Chapter 8

Industrial Criteria for Investment

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Aggressive industry investment in the production and use of advanced materials will be one key to the future competitiveness of these industries. Based on extensive interviews, OTA finds that the investment criteria used by advanced materials companies vary depending on whether they are suppliers or users, whether the intended markets are military or commercial, and whether the end use emphasizes high performance or low cost .

Suppliers of advanced structural materials tend to be technology-driven. They are focused primarily on the superior technical performance of advanced materials and are looking for both military and commercial applications. They also tend to take a long-term view, basing their R&D investment decisions on qualitative assessments of the technical potential of advanced materials.

On the other hand, users tend to be market-driven. They focus primarily on short-term market requirements, and they expect to recover their investments within 3 to 5 years.

Frequently, suppliers and users operate in both defense and commercial markets. However, the investment criteria employed in the two cases are very different. Defense contractors are able to take a longer term perspective because they are able to charge much of their capital equipment expenses to the government, and because the defense market for the materials and structures is relatively well-defined. Companies supplying commercial markets, on the other hand, must bear the full costs of their production investments and face uncertain returns. Their outlook is therefore necessarily shorter term. This difference in market perspective has hampered the transfer of defense-oriented materials technology to commercial users, and it underlines the importance of well-defined markets as a motivating force for industry investments in advanced materials.

The many applications of advanced structural materials do not all have the same cost and performance requirements. Accordingly, the investment criteria of user companies specializing in different product areas are different. In general, barriers to investment are highest in cost-sensitive areas such as construction and automobiles, where expensive new materials must compete with cheap, well-established, conventional materials. Barriers are lowest in applications that can tolerate high materials and fabrication costs, such as medical implants and aircraft.

The process of developing a new structural material and manufacturing products from it is very expensive, and may take 10 to 20 years. Most potential users require a payback period not longer than 5 years, and an initial sales volume of $5 million to $50 million per year to justify production investments. In general, commercial end users do not perceive that these criteria will be met by advanced structural materials, particularly in cost-sensitive applications. OTA agrees that these expectations are probably correct; solution to the remaining technical and economic problems will take longer than 5 years. The high risk associated with this market uncertainty is the biggest single barrier to commercial production.

The existence of well-defined markets for new structural materials appears to be a necessary but not sufficient condition to stimulate substantial investments by commercial end users. OTA's industrial respondents identified a number of additional barriers to commercialization that are likely to persist as these technologies and markets mature:

- export controls;
- lack of trained technical personnel;
- tax law changes in 1986, including the removal of investment tax credits and reduced depreciation allowances;
- liability concerns and costs;
- uncertainties associated with government procurement practices, particularly defense regulations and policies;

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- time and associated costs of certification testing for advanced materials; and
- threat of technological obsolescence and the inability to obtain a defensible proprietary position.

INTRODUCTION

When a company considers the introduction of a new material into a product, it is likely to pay more attention to the business climate and opportunities for profit than to the specific material used. Moreover, most of the government policies that affect the business climate in which such decisions are made are blind to any particular material or technology.

In this chapter, therefore, a different approach is taken to the subject of advanced structural materials. Instead of focusing on different types of materials, as done in previous chapters, this chapter emphasizes a spectrum of end uses—biomedical, aerospace, automotive, and construction—that span a range of material requirements from high performance to low cost. This emphasis highlights the various factors that affect a company's decision to introduce a new material in these end uses.

The discussion presented here represents a distillation of extensive interviews conducted for OTA with over 75 organizations involved in the supply and use of advanced structural materials. [1] These interviews were supplemented with a workshop held at OTA on December 15 and 16, 1986. The participating organizations, including companies, government agencies, and trade organizations, are listed in appendix 8-1. What emerges is a portrait of the factors considered most important in a company's decision to invest in advanced materials research, development, and production. This information is also used to inform the policy discussion in chapter 12.

[1] Technology Management Associates, "Industrial Criteria for Investment Decisions in R&D and Production Facilities, " a contractor report for OTA, January 1986.

CHARACTERIZATION OF ADVANCED MATERIALS SUPPLIERS AND USERS

Private sector interest in advanced materials is pervasive, and the list of key companies spans a wide variety of industries. Advanced materials suppliers include companies with core businesses in chemicals, commodity materials, and defense, whereas the advanced materials users include companies in construction, automotive, aerospace, and biomedical industries. This diversity is the result of three major factors:

1. broad applicability of advanced structural materials to military and commercial products due to their superior performance characteristics and potential for cost savings;
2. opportunities for diversification perceived by those domestic industries facing mature or declining markets and foreign competition; and
3. existence of specific government programs—especially defense programs—that have created a market for advanced materials.

All of the advanced materials supplier companies interviewed considered themselves to be technically sophisticated and motivated by the performance characteristics of advanced structural materials. Even commodity materials companies make a point of saying they address "technology development for our customers" or describe themselves as "engineered materials companies. " A sense that advanced structural materials is the "place to be" dispels the lack of hard economic justification for R&D and commercialization investments.

As one chemical industry executive put it:

> It **is not** unusual in this business–for that matter **in other similar kinds of materials technology businesses–for companies to say, "if the market looks like a $10 billion market 10** years **from now, then we are willing to invest** in that market without being able to do an accurate assessment of the potential return. " We think that we can play technologically—we are a technical-based company. So we are headed in that direction. If the market promises to be big enough, we want to play.

Advanced materials user companies in the construction, automotive, aerospace, and biomedical industries are focused on market needs and cost competitiveness. They put a major emphasis on the use of advanced structural materials to enhance market acceptance of their final products. However, enhanced material performance has value for them only if the potential market places a premium on performance. Otherwise, new structures and processes must demonstrate comparable performance with lower costs compared with the materials in current use.

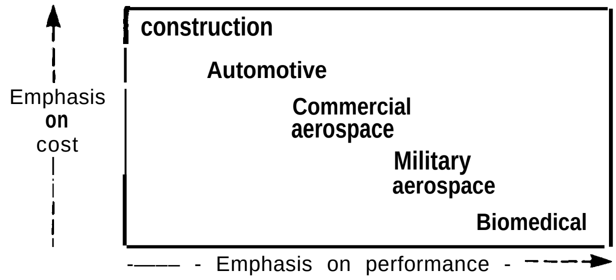
As portrayed conceptually in figure 8-1, cost and performance factors differ in importance among the various industry segments involved. In commercial aerospace, automotive, and construction markets, for instance, acquisition costs and operating expenses are the major purchase criteria, with a progressively lower premium placed on high material performance. In military aerospace and biomedical markets, on the other hand, functional capabilities and performance characteristics are the primary purchase criteria.

The sales potential of advanced materials is **greatest** in the markets in the center of figure 8-1; e.g., automobiles, and commercial aircraft. Construction materials are used in high volume, but must have a low cost; biomedical materials can have high allowable costs, but are used in relatively low volume. Characteristics of these potential markets for advanced materials are described below.

Construction Industry

The construction industry is extremely fragmented, being made up of many small companies, both suppliers and users. In general, the

Figure 8-1.– Relative Importance of Cost and Performance In Advanced Material User Industries



Barriers to the use of advanced materials decrease from upper left to lower right.

SOURCE: Technology Management Associates, "Industrial Criteria for Investment Decisions in R&D and Production Facilities," a contractor report for OTA, January 1986.

industry's products are low-cost, high-volume commodities and, except for specialty applications, introduction of new, more expensive products is extremely difficult.

The construction industry is mature and conservative in nature. Public safety requires long demonstration periods before the adoption of new approaches, and the industry itself has very little to do with the performance specifications. In general, the industry builds a structure that others have specified, to codes and regulations that change very slowly. Furthermore, the retraining of the labor force required to implement new materials and processes may be extensive. Therefore, construction companies are generally not innovative or R&D oriented, and new product developments are relatively rare.

To complicate matters, the current business climate is generally depressed. Construction materials companies have been losing money for several years, and they are taking defensive actions to protect existing markets. In explaining their plight, industry respondents cited a "foreign invasion" of "low-cost imports. " Foreign ownership of U.S. construction materials companies is estimated by industry executives to be 40 to 50 percent of the entire U.S. construction materials industry—up from 3 percent 15 years ago. Foreign companies are attracted by the current restructuring of U.S. industry, the strong U.S. technical base, and the very favorable currency exchange rates.

One promising approach to the use of new materials in construction is to use them in repair, maintenance, and rehabilitation of existing structures. In this way, the materials' performance can be evaluated over time without relying on them to sustain the fundamental integrity of the structure. By this means, innovative materials may become integrated into the system and may be considered in the development of new construction codes in the future.

Automotive Industry

The automotive industry companies–a few large automobile manufacturers and a large number of smaller component fabricators and suppliers–are faced with severe price competition. Although greater fuel economy has receded as a driving force for introducing new materials into automobiles, there is continuing interest in potential cost savings from the use of advanced structural materials through both part consolidation and reduced tooling costs.

The industry focuses on R&D that could be commercialized within 5 years; internally funded long-term research programs involving advanced ceramics and composites have been greatly reduced or postponed. For example, industry executives gave the following reasons for their companies having abandoned research on ceramic gas turbine engines:

- "limited fuel economy potential when compared to other available power plants";
- "multifuel possibilities not an asset in the domestic market";
- "no packaging or design flexibility benefits"; and
- "significant technical challenges—not available within the 1990 time frame."

Most of the current R&D is focused on near-term reductions of component costs and production expenses. Some of those cost reductions involve limited replacement of metal components in gasoline engines with ceramic materials. However, as one respondent said:

> Some components produced from advanced materials offer little advantage over conventional metal technology, and the production decision would depend on cost competitiveness.

The automotive industry is conservative in the application of advanced materials technology. From the perspective of advanced materials suppliers, the industry appears interested only in incremental improvements. As one supplier noted:

> When you go to apply a new material to the automobile design problem, the characteristic response is, "We made it in steel. Use the same diagram and give us a new material that we can make into the same equipment and then we'll buy your prod uct." They don't approach the car design from the systems design view as an integrated whole.

Automotive manufacturers require extensive static and fleet testing of new components and a minimum lead time of 3 to 5 years to introduce product innovations. However, it was the view of several materials supplier executives that given a change in attitude, advanced materials could be rapidly adopted by the industry. They noted that in Japan, the use of ceramic fiber-reinforced pistons for small diesel engines progressed in only 3 years from limited production of a specialized Toyota vehicle to use in all diesel engines of that size.

Most materials development for automotive applications is being conducted outside of the three major automakers, by both material and component suppliers—companies that manufacture valves, pistons, and other automotive components. One industry spokesman stated that:

> You will find that a lot of the innovation and a lot of the new design work and new materials work is being done outside of the automobile builders, who are becoming assemblers of components. There is a significant amount of work going on.

Aerospace Industry

Like the automotive industry, the aerospace industry is composed of relatively few large companies that manufacture aircraft, plus many smaller companies that manufacture and supply components. The military market for high-performance aircraft has driven the development and application of advanced materials in the aerospace industry. To a limited degree, use of these materials also carries over into the manufacture of commercial transport aircraft. For instance, composite materials are used in nonstructural components, such as control surfaces, fairings, and trailing edge panels; also, the European consortium Airbus uses composites in primary structural components of its commercial transports, including both vertical and horizontal stabilizers (tail assembly).

Commercial aircraft manufacturers, like automobile manufacturers, are facing stiff competition and are currently seeking to minimize the cost of their commercial products. Use of composite structures offers the potential for reduced aircraft weight and hence lower fuel costs. However, the recent decline in the price of fuel has reduced the attractiveness of composites. The industry attitude toward advanced structural materials R&D and production is reflected in this comment from an aerospace company manager:

> **During the era of the Boeing 767, composite materials were worth $300 per pound (in fuel savings over the life of the aircraft); today they are worth $75 per pound (because of lower fuel prices).**

For several years there have been intensive efforts to develop and certify general aviation aircraft that make extensive use of advanced composites. Because these aircraft are designed from the start with composite materials and fabrication processes in mind, the composite airframe is likely to be cheaper than a comparable metal airframe. According to one manufacturer in the general aviation market:

> **The cost has been driven higher than private users can afford to pay for airplanes.** We **think that the use of composites can help us get those costs down.**

Biomedical Industry

R&D on biomedical applications of advanced structural materials is conducted primarily i n orthopedics and dentistry. Companies in this industry make specialty products to solve medical or laboratory problems. Technical superiority or innovation confers an important competitive advantage and is the primary motivation for continued R&D. Fourteen of the fifteen companies interviewed currently have active R&D programs that are strongly product-oriented and market-driven.

In the dental and orthopedic segments, reduction of the cost of components or of product fabrication are not particularly important motivations for R&D because these costs are usually passed on to the customer. Furthermore, the actual cost of the product is small compared to the cost for the professional services (medical and dental fees) required to install the product.

in contrast to the automotive and construction industries, which are static or declining, the advanced biomedical materials industry is rapidly expanding. Advances in materials as well as advances in basic medical and dental research make this a rapidly moving field, so that products tend to last only a few years, This fuels the competitive pressure to invest in additional R&D.

R&D efforts are focused primarily on material evaluation, certification testing, and fabrication technology development. Most companies do not develop new materials. Rather, materials originate outside the biomedical industry —e.g., from aerospace materials suppliers. However, because the quantity of materials used in dental and orthopedic applications is so small, many such suppliers have not cultivated the biomedical market.

INDUSTRIAL DECISION CRITERIA FOR R&D AND PRODUCTION

The criteria used by industry sources interviewed by OTA fall into two groups, depending on whether the respondents represent suppliers or users. Suppliers of advanced structural materials tend to be technology driven—they focus primarily on superior technical performance of advanced materials and look for applications. Users tend to be market—driven—they focus primarily on market requirements.

There are two factors, however, that tend to blur this distinction. First, advanced materials suppliers are often supported partially or wholly by military contracts, and thus they have the luxury of focusing on high-performance materials for the long term. Second, R&D expenditures are typically an order of magnitude less than production expenditures; thus, while suppliers spend more freely on R&D than end users, both users and suppliers tend to focus ***on*** market-related criteria in making production investment decisions.

As pointed out by one executive from a company that is both a ceramic materials supplier and component manufacturer, companies must make investment decisions all along the spectrum from basic research through production:

> The decision making **process changes dramatically depending** on where **you are in** R&D and whether or not you're ready to go into production. In the research phase, numbers are pretty soft-you identify an opportunity and make a small investment by comparison to later phases. **As you move up that curve to the development phase, you're dumping a lot more money in.** When you make that final decision to go into production, you're talking about the big bucks and you want to have as hard a number as you can **get your hands on.**

R&D Investment Criteria

The major criteria employed by suppliers and users of advanced materials to assess R&D and production investments in advanced ceramics and composite materials are indicated in table 8-1. The more technology-oriented criteria are listed toward the top, and the more market-oriented toward the bottom.

Very few of the suppliers interviewed purported to use typical business assessment tools (e.g., return on investment) in selecting and ranking advanced materials R&D projects. Although some executives indicated that potential market size was considered, most often they used preliminary estimates merely as an order of magnitude indication of the potential market. A typical attitude was:

> **If you estimate market size–you'll quit. We don't know the ultimate markets yet. Discounted cash flow methods will tell you to get out of advanced ceramics research—you have to operate on faith that a ceramics market will** develop.

Table 8-1.—Industry Investment Decision Criteria

	Materials suppliers		Materials users
Decision criteria	R&D	Production	R&D and production
Corporate technical capabilities	★		
Material performance characteristics	★		★
Fit with corporate strategy	★		
Competitive threats	*		
Threat of technical obsolescence		*	
Sales **volume:** **• Market volume** **• Market share**		★	★
Return on investment or assets		*	★
Timing: • Payback period • Time to market			★

*indicates major investment criteria.

The more technology-oriented criteria are listed toward the top, and the more market-oriented toward the bottom, As a group, suppliers apply more qualitative, technology-oriented criteria to R&D investment decisions than users do. However, both suppliers and users apply quantitative, market-oriented criteria to production investment decisions.

SOURCE: Technology Management Associates, "Industrial Criteria for Investment Decisions m R&D and Production Facilities, " a contractor report for OTA, January 1986.

The attitudes of advanced materials suppliers and users toward the investment criteria listed in table **8-1** are discussed below. The technical capability of the company—viewed both in terms of research resources and production experience —was the criterion for R&D investment most often mentioned by materials suppliers. It is a general industry view that success in materials R&D is to a great extent dependent on technical experience and the existing corporate technology base, including facilities, personnel, and equipment. Highest priorities go to R&D projects that build on the corporation's technical experience in related materials research and production.

Some corporations without the technical capability to participate in specific aspects of advanced materials R&D obtain the necessary capabilities by hiring personnel, corporate acquisitions, or joint ventures. Many companies also supplement their R&D capabilities by participating in collaborative efforts with universities and Federal laboratories. Although some corporations feel that this is an appropriate R&D investment, results are considered "spotty," and many companies feel that the most beneficial aspect of the collaborative programs with universities is access to top-quality students. (This view is consistent with the analysis of university/industry collaborative programs in ch.10.)

Corporate consideration of the potential materials performance characteristics reflects an interest in material functions that have a higher value, such as thermal stability or strength. Both suppliers and users cited superior performance characteristics as a principal motivation for R&D investments. However, most of the user companies in the aerospace, automotive, biomedical, and construction industries conduct R&D that is closely tied to near-term production, such as material evaluation, fabrication technology development, and certification or qualification testing.

Many companies also use "fit with corporate culture" as a criterion for R&D investment. Suppliers identify themselves as "an engineered materials producer," "a chemical company's chemical company, " or in other similar terms that are consistent with the high-technology culture. A proposed R&D project that does not fit with this corporate image is often abandoned.

Some companies, concerned that their competitive position may change, pay close attention to the materials R&D that other companies are conducting. Many companies have made a conscious decision to maintain a technical lead in specific markets (e. g., aerospace) and conduct R&D to keep ahead of the competition. One supplier of composite materials indicated that:

> . . . **more improvements have been made in thermosetting composites in the last 12 months than in the last 10 years to compete with thermoplastic composites, because it looked like the Air Force was going to be inclined to use thermoplastics (for the Advanced Tactical Fighter).**

Production Investment Criteria

Although suppliers and users are not all in agreement about the timing and amounts of capital to invest in production facilities, most companies agree that the production decision depends on three major criteria: the threat of technological obsolescence, potential sales volume, and return on investment.

The threat of technical obsolescence is an important criterion in the production decision. Materials suppliers are concerned, for instance, that a facility could become uneconomical due to a significant advancement in production technology, or that a technically superior product could displace the company's own product in the market.

Suppliers interviewed indicated that **an initial** sales volume of $50 million to $200 million would be necessary to induce investment in a new production facility. However, most companies also expect the potential for that sales volume to grow to $1 billion in 10 years.

For some suppliers, such as manufacturers of aerospace composite materials, the production decision is simplified. If the company's products are qualified by the military for specific programs, such as the Advanced Tactical Fighter program, then the total market for composites can be estimated with reasonable certainty by using some judgment based on the number of other composites that are also qualified (an indication of market share).

Potential sales volume is also a very important criterion for materials users in evaluating both R&D and production investments. Initial sales volume requirements range from $3 million to $5 million among biomedical companies to $50 **million** to $100 million in the automotive and aerospace industries.

The potential return on investment (ROI) is an important criterion in the production decision for both suppliers and end users. The after-tax **ROI** required by supplier companies ranges from 10 to 30 percent. This range reflects corporate assessments of potential risks and uncertainties in the market. Suppliers of advanced materials to the military have generally lower ROI criteria—10 percent—whereas chemical and materials companies selling in commercial markets require higher ROIs–20 to 30 percent. However, this comparison may be somewhat misleading in that military contractors have traditionally been able to charge a significant amount of their development costs to the government instead of taking them out of sales, as in the commercial case.

The market timing criteria employed by commercial end users of advanced materials interviewed by OTA varied significantly with industry. The aerospace industry generally has a longer term view than most other end users, and timing is not a major factor **in either** R&D or production investment decisions among military aerospace companies. However, as a group, end users require that capital equipment costs be recovered in a shorter time than do the materials suppliers. Most end users require a payback period of 3 years or less, with profits in less than 5 years, before investment in production would be considered.

BARRIERS TO COMMERCIALIZATION OF ADVANCED MATERIALS

Although a diverse array of companies from various industries are involved in R&D and commercialization of advanced structural materials, some common themes emerged when industry executives were queried about the reasons why they would hesitate to establish new R&D programs or commercialize new products involving advanced ceramics or composite materials. The perceived barriers were somewhat different depending on whether the intended market was military or commercial.

In the case where the government is the customer for both R&D and advanced materials products (especially military programs), market uncertainties are reduced, and the planning horizons of materials suppliers and manufacturers are much longer. As one supplier of composite materials noted:

> **A** distinction needs to be made between an **industry** in which the government is a strong driver and a major customer, **such as the aerospace industry, which has been a champion of composite materials—a truly long term commitment—and** the part of the economy which depends on the general market situation.

Among commercial end users, the profits that could be projected within the planning horizons of the company in most cases do not justify the near-term production costs. Advanced materials involve a long and costly commercialization process in a business environment that often requires a short-term focus; moreover, the currently depressed business climate in certain sectors of the economy—including construction, automobiles, and general aviation aircraft-results in a preoccupation with protecting existing businesses.

Representative of industry views was the following comment made by an advanced material supplier to the aerospace industry:

> **There is a long gestation period–between the time that you develop a product, have it qualified, and when you sell it. A company has to have done it before or the management will probably get very impatient, because the R&D and qualification is done 3 to 5 years before the purchase. That is different from the commercial polymer business where you can start seeing some sales in a year or two. A company has got to be patient, and most companies are not.**

Observed one advanced ceramic supplier and component manufacturer:

> In the truly private sector **of the economy, a strong case can be made that a short-term preoccupation with cash** flow has made it difficult for material suppliers and component manufacturers.

Within this context of two very different market situations, military and commercial, several common barriers to production of advanced materials and structures were cited in industry interviews. These include: 1) the lack of an adequate experience base and data on the mechanical and processing properties of materials; 2) the lack of a suitable technology infrastructure for guaranteeing that advanced materials with specified properties can be produced; and 3) insufficient numbers of trained materials scientists and engineers. In addition, the high cost and long lead time associated with the safety and performance certification of new materials was perceived as a problem in both the biomedical and aerospace sectors.

On the other hand, the different market situations also led to some different perspectives on the principal barriers to investment. Not surprisingly, the defense-oriented side of the industry tends to single out defense policy-related concerns, while the commercial side cites broader economic and government policy concerns. These are discussed below.

Concerns of Defense-Oriented Suppliers and Users

The role of the Department of Defense in the R&D and production of advanced materials and structures is explored in detail in chapter 11. Here, however, it is appropriate to note some of the more commonly expressed industry attitudes.

Export restrictions and controls reduce the competitive position of U.S. companies abroad and can result in investment in production facilities outside of the United States.

Industry executives view government policy on the export of advanced materials as a major barrier to commercialization because it limits the ability of U.S. businesses to compete globally. Government delays in processing license applications, for instance, raise the costs of delivering the product to the market. Non-U.S. customers do not want to do the paperwork.

One supplier of composite materials declared:

> If I have to ask my customer to go to his government to get an import certificate so I can go to my government to get an export certificate, it just costs both of us money, plus the hassle and the time . . . [f I sell him the same material four months from now, we go through the whole show again.

Another supplier of composite materials made this point:

> Carbon fiber and carbon fiber-based prepregs are technologies that are freely available in Europe and the Pacific, yet a U.S.-based company shipping overseas must apply for an export license for technology and for product.

In addition, in the carbon fiber case, export licensing requirements place U.S. companies at a further disadvantage in foreign markets. A European aircraft manufacturer that buys carbon fiber prepreg material from a U.S. company must get permission from the U.S. Government to export the finished airplane. If the same European company buys from another supplier in Europe or Japan, the paperwork and U.S. restrictions can be avoided.

One consequence is that U.S.-based firms making composite materials have transferred production to Europe to supply European customers to avoid "messing with the bureaucracy." One advanced ceramics component manufacturer interviewed by OTA indicated that the U.S. requirements for export licensing of machined components have also resulted in U.S. ceramics corporations setting up component finishing shops in Europe to avoid the paperwork.

Delays in shipping caused by the necessity of going through the export license process gives the appearance that U.S. companies are unresponsive to market needs. Furthermore, as one supplier of ceramic materials noted:

> When we must file a statement with the Department of Commerce that describes the intended use, our customers complain about loss of confidentiality.

Industry interviews also indicated that the private sector is concerned over the inconsistencies in the overall Federal export policy. One source complained that:

> The Department of Commerce encourages exports and the Department of Defense restricts them.

Differing Federal standards among government agencies slow the commercial introduction of military technology.

Different standards, approaches, and experience levels of regulatory agency personnel can inhibit the transfer of technology from the military/defense arena and government space programs to private sector applications. In aerospace applications of advanced composite materials, for instance, one industry executive identified a key issue:

> Materials that spin out of the military aerospace programs (and supposedly are well-characterized or qualified for military applications) must be retested for the Federal Aviation Administration (FAA).

Aerospace industry executives suggested that FAA acceptance of military-qualified materials and applications could be enhanced by the accelerated development of a military specification handbook for advanced materials, comparable to the currently accepted Military Handbook 5 for metals. Such an effort is in fact under way. Military Handbook 17 on composite materials is currently under development by the Army Materials Laboratory in Watertown, MA.

Some executives, though, doubted that the availability of such standards would reduce the testing required by individual aerospace companies. As executives from the aerospace and advanced composite supplier fields stated the problem:

- "every corporation has its own specifications";
- "companies will not accept data from anybody else";
- "aerospace companies will not share their data"; and
- "if you've got six people vying for a military contract, you will have to qualify that given material six times. "

Government procurement practices may discourage some advanced materials developers from participating in government markets.

Some industry executives voiced specific concerns over certain procurement policies and practices which they encounter in the Federal sector. In particular, the following issues were raised in interviews and at the OTA workshop: 1) procurement contracts are made with more than one source, which may force a company to share its technology with its competitors; 2) awards are customarily made to the lowest bidder, which favors existing suppliers and materials over new suppliers and materials; and 3) there is too much burdensome red tape.

These issues were identified in interviews with every company that participates or has attempted to participate in government programs. Those companies that have been major suppliers to the military consider these issues "just the cost of doing business. " However, some companies trying to enter the government market identified them as real concerns. **In fact, some companies, particularly in the biomedical industry, have decided** to avoid government programs for these reasons.

A further issue is that government policies intended to assure domestic supply of scarce or strategic feedstocks may actually inhibit private sector investment. For example, the Title III program in the Defense Production Act (64 Stat. 798) permits the government to mitigate shortages of critical materials through purchasing mechanisms.

One advanced ceramics materials supplier described the private sector investors' problem in this manner:

> **You have an investment plan all ready to put before the board and here the government is coming** in with **a big attack on the issue. They're going to create multiple sources for domestic production. What should you do? You are interested in that business and you see that the government is going to throw money at a program which you might have a chance to get, and you know your competitors are going to be looking at. What do you do? You wait.**

Concerns of Commercial Market= Oriented Suppliers and Users

Liability issues increase the risk and cost of development programs.

The manufacturer's liability in the event of product failure is a disincentive to innovation for advanced materials suppliers and for users in all industry segments. In the construction industry, for instance, long demonstration periods are required to gain user and consumer confidence **in the safety of new or innovative materials.**

In other industry segments as well, liability protection, or extensive pre-testing to guard against liability, is one of the biggest costs in the introduction of new products. In the words of one supplier of ceramic materials:

> **The automotive industry is conservative, and very sensitive to the failure of a supplier's part that will cause General Motors to be liable for work under warranty. Extensive testing is required and must project well** below 3 percent failure rate to be within the automotive manufacturers' warranty limits.

A user of advanced biomedical materials made this observation:

> The government **has to fix the liability problem–it's the biggest cost. Industry has been very responsible; no company would knowingly put**

> **out an unsafe product. With most prostheses that break, it's a medical problem, not a materials or fabrication defect.**

Added a user of advanced composites in the manufacture of general aviation aircraft:

> **Liability costs have gotten to the point where the private user cannot afford to buy a new airplane.** The minute an airplane goes out the door, the customer has to pay around $70,000 and that just supports our legal efforts.

patent protection is a major issue for some advanced materials companies.

For many of the companies involved in advanced materials—especially manufacturers of advanced ceramic components—their inability to protect their patent position is a factor that inhibits investment in R&D and commercialization programs in advanced materials. A representative point of view, as expressed by a supplier of ceramic materials, is as follows:

> Ceramic component manufacturers have no way to protect processes with patents. A process patent law that will cover ceramic component fabrication technology is needed. Current infringements go unpunished.

However, several materials suppliers and users throughout all industry segments tend to disregard patents. One ceramic component manufacturer feels that patents are not very useful, noting that:

> patents today may not be worth much 5 years from now because technology is advancing so rapidly.

Recent changes in the tax laws may create significant barriers to R&D investment.

Changes in the tax laws in 1986 are likely to affect both suppliers and users of advanced materials. Industry executives cited several changes that may directly inhibit investments in R&D and the markets for products containing advanced materials. Chief among their complaints were the removal of investment tax credits and reduced depreciation allowances. On the other hand, one supplier of ceramic materials components pointed out that:

> . . . **if you look to the tax situation as a decisionmaker, you're making a mistake, because what the government can give they can take away in** the next Congress. **Any advantage due to the** current tax situation can erode.

Changing product certification requirements can p/ace a competitive disadvantage on *market leaders.*

Testing for product certification-primarily to meet government requirements—was one of the specific inhibitory factors cited most often both by suppliers and users, particularly in the aerospace and biomedical industries. Certification and licensing requirements contribute heavily to both development costs and the time required for R&D and commercialization. For example, in the words of one composites supplier to the aerospace industry:

> It costs $1 **million to get a new fiber and prepreg certified through the Federal Aviation Administration, and it could take 10 years.**

A supplier of ceramic materials made this comment:

> Acceptance testing for ceramic materials takes too long–on the order of 7 years for many applications. The **expense is not the key–it's the time.**

And a user of advanced biomedical materials complained:

> The biggest impediment is the Food and Drug Administration (FDA). Testing and retesting every small improvement takes time and money.

Certification expenses can include both the direct costs associated with testing a material or retesting a military-qualified material, as well as the indirect costs of "educating" personnel in Federal regulatory agencies, such as FDA and FAA. Companies that are first to market may be at a competitive disadvantage if "close follow" companies can avoid some of the costs and delays by marketing a very similar product.

A good example of this principle is advanced materials R&D in the biomedical industry. Biomedical products introduced after the 1976 Food and Drug, Device and Cosmetics Act (Public Law 94-295) that are "substantially equivalent" to products classified by FDA before 1976 can be sold on the open market on the basis of a short approval application. However, manufacturers of new technologies, such as advanced ceramic or composite implants, are required to file an "Investigational Device Exemption" (IDE) and to carry out expensive preclinical and clinical trials. After 2 to 3 years, the company may seek FDA approval of that specific product on the basis of the clinical trials.

In theory, each additional company with a similar product also has to go through the same **IDE** process. However, FDA may change the status of a material if clinical evidence shows that the material is safe. Once the material is reclassified, other companies seeking to market products made from the material for essentially equivalent applications need only file a short statement of the material's safety record. Therefore, every innovative leader must perform expensive tests to prove its product is safe to win FDA approval, but at the same time it risks wasting its investment in development and testing.

In summary, the concerns identified above constitute significant barriers to companies seeking to produce ceramic and composite products for commercial markets. However, the principal barrier remains the fact that investments in advanced materials R&D and production do not meet the cost/benefit criteria of most U.S. commercial end users today. Thus, there is very little commercial market pull on these technologies.

At the same time, it is important to recognize that some foreign competitors do not apply the same cost/benefit criteria to their investments; rather, they take a longer term "technology push" approach, and they are prepared to sacrifice near-term profits to obtain the experience in manufacturing with advanced materials necessary to secure a greater share of the long-term markets. This theme is developed further in the next chapter.

APPENDIX 8-1: ORGANIZATIONS INTERVIEWED

Corporations:

Aluminum Co. of America—Alcoa Laboratories
Aluminum Co. of America—Ceramics Division
AMOCO Performance Products Inc.
BASF Corp.—Celion Carbon Fibers Division
Beech Aircraft Corp. *
Biomet Inc. Research and Development
Blasch Precision Ceramics Inc.
Boeing Commercial Airplane Co.
Business Communications Co., Inc.
Calciteck Inc.
Calmat Co.
Cannon Publishing–Medical Devices and Diagnostic Industry
Ceiba-Geigy Corp.–Plastics and Additives Division
Champion Spark Plug Co.–Ceramics Division
Chrysler Corp.–Metallurgical Development Department
Concrete Technology Corp.–R&D
Coors Biomedical Co.
Coors Porcelain Co.
Dentsply International Inc.
DePuy Co.
Douglas Aircraft Co.
Dow Chemical Co. USA–Central Research
Dow Chemical Co. USA—Ceramics
Dow Corning Corp.–Advanced Ceramics Program
Du Pont Co.
Dural International Corp.
DWA Composite Specialties, Inc.*
Dynamet Technology, Inc. *
Ferro Corp.–Commercial Development
Fiberglass Structural Engineering Co.
The Garrett Corp.
General Dynamics Corp.
General Motors Corp.–AC Spark Plug
General Motors Corp.—Detroit Diesel Allison
Genstar Stone Products Co.
Grumman Corp.–Aircraft Systems*
Hercules, Inc.–Graphite Materials
Hexcel Corp.
Howmedica, Inc.
Hysol Grafil Co.
ICI Fiberite
Integrated Polymer Industries, Inc.
Johnson & Johnson–Dental Products Co.
Kaiser Cement Corp.
Kerr Sybron
Lockheed Corp.
Lone Star Industries, Inc.
McDonnell Douglas Corp.—Aerospace

● Workshop participants whose comments are reflected in this chapter.

Mobay Corp.
Northrop Corp.–Aircraft Division
Norton Co. *
Orthomatrix
Owens-Corning Fiberglass Corp.–Technical Center
PPG Industries, Inc.
Price Brothers Co.
Richards Medical Co.
Salt River Project–Structural Engineering
Shell Chemical Co. *
SOHIO Engineered Materials Co.–Structural Ceramics Division
Stanley Structures, Inc.
Sterling Winthrop Research Institute
Techmedica, Inc.
3M Co.– Health Care Group Laboratory
Transpo Industries, Inc.–R&D
Union Carbide Corp.–Specialty Products Group
Westinghouse Electric Corp.–Advanced Energy Systems Division
Westinghouse Electric Corp.–R&D Materials Science Division
Wiss-Janney-Elstner Associates

Government agencies:

Federal Highway Administration–Paving Materials
National Bureau of Standards
National Institutes of Health–Division of Research Services
State of Connecticut–Department of Transportation
State of Texas–Highway Department
U.S. Department of Commerce–Chemicals Group
U.S. Department of Commerce—Non-ferrous Metals Division
U.S. Department of Energy–Oak Ridge National Laboratories
U.S. Department of Energy–Argonne National Laboratories
U.S. Army Corps of Engineers

Industry trade groups and advisors:

ACI Concrete Materials Research Council
American Concrete Institute
American Society of Civil Engineers
Mount Sinai Medical Center*
National Ready Mix Concrete Association
Portland Cement Association
Prestressed Concrete Institute
Suppliers of Advanced Composite Materials Association
U.S. Advanced Ceramics Association

*Workshop participants whose comments are reflected in this chapter.