "plan" will be progressively updated, ultimately will look to the generation of reactor technologies beyond the present breeders, and represents the evolution of a long run way of doing things in civilian reactor technology.

It is less apparent, but we think it true, that the SST program represents

a very large permanent increase in governmental detailed responsibility for R and D in civil aviation, unless there is a change in policy. Governmental planning and programs, backed by funds, cannot help but drive out or greatly reduce private planning and programs, if these governmental efforts carry through development as is the new departure. Financing, and detailed planning of, final product development simply is very different in its impact on private R and D than support of basic research and exploratory development as in the old NACA days. Public funding of the early stages of the R and D process can be expected to spur private development spending by making clearer the development options, and reducing the cost of the developments needed to achieve a given performance enhancement. But if the Government finances development itself, private efforts are at a competitive disadvantage with respect to the subsidized programs. This is particularly so when, as appears to be the case in civil aviation, the Governmentally backed efforts aim for such major advances that competition is not possible unless there are comparable private funds in the development till. Under the new precedent, development of civil aviation is likely increasingly to follow the military pattern, with government and industry jointly deciding what to develop (with the Government bearing the lion's share of the cost and the risk), rather than the traditional pattern of civil aviation development in the United States. At the least there will be a "hypersonic" development to follow the supersonic development and already there is discussion of an "overall development strategy" for civil aviation.

It is not a short step, it is a very large step, to a significant additional expansion of the sectors to which this structure will be applied. However we think we already can see a significant expansion of Federal funding of,

and planning of, medical development as well as research. Here, as in atomic energy and aviation, the key ingredients seem to be, first, a large and competent group of scientist-technicians within the government and, second, a feeling that the pace of technical progress in the field could be much faster.

Several additional directions of likely expansion, fueled by like conditions, can be identified. The Interdepartmental Study of Energy R and D and National Progress provided a long list of areas in which it was judged R and D was "promising" and governmental encouragement (subsidy?) possibly warranted; the concentration of Federal largesse on atomic energy cannot continue for long. Likewise there is growing concern about concentration of Federal funds for transportation R and D on aviation, and it is a good bet that soon other areas of transportation will begin to get more attention. Perhaps most striking, and most in need of watching, is the growing discussion of the possibilities of tapping the R and D capabilities built up in private enterprise through the defense and space programs (now the SST program) and the public capabilities of the AEC laboratories for civil R and D more broadly.

We are bothered by these institutional concomitants of a philosophy that technological opportunities should be seized, and rapidly, and that a leisurely pace of private development is a good reason for public forced feeding, for two basic reasons. The first is really a reflection of the fact that these policies involve climbing far out along the time cost trade off curve; this kind of R and D institutional structure and strategy is likely to be very inefficient as well as costly. Our second concern is that Governmental commitments to particular technologies and products pose an unusually difficult public control problem.

One of the most striking aspects of the history of technological advance in most American industries is the diversity of sources. New products, processes, inputs, and equipment for an industry have come from firms in the industry, suppliers, purchasers, new entrants to the industry, outside individual inventors. The process certainly was not orderly and planned, and one has the impression that had one tried to impose order and plan the result in many (most?) cases would have been much worse. Many developments that early seemed to be very promising did not pan out. Many important breakthroughs were relatively unexpected and were not supported by the experts in the field. While detailed case histories are not plentiful, and many of these do not shed light on the question, one has the impression that in most of the technically progressive industries, like chemicals and electronics, most of the bad bets were rather quickly abandoned, particularly if someone else was coming up with a better solution, and good new ideas generally had a variety of paths to get their case heard.

Military R and D programs since the mid 1950's, the civil reactor programs, and experience to date with the supersonic transport are a sad contrast. In these areas the early bet batting average has been dismal, just as it has been in the domain of decentralized development. But there has been a proclivity to stick with the game plan, despite mounting evidence that it is not a good one, that appears only in exceptional cases in areas where R and D is more decentralized and competitive. The case of Convair throwing good money after bad on the 880 development rightly is regarded as an aberration, and the fact that General Dynamics had learned its style in military R and D undoubtedly was a contributing factor. But this kind of thing is the rule, not the

exception, in military R and D. The B-58 and TFX were pushed all the way through development despite mounting unfavorable evidence. The B-70 and Skybolt were halted short of procurement, but long after the signals were clear that they were bad ideas. A considerable amount of "bunching" of R and D efforts into a few large projects, with considerable stickiness in changing the list of projects or their internal strategy, probably is inherent in technology forcing. It has been argued elsewhere, however, that the extent of these characteristics in military R and D compounds the problems, as does the "double control" system of private management and detailed public monitoring. Our belief is that these aberrations will be applied with the big push philosophy, making a naturally costly strategy even more costly. It is a good bet that Boeing would not have persisted so long in pushing its swing wing SST design had the bulk of the funds been its own, and had it the ability to make that decision on its own. We think the signals are clear enough that the present design is in trouble. Only momentum and the awkwardness of changing the game plan now carry the project forward in its present conception. Similarly, throughout the history of the AEC's power reactor program there have been complaints that the AEC was persisting in R and D on a design long after evidence had accumulated that this was not an attractive route, and, conversely, that the AEC has been very sticky about initiating work on new concepts.

If we were not in so much of a hurry we would feel less compelled to adopt an institutional mode that not only is highly inefficient, but carries some rather dangerous implications regarding the role of Government as a product advocacy lobbyist. It is rather surprising that the producers of coal and oil and power generating equipment using conventional fuels have not raised

more noise than they have regarding the pressure being applied to the utilities by the AEC to install nuclear rather than conventional power. While the evidence on the nature of thermal pollution and nuclear waste problems now is far from clear, and nuclear power still probably looks good compared to conventional power in pollution and waste problems, we think we should feel some discomfort that a strong government lobby has a stake in the issue. There has been more vocal concern about the implications of a governmental financial stake in the SST, perhaps because of the explicit "revenue sharing" provisions in the program. But even without a financial stake, the relevant government agencies, and the higher executives and congressmen who support their program, have a personal credibility stake in the success of the products and processes they push so hard. It is relatively clear that the success of the SST program, measured in almost any dimension that has been talked about, will depend highly on the fare structure allowed and encouraged by the CAB. The CAB can go a long way towards making the SST program a financial success, by fighting for high fares (to cover the higher costs of the SST relative to the jumbo jets) and uniform fares (so that the lower cost technology will not be able to compete in the dimension where it is strongest). This implication of the "big push" policies we find very disturbing.

These programs are dangerous also in that they reinforce an already strong tendency on the part of the nation to look to technological fixes as the preferred way to deal with problems. One consequence of the technology fix cult, and it already is apparent in several areas, is an overstress on R and D in areas where other routes may strike more directly at the problem, or be more efficient if less glamorous. It is clear, for example, that while R and D can help improve our shelf of relevant technology for dealing

with problems of urban congestion and pollution, there exists technology now that can deal with many aspects of the problems, and what would do the most good would be significant changes in incentives and costs facing congestors and polluters. Indeed there is some reason to fear that the quest of an R and D fix may retard really dealing with the problems. Present solutions to congestion and pollution are politically fractionous. The argument that with R and D we can have better solutions provides an excellent excuse for avoiding doing much now.

We are advocates of more Governmental R and D both in support of industrial technology and on pressing social problems. The kinds of programs that are sensible, however, are those that recognize explicitly the uncertainties that reside in far reaching R and D and that avoid making large commitments to particular approaches prematurely. There is a strong case for extending the kinds of programs that characterized NACA during the twenties and thirties and the AEC during the fifties to a general policy in support of applied research and experimental engineering development. A specific institutional format for doing this has been suggested in another place.* For R and D on social problems where public sector agencies are responsible for the provision of the relevant good or service in many cases Federal R and D support will have to extend through final design, but here too it is important to avoid the style of Defense and NASA. We even see some merit in programs with the flair and excitement (but we suspect very small economic or scientific payoffs) of Project Apollo. However, the recent evolution of the power reactor and SST programs is movement in the wrong direction. It is not clear whether these particular programs can be turned off or cut back. But it is extremely important that they not become precedents.

*Nelson, Peck, Kalachek, Chapter 8.