STRATEGIC MATERIALS

ABSTRACT

A fundamental shift in thinking has occurred in the US over the past 50 years concerning strategic and advanced materials. Historically, the focus has centered on national defense, but with the increased globalization of national economies, a broader concept of strategic and advanced materials has emerged. The new perspective asserts that national security planning encompasses the broad welfare of a society, which includes economic and political as well as defense considerations. This broad perspective on national security is evident in many countries. The mechanism driving the strategic materials industry in this regard is the global market economy. Economic growth and prosperity has emerged as a primary goal in our national security strategy. Strategic materials both enhance the growth of our economy and promote national security. Therefore, it is vital to US national security that it maintains a commitment to further and continue development of these strategic materials industries.

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INTRODUCTION

Strategic materials and minerals are an integral part of everyday life. They are at the very core of US industry. But every nation is not equally endowed with the materials needed to promote the welfare of its citizenry or the continued growth of its economy. Some regions possess great mineral wealth but lack the requisite technological know-how, means, or economic policies to adequately exploit the materials. Other countries lack such minerals but have managed to thrive nevertheless.

The US is in the exceptionally favorable position of combining a very deep and diverse resource base with the advanced technology and market-based incentives required to exploit its resources to satisfy both its civilian economic needs and its defense industries. When the US had concerns about sufficiency of certain minerals and materials, it established national defense stockpiles to assure these minerals and materials would be available when required. This report will highlight the changing conditions of the strategic materials industry in the US and selected other countries.

THE STRATEGIC MATERIALS INDUSTRY DEFINED

The term "strategic materials" does not refer to any specific industry. Instead, "strategic materials" transcends many different industries from mining, to those converting raw minerals into usable materials, to those using the materials in the manufacture of intermediate and end products for civilian and military use.

In order to study this "industry," it was necessary to further categorize strategic materials along two lines: traditional materials that have been used for many years and advanced materials, many of which have recently emerged or are still being developed. This study focused its effort on two traditional strategic materials (aluminum and steel) and two types of advanced materials (ceramics and advanced composites).

The members of the strategic materials industry fall into two basic classes. First, there are the large, publicly traded corporations involved in the production, manufacture, and use of traditional materials. Second, there are the many smaller firms or government-sponsored organizations involved in the research, development, and promotion of advanced materials. The market for special advanced materials continues to be concentrated in special fields where, for example, low strength-to-weight ratios are of primary concern and cost is a secondary issue (e.g. aerospace). The market for traditional materials continues to be concentrated in areas where cost is of primary concern (e.g. construction).

Steel. Current steel making is accomplished by two basic methods. The first method, integrated steel making, is the process of making steel "from scratch," directly transforming iron ore into steel through two steps, melting the ore in a blast furnace and then adding alloys to the molten liquid to form hardened steel. The second method takes scrap steel and iron, melts this scrap down in a furnace heated by electric arc elements, and then again adds alloying agents. This recycling of iron and steel products is the electric arc furnace or mini-mill method. The industry overall is extremely energy-, capital-, and labor-intensive. Steel types and quality are defined by alloying agent purity and precision in casting and milling.

Aluminum. Aluminum is made through two basic methods. The first, the primary process, converts alumina (from bauxite ore) into aluminum through the electrolytic Hall-Heroult Process (HHP). The second, known as the secondary process, converts scrap aluminum into useable metal. This secondary method accounts for one-third of US aluminum production and is used almost solely in the container industry. Primary aluminum production is extremely energy- and capital-intensive. The secondary process requires only 5-8% of the energy required in the primary process. The US is the world's largest producer of aluminum.

Advanced Ceramics. Advanced ceramics are highly refined descendents of the ceramics we know in daily life as the material of dinner plates and coffee cups. Advanced ceramics have a long history in military systems, beginning in the late 1940s. Some of their good properties—hardness, compression strength, formability, imperviousness to high temperature, and chemical inertness—made them early candidate materials for improving the efficiency—both power to weight and fuel usage—of rocket, gas turbine, and piston engines. Hotter-running engines are more powerful, and even early ceramics showed potential to retain strength at far higher temperatures than metal alloys. From early days, advanced ceramics were also used for protective armor. Their controllable electrical and optical characteristics led to electronic "chip" packages and optical fibers.

Composites. Composites are man-made materials in which high-strength, high-stiffness fibers of one material are embedded in a supporting matrix of another material. The major classes of composite matrices are polymer, ceramic, metal, carbon/carbon, and hybrid (*National Advanced Composites Strategic Plan*). The principal advantages of composite materials are that they are lightweight and its high strength, flexible design and shaping characteristics, and corrosion resistance. The most common uses of composites are for recreation and sports equipment and in the aerospace industry. Currently, the US has only a few qualified producers of the fabrics (woven fibers) used in the composite preforms. Existing producers have limited capacity, which contributes to very long lead times – greater than 6 months – even on large high priority programs (*National Advanced Composites Strategic Plan*).

CURRENT CONDITION

The US continues to be one of the world's largest users of traditional strategic materials. Its reliance on foreign sources for the basic minerals required to make these materials continues to grow. The US was once thought to hold the dominant share of worldwide production capacity for traditional materials like steel, but today there are major steel producers found on every continent.

With advanced materials, several countries surpass the US in production. For example, half of the world's carbon fiber manufacturers are located outside of the US, and the United Kingdom is the primary source of the acrylic fibers used in producing carbon fiber composites in the US.

Defense needs, particularly for aerospace applications, were the main drivers for greater use of advanced strategic materials during the 1970s and 1980s. However, with the end of the cold war, and the steep decline in defense spending, fewer dollars are available for research and development (R&D) of strategic materials. While commercial needs and applications have continued to foster development and growth of some strategic materials, high capital costs, the need for positive returns on investment, and the relatively modest cost of traditional materials have slowed the progression of advanced strategic materials in the marketplace. Unless the costs of advanced materials can be substantially reduced, their use in markets dominated by traditional materials (e.g. transportation and infrastructure) will be greatly limited.

Steel. After enduring the traumatic downsizing and restructuring of the 1980s, the American steel industry in 1998 is leaner and more competitive. Overall, US consumption of steel was about 140 million tons in 1997. Domestic integrated steel making is operating at over 90% capacity, but it should be noted that integrated steel *capacity has essentially not changed since 1985*. Electric arc furnace (mini-mill) steel production continues to gain in overall domestic market share, garnering 43% of the total US steel production in 1997. Foreign steel accounts for about one fifth to one quarter of all steel sold in America, a fraction that has held relatively constant for over a decade. Steel has proven to be quite recyclable, with 57% of all steel produced in the US in 1997 having come from scrap iron and steel. Due to the worldwide abundance of steel, cost margins are very narrow.

The steel industry, with the immense amount used annually worldwide (approximately 700 million tons), is not known to be particularly innovative.

Aluminum. The US aluminum industry has been growing at about 3-5% annually, employs over 130,000 people, and contributes more than $30 billion annually to US Gross Domestic Product. The industry is heavily dependent on imported bauxite. The majority of new plants are for secondary processing of recycled materials. High energy and labor costs generally render construction of primary processing plants unprofitable. The US possesses three of the world's top six aluminum producers. While imports have increased dramatically in the past 25 years, the US continues to export (about half the quantity it imports) and maintains some excess capacity. Stagnant technology is an item of concern. Aluminum producers have relied on the HHP since 1886. They have achieved several refinements enhancing efficiency and techniques, but the electrolytic process pioneered by Charles Hall's Pittsburgh Reduction Company over 100 years ago remains the foundation of today's industry. As a bottom line position, the aluminum industry is economically healthy, about the right size, but technologically stagnant.

Advanced Ceramics. The $13 billion ceramics industry is global. The largest companies in the industry are in Japan, France, and the US. Japan's Ministry of International Trade and Industry targeted advanced ceramics with subsidies in the early 1980s and set ambitious R&D goals. Though many of these remain unrealized—a commercially viable all-ceramic engine, for instance—Japanese companies gained important manufacturing know-how through this program. Kyosera, a Japanese company, dominates the advanced ceramics electronic package sector, and Japan is the only country to employ complex advanced ceramic parts (turbocharger rotors) in mass-produced automobiles. The US dominates ceramics for chemical processes because ceramic-based catalytic converters proved the most economical way to meet government-imposed Combined Automobile Fuel Efficiency (CAFÉ) standards. Moreover, the US industry is accelerating again after years of modest growth because advanced ceramics technology is finally producing clear-cut commercial successes.

R&D has overcome many engineering problems. Despite this progress, ceramics remain expensive to manufacture. Though most of the base materials are common, some have high market costs. Achieving high strength involves complex chemical purification processes with hazardous solvents. Baking ("sintering") of ceramics is slow—done in batches at high temperatures, up to 3000°F, in a controlled gaseous atmosphere, often in intricate molds under heavy compression. This is tricky work with a large energy bill. Final machining is also difficult because ceramics are so hard. Special diamond and ultrasonic cutting tools do the job, but at a high price. Economically practical technologies for recycling ceramics are not yet available, closing a door to savings. Continuous reinforcements create a whole new set of high-cost manufacturing problems, not yet well understood.

Given this background, advanced ceramics have their widest applications in small but vital niches within complex systems, rather than as major structural materials like steel or aluminum. There are two broad categories of uses. First, engineers can choose advanced ceramics merely because no other material will do as well (e.g., infrared and radar-transparent sensors.) Second, ceramic parts serve as one-for-one replacements for parts made of metal or another material (e.g., valve trains for diesel piston engines.)

Composites. At present, there is limited domestic availability of certain materials needed to fabricate large quantities of composite components. The basic raw materials used in advanced composites generally consist of glass, metal or carbon fibers, and resin. Glass fibers are widely available in the US, but carbon and metal fibers of the quality required are more difficult to obtain. For example, the US is currently dependent on Japan for carbon fiber (Fink). Unless the US develops alternate sources for carbon fibers — perhaps based in the US — or stockpiles sufficient quantities to meet contingencies, this dependency could have a negative effect on production and sustainment activities especially during times of high demand generated by defense buildups or future conflicts.

CHALLENGES

Steel. Since steel is now essentially a commodity, foreign competition will continue to be the dominant challenge for the US steel industry. To put it in perspective, in 1960, 39 countries made steel. In 1995, 92 countries were producing steel. The challenge will be sharpened in the coming years by an anticipated glut of Asian and Russian steel on worldwide markets. This challenge has to be met by continued improvements in productivity and cost efficiency in order for the US steel industry to maintain its share of the US domestic market. Competition with other countries in foreign markets appears unrealistic.

Aluminum. The aluminum industry strategy to increase market share centers on replacing steel products. Its price (2-4 times that of steel) is an obstacle to attaining that goal. Challenges include reducing the cost of the huge amount of energy used in its production, reducing greenhouse gas emissions resulting from production, rising to challenge new advanced materials, and developing a cheaper, more efficient primary production process.

Advanced Ceramics. The greatest challenge to exploiting advanced ceramics is to overcome industry's natural tendency to stick with familiar, traditional materials, in part due to prejudices inspired by old performance deficiencies that no longer exist. Wide industry employment of advanced ceramics is advantageous to DoD because it creates a favorable environment for dual use acquisition strategies. The following steps are needed: educate the design community on the growing capability and long-term cost advantages of ceramics; advertise the swelling list of commercial successes; codify design procedures and testing standards so that manufacturers and engineers can speak a common technical language regarding advanced ceramics; and foster R&D that reduces production costs and further improves performance in ways most relevant to commercial industry practices. As use of advanced ceramics materials becomes more widespread in regular industry practices, costs will continue to fall and applications will be easier to introduce in more defense-related products.

Composites. The expanded use of composites depends on the resolution of several issues. First, manufacturing costs must be reduced. Many manufacturing techniques used with composites are labor-intensive, require special tooling, and generally result in higher costs and slower rates of production than those experienced with traditional materials. Additionally, while conventional material (aluminum) can be had for around $2 per pound, composites average $5 to $10 per pound. Second, standards and guidelines that can be used as references will have to be introduced and accepted as tools and guidelines by the engineering and logistics communities. Third, environmental issues have to be resolved. Most resins used in composite systems are hazardous. Composite fabrication and assembly usually calls for a new plant, with a controlled environment, sealed doors and specialized charcoal-filter scrubber systems, all built to conform with a phalanx of local, state, and federal regulations (Sweetman). Finally, reparability concerns must be addressed such as the lack of timely and effective procedures for detecting and repairing damaged composite structures. Dr. Bruce Fink, a composites expert at the Army Research Laboratory, says: "detecting damage in composites is much more difficult than you might imagine...ultrasonic imaging to find defects isn't available in the field and integrated armor cannot be interrogated using C-Scan. Other techniques are required" (Fink).

Deep Seabed Mining. Growing demand for the world's natural resources places the US in a position of facing increased competition for many nonfuel minerals. There is no doubt of the immense quantities of valuable mineral ores available on the seabed floor, particularly cobalt, copper, nickel, and manganese. Due to a lack of domestic sources or viable substitutions, requirements for some of these minerals, vital to our national defense and economic growth, will remain a potential point of vulnerability. The challenge is to combine technological and economic feasibility with an internationally acceptable regime that will protect the huge investments required to exploit these resources, while minimizing damage to the ocean habitat.

OUTLOOK

Short-Term Outlook

Steel. Steel production historically follows the economy, so the short-term outlook for steel is good. The impact that the Asian financial and economic crisis will have on domestic steel production remains to be seen, but it is likely to be muted. On average only 17% of US steel imports originate from Asia. Weakened Asian economies may try to expand exports to the US, but additional suppliers will be more likely to take market share from other exporters than American companies.

Aluminum. Short-term outlook is for continued but slow growth, following the industry's sustained 3-5% growth annually over the past 25 years. Growth in alumina and aluminum production is and will continue to be centered primarily in developed nations like the US; bauxite-mining operations will grow primarily in developing countries where the resource is plentiful. Recycled aluminum will continue to occupy a large segment of the industry. Advanced materials will erode market share, but aluminum industry initiatives and the mandate to reduce greenhouse gases may significantly increase the use of lighter weight aluminum to replace more steel in the transportation sector. Aluminum price reduction is key to such a strategy. If such a change does not occur, manufacturers may opt to move on to use the next generation of advanced materials.

Advanced Ceramics. Advanced ceramics technology is poised to accelerate its penetration in commercial and military systems after nearly 50 years of promising but limited successes. Detroit Diesel has announced an all-ceramic valve system that will be widely deployed, potentially in millions of engines. Several auto manufacturers are using advanced ceramic seals in water pumps. Machinery producers are employing ceramic bearings to cut maintenance costs dramatically. The C-17 and late model C-130s employ armor made of advanced ceramics. The Joint Strike Fighter will employ advanced ceramics to boost power and reduce weight.

Composites. The US leads the world's research in areas aimed at reducing the high costs associated with the manufacturing and repair of composite components (Fink). The goal is to move away from the big expensive autoclaves, which traditionally provided the best quality, and into much lower cost options. DoD and industry have made steady progress in developing composite repair equipment and procedures. Since 1987 McDonnell Douglas, Boeing, and other companies have been developing and improving repair procedures for systems such as the Army's High Mobility Multipurpose Wheeled Vehicle (HMMWV) (Repair Methods) and the Air Force's F-117 (F-117 Composites Structures).

Long-Term Outlook

Steel. A vital material such as steel is not going away anytime soon. Over 90% of all metal consumed in the world is steel. Advanced materials will, however, gradually eat into steel applications, especially in certain niche uses, but the cheap cost of steel should remain a powerful countering force. Domestic integrated steel-making capacity will probably continue to remain nearly static because of the industry's need to continue shouldering the "legacy costs" of earlier production times, which mainly involve substantial pension fund payments. The more efficient mini-mills should continue to compete effectively with foreign suppliers for the other half of the US market. Only after the debts of the earlier years are paid, will the US integrated steel industry be able to expand. No matter what, there is sufficient worldwide steel capacity to meet US strategic needs.

Aluminum. The aluminum industry will require significant investment in R&D to address a number of concerns. The first is to increase efficiency and thus competitiveness relative to alternative materials. Second is to reduce emissions to comply with Kyoto Accord requirements. Third is reduction in the cost of energy to reduce aluminum prices. Fourth is to develop technologies that may increase the use of aluminum in all applications such as manufacturing, welding, painting, etc.

The Aluminum Technology Roadmap recognizes the importance of each of these concerns. We should see sustained long-term growth if the aluminum industry invests R&D dollars wisely and benefits from efficiencies. If, however, industry focuses on short-term profits over long term capabilities (like the US steel industry did during the 1950s, 1960s and 1970s), the aluminum industry will be hard-pressed to compete with new and emerging technologies.

Advanced Ceramics. With the end of the Cold War, defense funding of advanced ceramics application has been reduced significantly. However, the high capabilities inherent in advanced ceramics will continue to be recognized, but funding will undoubtedly be stretched out over a longer period, more linked with commercial applications.

Composites. Just 6 years ago, a total of 22.5 million pounds of composite fibers found their way into all manner of products. By 2007, industry experts estimate composite fiber use will top 200 million pounds annually (Graham). As manufacturers continue to reduce the cost, improve mass production techniques, and resolve reparability issues, we can expect to see a rapidly growing composite presence, particularly in the defense and construction industries. With composite "smart materials" (embedded sensors in a composite structure) that sense the environment and transmits stimuli to piezoelectric devices are now possible. These signals cause the composite material to contract or relax, simulating what occurs in animal muscle action. Hence, the designation "smart materials"(Robinson). A version of this technology is under development in the vibration monitoring and self-correction capability of next generation Army helicopter rotors. Similar advances are expected in the use of smart materials for roadways and bridges, transmitting signals about materials fatigue and other dangers (Jacobson, p. 3).

GOVERNMENT GOALS AND ROLE

The role of governments in traditional and advanced strategic materials industries range across the globe from a central planning approach to a laissez-faire approach where most decisions are made by the market. The US government has historically been most comfortable somewhere closer to a hands-off approach. This approach is particularly applicable in the current peacetime environment. In the US, central planning has been introduced during times of national emergency or war.

United States

The US imports strategic minerals such as chromium, cobalt, manganese, and platinum because of a lack of domestic sources. This fact drives certain US goals and policies, even if implicitly rather than explicitly. US policy has been to obtain adequate mineral supplies at the lowest possible cost, taking into account the interests of allies (Hodges, 1995). This is essentially a laissez-faire free market approach (Hodges). This approach is based on ample short-term supplies of strategic minerals and the premise that third world exporters of strategic materials have no immediate alternative to supplying the large US market. As Hodges (1995) summarized, "concerns about self sufficiency and minerals security of the US are no longer overriding." Lack of strong interest in ratifying the 1982 Law of the Sea Convention, which covers deep seabed mining, also demonstrates the US government's hands-off approach.

In manufactured goods made with composites and ceramics, however, there is US government and private sector efforts to support R&D. Composites and ceramics have clear linkages to national security because of their applications across the defense spectrum from aerospace to telecommunications to undersea use. Composites and ceramics also have dual use private sector applications. However, there is a disturbing trend of declining funding for R&D.

Current US Government Role. The US applied lessons learned from World War II (WWII) during the cold war to ensure strategic materials such as chromium, cobalt, manganese and platinum were stockpiled so that they would be available for the next war. Competition with the Soviet Union helped drive the engine of weapon systems and advanced materials development. Today this approach is being abandoned somewhat haphazardly mainly because no perceived threat exists that drives the US to stockpile. For similar reasons, weapons systems procurement is in decline, so strategic materials development has begun to slow noticeably.

As a result of this policy shift, US government research funding for strategic materials is declining with the apparent goal of allowing the private sector to fund a larger share of future R&D. This approach appears "smart" from a cost savings point of view, but it contains risks. The biggest risk lies in the fact that most private industrial enterprises are reluctant to engage in mid- to long-term R&D because publicly–owned businesses tend to operate with a short-term focus on profits. The long-term interests of the nation are not often served by focus on short-term interests of private enterprise.

Another weakness in this reduced funding approach is that many R&D efforts require more funding than the private sector can afford. The space program and nuclear power are two historical examples of national efforts that private industry arguable could not have achieved without substantial government funding. No private sector materials research efforts were observed that began to approach the work being done at the Naval Research Laboratory in Washington, DC. Government-funded laboratories are national treasures that should be very carefully examined before irreparable damage occurs as a result of underfunding.

Roles the US Government Should Play. The US government should avoid the temptation of allowing the pendulum to swing too far in the laissez-faire direction. The government needs to be a player in the materials industry. This will ensure the country's maintenance of military superiority and will invigorate our global economic competitiveness.

Government's role should include a recurring advisory mechanism by which the nation's vital or strategic materials are defined and evaluated. Strategic vulnerabilities or shortcomings should be identified and addressed. From this mechanism should spring the planning and development of a strategic vision and roadmap for preserving national security and economic prosperity. This vision should include government partnership with industry to promote R&D in both traditional and strategic materials. This role should focus on mid- and long-term national and security application because of the growing tendencies of US industries to focus only on shorter-term profit motives. The government needs to encourage, through incentives, private sector R&D on materials with mid- and long-term benefits.

The government possesses other responsibilities. There must be a level global economic playing field for US materials companies. Access must remain open to domestic and international sources of both raw and finished materials. Finally, the government must remain vigilant to problems and prepared to act in those cases where market dynamics fail to ensure attainment of US strategic materials objectives.

Canada

Canada is a net exporter of strategic minerals, a significant difference from the US. Thus, Canadian goals are oriented more towards maintaining international competitiveness while enhancing the domestic economy. Canada also has relatively healthy steel and aluminum industries. Of note, 15% of all steel imported by the US comes from Canada.

Canada supports a limited amount of materials R&D at universities and government laboratories. It is at the leading edge in some fields. Overall, however, lack of emphasis in materials research at the university level has resulted in degradation of metallurgy and materials departments. Canada frequently appears to rely on the R&D efforts of others, often the US. As a smaller actor on the world scene, Canada generally takes a more internationalist approach, supporting international agreements more than the US does as a means of achieving national goals.

Hungary

Hungary's materials industrial activity is comparatively rudimentary. The period following the fall of the Iron Curtain saw the collapse of about one third of Hungary's steel industry. Consequently, Hungarian steel is now the third smallest industry in all of Europe, ranking ahead of only Albania and Switzerland. Fifty-six percent of Hungarian steel is also privatized, primarily through foreign investment. The eastern part of the country still suffers 35% unemployment because of the state of this industry. The aluminum industry, which relied on subsidized energy and alumina from the Soviet Union, has all but disappeared.

One advanced materials manufacturing concern was identified. Zoltek, an US-based composites manufacturer, operates a carbon fiber production facility northwest of Budapest. This facility houses carbon fiber manufacturing equipment identical to Zoltek's Abilene, Texas plant. In addition, Zoltek is attempting at this Hungarian site to cheaply produce acrylic fiber precursor material, which now must be obtained from the United Kingdom. The success of this venture will determine whether significant reductions in carbon fiber costs will be achievable. Such cost reductions are vital to Zoltek's strategic plan to expand its worldwide market share.

Meetings with Hungarian government officials were encouraging. Despite many lingering trappings of a centrally planned economy and a massive communist bureaucracy, Hungary appeared to have an accurate, realistic view of where it stood economically, where it needed to go, and generally how it intended to get there. Future entry into NATO and later, the European Union, are positive in that regard.

Austria

Only one strategic materials industry was observed, Voest-Alpine Stahl or VA Steel, located in the city of Linz. This integrated steel company enjoys the luxury of being one of the very few mills geographically located near the major European automobile manufacturers Audi, Mercedes-Benz, and BMW. This resulted in a market that provides an exceptionally stable demand base. In addition, VA Steel facilities are relatively modern, state-of-the-art, and they are well maintained and run. The absence of mini-mills within the area has further enhanced VA Steel's competitive position.

Even more impressive than VA Steel was the Voelst Alpine Technology Company (VA Tech), a sister company to VA Steel. VA Tech specializes in the engineering of steel production equipment. Its business is global and includes setup and building, from the ground up, of steel mills in developing countries. Of note, VA Tech provides engineering services for US steel companies.

Government involvement in the Austrian steel industry is significant, though declining. Both VA Steel and VA Tech were completely government owned until 1995. Both companies have been privatized with the Austrian government retaining ownership of approximately one-third share. However, even under their new privatized state, both companies continue to benefit from the original government outlays for capital equipment and labor. In particular, Austria's social security pension system relieves VA Steel of many of the "legacy costs" encountered by US steel companies. Long-term problems could develop for the Austrian steel industry, however. A firmly entrenched pro-labor political base, which pushes full employment, could cause the steel industry to keep its labor force artificially high, resulting in excessive labor costs.

Recommendations

Industrial Policy. As the term is currently understood, the political and economic leaders of the US are clearly not prepared to accept anything that could be called "Industrial Policy." The study group suggests, however, that the government fund some independent analyses (through, perhaps, reactivation of the National Security Advisory Panel on Critical and Strategic Materials) that would explore specific technological fields. These might be areas that, in the years ahead, could be particularly useful in a strategic way, or on the leading edge of rapid growth or more widespread application. The US government should *not* be responsible for selecting or funding specific technological fields or for favoring them in any way; rather, the independent (but government-funded) research would be responsible for disseminating promising research conclusions through the US private sector. It would be up to the private sector then to make its own decisions for follow-up R&D, practical applications, etc.

Use of the Stockpile. We recommend that the materials stockpile continue being phased down in a gradual, responsible manner. Materials processing and manufacturing, and the entire use of materials, have changed enormously since our mobilization experiences for WWII, Korea, and Vietnam. Where stockpiles may be needed for any protracted war contingency, we recommend that incentives be developed to privatize the stockpile.

Dependence Upon Strategic/Advanced Materials—There is no doubt that our selected use of strategic or advanced materials has provided us the leading edge in many military applications: power, speed, stealth, and survivability have all been enhanced by the use of specialized materials. However, these advantages are not without added costs and risks. These materials, many of them composites, are often more expensive to acquire (usually because of their limited use), more difficult and complex to fabricate, more demanding to work with, and frequently almost impossible to repair. Nevertheless, we believe that the payoff in performance characteristics more than compensates for the problems. If industry does not find it profitable to find ways to lessen or eliminate these problems, we believe it is in the government's interest to do so.

CONCLUSIONS

A fundamental shift in defining strategic materials has occurred over the past 50 years. Subtly changing since the end of WWII, the pace rapidly quickened with the passing of the cold war. Our historic focus revolved around products and materials required for national defense, particularly those held at risk by hostile forces. A globalized economy lends a broader perspective on what should be considered of strategic importance to a nation. Strategic materials now both expand our economy and promote national security. Their spectrum is widely diverse and highly dynamic, ranging from traditional metals, such as steel and aluminum, to emerging composite fiber and ceramic materials. What is of significant strategic importance to one nation may not carry the same emphasis in another, if the raw materials are abundant and processing capability exists within national borders.

The whole of strategic materials is larger than the sum of its parts. The original raw materials are the building blocks on which all else is based. Still, without innovation and technical capabilities to refine this material, there is no development or evolution.

More technologically developed nations, such as the US and Austria, hold a distinct qualitative and quantitative advantage over their less developed neighbors. The ĕngine driving materials development is becoming progressively more market-driven. As has been proven by events of the last decade, governments cannot dictate the direction or pace of economic and technological development as well as the free market. Despite this recognition, conflicting realities emerge within different geographic regions. The European Economic Union is expected to encourage free trading between European member states, but may also emerge as a trading bloc that limits external trade opportunities. In the Western Hemisphere, NAFTA is opening trade between the Americas but is sometimes viewed as threatening by our European trading partners.

Economic forces have other stark realities, particularly regarding investment in R&D. Business must see a clear objective to justify funding material development. Often this objective must be attainable in the short-term to satisfy shareholders with a positive cash flow. This, in turn, creates a clear need for government involvement in long-term R&D, such as that being performed at the Naval Research Laboratory. If basic research progresses to the point of clear commercial or military application, a partnered hand-off to industry offers an opportunity for practical technological improvements. Both government and industry win by employing their relative strengths in the national interest.

BIBLIOGRAPHY

F-117 Composite Structures. [Online] Available: http://www.mcclellan.af.mil/MLS/f117.html.

Fink, Bruce. 1998. Army Research Laboratory, University of Delaware E-mail, (April 3).

Graham, Vickie. 1993. "Better and Cheaper Mousetraps," *Airman Magazine.* (December).

Hodges, Carol Ann. 1995. "Mineral, Resources, Environmental Issues, and Land Use." *Science,* (June 2), pp. 1-13. Washington, DC.

Industry Canada. 1998. Briefing. (April 8).

Jacobson, Louis, 1998. "Sensors Bridge Gap in Communication about Repair Needs." *Washington Post,* (May 18), p. 3.

The National Advanced Composites Strategic Plan (NACSP). 1990. December).

Repair Methods for Composite Components of the US Army HMMWV Vehicle. [Online] Available:http://dsmc.dsm.mil/r/port /s/str6579c.htm.

Robinson, Clarence A. Jr. 1997. "Smart Structures Unharness Startling Aerodynamic Boom," *Signal,* (July). Falls Church, VA.

Sweetman, Bill, 1992. "Why Composites Wait in the Wings," *Interavia,* (April).