Chapter 12

Policy Issues and Options

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Given the high risks associated with the commercialization of advanced materials, the Federal role in accelerating this process is likely to continue to be very important. OTA identifies four general Federal policy objectives that could improve the climate for commercialization of advanced materials in the United States. Options for pursuing these objectives range from those with a broad scope, affecting many technologies, to those specifically affecting advanced materials.

Objective 1:
Encourage long-term capital investment in advanced materials by potential end users.

Greater advanced materials investments by potential end users would help to generate more commercial market pull on advanced materials in the United States. The climate for such investments can be improved by several policy options aimed at making patient capital available, including providing tax incentives for long-term capital investments, reducing the cost of capital by encouraging greater national savings, and comprehensive tort law reform aimed at making product liability costs proportional to proven negligence.

Objective 2:
Facilitate government/university/industry collaboration in R&D for low-cost materials fabrication.

The high cost of advanced materials development and the small near-term markets are forcing companies to seek collaborative R&D arrangements to spread risks and raise the large amounts of capital required. Three major reservoirs of materials expertise are available to U.S. companies: universities, Federal laboratories, and small high-technology firms. At present, industry considers the scale-up costs too high and the payoffs **too uncertain to justify commercialization of research results from current industry/university and industry/Federal laboratory collaborations.** The government could encourage the commercialization step by establishing collaborative centers in which government and industry would share the costs of downstream materials fabrication technology development. An alternative would be to provide incentives for large companies to work with those small, high-technology firms that have advanced materials fabrication expertise, but lack the capital to explore its commercial potential.

Objective 3:
Facilitate more effective commercial exploitation of military R&D investments where possible.

The large U.S. military expenditures on advanced materials technology development represent a potential boost to the commercial competitiveness of U.S. firms, However, national security restrictions imposed on militarily important materials and processes can also inhibit commercial development. Ultimately, both national security and a competitive commercial manufacturing base depend on a strong domestic advanced materials capability. Therefore, a major objective of U.S. policy should be to balance these conflicting interests, and, where possible, to make it easier for commercial firms to exploit this resource. Among the options which could be considered area greater advisory role for commercial materials companies in reviewing export control policy; greater support for military programs aimed at developing low-cost materials and fabrication processes; and clarification of military domestic sourcing policies for advanced materials.

Objective 4:
Build a strong advanced materials technology infrastructure.

A broad range of technical data and an adequate number of trained personnel must be available to exploit materials technology developments in a timely fashion, whether they originate in the United States or abroad. The Federal Government could gather and disseminate informa-

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tion on ongoing R&D projects, business statistics, and technical developments abroad. It could also provide increased support for efforts aimed at establishing standard test methods for advanced materials, and for the development of databases containing relevant design and processing information. Increased funding could also be provided for university programs in advanced ceramics and composites, and for retraining programs for engineers who are not familiar with the new materials.

Congress and the Administration have adopted conflicting views of advanced materials. According to the congressional view, national goals and priorities should be established for advanced materials R&D above the agency level, and agency spending on materials programs should be made consistent with them. This view is expressed in the National Critical Materials Act of 1984, in which Congress established the National Critical Materials Council (NCMC) in **the Executive Of**fice of the President. The NCMC is charged with the responsibility of working with the principal funding agencies and the Office of Management and Budget to define national goals and priorities for materials R&D, and to coordinate the various agency efforts in developing a national program plan for advanced materials.

In the Administration's view, priorities for advanced materials R&D cannot be separated from the functional requirements of the structures in which they are used. Because different agencies have different requirements for materials, determination of R&D priorities is best made at the agency level. According to this **view, the information exchanged through various existing interagency materials committees is adequate to avoid excessive duplication and waste. The** NCMC is considered redundant with these committees.

OTA finds that it is more difficult to define national policy goals for advanced materials than for **more traditional critical materials. To succeed** in its task, the NCMC will need to establish a more precise definition of the goals that would motivate a national materials policy, as well as to develop high-level Administration commitment to the concept of such a policy. At present, Congress and the Reagan Administration remain far apart in their views of the appropriate scope of a national materials program plan, and of the role of the NCMC. **Pending the resolution of these differences, there are three further functions that** the NCMC could perform:

- a point of contact for monitoring industry concerns and recommendations regarding joint industry-government initiatives;
- gathering information on domestic and foreign materials R&D efforts and disseminating it to industry; and
- a broker for resolving conflicts between military and commercial agency goals for advanced materials.

INTRODUCTION

Advanced materials technologies clearly represent great potential opportunities for the U.S. economy. Today, materials account for between 30 and 50 percent of the costs of most manufactured products. In the 1990s and beyond, introduction of new materials that can reduce overall production costs and improve performance will bean important factor determining the competitiveness of U.S. manufactured products such as aircraft, automobiles, and industrial equipment.

But will the United States be able to capitalize on these opportunities? In spite of the fact that the United States invests more Federal money in materials R&D than any of its foreign competitors, there is serious doubt as to whether U.S. industry will aggressively transfer this R&D into commercial products.

Perhaps the central finding of this assessment is that potential commercial end users of advanced materials, whose investment decisions are determined by expected profits, do not believe that use of these materials will be profitable within their planning horizon of 5 years. Thus, there is virtually no market pull on these technologies in the United States. While U.S. commercial end users have placed themselves in a relatively passive, or reactive role with respect to use of advanced materials, their competitors, notably the Japanese, have adopted a more aggressive, "technology push" strategy. This strategy involves incorporating advanced materials into existing products to gain manufacturing experience for the future. in contrast to the United States, where industry and government investments in advanced ceramics and composites research are roughly comparable, in Japan such research is overwhelmingly funded by private industry.

On the whole, a strong case can be made that the profit expectations of U.S. advanced materials end users are accurate, within the 5-year time horizon. in most cases, it will take longer than 5 years to develop solutions to the remaining technical and economic problems. Although precise production cost data are not available, it is likely that Japanese structural ceramic components are not produced at a profit; rather, the Japanese firms gain the manufacturing experience necessary to position themselves favorably for future opportunities. **Early indications are that these efforts have been successful. While the U.S. Department of Energy has provided massive fund**ing to a consortium of companies to develop ceramic gas turbine engine prototypes for automobiles since the late 1970s, the most highly stressed component of these engines, the ceramic turbine rotor, **is** currently made in Japan.

This Japanese technology push strategy is not without risks. In addition to reducing profits in the near term, it may also lead to premature commitment to obsolescent technology. Historically, Japan has concentrated on making incremental improvements in the properties of monolithic structural ceramics, whereas the United States has given greater emphasis to developing tougher (and more expensive) ceramic matrix composites (CMCs). Japan now appears to be shifting more resources toward CMCs.[1]

Ultimately, the future competitiveness of U.S. advanced materials industries in worldwide commercial markets will depend on the investment decisions made within the industries themselves. The risks of such investments are high. To develop a manufacturing capability with advanced structural materials requires enormous capital investment, while the payoffs are often 10 to **20 years away. However, most experts contacted by** OTA stressed that manufacturing experience over time with advanced materials is essential; U.S. companies cannot expect to step in and produce competitive advanced materials products after the manufacturing problems have been solved by others.

The Federal Government directly affects the development of advanced materials through funding of basic research, technology demonstration programs associated with the missions of Federal agencies, and military/aerospace procurement of advanced materials and structures. State and Federal policies and regulations, such as R&D **tax incentives and product liability laws, also indirectly affect the climate for industry investment in long-term, high-risk technologies such as advanced materials.**

Of the roughly $167 million invested by the Federal Government in advanced structural ceramics and composites R&D in fiscal year 1987, * about 60 percent was sponsored by the military. This proportion would have been even higher if military funds for testing, evaluation, and classified programs had also been included. Advanced materials are truly enabling technologies for military missions. Without their unique properties, including high strength and stiffness, light weight, and high-temperature capabilities, many of the major military programs under development, such as the Strategic Defense Initiative, the National Aerospace Plane, and various Stealth weapons systems, would not be feasible.

Historically, programs within the Department of Defense (DoD) and, to a lesser extent, the National Aeronautics and Space Administration (NASA), have driven the development of many advanced materials, particularly various kinds of composites. The high cost of advanced materials for military applications is justified by the high performance they deliver. As long as this emphasis continues, the military will remain one of the

[1] Dick J. Wilkins, Director, Center for Composites Research, University of Delaware, personal communication, November 1987.

*This total encompasses R&D involving: monolithic ceramics; ceramic, polymer, and metal **matrix composites; and carbon/carbon** composites.

largest and fastest growing markets for new materials.

The commercial benefits of military materials investments remain controversial. Military applications often help to boost a new technology up the learning curve, and new materials are made available that otherwise would have gone unexplored. However, because the cost of military materials is typically high and production volumes are low, often neither the materials nor the production methods are appropriate for commercial applications. For national security reasons, the military may also place restrictions on the dissemination of DoD-funded materials R&D, thereby creating an additional barrier to the diffusion of R&D results into the commercial sector.

In military applications, the government is the customer for materials technology and hardware. As such, it has an interest in securing stable, domestic sources of material supply. However, military markets will not be large enough to sustain a viable domestic advanced materials industry in the future. Critics charge that the expanding military role is likely to skew the national advanced materials agenda toward development of more exotic, high-performance materials, such as carbon/carbon composites, and to low-volume, high-cost manufacturing processes that will have at best indirect benefits for commercial applications. These concerns are all the more acute given that the other countries–notably Japan, which has a very small military establishment–are already giving heavy emphasis to commercial uses of advanced materials.

About 40 percent of Federal spending for advanced structural ceramics and composites R&D is nonmilitary in nature, including most of that funded by the Department of Energy (DOE), NASA, the National Science Foundation, the National Bureau of Standards, and the Bureau of Mines. These civilian agencies generally do not act as the procurers of hardware. Rather, they sponsor materials R&D performed by universities, Federal laboratories, and industry contractors. The R&D ranges from basic science to technology demonstration programs, according to the particular agency's mission objectives.

Where appropriate, the civilian agencies encourage industry to commercialize the new technologies. To date, though, these efforts have not been very successful, in large part because industry has lacked the near-term market incentives necessary to justify the costs of adapting these technologies for commercial production. The recent concern about U.S. industrial competitiveness has focused attention on how this federally funded research can be transferred more effectively to the private sector.

If U.S. advanced materials industries are to be competitive in the future, more will be required than early leadership based on military investments. The United States has learned from bitter experience in microelectronics that early technological dominance is no guarantee of long-term competitiveness. Technologies flow rapidly across national borders, and a competitor who comes second to market may enjoy the benefits of the leader's efforts but have lower production costs. One example of the rapid loss of a new materials market is the electronic ceramics industry, which constitutes about 80 percent of the value of all advanced ceramics produced today. In the past 10 years, the United States has largely lost the electronic ceramic components business to Japan, particularly in the important area of integrated circuit substrates and packages.

Why has Japanese industry been able to make such a massive commitment to such a risky technology as structural ceramics? Observers suggest several reasons. In Japan, aggressive movement into promising new technologies is considered less in terms of short-term economic return than as a matter of long-term survival for Japanese industry. This sense of vulnerability and urgency is generally lacking in Western business plans. A second reason is that Japanese industry enjoys a relatively low cost of capital, in large part due to the high national savings rate. A third reason is the capacity of the Japanese system to spread the risks effectively among the many participants in the precompetitive stage of technology development. This is facilitated by the close cooperation among the Japanese Government, financial institutions, and the highly integrated advanced materials companies.

PROJECTIONS BASED ON CONTINUATION OF THE STATUS QUO

Given that the Federal Government plays such an important role in advanced materials development, it is evident that government policy choices will have a significant effect on the competitiveness of U.S. advanced materials industries. Before discussing policy issues and options, though, it is useful to consider scenarios that can be projected based on continuation of current trends.

Because U.S. military markets will expand faster than commercial markets in the near term, the military role **in determining the development agenda** for advanced materials is likely to broaden. As explained above, military investments in advanced materials could be an asset **to U.S. firms;** however, they could also tend to skew advanced materials activities in the direction of high-performance, high-cost materials inappropriate for commercial applications.

Meanwhile, the reluctance of U.S. commercial end users to commit to advanced materials suggests that foreign firms will have an advantage in exploiting the growing global markets. Almost certainly, a successful product using an advanced material produced abroad would stimulate a flurry of R&D activity among U.S. companies. However, given the lack of experience in the United States with low-cost, high-volume manufacturing technologies for advanced materials, U.S. companies would be faced with a formidable challenge in trying to catch up.

The high cost of R&D, scale-up, and production of advanced materials, together with the poor near-term commercial prospects, will drive more and more U.S. companies to pool resources and spread risks through a variety **of joint ventures, consortia, and research centers. Currently, many such collaborative programs are springing** up across the country. These programs will provide **an excellent environment** for generic research and the training of students. **However, they will not necessarily lead** to more aggressive commercialization of advanced materials by participating companies (see ch. 10).

Worldwide, advanced materials industries will continue to become more multinational in character through acquisitions, joint ventures, and licensing agreements. Technology will flow rapidly between firms and across national borders. For U.S. companies, critical advances will continue to come from abroad, and the flow of materials technology into the United States will be as important as that flowing out. U.S. efforts to regulate these flows for national security reasons will meet increasing resistance from multinational companies intent on achieving the lowest production costs and free access to markets.

These projections suggest there is reason to doubt that the United States will be a world leader in advanced materials manufacturing in the 1990s and beyond. The full-scale commercialization of these materials is presently blocked because they do not meet the cost and performance requirements of potential end users.

PROPOSED POLICY OBJECTIVES AND OPTIONS

OTA believes there are four general government policy objectives which could help to reduce the barriers to effective commercialization of advanced materials in the United States.

1. **Encourage long-term capital investment in advanced materials by potential end** users.
2. Facilitate govern merit/university/industry collaboration in R&D for low-cost materials fabrication processes.
3. Facilitate more effective commercial **exploitation of military** R&D investments where possible.
4. Build a strong advanced materials technology infrastructure.

The following discussion of policy options is framed by these four general objectives. Options range from those with a broad scope, affecting many technologies, to those specifically affecting advanced materials. These options are not mutually exclusive, and most could be implemented without inconsistency.

Following the discussion of policy options is a section on alternative approaches to setting the Federal Government goals and priorities with regard to advanced materials.

Encourage Long-Term Capital Investment by Advanced Materials End Users

Greater investment in advanced materials by potential end users would generate more market pull on these technologies **in the United States. The shortfall of long-term investment in advanced materials by potential end-user companies reflects** a more widespread shortfall found in many U.S. industries. Such shortfalls have been attributed to a variety of generic barriers to the commercialization of emerging technologies, as summarized in table 12-1. (Many of these barriers were also identified as critical by materials industry representatives contacted by OTA as described in ch. 8.)

Table 12-1.—Commonly Cited Generic Barriers to Commercialization of Emerging Technologies in the United States

- High costs of capital funds in the United States relative to foreign competitors
- Lack of tax incentives for U.S. companies relative to foreign competitors to deploy emerging technologies (including the stability of tax regulations)
- Poor integration of manufacturing, design, and R&D functions
- Inadequate laws, regulations, and enforcement protecting intellectual property rights in the United States or overseas
- Complacency of US. manufacturers and dependence on the domestic market
- Restrictive trade policies in foreign markets
- Time-consuming Federal and State regulations on corporate activities intended to protect the public health and safety (e.g., building codes, environmental laws, drug approval regulations, and occupational health regulations)
- Export controls on advanced technologies and high-technology products
- Uncertainty caused by product liability and tort laws
- Anti-trust restrictions against cooperative ventures for marketing or production methods

SOURCE: U.S. Department of Commerce, "The Status of Emerging Technologies: An Economic/Technical Assessment to the Year 2000,'" report to the Deputy Secretary of Commerce by the Emerging Technologies Committee, 1987.

The climate for long-term industry investment is strongly affected by Federal policies and regulations, including tax policy, intellectual property law, tort law, and environmental regulations. Public debate regarding the relationships between these Federal policies and regulations and U.S. industrial competitiveness has given rise to a voluminous literature. Suggested policy changes include: providing tax incentives for long-term capital investments; reducing taxation on personal savings and corporate retained earnings to make more investment capital available and thus reduce its cost; revising banking law to encourage financial institutions to make patient capital available; and enacting comprehensive tort law reform aimed at making product liability costs proportional to proven negligence.[2]

Such policy changes affect the general climate for innovation, and have been extensively discussed elsewhere.[3] They have implications far beyond advanced materials technologies, and an analysis of their effects is beyond the scope of this assessment. Although it is conceivable that such broad policy instruments could be narrowed to focus on advanced materials technologies specifically, there would appear to be little justification for singling out advanced materials—as opposed to, say, microelectronics, computers, or biotechnology–for special consideration. This theme is developed further at the conclusion of this chapter.

Facilitate Government/University/Industry Collaboration in R&D for Low-Cost Materials Manufacturing Processes

There is evidence that existing university/industry and Federal laboratory/industry joint R&D centers in advanced materials do not address the problem of commercialization of research results very effectively (see ch. **10).** Rather, these programs tend to be seen by industry as promoting the infrastructure of the technology; i.e., provid-

[2] *Technology and the American Economic Transition,* an upcoming OTA report.

[3] See, for instance, the report of the President's Commission on Industrial Competitiveness, "Global Competition, the New Reality," January 1985.

ing access to new ideas and trained students. Although such contributions are essential and should be encouraged, it appears that a significant gap still remains between the point at which current collaborative materials R&D leaves off and the point at which industry is prepared to make significant investments to bring this R&D to **commercial fruition.**

There are two major policy options which could help to bridge this gap.

Option 1: Establish a limited number of collaborative centers dedicated to advanced materials manufacturing technology.

Given the nature of the risks posed by manufacturing with advanced materials–very high scale-up and production costs in an uncertain market environment—it may be necessary for the government to share these costs by supporting collaborative centers designed to develop more cost-effective manufacturing methods.[4] The cost sharing could be accomplished directly through Federal matching funds, or indirectly through tax credits designed to stimulate cooperative research. These centers would not necessarily require the building of new facilities; rather, they could be based at existing centers of excellence.

There are several characteristics that such collaborative manufacturing centers should have if they are to be successful **in promoting technology utilization (see ch. 10). First, the centers should incorporate the commercialization perspective into the fabric of their structure from the beginning. They should be located in** settings that are very conducive to the intermingling of industry and research staff concerns. Industry should be directly involved in the planning, funding, and administration. The centers should feature direct, bench-level collaboration between visiting industrial scientists and the facility research staff. Industry managers, production engineers, and marketing personnel should have temporary assignments to work with the center staff to develop the manufacturing infrastructure needed. The centers should have ample opportunities for proprietary projects to be carried out for individual industry clients in parallel with the broader program of widely disseminated nonproprietary projects. Finally, the industry participants should commit sufficient resources to their own internal R&D efforts to be able to employ effectively the research output of the centers.

Depending on the agenda of an industry consortium aimed at developing manufacturing technology for advanced materials, there could be an antitrust conflict with the Clayton Act, Section 7 (15 U.S.C. 18). This section prohibits acquisitions and joint ventures where the effect is to lessen competition between firms. **In the National Cooperative Research Act of 1984 (Public Law 98-462), the Clayton Act was amended to permit joint** R&D ventures at a basic level.

Further legislation may be required to permit cooperative manufacturing development where such cooperation clearly enhances the competitiveness of U.S. industry in the global marketplace. Antitrust reform proposals along these lines are a prominent feature of the President's Competitiveness Initiative released in January 1987. Because similar consortia are now being planned in other industries, notably microelectronics, it appears unlikely that structural ceramics consortia would be the first to test this legal ground.

Option 2: Encourage large companies to work with small advanced materials firms that have manufacturing expertise but lack the capital to explore its commercial potential.

Ultimately, large integrated companies are likely to be more competitive in high volume markets for advanced materials than small companies (see ch. 9). However, the current small markets **for advanced materials technologies have spawned many small materials companies that supply materials for specialty applications, especially military applications.**

Like universities and Federal laboratories, these small companies represent a technology resource that could make large materials suppliers and end users more competitive in the future. Whether through acquisitions, joint ventures or other financial arrangements, large companies could use relationships with small ones to acquire access

4A similar suggestion appears in the Report of the Research Briefing Panel on Ceramics and Ceramic Composites (Washington, DC: National Academy Press, 1985).

to technologies that have commercial promise, but that are not cost-effective for large companies to develop in-houses Furthermore, from a national perspective, the commercialization goal may receive greater emphasis in collaborations between large and small companies than in those involving industry and academia or industry and Federal laboratories.

In spite of these possible benefits, though, there is evidence to suggest that this small company resource is not receiving Federal support commensurate with its productive potential.

Executives of small materials companies contacted by OTA expressed concern that the share of Federal sources of capital going to small businesses has been declining. As shown **in table 12-2, the share of Federal R&D contracts awarded to small businesses has declined since 1979, although the implementation of the Small Business Innovation Research** (SBIR) program, which began in 1983, has helped to reverse this trend.[6] One reason for this decline is a trend in government procurement toward aggregating contracts into larger packages awarded to large companies that supply the overall system. Small firms involved in the government procurement process thus depend on subcontracts from the systems suppliers, rather than direct support for technology development.

A large number of small advanced materials companies have participated in the SBIR program. Those contacted by OTA have been uniformly enthusiastic about their experiences. Sources familiar with the SBIR program report that since 1982, 60 percent of Phase I awards each year have gone to firms that had no previous contact with the program.[7] This implies a geometric increase in the number of firms that have participated in the program.

Federal program managers report that they receive many more high-quality proposals than can be funded. Furthermore, they also state that they are impressed with the quality and cost-effectiveness of the research performed. This suggests that the SBIR program could be expanded without compromising the quality of the research or exhausting the supply of innovative small companics.[8]

Expanding the SBIR program is only one option for increasing the amount of capital made available for small advanced materials companies. Other alternatives could include specific provisions for reducing the cost of their participation in federally funded collaborative R&D centers, as well as encouraging prime contractors in large Federal projects involving advanced materials to subcontract more extensively to small companies.

Facilitate More Effective Commercial Exploitation of Military R&D Investments Where Possible

In the United States, the military has generally been the driving force behind the development of various kinds of composites, including those having polymer, metal, ceramic, and carbon matrices. Because of the strategic importance of some advanced materials, restrictions are placed on the dissemination of these materials and information relating to them. These restrictions tend to limit the international business opportunities of U.S.-based advanced materials companies, particularly as the advanced materials capabilities of foreign countries reach parity with those of the United States. (See ch. 11 for a discussion of the advantages and disadvantages of defense fund-

[5] It should be noted that these small companies are a resource for large foreign companies as well as large U.S. companies, and their acquisition by foreign companies can bean important mechanism for transferring U.S. technology abroad.

[6] Enacted in 1982 (Small Business Innovation Development Act, Public Law 97-21 9) and phased in over 5 years, the SBIR program requires that Federal agencies with extramural R&D budgets in excess of $100 million set aside 1.25 percent of those budgets for awards to small businesses. The SBIR program is intended to meet the R&D needs of the funding agency while at the same time helping the small companies to explore avenues to commercialization of that research. It fills a unique need in the innovation process because it provides funding for the translation of a technical concept into a prototype; once the innovation has reached the prototype stage, it is expected that the small company involved will obtain additional funding from private or non-SBIR Federal sources.

[7] Ann Eskeson, President, Innovation Development Institute, personal communication, November 1987.

[8] A proposal to increase the small business set-aside from 1.25 percent to 2.5 percent is discussed in "Innovation in Small Firms, " Small Business Administration Issue Alert, July 1986. Any such expansion, however, is likely to be opposed by university groups and agencies whose primary mission is to fund university research.

Table 12-2.—Share of Federal R&D Contracts Going to Small Business, 1979-86[a]

Category	Fiscal year							
	1979	1980	1981	1982	1983b	1984	1985	1986
Total contracts ($millions)	12,889	14,195	16,741	20,025	22,116	24,452	25,749	25,680
Small business ($millions)	846	958	987	955	1,054	1,198	1,526	1,648
Small business share (percent)	6.6	6.7	5.9	4.8	4.8	4.9	5.9	6.4
Small business share without SBIR funds (percent)	–	–	–	–	4.6	4.6	5.4	5.5

[a]Federal R&D outlays are divided roughly as follows: contracts 50%; **grants 25%;** and intramural 25%. Small business is defined as companies with fewer than 500 employees.
[b]Year that the Small Business Innovation Research (SBIR) Program was phased in.

SOURCE: William K. Scheirer, Small Business Administration.

ing and procurement policies for advanced materials suppliers.)

As commercial applications grow and DoD becomes less of a driver and more of a consumer of advanced materials technology, the viability of the domestic industry will become the paramount consideration, from both an economic and a military point of view. To strengthen the domestic advanced materials manufacturing base, it will become more and more important **to strike a balance between the competing goals of military and commercial users of ceramics and composites. If the history of the U.S. microelectronics industry is any guide, transfer of commercially developed materials and processes to the military will eventually become** more important than military-to-commercial transfer.

The principal policy issues likely to be involved in developing a military/commercial balance are those associated with export controls, information controls, military research in manufacturing technologies, procurement practices, and offsets.

Export Controls

Early in 1987, the Department of Commerce proposed several changes in the administration of export controls intended to alleviate their impact on U.S. high technology trade.[9] Among these are proposals to remove from the control lists those technologies that have become available from many foreign **sources, and to reduce** the review period for export license applications. These changes could be helpful, but some further steps should be considered.

Option 1: Increase representation by nonmilitary materials industries (including end users) in policy planning for export controls.

Currently, policymaking decisions about export controls tend to reflect the interests of the defense community—both government personnel and defense contractors. To achieve a more balanced policy, it would help to have nondefense industry managers participate in the process.

The Department of Commerce has already taken a step in this direction, with the chartering of the Materials Technical Advisory Committee in April 1986. The purpose of the committee is to provide an industry perspective for policymakers in the materials field. When the committee has its full complement of members, the group could provide timely advice to the **Department of Commerce on export control policies relating to advanced materials.**

Option 2: Eliminate or loosen reexport controls.

The United States is the only country that imposes controls on the reexport by other countries of U.S.-made dual-use products (i. e., products that have both military and commercial uses), or systems that contain U.S.-made parts and components. Many countries view U.S. reexport controls as unwarranted interference in their political and commercial affairs, and this has led to a process of "de-Americanization," in which foreign companies avoid the use of U.S.-made materials and components in their systems.[10]

[9]"Export Controls: Advancing Our National Security and Economic Vitality, " *Business America,* Mar. 2, 1987.

[10]*Balancing the National* ***Interest:*** *U.S. National Security Export Controls and Global Economic Competition* (Washington DC: National Academy Press, 1987).

The Department of Commerce has recently revised the parts and components regulations for reexports from member countries of the Coordinating Committee for Mukilateral Export Controls (CoCom), so that, for most destinations, a U.S. **reexport** license is needed only if U.S.-made parts and components are valued in excess of 25 per**cent** (up from 10 percent) of the system value. This relaxation could encourage foreign companies to use more U.S.-made parts, but its effects should be assessed after a suitable period to see if it goes far enough. For shipment to proscribed countries (e.g., Eastern bloc countries), a license is required if U.S.-made parts exceed 10 percent of the system value or $10,000.

No revisions have been made in the regulations concerning reexports of stand-alone items, and a reexport license must be obtained for quantities of these items above certain threshold values. For instance, a threshold of zero applies to advanced ceramics, so that licenses are required for reexports of all advanced ceramic items. Low threshold values are used to control reexport of relatively inexpensive items that have significant military value, such as ceramic rocket nose cones. One option for encouraging foreign companies to make greater use of U.S.-made advanced materials and components would be to raise these threshold values in a product-specific way within the existing regulations.

An alternative method would be to eliminate **the U.S. reexport restrictions entirely, while encouraging foreign trading partner nations to de**velop and maintain their own export controls for these products. In light of the recent Toshiba scandal,[11] this may be an opportune time to offer such an incentive to encourage U.S. trading partners to tighten their internal export controls.

Option 3: Streamline and coordinate the various export control lists.

All of the various lists under which technologies are controlled should receive careful review for correctness and current relevance. In particular, a better mechanism should be found for removing technologies from the lists as necessary. The Department of Commerce could be made responsible for meshing the Commodity Control List more closely with the CoCom international list and for removing outdated or widely available technologies. This review issue is important for many technologies, including advanced materials, and should be dealt with on an appropriately larger scale. However, for advanced materials in particular, reviewing the various control lists could become the responsibility of the Materials Technical Advisory Committee in the Department of Commerce.

One alternative for streamlining the advanced materials items on the control lists would be to concentrate on controlling processing technologies rather than the materials themselves. Many experts agree that because of the large number of processing variables, it is very difficult to "reverse engineer" a composite material from a chunk of the material or structure. To more effectively balance national security and commercial trade interests, it may be better to control exports of process information and loosen restrictions on material components and structures.

Option 4: Clarify the export control regulation of metal matrix composite (MMC) products and information.

At present, the Departments of Commerce and State have overlapping legal and regulatory authority to control the export of MMC **technology. This arrangement is extremely confusing to U.S. companies, which have experienced long delays in obtaining approval** for export licenses. In some cases, these delays have prevented U.S. MMC suppliers from establishing business relationships with foreign end users for the purpose of exploring the potential of MMC materials for commercial applications.

It would be less confusing and less time-consuming for U.S. companies to be able to deal with a single agency regulating the export of these materials and technical data. Congressional action could be appropriate to limit the control of these materials to one agency. Alternatively, the National Security Council could arbitrate a discussion between Commerce and State for the pur-

[11] Toshiba Machine Co. and a Norwegian firm, Kongsberg Vaapenfabrikk Trading Co., are charged with selling sophisticated milling equipment to the Soviet Union. This equipment may enable the Soviet Union to build quieter submarines that are more difficult to detect.

pose **of housing the control of these materials and data related to them under one** roof.

Information Controls

Technical information about advanced materials is controlled under a complex regime of laws and regulations administered by the Departments of State, Commerce, and Defense. Currently, dissemination of advanced materials technical information can be controlled via: International Traffic in Arms Regulations of the Department of State; the dual-use technology restrictions of the Department of Commerce; the Defense Authorization Act of 1984; government contract restrictions; and the government system of document classification.

There are so many ways to restrict information that actual implementation of restrictions can appear arbitrary. Under some of these laws, regulations and clauses, a company can file for a license to export, but under others, there is no mechanism to permit export of the information.

Excessive information restrictions can inhibit domestic technology development and prevent technology transfer between military and commercial applications.[12] Furthermore, they can prevent companies from becoming military contractors and also prevent military contractors from exploiting the full commercial potential of a technology. Minimizing this segregation of technology should be a goal of both the military and commercial sectors.

The present system of information controls has **also led to** disruption of scientific meetings and restriction of some advanced materials conference sessions to U.S.-only participation. Such U.S.-only sessions, however, can be self-defeating when—as can happen—superior technology is already available abroad. The following are two options that could help alleviate these problems.

Option 1: Simplify and clarify the various information restriction mechanisms.

One method of reducing the confusion would be to rely more on classification (the main mechanism for information control as reiterated in the President's National Security Decision Directive of 1985) and less on the other more tenuous mechanisms of control (e.g., the Defense Authorization Act and contract clauses). This would have the advantage of reducing the uncertainty that now pervades advanced materials conferences and professional societies. However, there is a trade-off between simplicity of controls, on the one hand, and flexibility on the other. If **all** information that is now controlled became classified, this could have the effect of making such information even less accessible.

Option 2: Make military materials databases more available to U.S. companies.

The military has a number of databases on advanced materials projects that could be made more widely available to U.S. **companies. This information, now available only to defense contractors through the Defense Technical information Center** (DTIC), is more comprehensive and up-to-date than that offered by the National Technical Information Service (NTIS). DTIC contains a significant amount of information that is neither classified nor proprietary, but is still limited to registered users. Such information could be of value to U.S. commercial firms that are not government contractors.

If it is determined that it would be desirable to transfer defense databases selectively to U.S. companies, a workable definition of a U.S. company must be found. As advanced materials companies take on an increasingly international character (see ch. 9), such distinctions are becoming moot. Another alternative would be to transfer more of the DTIC databases to NTIS. However, this would make the information available to U.S. and non-U.S. companies alike.

Military Research in Manufacturing Technologies

Although military applications for advanced materials can generally tolerate higher costs for materials and processes than commercial applications, both could benefit greatly from research on low-cost manufacturing methods. The desire to reduce procurement costs led DoD to implement its Manufacturing Technologies (ManTech) program, which includes projects devoted to

[12] F. Karl Willenbrock, "Information Controls and Technological Progress, " Issues in Science *and Technology,* fall 1986.

many different materials and manufacturing technologies.

Total ManTech funding **for the three** services plus the Defense Logistics Agency is $124 million for fiscal year 1987, with $165 million requested **for** fiscal year 1988. However, it is difficult to ascertain what proportion of these funds can be considered materials-related in that individual projects can be considered either as structures or materials processing efforts.

Option: Increase support for advanced materials manufacturing research through the ManTech program.

Low-cost manufacturing technologies represent a convergence of interests between DoD and the commercial sector that could hasten the commercial utilization of advanced materials technologies developed for the military. One alternative could be to augment the budget for those ManTech projects aimed at decreasing production costs and increasing reproducibility and reliability of advanced materials structures.

Procurement Practices

DoD constitutes a special market with unique materials requirements. However, like other customers for advanced materials, DoD strives to have the widest variety of materials available at the lowest possible cost. Therefore, it employs regulatory means to simulate the conditions of commercial markets. This makes the participation by materials suppliers extremely dependent on defense regulations and policies, rather than on conventional economic criteria. Through its policies on dual sourcing, materials qualification, and domestic sourcing of advanced materials, DoD has a profound influence on the cost and availability of a variety of high-performance materials and technologies.

Option: Provide a clear plan **for implementing domestic sourcing regulations for advanced materials.**

Carbon fibers used in advanced composites provide a useful example of the need for a clear plan for implementing domestic sourcing policies. Most high-performance carbon fiber is derived from an organic precursor material called polyacrylonitrile (PAN). Although there are many companies in the United States that are capable of manufacturing carbon fiber from PAN, 100 percent of PAN precursor for composites qualified for U.S. military use is imported. At present, Amoco is the only domestic producer of PAN precursor; however, Amoco's carbon fibers are still undergoing qualification testing.

In the Defense Appropriations Act of **1987 (Public Law 100-202)** Congress specified that 50 percent of all defense requirements for PAN-based carbon fiber be produced domestically by 1992.[13] Congress has required that DoD provide a program plan to fulfill this PAN requirement; the plan is due to be presented in June 1988.[14]

A prior DoD directive on domestic sourcing of PAN requires two or more domestic suppliers. Such suppliers would not have to be U.S.-owned as long as their plants are located in the United States.

Domestic suppliers of carbon fiber made from imported PAN welcome this legislation, but they are uncertain about how it will be implemented, and about which weapon systems would be involved.

To make intelligent investment decisions, U.S. carbon fiber suppliers would like DoD to provide a comprehensive plan for implementing the proposed directive. The greater the percentage of domestic PAN precursor used in military systems, the more attractive it will be to invest in the opening of a plant; the proposed requirement of 50 percent by 1992 is considered very appealing by industry.

To be effective, the program plan must specify which weapons systems will be required to use domestically produced PAN **and** in what quantities. In addition, industry would like assurances that domestically produced PAN will be procured even if foreign-produced PAN is initially less expensive. It would also be necessary for DoD to guarantee to purchase minimum quantities of the fiber in order for industry to establish new production facilities.

13 *Congresslona/ Record,* Dec. 12, *1987,* vol. *133,* No. 205, part III, pp. HI 2546-7.

14 Ken Foster, U.S. Department of Defense, personal communication, May 7, 1987.

Offsets

Offsets are a foreign policy-related marketing device that can be detrimental to the U.S. advanced materials technology base. Technology offsets are commonly required by foreign customers before they will consider bids from U.S. or other systems suppliers. In recent years, little attention has been paid to the effects of offsets.

It appears that the best way to prevent the distribution of U.S. advanced materials technology through offsets is to prevent foreign nations from requiring offsets from U.S. companies. Perhaps this is best addressed in the context of trade negotiations on specific systems, such as military and commercial aircraft. However, offsets are **only a small part of such trade negotiations, and foreign policy goals may preempt this approach. This** issue is of increasing importance to materials suppliers as foreign nations become more and more interested in acquiring U.S. technology and competing in U.S. markets.

option: Initiate a thorough study of the effects of offsets on the competitiveness of U.S. advanced materials industries.

Build a Strong Advanced Materials Technology Infrastructure

For U.S. advanced materials suppliers and users to rapidly exploit materials technology developments over the long term, whether these developments occur within the United States or abroad, a strong U.S. technology infrastructure must be built to support the cost-effective use of the new materials. Such an infrastructure would include the availability of basic scientific knowledge, technical data to support design and manufacture, and an adequate supply of trained personnel. Infrastructure investments are generally considered the responsibility of the Federal Government, since they are a public good, i.e., they cannot be appropriated for an individual company's benefit. **There are several policy options to be considered as a means of supporting the development of a strong technology infrastructure.**

Option 1: Increase the funding for R&D in advanced materials and their manufacturing processes to reduce costs and increase reliability and performance.

Although ceramics, polymer matrix composites, and metal matrix composites technologies are at different stages of maturity and have different applications, there are four R&D priorities common to all three technologies:

1. **Manufacturing science research is needed to support the development of cost-effective manufacturing processes.**
2. The relationships between structure, mechanical properties, and failure mechanisms must be understood to take advantage of the anisotropic properties of advanced materials.
3. The behavior of advanced materials in severe environments must be determined to facilitate reliable design and life prediction.
4. The interracial region between matrix and **reinforcement in composites, which has a critical influence on composite behavior, must be properly understood.**

These priorities are widely appreciated, and OTA finds that current agency R&D programs are generally consistent with them. However, greater funding in these priority areas could accelerate commercial use of advanced materials. Alternatively, if overall funding is reduced, preservation of funding in these areas should be a priority.

Option 2: Develop a comprehensive account of collaborative R&D efforts in advanced materials at the Federal, regional, and State levels, including program goals and funding.

Collaborative R&D programs promise to spread the risks of industry investments in advanced materials. Numerous centers of excellence focusing on various aspects of advanced materials technologies have been initiated in the past several years, and little attention has been paid to wasteful overlap or the possibility of exhausting common sources of funding.

The ad hoc process by which collaborative centers are currently established has both advantages and disadvantages. The principal advantage is that many different competing organizational models can be explored, leading to a Darwinian "survival of the fittest. " This approach also fosters more diverse solutions to technological problems, as well as providing broader educational opportunities for students.

One of the disadvantages is that the resulting dispersion of talent and resources could prevent a coalescing of all the factors necessary to create a first class advanced materials industry.[15] This especially appears to be a problem with advanced materials, in which design, processing, and testing are so closely integrated. The best solution may be a mix of small, dispersed centers with a limited number of larger, integrated centers in which design, processing, and evaluation are undertaken under one roof.

A comprehensive account of collaborative R&D efforts in advanced materials would be a necessary first step in drawing lessons from experience with various collaborative models, and in minimizing wasteful duplication of effort. It would not be appropriate for the Federal Government to attempt to discourage States from establishing collaborative centers of excellence in any technology. However, to the extent that Federal funding is sought by these centers, the government could use its leverage to encourage them to work together as much as possible. New Federal centers should only be undertaken after taking into account the existing context of State and regional centers.

The Omnibus Trade and Competitiveness Act of 1987 (H. R. 3) contains a provision to create a central clearinghouse within the Department of Commerce's Office of Productivity, Technology, and Innovation to keep track of State and regional competitiveness initiatives, including collaborative centers. Such a clearinghouse could be the vehicle for gathering information on advanced materials centers. Alternatively, an organization such as the National Critical Materials Council could undertake to gather this information.

Option 3: Gather comprehensive information on current activities in government-funded advanced materials R&D.

One persistent need identified by many industry sources is information on the many different government activities in advanced materials. In general, this information exists but is rarely in a form readily accessible to researchers. A database could be assembled containing a listing of projects by subject and sponsoring agency, each entry accompanied by the name of a contact, annual budget, milestones achieved, bibliography of project reports, and technology transfer activities. Some of the specific benefits **of such a database** would include:

- A point of access for those interested **in perusing recent reports or those seeking information on current programs** in an area of interest.
- A source for tracing trends in funding and priorities for materials science and engineering over time.
- A source for assessing the effectiveness of government-to-industry technology transfer efforts in materials.

The preparation of such a database would not be difficult, as most of the information exists in various forms in the funding agencies.[16] Such a project would be consistent with the mandate of the National Critical Materials Council. The Council could work with other government groups such as the Center for the Utilization of Federal Technologies at the National Technical information Service (NTIS), and it could also oversee the annual updating of the database by tapping program managers in the various Federal agencies involved.

Option 4: Establish a mechanism for gathering business performance statistics for advanced materials industries.

It is very difficult to obtain accurate, up-to-date business statistics on advanced materials production, imports, and exports. The Standard industrial Classification categories now in use do not distinguish these advanced materials from conventional materials. For instance, advanced ceramics are aggregated together with ceramic tableware and sanitary ware. This situation contrasts sharply with that in Japan, where each month the Ministry of International Trade and In-

[15] R.M. Latanision, "Developments in Advanced Materials in the Industrialized Countries, " proceedings of the Federation of Materials Societies' Ninth Biennial Conference on National Materials Policy, Fredericksburg, VA, August 1986. p. 21.

[16] Such a database collected on government funding of structural ceramics in 1985 was used in table 3-11 to compare the recommended R&D priorities for structural ceramics with actual agency spending.

dustry publishes detailed statistics on the production and export of advanced ceramics broken out by product type. Such statistics are extremely useful **in understanding production trends and in assessing the competitive status of the U.S. advanced materials industries.**

Proposals to revise SIC **codes to take account of advanced ceramics industries** have been under study since 1985 by the United States Advanced Ceramics Association.[17] However, this issue has not received a high priority within the industry, and no action is currently contemplated, This may turn out to be a short-sighted decision, As international trade in advanced materials and components grows, these statistics could also provide the documentation required to prove damage to domestic ceramics industries from unfair trading practices abroad.[18]

Option 5: Increase funding for person-to-person efforts to gather and disseminate data on international developments in advanced materials.

The cultural and scientific parochialism of Americans has been widely recognized, and there have been many calls for programs to gather technical data from abroad and to translate foreign technical publications into English.[19] As several countries approach and exceed U.S. capabilities in advanced materials technologies, it becomes imperative **for** U.S. companies to have access to such information. Particularly acute is the lack of qualified translators who also have a technical background. The establishment of first-class technology information networks worldwide is one of the strengths of Japan, a principal economic competitor of the United States.

The Federal Government currently has several scattered programs to address this problem. In 1986, Congress passed the Japanese Technical Literature Act (public Law 99-382), which reallocated $1 million within the Department of Commerce for assessing and monitoring Japanese technical publications. Other Federal programs include the National Science Foundation's (NSF) JTECH reports, which provide an assessment of Japanese efforts **in various technical areas.**[20]

The Federal Government's efforts to gather technical data are hampered by several factors. One is that the demand for such information is not very well defined. Not everyone has a desire or need for the same data, making it difficult to select a commonly agreed upon subset of available data for translation. Critics of translation programs argue that the most useful information is obtained through informal discussions of ongoing work, rather than through publications, which may contain data more than a year old. Another factor is that large companies tend to rely on their own data-gathering mechanisms, which smaller companies cannot afford. In addition, many private firms offer data-gathering and translation services in foreign countries for sale to other parties.[21] Federal Government translation programs thus risk competing with the private sector.

A policy alternative to massive government translation of foreign technical articles would be to recognize the importance of person-to-person contact in technology exchange. Congress could mandate that increased funding be provided **for** exchange programs, travel to international scientific meetings by U.S. scientists, language training for U.S. science graduate students, and sabbaticals abroad for U.S. technical personnel. Such funding is essential for U.S. visitors to Japan, for instance, where the national laboratories do not provide funds to cover the salaries of visiting scientists, and where postdoctoral fellowships are not available. **In addition, U.S. beneficiaries of these programs should be encouraged to publish accounts of their experiences, and to disseminate this information to U.S. industry.**

[17] A similar option is proposed in "A Competitive Assessment of the U.S. Advanced Ceramics Industry," NTIS PB84-1 62288, Department of Commerce, March 1984.

[18] Michael T. Kelley, Department of Commerce, personal communication, August 1987.

[19] For a review see "Monitoring Foreign Science and Technology for Enhanced International Competitiveness: Defining U.S. Needs," the proceedings of a workshop conducted by the Office of Naval Research and the National Science Foundation, Washington, DC, October 1986.

[20] See, fo, instance, Science Applications International Corp., "JTECH Panel Report on Advanced Materials in Japan," JTECH-TAR-8502, a contractor study prepared for the National Science Foundation, May 1986.

[21] One such firm is the Japan Technical Information Service of University Microfilms International, located in Ann Arbor, MI.

Option 6: Increase support for the development of standards for advanced materials.

Standardization, particularly the need for standard test methods, has long been identified as an important priority **for advanced materials (see ch. 5)**. The problems inherent in setting standards in rapidly moving technologies are clear. Standards development is a consensus process that takes years, and it is all the slower with advanced materials because of their complex and unfamiliar behavior. However, tackling the standards problem now rather than later **could** not only speed the development of the technologies, but also enhance the future competitiveness of U.S. advanced materials companies.

There are already international organizations that are pursuing advanced materials standards. Among these are the Versailles Project on Advanced Materials and Standards (VAMAS), with projects in 13 materials areas, and the International Energy Agency which is focusing on characterization of ceramic powders and materials. Currently, U.S. participation in these international standards-related activities tends to be part-time, with funds set aside from other budgets. Provision of separate funds for VAMAS liaison and international travel **for the** U.S. **officials involved could make** U.S. representation more effective.

Although U.S. participation in these international efforts **is** likely to be important, it will also be essential to develop domestic standards for advanced materials. Standards implicitly reflect the domestic capabilities of the originators, including specialized equipment and expertise. Having viable domestic standards would thus not only help U.S. industry to capitalize on domestic practices and capabilities but would also serve as a basis for negotiations on international standards.

Among the United States' foreign competitors, Japan appears to be making the largest overall effort in ceramics standards. Japan is actively seeking to establish international standards, and would prefer that those international standards resemble Japan's domestic standards as closely as possible—just as U.S. ceramics companies would prefer that those standards be close to U.S. domestic standards.

The principal disadvantage stemming from U.S. adoption of Japanese standards would be the loss of time involved with compliance. Moreover, Japan's quality control standards already allow the Japanese to produce ceramics at a lower cost. The rejection rate for final ceramic products, a major factor determining overall production costs, is significantly lower in Japan than in the United States.[22]

Option 7: Increase the pool of trained materials scientists and engineers by providing increased funding for multidisciplinary university programs in advanced structural materials and by providing retraining opportunities for technical personnel in the field.

To take advantage of the opportunities presented by advanced materials, the United States must maintain a viable population of trained materials scientists and engineers. Industrial **sources contacted** by OTA were nearly unanimous in their recommendation that more trained personnel are needed. Because materials science and engineering cut across many traditional academic disciplines, it will be essential to train students in multidisciplinary programs. This training should prepare them to take a systems approach in designing and manufacturing with advanced materials (see ch. 5).

Another important source of manpower is likely to result from the retraining in the field of designers and manufacturing engineers who are unfamiliar with the new materials. Small businesses, professional societies, universities, and Federal laboratories could all play a role in providing such retraining services.

[22] Steve Hsu, Chief, Ceramics Division, National Bureau of Standards, personal communication, November 1987.

TWO VIEWS OF ADVANCED MATERIALS POLICIES

Congress and the Reagan Administration have adopted conflicting views of policymaking with respect to advanced materials. In the congressional view, the Federal Government should formulate a high-level national plan for advanced materials research, development, and technology, whereas in the Administration's view, such goals and priorities should be established in a decentralized fashion by the principal funding agencies according to their various missions.

As indicated in table 12-3, Congress has long been concerned with materials issues, dating back to the Strategic War Materials Act of 1939 (53 Stat. 811). Through the 1950s, congressional legislation continued to focus on ensuring access to reliable supplies of strategic materials in time of national emergency. The 1970s saw congressional interest broaden to include the economic and environmental implications of the entire materials cycle, from mining to disposal. **In Title II of the Resource** Recovery Act of 1970 (Public Law 91-512), Congress called upon the executive branch to develop a comprehensive national materials policy relating to materials supply, use, recovery, and disposal. The Act authorized the National Commission on Materials Policy to identify national materials requirements and priorities, enhance coordination among Federal agencies' materials activities, and assign responsibilities for the implementation of national materials policy.

The National Materials and Minerals Policy, Research, and Development Act of 1980 echoed these themes, noting that the United States lacks a coherent national materials and minerals policy. It called on the President to coordinate Federal efforts to identify and assess materials **needs for commerce, the economy, and national security. It also mandated that the President submit to Congress a program plan outlining mechanisms for responding to these needs.**

In 1984, Congress explicitly extended these concerns to cover advanced materials with the passage of the National Critical Materials Act

Table 12-3. -U.S. Materials and Minerals Legislation

Strategic War Materials Act–1939
53 Stat. 811
Established the National Defense Stockpile, intended to accumulate a 5-year supply of critical materials for use in wartime or national emergency.

Strategic and Critical Materials Stockpiling Act–1946
60 Stat. 596
Authorized appropriation of money to acquire metals, oils, rubber, fibers, and other materials needed in wartime.

Defense Production Act–1950
64 Stat. 798
Authorized President to allocate materials and facilities for defense production, to make and guarantee loans to expand defense production, and to enter into long-term supply contracts for scarce materials.

Resource Recovery Act–1970
Public Law 91-512
Established the National Commission on Materials Policy to develop a national materials policy, including supply, use, recovery, and disposal of materials.

Mining and Minerals Policy Act–1970
Public Law 91-631
Encouraged the Secretary of the Interior to promote involvement of private enterprise in economic development, mining disposal, and reclamation of materials.

Strategic and Critical Stockpiling Revision Act–1979
Public Law 96-41
Changed stockpile supply period to 3 years, limited to national defense needs only; established a stockpile transaction fund.

National Materials Policy, Research and Development Act– 1980
Public Law 96-479
Directed the President to assess material demand, supplies, and needs for the economy and national security, and to submit a program plan to implement the findings of the assessment.

National Critical Materials Act—1984
Public Law 98-373
Established the National Critical Materials Council in the Executive Office of the President; the Council was authorized to oversee the development of policies relating to both critical and advanced materials; and to develop a program for implementing these policies.

SOURCE: Off Ice of Technology Assessment, 1988.

(Public Law 98-373, Title II). In **this Act, Congress established the National Critical Materials Council** (NCMC) in the Executive Office of the President and charged it with the responsibility of overseeing the formulation of policies relating to both critical minerals and advanced materials. The intent was to establish a policy focus above the agency level to set responsibilities for developing materials policies, and to coordinate the materials R&D programs of the relevant agencies. The NCMC is also directed to establish a national Federal program plan for advanced materials R&D.

Thus, the idea of a national materials policy for advanced materials is an extension of policy goals already articulated for a broad class of materials considered critical for the economy and national defense. Implicit in the congressional view is that national goals and priorities for advanced materials can be identified as readily as those for more traditional critical materials. According to this view, such goals and priorities should be established above the agency level, and agency spending on materials programs should be made consistent with them.

The United States has long had a decentralized approach to advanced materials policy. To a great extent, the major agencies that engage in materials R&D—DoD, DOE, NASA, and NSF—sponsor projects according to their distinct missions. In the congressional view, the growing technological capabilities of overseas competitors have underscored the urgency of establishing a nationally coordinated approach to advanced materials development. Advocates of a national materials policy point to the apparent capacity of Japan to identify key technologies for the future and pursue their development in a coordinated, government-industry effort, as has already occurred in Japan in advanced ceramics.

In the Administration's view, it is not appropriate for the Federal Government to engage in strategic advanced materials planning. Such planning would constitute putting the government in a position of "picking winners"—which, according to current Administration thinking, is best left to the private sector. Because different agencies have different missions and requirements for materials, the determination of R&D priorities is best made at the agency level. Administration critics of the national materials policy concept maintain that attempts to make materials policy above the agency level risk the worst aspect of Japanese policies—the creation of an overbearing bureaucracy—without achieving the best effect, which is the commitment and coordination of industry.

Although the materials requirements of different government agencies are diverse, meetings among agency managers of programs involving advanced materials are fairly frequent. In fact, several government committees meet to exchange information about ongoing advanced materials projects. These include the Committee on Materials (COMAT), within the White House Office of Science and Technology Policy; the interagency Materials Group hosted by NSF; and the Interagency Coordinating Committee for Structural Ceramics, which has a rotating chairmanship. A variety of coordinating groups also exist within various agencies, such as the Energy and Materials Coordinating Committee in the DOE. In the Administration's view, information shared through COMAT and the other interagency materials committees is adequate to avoid excessive duplication and waste in Federal materials R&D programs. Therefore, the congressionally mandated NCMC is considered redundant.

While the Administration has resisted the concept of strategic advanced materials planning for commercial competitiveness, it has embraced it with regard to national defense needs. DoD is currently preparing a comprehensive policy initiative aimed at preserving the U.S. defense industrial base. This initiative will target for support a portfolio of technologies, including machine tools, bearings, castings, semiconductors, and advanced composites. In addition, it will address such issues as technological obsolescence, availability of trained personnel, foreign acquisitions of U.S. companies, international cooperation, and government/university/industry collaboration.[23]

The congressional and Administration views reflect different philosophies regarding the appropriate Federal and private sector roles in technology planning and development. These two views are not easily reconciled. However, if some

[23] Robert Costello, Department of Defense, in a presentation to the annual meeting and industry conference of the Suppliers of Advanced Composite Materials Association, Arlington, VA, May 5-8, 1987.

of the debate can be clarified, common ground may emerge. Much of the confusion has to do with exactly what is meant by a "national materials policy."

There are several problems in defining the concept of a national materials policy clearly. One is that the scope of materials science and technology is extremely broad; even the rubric of "advanced materials" includes structural, electronic, optical, magnetic, and superconducting materials technologies. These technologies all have different levels of maturity and applications. This diversity cannot be fully addressed in the context of a single policy.

A further problem is that the policy considerations appropriate to various types of materials may be very different. Whereas policy goals such as conservation of scarce materials or reliable access to strategic minerals are easily understood in the context of conventional materials, it is much more difficult to define national goals for advanced materials. Advanced materials technologies tend to be application-driven, with specific performance requirements determined by specific applications. For instance, the cost and performance requirements of a ceramic tile for the space shuttle are very different from those of a ceramic diesel engine.

Perhaps the first steps toward a national policy would be to identify those materials (e.g., advanced ceramics) that may be regarded as especially promising, and to make the determination that a strong domestic fabrication capability is a national goal. The next step could be to identify and pursue—in consultation with industry—generic cost and performance objectives (strength, reproducibility, etc.) that will be required for the material to compete in a large number of products and processes. Japan's Ministry of international Trade and Industry has used this approach successfully in its collaborative ceramics programs with Japanese industry.[24] Alternatively, large demonstration programs could be undertaken that require major development and use of new materials. However, unless the end product of such a demonstration program is something that industry wants to commercialize, the program may not result in significantly greater commercial use of the materials.

A national policy approach to advanced materials is likely to have several potential advantages. First, it could provide a focus for the efforts of individual agencies and collaborative government/industry projects. Second, it could provide continuity of funding in a given area as fashionable R&D areas change from year to year. Third, it could provide a rationale for committing large amounts of resources for expensive demonstration programs. To be successful, such a national program should be structured with consultation and participation of academia, the Federal laboratories, and the industry community that will ultimately implement it.

Such a national approach also has several potential disadvantages. First, it may focus on the wrong materials and be too inflexible to capitalize on new opportunities that arise. Second, it may tie up resources and manpower in long-term projects that are better invested elsewhere. Third, because it cannot address the actual cost and performance requirements of materials in commercial markets, it may fail to produce materials or processes that are economically attractive to U.S. industry.

An alternative approach would be to enhance the present decentralized policy. The decentralized approach permits maximum flexibility of response to rapidly changing technologies and applications, and support for the broadest range of new materials technologies. One potential disadvantage of this approach is that the overall effort could be too fragmentary to bring together the critical mass of talent and resources necessary to solve the most difficult problems. This situation is particularly serious when investment risks are high, when the resources required are substantial, and when it is difficult for private companies to appropriate the full benefits of their investments. For instance, these conditions appear to apply to the development of more cost-effective advanced materials manufacturing technologies.

24 National Materials Advisory Board, *High Technology Ceramics in Japan,* NMAB-418 (Washington, DC: National Academy Press, 1984).

In such cases, collaborative efforts involving government, university, and industry participants are necessary to enhance the decentralized approach. Another critical requirement of this approach is continuous exchange of information among government agencies and industries involved in advanced materials R&D. This is necessary to ensure against excessive duplication of effort and to select for the highest quality research. Specific policy options for promoting more effective govern merit/university/industry collaboration and information exchange are discussed above.

The Critical Materials Act of 1984 invests the responsibility of developing a national materials program plan in the NCMC. To **succeed** in this task, the NCMC will need to establish a more precise definition of the goals that **would motivate** such a national plan, as well as to develop high-level Administration commitment to the concept of a national materials policy. At present, Congress and the Reagan Administration remain far apart in their views of the appropriate scope of a national materials program plan, and of the **role of** the NCMC. pending the resolution of these differences, there are three further functions that the NCMC could perform:

1 ***Serve as a point of contact to receive and monitor industry concerns relating to advanced materials.*** An organization **such as** the NCMC could provide forums for interaction between industry and the Federal Government on issues relating to advanced materials, particularly those that transcend the purview of any one agency, These forums could promote better mutual understanding of government and industry perspectives on advanced materials development, and they could eventually lead to the development of a consensus on promising future directions.

2. ***Serve as a source of information and referral regarding advanced materials.*** U.S. advanced materials programs and expertise are widely dispersed throughout various Federal agencies and laboratories. There is currently no definitive source of information that would provide an overview of ongoing efforts. An organization such as the NCMC could gather this information from the relevant agencies, analyze it, and disseminate it. Examples of the kinds of information desired include data on advanced materials projects **in Federal laboratories, agency** budgets for advanced materials, data on collaborative materials R&D at both Federal and State levels, industry performance statistics, and foreign materials R&D developments.

3. ***Serve as a broker for resolving conflicts between military and commercial agency goals for advanced materials.*** Some materials issues transcend individual agencies and therefore could be addressed most effectively by an organization operating above the agency level. For instance, the export control regime for regulating advanced materials and information relating to them is spread over the Departments of Commerce, State, and Defense, creating a situation that is very confusing to U.S. industry (see ch. 11). An organization such as the NCMC could work with the National Security Council to help simplify and clarify the three agencies' responsibilities.

ADVANCED MATERIALS POLICIES IN A BROADER CONTEXT

For U.S. industry, the risks of commercial investments in new structural materials technologies are great in the current business environment; however, the risks of failing to invest could be much greater. In the near term, there is little money to be made from **such investments,** The extent to which government and industry can cooperate in reducing or spreading these risks will have much to do with future U.S. competitiveness in advanced materials technologies.

In many respects, the competitive challenges facing advanced materials companies are a microcosm of the challenges facing the U.S. manufacturing sector as a whole. Therefore, advanced materials policy cannot be discussed in a vacuum.

Objectively, there is no more justification for the NCMC **than for a national microelectronics council or a national biotechnology council.** Moreover, policy options such as tax incentives for long-term capital investments or revising export controls could serve to stimulate a broad range of technologies, not just advanced materials.

Such far-reaching policies cannot be initiated at the agency level or in interagency committees; they clearly must be initiated in the highest councils of government. **Advanced materials policies,** therefore, can most effectively be addressed as one facet of a high-level, high-priority policy of strengthening the Nation's entire industrial and manufacturing base.