Commercializing Technology --
What Should DoD Learn from DOE?

John Deutch
Department of Chemistry
Massachusetts Institute of Technology
Cambridge, MA 02139

January 1990

This paper has been prepared for
The Carnegie Commission on Science, Technology, and Government

I. INTRODUCTION

The energy crises of the nineteen seventies led to the establishment of the Department of Energy(DOE), which had as a central part of its mission the development and commercialization of energy technologies which would benefit the domestic economy. This mission, both at that time and since, led to a great debate about the federal government's role in private energy markets, about various mechanisms that might be used by the federal government to intervene in energy markets, and about the appropriate criteria the federal government should adopt with regard to the efficiency and equity of its programs. The purpose of this paper is to review the experience of DOE in the 1970's, to learn about the government's role in private markets, and to apply these lessons to the current debate concerning the role of the Department of Defense (DoD) in strengthening the productivity and competitiveness of the the civilian economy.

There are two distinct reasons that make understanding the relationship between DoD and the private economy crucial in the 1990's and beyond. First, there is the realization that there is much greater potential today than a decade or two ago for dual use technology and products. Here "dual use" refers to the advantageous use of civilian technology or products by defense industry to achieve greater efficiency in national security activities. Two decades ago technology developed for defense found successful application in the private sector, while today the military is making progressively greater use of technology developed for commercial purposes.

The second reason for the renewed interest in the relationship of DoD to the commercial sector arises from concern about the adequacy of the defense industrial base in relation to selected capabilities of foreign industries. There is a realization that US national security depends upon critical technology and products which are provided by foreign suppliers, e.g. semiconductor chips; such dependency was not present much before 1980. This dependency is part of the larger concern that the US domestic economy is not performing adequately compared to the past or to foreign competition.

These developments have led to great interest in how DoD might more effectively assist in the improvement in the performance of the civilian economy. It is important to understand that the nature of this assistance will be very different than in the past. During the 1960's and 1970's, the DoD principally influenced the civilian economy through technologies developed for military application which were adopted by the civilian sector. The most prominent examples include microelectronics, computer systems, and jet aircraft and engines.

Today, the major problems of the performance of the US civilian economy and its lagging industrial productivity, both relative to the past and to foreign competition, do not principally involve the development of new technology. Rather they appear to involve the entire spectrum of industry activity in a free market place. These problems include: (1) transferring technology to production, (2) designing, manufacturing and maintaining products of high quality and low cost for a rapidly changing market, (3) achieving a combination of capital, labor, and raw materials with management and technology that meets the foreign competition, in situations where foreign firms may enjoy more favorable government incentives, regulations and taxes. Given these problems, the question of how DoD might effectively intervene in assisting the US civilian industry becomes very different from the past when attention was restricted to the valuable but limited function of creating new technology.

In the following sections, I shall address : (1) the basis for federal government intervention in energy markets, (2) the mechanisms DOE employed to assist in the commercialization of energy technology, (3) the energy development cycle and the problem of deciding where government support is best allocated, and (4) my observations about the lessons learned.

II. THE BASIS FOR FEDERAL GOVERNMENT INTERVENTION IN ENERGY MARKETS.

The energy crisis of 1973 and the second crisis of 1978 led to sharply higher prices of oil and gas as well as serious problems of availability of gasoline and home heating oil for many consumers. Domestic oil and gas prices were regulated so that as world market conditions changed there was the potential for significant shifts among winners and loser in the economy, especially between producers and consumers of energy. This shift is politically significant in the US since producers are located mostly in the southwest while consumers are located mostly in the northeast and Great Lakes region. These developments influenced the attitudes of many citizens and their elected representatives and led to vocal calls for government action.

The price shocks also made apparent the connection between oil supply and national security. Energy issues became central to existing alliances, dividing those nations which which had reasonable access to domestic energy supply (US, UK) from those who had little domestic supply (France, Japan, and FRG).

A climate set by angry citizens and strained allies is not an easy one in which to craft and implement government policies which have sensible economic and technical underpinnings. There is an inevitable tendency to formulate policies on the basis of political considerations. This is surely not all bad, except that the considerations regarded as compelling frequently were short sighted and determined by special interest groups motivated by the opportunities and barriers created by federal price controls.

Nevertheless, there was a laudable and persistent effort by many, both inside and outside of government, throughout the 1973-1980 period which is the focus of this paper, to inquire about the justification for government action both in general and in relation to specific proposals. In brief, four reasons for federal intervention were put forward.

(1) Support for basic research and environmental effects. There was universal agreement that the federal government had a role in supporting basic energy science and technology and energy related environmental research, because of the external benefits of this activity to the economy: For example; DOE mounted major research programs on catalysis, thermochemical and thermophysical data collection, health effects of synthetic fuels, and global warming.

(2) Support because of Energy Security Concerns. The fact that OPEC oil was largely found in the Middle East, a most unstable part of the world, suggested that the US and its allies should be prepared to spend more than the private sector would on its own, in order to minimize the economic costs of a future disruption. For example; DOE created the strategic petroleum reserve.

(3) Support to compensate for market imperfections. The federal government had a responsibility to compensate for the market imperfections which resulted from price controls. In particular, low energy prices relative to the world market implied a lower than optimal level of investment in new energy supply or energy productivity measures. For example; federal subsidies were introduced to encourage the development and production of high cost 'unconventional' gas from coal bed seams, shales (both eastern and western, of course.), and tight sands.

(4) Support to augment the investment decisions of industry. Many believed that industry would make investment decisions which were too short sighted, based on "most likely" outcomes without adequate hedging, and, frequently, simply wrong. This attitude prompted greater interest in government action to create new technology and transfer it to the private sector to compensate for what was judged to be the limitations of private firms left to their own devices. For example; a major federal effort was undertaken to create a photovoltaic industry which it was believed the private sector would not pursue on its own.

The justification for federal involvement is reinforced when there is a joint benefit for both the government and commercial sector from some industry's activity. For example both the government and the private sector benefit from DOE's programs in isotope enrichment, reprocessing and waste management technology. The argument of joint benefit is also important in the case of DoD programs which would support industries that employed dual use technologies.

Of these four reasons for government intervention, the most problematic is the last one -- the notion that the private sector would make investment decisions that were not in the long term interests of the economy because the level of investment was too low or misdirected to near term opportunities. The underlying assumption is that the federal government is in a better position to estimate the future course of energy markets with respect to relative prices as well as supply and demand, and that the government is better able to implement development or investment programs and projects than the private sector. This is frightening national industrial policy in an almost pure form.

The Carter Administration energy policy implicitly accepted this assumption, and federal R&D and Demonstration expenditures rose dramatically for coal, nuclear, conservation and renewable energy technology. But the assumption was as firmly rejected in the Reagan administration, when any involvement in energy technology beyond basic and applied research was terminated and no effort was willingly undertaken other than deregulating energy markets.

The welcome collapse of energy prices in the 1980's which accompanied the moderation in the growth of energy demand is taken by many as evidence of the wisdom of a laissez faire policy. Others note that the subsequent steady increase in US reliance on imported oil has simply set the stage for another energy crisis, when there again would be a shrill call for a return to an aggressive energy development policy.

There is no decisive answer to the question of when and how much government involvement in the private sector is justified. However, one must acknowledge that the political system has an unfortunate tendency to favor significant involvement in times of public crisis. Accordingly, there is good reason for skepticism about the assumption that the government is more accurate than the private sector at projecting the future or better at implementing programs designed for a particular economic outcome.

There is some important similarity between the circumstances of the debate about the government role in energy in the seventies and the present debate about the role of DoD in stimulating domestic productivity. In particular, both situations are based on the perception that the long term national interest will not be served adequately by action of the private sector. There is also the common assumption that the federal government knows what to do and that it can do it well. In short, to pursue such a policy of government intervention, one must believe that the federal government is able to pick intelligently winners and losers.

III. MECHANISMS FOR GOVERNMENT INTERVENTION IN ENERGY MARKETS

DOE and its predecessor agencies the Energy Research and Development Administration (ERDA) and the Federal Energy Administration (FEA) recognized that they would be centrally concerned with activities which were largely in the private sector. In contrast to the more traditional areas of defense and space, the technology developed by these agencies was destined for private markets and therefore technology transfer from government to industry was of major importance.

During the seventies, two types of mechanisms were adopted to assist in this technology transfer. First, there are direct incentives which involves the federal government in the management and technical direction of projects which receive either full or partial federal support. The traditional federal R&D programs are all examples of direct government incentive mechanisms. Thus DOE programs in basic energy sciences, energy technology development programs in universities, the national laboratories, and industry, all fall into this category of direct government incentives. It is almost exclusively the mechanism employed by the DoD in fulfilling its RDT&E function (although IR&D is a notable exception). The use of the direct incentive mechanism by DOE will be discussed further in the next section.

Second, there are indirect incentives, which provide opportunity and reward for industry activity, without direct government financial or technical participation. A list of the major indirect incentives employed during the Carter Administration follows, with an example of how the incentive was proposed or implemented.

1. Regulatory incentives - Regulations were adopted that either required or provided benefits for private companies to pursue development or commercialization of an energy technology which was judged to be of benefit to the country and that would otherwise not be pursued by industry.

An important example is the regulatory measure which encouraged the domestic oil industry to undertake tertiary oil recovery projects. Oil companies which undertook tertiary oil recovery projects and documented the results (so that the benefits would be available to others) were permitted to exclude the oil produced from the entitlements program and thus effectively receive a price higher than the regulated price for their crude. This program was highly successful and, to this day, provides the best information available on the technology, cost, and environmental effects of tertiary recovery. This mechanism was effective because the oil industry had the technical competence to pursue tertiary recovery. The industry would not pursue tertiary recovery technology without the government incentive because of the perceived technical risk and financial unattractiveness compared to conventional exploration and production activity. This program ceased once oil became fully decontrolled.

A second case concerns the adoption of mandatory Building Energy Performance Standards (BEPS). This controversial conservation program required commercial builders to construct to a specified standard of energy efficiency in a new building depending upon building use, fuel type and many other considerations. The purpose of BEPS was to stimulate improvements in energy conservation technology in building construction beyond what could be expected to happen in response to market price. Advocates argued that private decisions about the relative discounted cost of capital expenditures directed to conservation relative to fuel use would inevitably result in too little conservation and too slow a rate of advance in conservation technology.

There was considerable debate about the justification for the BEPS program once oil and gas prices were decontrolled. The program failed because of the complexity of application of the BEPS standards, and the requirements have been repealed. The BEPS program, while noble in purpose, provides an excellent an example of the dangers of too specific regulation of private market activity by the government. A similar example which, while more successful, remains controversial, is the adoption of automobile fuel economy (CAFE) standards instead of imposition of some "gas guzzler" tax.

2. <u>Taxes and Tax Credits</u> - The DOE frequently employed tax measures as a means of encouraging the adoption of new technology for both energy conservation and supply. Attractive tax benefits were introduced to encourage cogeneration and alternative renewable energy sources such as photovoltaics and wind.

A particularly interesting example is the gasohol tax credit which provided an exemption from federal and, in many cases, state taxes on gasoline which included 10% or more ethanol derived from agricultural products. The purpose of this tax was to encourage biomass as a source of liquid fuels to displace petroleum transportation fuels. The problem with this tax credit was that existing technology required more high quality fossil fuels (natural gas and diesel oil) to produce the corn and distill the ethanol than gasoline displaced in the gasohol. Even taking into account complicated byproduct credits, there was no rational basis on energy, much less economic grounds, for the tax credit. The tax credit made an inefficient energy investment financially attractive and provided no incentive to introduce new fermentation and distillation technologies which relied on coal or non-fossil fuels for energy.

The entire basis for this highly popular tax credit was political. Approximately ten agricultural states with key 1980 senatorial elections strongly favored gasohol and the tax credit was adopted although it was not advocated by any serious energy expert. [It is interesting to note that the Democrats lost every one of these states in the 1980 election]. The gasohol program remains one of the great examples of the danger of federal involvement in energy markets.

Tax credit programs are politically difficult to adopt. They are, of course, universally opposed by the Treasury Department and OMB because of the loss of revenue. And the tax committees in the House and Senate are different than the authorizing committees for the executive department advocating the credit. The DOE was successful in gaining approval for tax credits in large measure because the chairman of the Senate Finance Committee, Russell Long, came from an important oil producing state and was willing to trade tax benefits for other provisions which were of benefit to the oil and gas industry. It is highly uncertain that DoD could easily develop the political relationships required to make tax credits a realistic mechanism for any of its activities.

3. Guaranteed Purchases and Loan Guarantees - Loan guarantees and guaranteed purchases were particularly attractive mechanisms for the DOE to encourage large projects in the later stages of development, as these mechanisms were essentially off budget and did not directly affect the deficit.

Guaranteed purchases at specified prices was advocated when it was believed that providing a guaranteed market for a volume of product would be sufficient to make a particular energy technology economic. For example, it was proposed that the government buy a sufficient amount of photovoltaic arrays for federal use (including, amusingly, for remote power for MX shelters) to drive costs down the learning curve to a point where an energy technology was economically competitive.

Similar proposals have been advanced recently to have the DoD buy sufficient semiconductor memories or other microelectronic devices to make US industry competitive. And, it can be argued that our present favorable position in commercial jet aircraft and engines is due to past effective use of this mechanism. While sound in principle, success in any particular case is problematical. Depending on market timing, the mechanism of guaranteed purchase can be an important way of gaining market dominance or of making a costly and inefficient subsidy.

The best example of the use by DOE of loan guarantees is the synthetic fuels program established in the Energy Security Act of 1980. The synthetic fuels program was based on the conviction that private industry would not undertake large scale synthetic fuels projects because of the uncertainty about future oil prices and the technical and environmental risks associated with the synfuels technology. The federal government believed the nation would be in a better position to respond with synfuels production should higher prices prevail in the future, if some key commercial scale projects were undertaken to demonstrate the technology, verify the costs and the procedures required for environmental permitting.

The DOE proposed and Congress approved the establishment of a quasi-independent corporation to extend loan and price guarantees for selected synthetic fuels projects, including, liquid fuels from shale and coal and high and medium BTU gas from coal. Each billion dollar plus project was financed on the basis of the federal guarantees. Evidently, the synthetic fuels program was an insurance program. If future oil prices increased according to the government projections, the revenue generated by the synfuels projects would cover the investment and operating cost and the price and loan guarantees would become irrelevant. If prices fell, as turned out to be the case, the federal government would be left with a very big bill, but that is in the nature of insurance of this kind. To argue that the synthetic fuels program was a failure is a bit like arguing that a life insurance policy has been a failure when the insured person has lived beyond normal life expectancy. The synthetic fuels program was certainly not successful in narrow financial terms but it did meet the goal of demonstrating that a few key synthetic fuel plants could be operated in an environmentally acceptable manner and within anticipated cost and technical specifications.

Such mechanisms as were available to DOE to encourage the commercialization of energy technologies and to influence the investment decisions of the private energy sector might be considered for DoD in its effort to strengthen US industry, especially in those sectors which involve dual use technology. But it is important to observe that the broad array of mechanisms employed by DOE is relatively unfamiliar to the DoD. The DoD depends almost entirely on the mechanism of direct incentive: federal support and technical direction of projects which create and transfer technology. On the one hand, serious efforts by the federal government to commercialize technology should have this array of mechanisms available to support commercialization efforts. On the other hand, extending DoD authority to employ such mechanisms is somewhat problematic since the agency has no experience in their use.

IV. DOE'S MANAGEMENT OF RESEARCH, DEVELOPMENT AND DEMONSTRATION PROJECTS

In this section a brief description is given of how DOE managed programs which relied on direct federal incentives. These are the research, development and demonstration programs which the DOE undertook to create new energy technologies and to transfer these technologies to the private sector. It is this direct federal involvement in the sponsorship and direction of technology creation and transfer that most people have in mind when they envision a broader role for DoD in encouraging commercial technology.

The underlying model of commercialization adopted by the DOE is the conventional linear model in which technology innovation proceeds smoothly from idea creation in a first stage of basic research (6.1, in DoD parlance), to applied research and exploratory development where these ideas are tested in the laboratory (6.2), to the more expensive stage of advanced and engineering/ systems development (6.3 and 6.4). While this model has serious shortcomings when compared to reality, it is not a bad basis on which to manage federal R&D programs.

In practice, DOE saw the commercialization process as consisting of three stages: (1) basic and applied research, (2) technology development and, (3) technology demonstration. As noted, this separation is not particularly novel. What is novel is that the DOE took the mission of commercialization so seriously that it initially organized the Department on the basis of the model. Thus, there was an assistant secretary responsible for each of the three stages of the commercialization process. The idea was to emphasize the process of technology commercialization rather than simply the creation of technology. [Alternatively, a more conventional organization which emphasized technology would be organized by fuel type -- nuclear, fossil, renewables.] Each Assistant Secretary was concerned with making choices among competing projects in the same stage of evolution with the objective of transfer to the next stage of development, rather than among projects of a particular fuel technology. The idea is as radical as if the DoD were organized by mission in contrast to service.

In fact, the initial organizational scheme for the DOE proved unworkable and when Charles Duncan replaced James Schlesinger as Secretary of Energy, the Department adopted the more conventional structure based on fuel type. The conceptually sound organizational structure which stressed commercialization failed because Congress was most strongly influenced by industry organizations that were largely based on fuel type. Thus an interesting question to pose to those who advocate that DARPA should be given a broader role in commercializing technology is: "How should this change the organizational structure of DARPA"?

The DOE understood very well some general characteristics of the commercialization process:

-- Projects become larger, more costly and more difficult to manage in the later stages of development;

-- Industry involvement is essential for commercialization, especially in the demonstration phase;

-- Project selection should be determined by economic and technical analysis not technology fascination or special interest.

An appropriate response flows from each of these characteristics of the commercialization process. Large demonstration projects should be managed by industry, not the federal government. These projects should be supported preferably through the indirect incentive mechanisms discussed in the previous section.

Industry involvement is important to encourage at the technology development stage and should be required at the technology demonstration stage. There are many mechanisms available to achieve industry involvement in technology development such as direct government R&D grants and cooperative agreements between government, industry, national laboratories and universities. However, there are important difficulties to overcome. For example, cost and risk sharing become an issue of balancing the need to provide an incentive for industry involvement and the desire to avoid unnecessary subsidies. Rules about intellectual property constitute a serious barrier to cooperation between industry and DOE reflecting the tension between the positive incentive of granting exclusive rights and the federal interest in maintaining some control over inventions it had supported. Finally, transfer of technology from the highly competent and large DOE national laboratory system proved more difficult than expected.

But all problems of effective federal management fade in comparison to the problem of deciding upon the allocation of resources to alternative technologies and projects. Too often at DOE the choice among alternative projects was not made based on analysis of economic, technical and environmental factors, but in response to congressional demands which reflected constituent interests. Thus senators from Montana supported magnetohydrodynamics (MHD) through thick and thin, senators from Hawaii preferred Ocean Thermal Energy Conversion (OTEC) technology. The Clinch River Breeder Reactor demonstration project was managed and paid for by the federal government long after all serious analysis indicated it should be terminated.

The situation with respect to small scale demonstration projects was equally illogical: Twenty six photovoltaic demonstration project were funded where ten would have been ample; fifty fuel cell demonstration projects (one per state) were funded; there were too many large windmill projects; each automobile manufacturer was given a contract to develop a gas turbine engine, there were two solvent refined coal projects, each costing over a billion dollars. The list of programs and projects which were undertaken for political reasons is impressive; this should serve as a warning to those who advocate DoD becoming more involved in commercializing dual use technology.

Congress also gave conflicting messages about priorities for energy commercialization. The popular technique was to vote for ambitious authorization bills which would please particular constituents with the knowledge that there was no chance of money being appropriated for the ostensibly noble purpose. Thus there were bills for wind, photovoltaics, OTEC, fusion, gasohol, hydroelectric which set goals that were not consistent with technical or economic reality, adopted erroneous criteria for success, imagined a competence in the federal government for achieving program goals which was totally unrealistic. Once energy became an important public issue and it appeared that money would be spent in large quantities on commercializing energy technology, the political system gave faulty and changing strategic direction and influenced program and project choices which frequently did not reflect the best economic and technical judgment.

It would be wrong to conclude that all the poor choices at DOE were the result of political intervention. Many poor choices were the result of inadequate technical direction, principally when the commitment to a technology or a project went beyond the point that a prudent manager would go. For example, the DOE supported battery programs because the technology was important, but the support went on for years in the same way even though there was essentially no interesting technical output. And the DOE continued the Barstow central solar power tower with little technical justification.

It would also be wrong to conclude that there were no examples of success in DOE's efforts to commercialize energy technology. Successes include: (1) the light water reactor improvement program, (2) the passive solar and solar hot water heating programs, (3) the atmospheric fluidized bed and coal-water slurry coal combustion programs, and (4) the electric energy system power management program. The characteristics of the successful programs are easily identified: competent technical management at DOE, intelligent program planning with a market orientation which included attention to technical, economic and environmental considerations, stable and adequate funding support, and involvement of technically capable industrial partners.

The successful DOE commercialization programs were supported by multiyear plans that addressed in a credible manner the economic, technical and environmental goals for the technology and how these goals might best be achieved. The plans also addressed key management issues, for example, the mix of performers of the R&D, important uncertainties, and the cost and performance schedule for various projects. Criteria were also set for the evaluation of program success and failure. The integrity of this planning process was difficult to maintain for two reasons: bureaucratic advocates resisted scrutiny of their programs which could slow program growth and external interested parties rejected efforts at tradeoffs between "their" technology and its competitors. But there was a strong correlation between programs which managed to produce credible plans and the success of the commercialization effort.

V. LESSONS FOR DoD FROM THE DOE EXPERIENCE

The preceding discussion describes the serious conceptual and practical difficulties DOE encountered in pursuing its mission to commercialize energy technologies. However, the purpose of the discussion is not to argue that the federal government has no business pursuing this or other commercialization strategies. I believe it had and it does. Rather, my purpose is to draw constructive lessons for those who currently argue for a more aggressive DoD role in commercialization of dual use technologies.

Advocates for an expanded DoD role are responding to an important national need: many US high technology industries, including several which are critical to the DoD mission, are not performing adequately in comparison to the past and to foreign competition. It is entirely appropriate to consider what DoD can and should do to help. The implications of the DOE experience for deciding what DoD should do are important at two levels: understanding the appropriate limits for DoD involvement and appreciating the practical problems which DoD is likely to confront.

The basis for a DoD role in commercialization is that DoD is becoming progressively more dependent on dual use technology i.e. technologies which have a significant end-use in both the military and commercial sector. In these dual use technologies DoD is both a significant force in the market and an important creator of technology. Examples of industries which meet these criteria are microelectronics and computers; examples of industries which do not meet the criteria are textiles, automobiles, and petrochemicals. And there are borderline cases; for example, telecommunications and high performance materials. But the main point is that the federal government is not always better than the private sector at projecting the future or at the efficient allocation of resources in a commercialization program. So when DoD proceeds beyond the familiar and justified activity of technology generation it should do so with caution. In these case, the appropriate criterion for success is that, as a result of the federal program, the private sector is in better position to make investment decisions which lead to the more efficient production of dual use products.

The important lessons about implementation are the following:

(1) The commercialization program should be based on a market oriented strategy. This means that the program must reflect realistic economic circumstances, not just technology opportunities. The program should be governed by a written plan which specifies risks and anticipated results, schedules and costs.

(2) The commercialization program must include both R&D and demonstration components. Technology transfer is vital and requires industry involvement with an equitable sharing of costs and risks. In there cooperative ventures, normal DoD acquisition rule are not appropriate.

(3) The demonstration phase presents the greatest danger for inefficient or ineffective federal involvement. The tendency for the government to undertake large, federally managed, projects should be avoided. Rather indirect incentives should be employed, when possible.

(4) Substantial bureaucratic and political pressures will emerge to enlarge commercialization programs beyond what is prudent. DoD leadership must be prepared to resist these pressures or accept significant budgetary waste.

(5) Program stability and the participation of technically competent managers is vital to the success of these programs.

It is interesting to inquire if these lessons have been followed in the commercialization efforts undertaken by DoD to date. A prominent example is the Sematech project where DoD and industry are each spending $100 million per year to develop a new generation of semiconductor manufacturing equipment with the purpose of reestablishing the US position in the world wide semiconductor market. At least two of the preceding lessons may not have been properly applied here. First, Sematech is largely concerned with creating new equipment technology. Relatively little attention have been devoted to assessing the role of a new generation of equipment for improving the position of the US semiconductor industry. The Sematech project does not focus on the overall manufacturing process or to understanding how new equipment will be adopted by the industry given the large investments required. In brief, the approach is based on technology push, not market pull.

Second, there is significant federal management involvement in the Sematech project. To the extent that Sematech is to serve as a demonstration for industry in the value of new technology, indirect incentives, such as tax credits for new equipment purchases from US suppliers, might well be a more effective alternative. In sum, the Sematech project may not go far enough. It hopes to achieve a revitalization of the semiconductor industry by relatively conventional support for R&D on new equipment technology. But to achieve the revitalization objective requires a more comprehensive evaluation of the industry's problems and a broader range of support mechanisms.

DoD faces an interesting question in how to proceed in the commercialization of dual use technology. At one extreme, the DoD can continue the valuable function, which it does well, of technology generation. At the other extreme, DoD can adopt an aggressive commercialization strategy for a few key dual use technologies. However, in order to be successful in these commercialization efforts, DoD must be prepared to change the way it does business in a substantial way.