# Government-Sponsored Demonstrations of New Technologies

## A well-developed technology, user participation, and risk-sharing lead to more rapid commercial adoption.

Walter S. Baer, Leland L. Johnson, Edward W. Merrow

The federal government is becoming increasingly active in stimulating technological change and innovation in the civilian economy. Unlike space and defense technologies, where the federal government is the principal purchaser of new products and services as well as the sponsor of research and development (R & D), civilian-oriented technologies must be adopted by commercial firms or state and local public agencies. Consequently, federal agencies have supported "demonstrations" of such innovations as nuclear power reactors, personal rapid transit vehicles, and desalination plants in order to speed their introduction into commercial use. Other demonstrations have provided information for regulatory decisions, especially in the environmental field. A few have promoted U.S. foreign policy objectives. All are intended to show how a technology operates in the "real-world" environment.

A demonstration project generally involves the final stage of the scaling-up process from the laboratory to commercial use. Often, the technology has progressed through R & D and pilot-plant operations or field tests. These activities concentrate on proving technical feasibility and providing early estimates of costs. In contrast, a demonstration focuses on market demand, institutional impact, and other nontechnological factors, the goal being to provide the basis for well-informed decisions on whether to adopt the technology (*1*).

Federally supported demonstrations of civilian technologies are by no means new. In 1843, Congress appropriated $30,000 to demonstrate Samuel Morse's American Telegraph System between Baltimore and Washington, D.C. The telegraph line was completed by June of 1844, and its success led to the commercial expansion of telegraph service in the United States (*2*).

Only in the last two decades, however, has the federal government accumulated extensive experience in funding demonstrations in many fields, including energy, housing, transportation, environmental protection, and health care. The results have been mixed. Some demonstrations, such as the Atomic Energy Commission (AEC) Power Reactor Demonstration Program in the 1950's and early 1960's, are generally considered to have speeded commercial adoption of the technology. But others are not, such as the Department of the Interior's attempt to produce an edible fish protein concentrate from whole fish. Surprisingly, apart from several studies of the role of the U.S. Department of Agriculture (USDA) in agricultural innovation (*3*) and Hilton's discussion of mass transit demonstrations (*4*), there has been little systematic analysis of past experience that would enable us to understand when and why some demonstrations have worked well and others have not.

We based our present analysis on detailed studies of 24 federally funded demonstrations. We begin by discussing the rationale for government involvement, the scope of federal demonstration activities, and a framework for analyzing outcomes in terms of project goals, initial uncertainties, and other factors.

### Why Should the Government Sponsor Demonstrations?

The traditional rationale for government involvement in civilian technology is that, left to its own devices, the decentralized private market mechanism will not generate the level and kind of technological innovation that maximizes the welfare of society as a whole. This problem of market failure can arise from three sources. First, the benefits to society from a firm's R & D activities may exceed the benefits that the firm can capture as profits. The unpredictable results of research are especially hard for the originating firm to capture, since the cost of producing new knowledge through research usually is high, but the cost of reproducing it is low. Patents and copyrights only partially alleviate the disparity, which leads firms to invest less in R & D activities than would be socially optimal. However, this argument is stronger for activities near the basic research end of the spectrum than for demonstration projects.

Second, the production of some goods and services gives rise to externalities that are not reflected in the price of the good or the service, or of the inputs into its production. Externalities can be either positive or negative. Reduced dependence on foreign fuel is a positive externality associated with developing new domestic energy supplies. Consequently, government may want to demonstrate a new energy technology to produce information about its commercial feasibility. If the technology proves economically advantageous, the demonstration will speed its commercial introduction and diffusion; if not, the demonstration can determine the level of subsidy needed to stimulate adoption. In other cases, a new technology may reduce a negative externality, such as jet engine modifications to cut aircraft noise around airports. While the airlines may have no profit incentive to introduce the technology, a government-sponsored demonstration may pin down the cost of requiring its use by regulation.

Finally, private markets may operate inefficiently because of excessive concentration, high information or transaction costs, or distortions caused by government itself. The rigidities and distortions in the residential housing market, introduced by multiple local building codes and labor union practices, have been the rationale for government-sponsored demonstrations of new building technologies. The low rate of innovation in the U.S. shipbuilding industry, caused largely by government subsidies for ship construction and cargo preference laws favoring ships built in the United States, was the justification for additional government intervention in the form of research, development, and demonstration (RD & D) support. To be sure, it would be a better policy to remove the original

The authors are with The Rand Corporation, Santa Monica, California. Dr. Baer is deputy director of the energy policy program, Dr. Johnson is manager of the communications policy program, and Mr. Merrow is a member of the social science department.

distortions, that is, the cargo preference laws and subsidies. But this may be politically infeasible or beyond the authority of the agency sponsoring the RD & D (5). Consequently, demonstrations can become part of a "patch-up" policy to remedy government-induced market distortions.

In cases of market failure, federally supported demonstrations may be useful in generating information and stimulating diffusion. But the rationale must be clearly defined, since market failure is a general and often fuzzy concept that can easily be misapplied in support of ill-conceived government projects (6). "Government failure" occurs as well as private market failure. Attempts by government to compensate for distortions in the marketplace can lead to other, more serious, distortions.

## Scope of Federal Demonstration Activity

In addition to operating in a real-world environment, the demonstration projects included in this study share three characteristics:

1) They are supported by federal funds, although they may also receive funding from nonfederal government agencies and from private firms.

2) They are intended to provide direct stimulation of technological change in the civilian sector (we exclude space and defense activities that may have civilian spin-offs as an ancillary objective).

3) Private sector firms are expected to adopt the technologies, or to supply the technologies to public sector adopters. Health insurance, school voucher, negative income tax, and other projects aimed at social change (7) are thus excluded from our study.

Using these criteria, we surveyed all federal departments and agencies outside space and defense to determine the scope of their demonstration activities. By reviewing agency budgets, program descriptions, and reports, as well as through interviewing agency officials, we identified 41 programs in 12 federal departments and independent agencies that include demonstrations. We estimate that demonstration projects account for about 10 percent of the $8.6 billion budgeted for all civilian RD & D activities in fiscal year 1977 (8). Demonstration funding is expected to increase substantially in the future, especially in the energy field. The Energy Research and Development Administration (ERDA) has listed more than 50 demonstration projects in its 1976 National Plan (9). Most are scheduled to begin within the next 10 years, including several fossil energy and solar demonstrations, each estimated to cost over $200 million.

From the 41 agency programs, we selected 24 projects for closer analysis (Table 1). They were chosen to span a wide range of technologies; federal agencies; project sizes; and uncertainties in terms of technological development, the market for the innovation, and organizational and institutional impediments to adoption. Half of the projects were judged by their sponsors or others to have been successful. Additional criteria were the adequacy of available data and a history sufficient to permit our independent assessment of outcomes. Three of the projects were pilot plants or field tests, selected to sharpen the distinctions between these activities and true demonstrations.

Eleven of the 12 agencies and departments conducting substantial demonstration activities are represented among the 24 projects selected for analysis. The exception is the USDA, whose projects were excluded because the department's unique role in agricultural innovation over more than a century, through the Experimental Stations and Extension Service, makes comparisons with other economic sectors difficult.

Table 1 groups the 24 projects in three rounds of case studies. Given the lack of

Table 1. Selected case studies of federally funded demonstration projects.

| Federal agency | Project | Location |
|---|---|---|
| | *First round (develop conceptual framework)* | |
| Atomic Energy Commission-Maritime Administration | Nuclear ship *Savannah* | |
| Environmental Protection Agency | Mechanized refuse collection (Godzilla) | Scottsdale, Ariz. |
| Health, Education, and Welfare | Computer-assisted electrocardiogram analysis | Denver, Colo. |
| Health, Education, and Welfare | Teleprocessing of Medicaid claims | Montgomery, Ala. |
| Maritime Administration | Shipbuilding research, development, and demonstration program | U.S. shipyards |
| National Marine Fisheries Service | Fish protein concentrate plant | Aberdeen, Wash. |
| Office of Saline Water | Saline water conversion plant | Freeport, Tex. |
| Urban Mass Transportation Administration | Dial-A-Ride transportation system | Haddonfield, N.J. |
| | *Second round (develop hypotheses)* | |
| Atomic Energy Commission | Yankee nuclear power reactor | Rowe, Mass. |
| Atomic Energy Commission | Connecticut Yankee nuclear power reactor | Haddom Neck, Conn. |
| Environmental Protection Agency | Refuse Firing Demonstration (solid-waste-to-fuel conversion) | St. Louis, Mo. |
| Energy Research and Development Administration | Synthetic fuels program* | Various |
| Housing and Urban Development | Operation Breakthrough (industrialized housing techniques) | Various |
| Urban Mass Transportation Administration | Personal rapid transit system | Morgantown, W.Va. |
| Veterans Administration | Hydraulic knee prosthetic device | Various |
| | *Third round (assess hypotheses)* | |
| Bureau of Mines | REAM (rapid excavation and mining) gun* | Hope Valley, Calif. |
| Environmental Protection Agency | Resource recovery from refuse | Franklin, Ohio |
| Environmental Protection Agency | Poultry waste processing | Durham, N.C. |
| Federal Highway Administration | Expressway surveillance and metered ramp control | Chicago, Ill. |
| Maritime Administration | Maritime satellite program | |
| National Aeronautics and Space Administration–Federal Aviation Administration | Refan jet engine program | |
| Office of Saline Water | Saline water conversion plant | Pt. Loma, Calif. |
| Urban Mass Transportation Administration | Bus-on-metered-freeway system | Minneapolis, Minn. |
| Urban Mass Transportation Administration | Automatic vehicle identification* | New York, N.Y. |

*Field test stage.

prior analysis, the first round provided an empirical basis for developing a conceptual framework for the study. The second round generated hypotheses and tentative conclusions about demonstrations that were tested and refined in the third round. These 24 projects constitute a substantial fraction of all federally funded demonstrations meeting the criteria for the study and for which adequate case histories could be drawn (*10*).

## Demonstration Project Goals and Outcomes

Government agencies generally support demonstrations with the intent of speeding diffusion. The principal "target audiences" are the potential adopters of the technology, or the government agencies that may mandate adoption through regulation. The Environmental Protection Agency (EPA), for example, conducts demonstrations of new pollution control technologies to determine the advisability of setting new regulatory standards. Occasionally, a demonstration project also supports a high-level national policy goal, as did the construction of the nuclear ship *Savannah* as part of President Eisenhower's Atoms for Peace program. However, the *Savannah* demonstration was also intended as a step toward commercial adoption of nuclear merchant ships by the U.S. shipping industry.

Demonstrations have other specific objectives in support of their primary goal. First, and usually most important, is the production of new information to aid decision-making by potential adopters and other target audiences. All of the demonstrations in our sample sought to generate new information. We characterize information production as directed to reducing five kinds of uncertainty:

*Technological uncertainty*. This is uncertainty about the feasibility of a technology for a particular use.

*Cost uncertainty*. Such uncertainty concerns the monetary costs of manufacturing a product or of operating a process using the technology.

*Demand uncertainty*. There may be uncertainty about the benefits (private or public) that will accrue from use of the technology.

*Institutional uncertainty*. This covers uncertainty about how adoption will affect the functioning and structure of the adopting organization, and its relationships with other organizations, such as labor unions or competitors.

*Uncertainty about externalities*. There may be uncertainty about the health, safety, environmental, and other effects of the technology that are unaccounted for in prices.

Uncertainties usually materialize as concrete problems during project planning and implementation. High technological uncertainty must be reduced before the demonstration can even begin operations. Demand uncertainty is important in projects demonstrating a new product or service, as in the Dial-A-Ride demonstration of a public transit service falling between a fixed-route bus system and taxicabs. Institutional uncertainty can become an issue, as it did when crewmen went on strike in the *Savannah* demonstration. Uncertainty about externalities can become a problem when, for example, the demonstration plant starts causing pollution, as in the case of the fish protein concentrate plant. Uncertainties are reduced largely through solving such problems.

Figure 1 illustrates the information production process. Demonstration planning and operations are affected by the extent and nature of the uncertainties associated with real-world use of the technology, by the extent to which target audiences (the intended recipients of the information) participate in the demonstration, and by the political environment surrounding the project. Political supports and constraints are obviously important to the outcomes of any government-sponsored project.

The second objective of demonstrations is to disseminate already-existing information about the innovation. Potential adopters are more likely to make a positive adoption decision after seeing an operating system than by reading a technical report or hearing about it at a conference. The Maritime Administration's shipbuilding program, which demonstrated a number of off-the-shelf techniques, seems the best example among our projects of an exemplary demonstration.

A third objective may be to encourage the institutional and organizational changes that would facilitate adoption of a new technology. This goal is rare among the demonstrations we have studied. Operation Breakthrough seems the best example; it explicitly sought to bring about changes in building codes and labor union practices that hinder adoption of industrialized housing technologies.

Demonstration outcomes, then, reflect these objectives, and we can measure the outcomes by (i) information success, (ii) application success, and (iii) diffusion success. To be an information success, all uncertainties must be reduced to a point where potential adopters can make an informed decision on whether or not to adopt the technology. We emphasize that a demonstration can be an information success if it shows that a technology is not currently economic and should not be adopted. For regulation-oriented demonstrations, information success occurs when the relevant agencies can make informed regulatory decisions. For example, the Refan demonstration generated information on the technical performance and cost of noise-reducing jet engine modifications, so that the Federal Aviation Administration (FAA) could decide whether to set new noise standards for commercial aircraft.

A demonstration is an application success to the extent that the technology works well in the local setting. Such success is important for all demonstrations, but particularly for those with strong exemplary aspects that are intended to broadcast information about a proven technology. Information and application success are largely independent measures, and one can be achieved without the other.

Diffusion success is defined as the extent to which the technology passes into general use as a result of the demonstration project. Diffusion success is not applicable to demonstrations aimed solely at meeting "high policy" goals, nor to regulation-oriented projects in which decisions about the technology's use are made largely by a regulatory agency and not by potential adopters. But for all market-oriented demonstrations that show relative economic advantage, diffusion can be considered the "payoff" measure of success.

Diffusion is not the same as technology transfer. The latter occurs when a technology used in one application is picked up for a substantially different use. For example, many safety and control system features of the *Savannah*'s nuclear reactor were subsequently transferred to civilian land-based power reactors. Transfer generally involves only some features or components of a system. Diffusion occurs when the technology is adopted beyond the demonstration project for the same basic use. We attribute "significant" diffusion to a demonstration when adoption proceeds without further government intervention; that is, when the diffusion process is self-sustaining. There is a mid-range of "some" diffusion when the technology is adopted in a few cases, but diffusion does not appear to be self-sustaining without additional government support. And, of course, some demonstrations lead to little or no diffusion (*11*).

## Relationships Among Outcomes

Not surprisingly, the seven of our 24 demonstrations that showed significant diffusion success also were information and application successes: the Yankee nuclear power reactor in Rowe, Massachusetts; the Refuse Firing Demonstration (solid-waste-to-fuel conversion plant) in St. Louis, Missouri; shipbuilding innovations demonstrated in several U.S. shipyards; poultry waste processing techniques demonstrated in a plant near Durham, North Carolina; a water desalination demonstration plant built at Pt. Loma, California; expressway surveillance and metered ramp controls demonstrated in Chicago, Illinois; and hydraulic knee prosthetic devices demonstrated in several Veterans Administration clinical facilities.

In each case, the demonstration worked well at the site (application success) and reduced uncertainty to low levels in the five dimensions of technology, cost, demand, institutional impact, and externalities (information success). As a result, potential adopters and regulatory agencies could make well-informed decisions about adoption, and application success added credibility to the information that the demonstration generated. In contrast, little or no diffusion took place in cases where application success was low or where major uncertainties persisted.

As one example, the Refuse Firing Demonstration—the conversion of trash to fuel as a substitute for coal in utility boilers—appeared on paper as an attractive possibility. But adopters still faced uncertainties about the cost of processing trash, and the potential problems of clogged boiler firing mechanisms, excessive ash, and air pollution. The St. Louis demonstration reduced these uncertainties by showing that the conversion process is cost-advantageous and does not have prohibitive environmental effects. It also worked well in its local setting. Because of the mounting problem of solid-waste disposal, and the strong demand for boiler fuel, the St. Louis experience has led to adoption by other cities.

Neither information success nor application success guarantees diffusion success, however. Information can lead to a decision not to adopt—if, for example, the innovation does not appear cost-advantageous over alternatives. Or the demonstration may show a relative cost advantage, but formidable institutional barriers to adoption may remain, such as labor union resistance. Or the demonstration can be an application success, but at a site so specialized that the results are not generalizable. Apparently, then, both information success and application success are necessary but not sufficient conditions for diffusion success.

## Technological Uncertainty and Diffusion Success

Demonstrated innovations that are adopted for commercial use are, of course, those that show relative economic advantage. Our analysis indicates that a demonstration's ability to determine whether such economic advantage exists depends on having the technology "well in hand," that is, developed to a point where potential users are confident that it will perform reliably. This then enables the demonstration to reduce other uncertainties.

Figure 2 shows the relationship between technological uncertainty before the demonstration and diffusion success (*12*). We define technological uncertainty as high when the technology has not previously been field tested, or basic problems with the technology are known to exist and techniques for dealing with them are not clear at the time the demonstration starts (*13*). For example, the fish protein concentrate project involved scaling up from batch processing in the laboratory to a continuous process at near-commercial scale, without a pilot plant. The personal rapid transit system demonstrated in Morgantown, West Virginia, included a vehicle design not previously field tested.

Uncertainty is defined as medium when the technology has been tried at lower scale, but it is still uncertain whether it will work reliably in a scale-up to a commercial or near-commercial level. Or, in cases that involve a reconfiguration of off-the-shelf components, uncertainties may arise that cannot be resolved through design studies but require a test under day-in, day-out operating conditions. In the Refuse Firing Demonstration, for example, the components of the system had been used at similar scale, but never in the use to which they were put in the demonstration. In the Yankee reactor demonstration, the pressurized water reactor technology had been piloted in the earlier Shippingport reactor, but substantial scale-up questions remained.

Uncertainty is low when the technology involves essentially off-the-shelf hardware, but perhaps in a configuration different from that used previously. Design studies can resolve uncertainties in such cases. An example is the mechanized refuse collection demonstration in Scottsdale, Arizona (affectionately dubbed "Godzilla" by the participants because of the size and shape of the modified vehicle). All the hardware com-

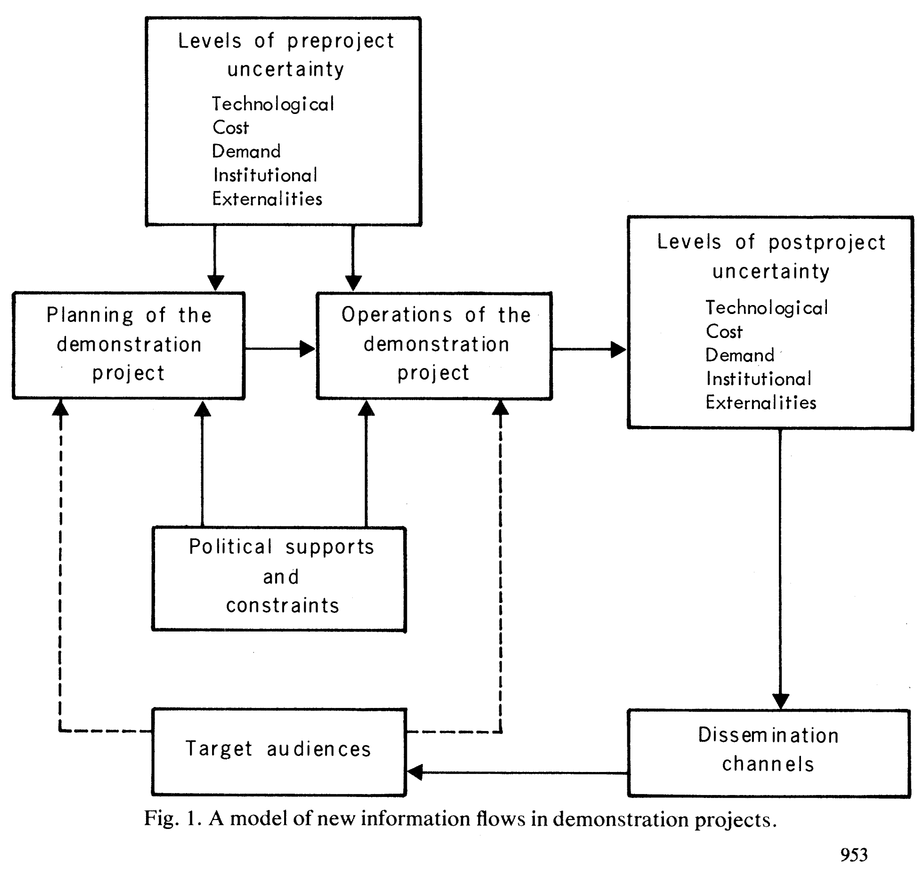


Fig. 1. A model of new information flows in demonstration projects.

ponents had been used before and there was little doubt that the new configuration would operate well.

The association between diffusion success and low or medium technological uncertainty is not surprising. The value of a demonstration project in generating information useful to potential adopters depends on its operating reliably in a real-world environment. If the technology is not well in hand, there will be frequent breakdowns, delays, and frustrations. The four projects in the upper left cell of Fig. 2 [Dial-A-Ride (computer dispatched), personal rapid transit, fish protein concentrate, and *Savannah*] encountered such difficulties. They were so engrossed with technical problems that they could not successfully address other dimensions of uncertainty.

Figure 2 also illustrates that low or medium technological uncertainty by no means guarantees diffusion success. Other factors may deter adoption. The houses constructed in Operation Breakthrough, for example, showed little cost advantage over conventionally built houses, partly because the housing market is characterized by unstable, fragmented demand that generally makes such large-scale construction efforts uneconomic. Breakthrough could not address the demand-related policies necessary to change these market conditions and thereby insulate the residential construction industry from changes in credit conditions elsewhere in the economy. Also, barriers remain as a consequence of continued unacceptability of performance standards to some mortgage lenders, and the persistence of restrictive building codes and labor union rules. Without showing large cost advantages, it is doubtful that any demonstration could overcome these institutional barriers.

The teleprocessing of Medicaid claims demonstration failed to diffuse largely because the Medicaid insurance carrier (the primary potential user) concluded that the technology showed no cost advantage over another system the carrier was already planning to use. The desalination demonstration in Freeport, Texas, resulted in little diffusion primarily because potential adopters wrongly perceived the technology as unreliable. During the demonstration, experiments aimed at process improvements were conducted. The experiments required equipment modification and frequent shutdowns. This conveyed incorrect signals to the plant's users and it contributed to both application and diffusion failure.

| Preproject technological uncertainty | Diffusion success: Little or none | Some | Significant |
|---|---|---|---|
| High | Dial-A-Ride (computer)<br>Personal rapid transit<br>Fish protein concentrate<br>*Savannah* | | |
| Medium | Desalination (Freeport) | Dial-A-Ride (manual)<br>Electrocardiogram<br>Maritime satellite<br>Resource recovery from refuse | Yankee nuclear reactor<br>Refuse Firing Demonstration<br>Desalination (Pt. Loma) |
| Low | Medicaid claims<br>Breakthrough<br>Bus-on-metered-freeway | Connecticut Yankee<br>Godzilla | Poultry waste processing<br>Shipbuilding RD & D<br>Chicago expressway<br>Hydraulic knee |

Fig. 2. Technological uncertainty and diffusion success.

| Share of federal funding | Diffusion success: Little or none | Some | Significant |
|---|---|---|---|
| Less than 50% | Breakthrough | Connecticut Yankee<br>Electrocardiogram | Yankee nuclear reactor |
| 50% to 90% | Bus-on-metered-freeway<br>Desalination (Freeport) | Resource recovery from refuse<br>Godzilla | Refuse Firing Demonstration<br>Poultry waste processing<br>Shipbuilding RD & D<br>Chicago expressway<br>Desalination (Pt. Loma) |
| 90% or more | Fish protein concentrate*<br>*Savannah**<br>Personal rapid transit<br>Medicaid claims*<br>Dial-A-Ride (computer) | Maritime satellite<br>Dial-A-Ride (manual) | Hydraulic knee |

Fig. 3. Nonfederal cost-sharing and diffusion success. The projects marked with an asterisk received 100 percent federal funding.

## Cost- and Risk-Sharing with Nonfederal Participants

Figure 3 shows the relation between diffusion success and the percentage of federal funding in the total cost of the demonstration. All seven projects showing significant diffusion success involved nonfederal cost-sharing; the three funded entirely by the federal government, denoted by asterisks, resulted in little or no diffusion. Moreover, only one of the eight projects showing little or no diffusion success included substantial cost-sharing with private sector firms that had profit incentives to promote use of the technology. That case—Operation Breakthrough—enjoyed little diffusion success for reasons discussed above.

The reasons for the link between cost-sharing and diffusion are readily apparent. The willingness of nonfederal participants to share costs and risks suggests that they judge the prospects for success as good. Their interest helps answer such questions as how one is to ascertain whether the technology is "in hand"; whether the project promises useful information about costs, demand, and externalities; and whether organizational and institutional factors are likely to be important.

Cost-sharing therefore can be a useful filter for demonstration planners and reduce the number of expected failures. One could contend that the government's role should be to undertake potentially high payoff but risky projects that the private sector is unwilling to fund, so that cost-sharing is an inappropriate criterion for project selection. This argument seems more persuasive for research than for demonstration projects, however. As a technology moves from research through the development and demonstration stages, a firm can expect to capture more benefits from its investment and consequently should be more willing to share costs with the government sponsor. The more appropriate government role is to reduce but not eliminate risks to private firms where significant public benefits are expected from the introduction of the new technology. A demonstration thus represents a bridging activity between the public and private sectors.

Cost-sharing, however, is not an infallible predictor of successful diffusion. In particular, it must be distinguished from risk-sharing. Cost-sharing may involve little risk if the nonfederal costs are fixed and the federal government absorbs any overruns, or if local contributions are contingent on project success. In the Morgantown personal rapid transit case, for example, West Virginia University, the county, and the city of Morgantown donated land for rights-of-way as their cost contribution. But the contract between the federal Urban Mass Transportation Administration and West Virginia University stipulated that if the system did not operate satisfactorily, the federal government would dismantle it and restore the land to its original condition.

This discussion of cost- and risk-sharing appears relevant to current policy questions concerning demonstration and commercialization of breeder reactor technology (*14*). Like the earlier commercialization of nuclear light water reactors (LWR's), the government has expected the electric utility industry to purchase breeder reactors after a government-sponsored demonstration program. In the 1950's and 1960's, the AEC made fixed contributions to LWR demonstrations such as Yankee and Connecticut Yankee. Electric utilities—public and private—assumed principal financial responsibility for each project, including responsibility for cost overruns. This relationship was reversed in the breeder reactor program. In the early 1970's, the utilities restricted their commitment to the Clinch River breeder reactor demonstration plant to a fixed sum and were not willing to share the risks of cost overruns. Since the utilities made their decision, the estimated cost of the Clinch River plant rose from about $700 million to more than $2 billion.

The utilities' reluctance to share risks reflected their uncertainties about the viability of the breeder fuel cycle, the economics of commercial breeders, and the resolution of nuclear proliferation, safety, and environmental issues. These uncertainties, particularly those surrounding proliferation and the breeder fuel cycle, would not be resolved by the Clinch River demonstration. Consequently, the utilities' reluctance to assume a greater share of risk for the Clinch River plant and for the Prototype Large Breeder Reactor (PLBR) demonstration proposed by ERDA is a warning signal that the breeder reactor program is not yet ready for commercialization. Specifically, ERDA's 1976 projection that utilities would purchase and have in operation 30,000 to 60,000 megawatts of breeder reactor generating capacity before the year 2000 was unrealistic even if the Clinch River and PLBR plants had proceeded as planned. Based on the past experience with federally supported demonstrations, we suggest that basic uncertainties such as the acceptability and cost of the breeder fuel cycle must be resolved before any realistic schedule for commercialization can be set. By themselves, demonstrations such as the Clinch River plant or the PLBR are not likely to lead directly to private sector adoption of breeder technology. Reflecting these concerns, especially those relating to proliferation and the breeder fuel cycle, the Carter Administration has stopped work on the Clinch River demonstration, leaving the future of the breeder program in doubt.

## Other Project Attributes Associated with Diffusion Success

Besides having a technology well in hand and cost-sharing with nonfederal participants, projects successful in diffusion tend to have the following attributes:

*Project initiative from nonfederal sources.* Demonstration projects originating with private firms or local public agencies enjoyed greater diffusion success than did those directly promoted by the federal government. Of course, federal officials often "seed" an idea for a demonstration locally after the federal agency has developed it. But unsolicited proposals, or local projects suggested in response to a broadly stated request for proposals, appear to have better diffusion prospects than do demonstrations whose approach and technology are specified at the federal level. Although this finding may seem obvious or tautological, because a local initiative presumably reflects a perceived need, two-thirds of the demonstrations we examined were initiated by federal agencies.

*The existence of a strong industrial system for commercialization.* Diffusion proceeded more rapidly when there were obvious manufacturers and purchasers of the new technology, and when markets for similar products existed. In the successful demonstration of metered ramps for expressways, for example, the new system could readily be manufactured and sold by existing suppliers to their current customers. In contrast, a wholly new market for fish protein concentrate had to be created if the demonstration was to lead to commercialization. No diffusion has resulted from that demonstration.

*Inclusion of all elements needed for commercialization.* Demonstrations showing significant diffusion success included potential manufacturers, potential purchasers, regulators, and other target audiences in project planning and operations. Demonstrations that did not were less successful. Godzilla, for example, was shown to be cost-advantageous, and the demonstration was a striking application success. However, the city of Scottsdale, Arizona, assembled the system without including a vehicle manufacturer or supplier of trash collection equipment. Such suppliers have been slow to pick up the innovation, and Scottsdale has no incentive to market it elsewhere. As a result, diffusion seems to be proceeding more slowly than it might have if a commercial supplier had participated in the demonstration.

*Absence of tight time constraints.* Demonstrations facing externally imposed time constraints fared less well than others. Political pressure from Congress or the White House imposed severe constraints in several of our cases, including the nuclear ship *Savannah*, the fish protein concentrate plant, the Morgantown personal rapid transit system, and Operation Breakthrough. Time constraints generally reduced the information produced by the demonstrations and hampered their diffusion success.

## Some General Observations About Demonstrations

Although we cannot establish causal relationships from our analysis, each of the above attributes was associated with demonstration success in the projects we examined. Together, they reinforce the greater importance of the market's "pull" over the technology's "push" as the principal factor determining diffusion (*15*). Like prior studies (*6, 16*), this analysis confirms the danger of promoting a technology without sufficient attention being paid to the markets for its use. A number of past federal demonstration projects have advanced a new product or service in the face of scant evidence of demand. As a result, even when technical feasibility was shown, the demonstration attracted little commercial interest.

To be sure, government may find a technology so socially attractive that it is worth generating a wholly new market for it. Personal rapid transit systems and synthetic fuels may be two current examples. But creating new markets and the supplier industries to serve them will almost certainly require subsidies, new regulations, and other government interventions beyond demonstrations. In the absence of a well-articulated market demand, demonstrations are especially risky; whatever successes are achieved will be accompanied by many failures.

Demonstrations also appear to be ineffective in tackling institutional and organizational barriers to diffusion. Jurisdictional disputes among government agencies, labor union practices, excessive industry concentration or fragmentation, government subsidies, and regulations can block or discourage innovation. Although only three projects in this study—Operation Breakthrough, *Savannah*, and shipbuilding—faced significant institutional and organizational problems, their experience suggests that demonstration projects by themselves rarely break down those barriers. This is well illustrated by the recent abandonment of plans to expand the Refuse Firing Demonstration system in St. Louis because the local governments could not agree on suitable sites. In situations where institutional problems arise, other interventions such as changes in regulations or subsidies seem more effective stimulants to diffusion than demonstrations.

The Maritime Administration's shipbuilding RD & D program is a positive illustration of how to deal with institutional problems. Facing an industry with low incentives to innovate, the shipbuilding program has sought to restructure industry RD & D by forming a consortium of shipbuilding firms to propose and help manage innovative projects. Demonstrations figure to an important extent, but are only a means to the program's principal end of promoting change in the industry's RD & D patterns.

Our results suggest that large demonstration projects with heavy federal funding tend to do poorly in terms of information, application, and diffusion success. The federal investment in Operation Breakthrough (over \$70 million), personal rapid transit (over \$60 million), and *Savannah* (over \$100 million) made these projects highly visible and vulnerable to political pressures. The pressures tended to impose unrealistic goals in view of what could be expected with the time, money, and technology at hand; and to subject the project to the vagaries of changes in administration, federal agency staff, and budget priorities. In general, the most damaging result of political pressure is the push to demonstrate before the technology is well enough developed.

Dissemination of information from demonstration projects has generally not been a serious problem. Information channels from the project to potential adopters operate well. One might conjecture that some projects contain good ideas that somehow do not get into the hands of potential adopters because of inadequate information dissemination links. In our sample, however, this seems not to be true. The projects that failed to achieve diffusion success did so not because of weaknesses in the information network but for the other reasons discussed above. Of course, dissemination of information is important, but past experience suggests that if the results are good, diffusion is likely to take place. If the results are poor, diffusion will not take place—and for good reason.

## Conclusions

Our analysis of federally funded demonstration projects suggests several characteristics that are associated with success in speeding commercialization of a new technology. They include a technology well in hand, cost- and risk-sharing with nonfederal participants, project initiative at the local level, a strong industrial system for commercialization, participation in the demonstration by those who will take responsibility for further diffusion, and the absence of tight time constraints. That demonstrations with these attributes achieve greater diffusion success than others is hardly surprising; what is surprising is that so many past demonstrations have not incorporated them in their planning and operation. These associations from previous experience should provide useful guidance in the design and conduct of future demonstration projects.

The analysis also leads us to conclude that demonstrations have a narrow scope for effective use. They are most successful when diffusion would otherwise be hampered by potential adopters' lack of knowledge about the use of the technology under commercial operating conditions. Demonstrations are not cost-effective substitutes for laboratory experiments, field tests, or pilot projects when technological uncertainty is high. They are unlikely to speed commercialization when demand is weak. Nor are they effective in directly tackling institutional barriers to diffusion.

Government support of demonstrations is best justified when identifiable market failures cause the private sector to under-invest in commercializing R & D results that are likely to be socially beneficial. Demonstrating the commercial feasibility of a pollution-reducing technology is a prime example. Other cases occur when a technology appears ultimately profitable, but firms are unwilling to incur the first-of-a-kind costs associated with reducing uncertainties and moving from R & D to the marketplace (*16*).

If uncertainty is high in most or all of the five dimensions discussed above, the prospects for demonstration success are dim. Yet if uncertainty is low, the question is why a federally supported demonstration project is warranted—that is, why the private sector cannot undertake any further development needed. It is for the middle ranges of uncertainty, combined with a strong rationale for government involvement, that federally funded demonstration projects are most appropriate and effective.

### References and Notes

1. We define adoption as the decision by an individual or organization to use the technology to produce the good or service in question. Diffusion is the process of adoption over time within a particular industry or economic sector.
2. G. Iles, *Leading American Inventors* (Holt, New York, 1912).
3. R. Evanson and Y. Kislev, *Agricultural Research and Productivity* (Yale Univ. Press, New Haven, Conn., 1975); Y. Hayami and D. Ruttan, *Agricultural Development: An International Perspective* (Johns Hopkins Press, Baltimore, 1973).
4. G. W. Hilton, *Federal Transit Subsidies* (American Enterprise Institute for Public Policy Research, Washington, D.C., 1974).
5. Solar heating of buildings represents another example of a federal demonstration program undertaken in part to ameliorate a government-induced market distortion—in this case the regula-

tion of natural gas prices at artificially low levels that makes solar heating less attractive. The government agencies authorized to promote solar heating technologies—ERDA and HUD—have no authority over natural gas regulation.
6. R. Gilpin, *Technology, Economic Growth, and International Competitiveness*, prepared for the Subcommittee on Economic Growth of the Joint Economic Committee, Congress of the United States (Government Printing Office, Washington, D.C., 1975); G. Eads, *Res. Policy* **3**, 2 (1974); ______ and R. Nelson, *Publ. Policy* **19**, 405 (1971).
7. See, for example, P. Berman and M. W. McLaughlin, *Federal Programs Supporting Educational Change*, vol. 1, *A Model of Educational Change* (The Rand Corporation, R-1589/1-HEW, Santa Monica, Calif., 1974).
8. Office of Management and Budget, *Special Analyses: Budget of the United States Government: Fiscal Year 1977* (Government Printing Office, Washington, D.C., 1976), p. 277.
9. Energy Research and Development Administration, *A National Plan for Energy Research, Development and Demonstration: Creating Energy Choices for the Future, 1976* (Government Printing Office, ERDA 76-1, Washington, D.C., 1976), vol. 2; Congressional Budget Office, *Energy Research: Alternative Strategies for Development of New Energy Technologies and Their Implications for the Federal Budget* (Background Paper No. 10, Washington, D.C., 15 July 1976).
10. Twenty-four observations clearly do not allow us to test for the statistical significance of our results. We chose to conduct in-depth case studies rather than analyze a larger sample randomly drawn from the 41 agency programs for three principal reasons. First, the lack of previous analysis provided little guidance for choosing a priori the critical variables for investigation. In-depth studies were necessary to construct a conceptual framework for the subsequent analysis of other cases. Second, a few agency programs, such as the Environmental Protection Agency's programs for air and water pollution control, contain large numbers of demonstrations with similar characteristics. A random sample of projects would bias the results toward these particular programs; on the other hand, a sample of programs would not provide enough observations to yield statistically significant results. Finally, the goal of the analysis was not to determine how many federal demonstrations succeed and fail, but to find attributes of demonstrations that are associated with success and failure. We thus selected cases to provide variance in the dependent variables—the measures of success.
The 41 agency programs containing demonstrations are listed in *Analysis of Federally Funded Demonstration Projects: Final Report* (The Rand Corporation, R-1926-DOC, Santa Monica, Calif., 1976) along with descriptions of the 24 projects selected for analysis. See also *Analysis of Federally Funded Demonstration Projects: Supporting Case Studies* (R-1927-DOC, 1976) for the full case studies of the 15 demonstrations analyzed in the first and second rounds (Table 1).
11. Measurement of diffusion success involves two major difficulties. Ideally, diffusion success would measure the difference between the actual rate of diffusion and that which would have occurred without the demonstration. However, existing data on industry adoption rates are too fragmentary to make baseline comparisons. A second problem arises because the projects studied vary greatly in their observable histories. Many demonstration projects were begun in the past 10 years—a time that may be too short to expect significant diffusion results. Consequently, a project we judge today to have resulted in "little or no" diffusion may in tomorrow's hindsight be viewed as a significant milestone. Operation Breakthrough is a possible example of this sort. Our definitions of the levels of diffusion success partly cope with this problem by focusing on the diffusion process rather than simply counting the number of adoptions that have taken place. Consequently, even if the absolute number of adoptions is low, we can still characterize diffusion as "significant" if the process is self-sustaining. In such cases we have made our best judgments about prospects for diffusion, based upon our interviews with potential adopters and others familiar with the demonstration.
12. Figures 2 and 3 include 21 observations from the 24 projects because (i) the Dial-A-Ride demonstration is split into two modes of vehicle dispatching—manual and computer—for purposes of analysis because outcomes differed for the two modes; and (ii) four cases are excluded: the synthetic fuels program, the automatic vehicle identification project, and the REAM gun project, all of which are in the field test or pilot stage rather than in the demonstration stage; and the NASA/FAA Refan project because it is a regulation-oriented demonstration for which diffusion success is an inappropriate measure.
13. The "high," "medium," and "low" rankings of technological uncertainty correspond to other ordinal scales derived for military systems that use such measures as the extent to which the same technology has been successfully used in other applications, the number of components that must be assembled into the new system, and the scale-up required. See, for example, the discussion of "technological advance ratings" by R. L. Perry, G. K. Smith, A. J. Harman, and S. Henrichsen [*System Acquisition Strategies* (The Rand Corporation, R-733-PR/ARPA, Santa Monica, Calif., 1971)].
14. L. L. Johnson, E. W. Merrow, W. S. Baer, A. J. Alexander, *Alternative Institutional Arrangements for Developing and Commercializing Breeder Reactor Technology* (The Rand Corporation, R-2069-NSF, Santa Monica, Calif., 1976).
15. J. M. Utterbach, *Science* **183**, 620 (1974); E. Mansfield, *The Economics of Technological Change* (Norton, New York, 1968); *Industrial Research and Technological Innovation: An Economic Analysis* (Norton, New York, 1968); R. R. Nelson, M. Peck, E. Kalachek, *Technology, Economic Growth, and Public Policy* (Brookings Institution, Washington, D.C., 1967).
16. L. C. Thurow, "The relationship between defense-related and civilian-oriented R & D priorities," a study prepared for the Subcommittee on Priorities and Economy in Government of the Joint Economic Committee and the Library of Congress, Washington, D.C., 23 April 1976.
17. Supported by the Experimental Technology Incentives Program (contract 4-35959), U.S. Department of Commerce. C. Johnston Conover, Cheryl Cook, Patricia Fleischauer, Bruce Goeller, William Hederman, Richard Nelson, Richard Rettig, and John Wirt undertook some of the individual case studies and made other contributions to this study. We thank J. Hosek, J. Lewis, J. Logsdon, and E. Rolph for helpful comments on earlier drafts. Portions of this article were drawn from Rand reports R-1925-DOC and R-1926-DOC.

**NEWS AND COMMENT**

# Charged Debate Erupts over Russian Beam Weapon

The affair of the charged particle beam, the death-ray weapon with which the Soviets will allegedly soon be able to neutralize an American strategic missile attack, has been the sensation of the week in Washington. Congressmen have received secret briefings, the CIA has been moved to issue one of its infrequent statements, and there has even been a presidential assurance that the nation is not in jeopardy.

The immediate cause of the stir is a 7000-word article in the 2 May issue of *Aviation Week* detailing the case for believing that the Soviet Union has made a breakthrough in the field. An accompanying editorial by editor Robert Holtz states that the United States is in danger of "a crippling technological surprise that could render its entire strategic missile force ineffective."

The weaponeers' hope is to generate a beam of charged particles, similar to those used in accelerators but much more powerful, and to use it to inactivate incoming missiles. According to *Aviation Week*, Soviet scientists have learned how to harness nuclear explosions to drive such a beam. Unnamed officials quoted in the article suggest that the weapon "could be in operational form by 1980" and that the Russians are "years ahead in most areas" of particle beam technology.

*Aviation Week* is a copious source of military and intelligence information, so much so that it has earned the sobriquet of *Aviation Leak*. Its statements on the charged particle beam could not be ignored, and the Administration was soon set abuzz with denials that the Soviets had achieved any breakthrough in developing the weapon. Briefed by his science adviser and others, President Carter said that "We do not see any likelihood at all, based on our constant monitoring of the Soviet Union as best we can, that they have any prospective breakthrough in the new weapons systems that would endanger the security of our country."

The CIA announced it did "not believe the Soviet Union has achieved a breakthrough which could lead to a charged particle beam weapon capable of neutralizing ballistic missiles." The agency also denied the assertion in *Aviation Week* that CIA analysts had failed to pass on information about the beam weapon to higher government officials.

Far from being chastened by these high-level denials, *Aviation Week* responded that the President was being "screened from vital technical developments" by the bureaucracy of the CIA and the Defense Intelligence Agency. Carter had been incompletely briefed,