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Materials Policy--Issues for the 100th Congress

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INTRODUCTION

As clearly illustrated by the tragedy of the *Challenger* shuttle[1] as well as by the remarkable triumph of the *Voyager* ultralight aircraft,[2] materials are responsible for success as well as failure in our modern world. The *Challenger* disaster hinged on the failure of a small rubber seal, used at the wrong temperature and in the wrong place. I am reminded of the famous quote by Benjamin Franklin "for want of a nail the shoe was lost. . . ."[3] On the other hand, as noted by pilot Dick Rutan at hearings following his remarkable achievement: "To make this flight possible, we needed to have two things primarily: advanced aerodynamics for stability and efficiency, and . . . the use of composite materials . . . this flight was not possible with conventional aluminum technology. . . ."[4]

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[1] The Space Shuttle *Challenger* exploded during launch on January 28, 1986, killing the seven astronauts and setting back the U.S. space program by more than two years. The first mission since then occurred on September 29, 1988. 1988 INFORMATION PLEASE ALMANAC 133-34.

[2] *Id.* (The *Voyager* ultralight aircraft, piloted by Dick Rutan and Jeana Yeager completed a historical round-the-world, nonstop flight on December 4, 1986.).

[3] B. FRANKLIN, POOR RICHARDS ALMANAC 17 (D. McKay 1963).

[4] *Flight of the Voyager, 1987: Hearing Before the Comm. on Science, Space, and Technology U.S. House of Representatives*, 100th Cong., 1st. Sess. 6 (1987) (statement of Dick Rutan, pilot of *Voyager*).

While Congress and the Federal government have had a long standing interest in materials and materials policy,[5] it was the oil crisis of the 1970s which focused our attention on the *economic* as well as strategic vulnerability represented by certain critical materials. Our import oil dependence, hovering around thirty to forty percent of U.S. needs in the past couple decades,[6] was far exceeded by our import dependence of major mineral and material groups. For instance, of twenty-nine selected nonfuel minerals, the Bureau of Mines reports[7] that twenty are imported at levels exceeding fifty percent of use; in fact, of those more than a third (eight) exceed ninety percent of use.[8] During the 1970s the realization quickly set in that petroleum, as a liquid mineral, might be the harbinger of a more costly and even more damaging materials crisis created by supply interruption or cutoff in many of the critical hardrock minerals.

The dependence on heavily used imported minerals by itself is not sufficient to define strategic vulnerability. However, when matched with our critical economic and strategic needs as well as the instabilities of the source countries (including Zambia and Zaire, our principal source of cobalt,[9] and South Africa our principal source of manganese, chromium and platinum)[10] this

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[5] Government interest in materials and materials policy predates World War II with the establishment of the National Strategic Stockpile in 1939. For major laws dealing with materials policy, *see* National Materials Policy Act of 1970, 42 U.S.C. § 3251, note. Sections 3251-3254(f) were omitted in the general amendment of the Solid Waste Disposal Act, 42 U.S.C. §§ 3251-3259, by Pub. L. 94-850, § 2, Oct. 21, 1976, 90 Stat. 2795. Defense Production Act of 1950 [hereinafter Defense Act], 50 U.S.C. §§ 2061, 2062, 2071-2073, 2081, 2091-2094, 2101-2110, 2121-2123, 2131-2135, 2151-2166; Strategic and Critical Materials Stockpiling Revision Act of 1979, 7 U.S.C. §§ 1743, 1745, 15 U.S.C. § 7146, 50 U.S.C. §§ 98 to 98h-4, 50 U.S.C. App. § 2093; National Materials and Minerals Policy, Research, and Development Act of 1980, 30 U.S.C. §§ 1601-1605, 30 U.S.C. § 1601. *See also* PRESIDENT'S MATERIALS POLICY COMMISSION REPORT, RESOURCES FOR FREEDOM (U.S. Government Printing Office, 1953).

[6] 1987 ENERGY INFO. ADMIN., DEP'T OF ENERGY, ANN. ENERGY REV. (Doe/EIA-0384 (87)).

[7] BUREAU OF MINES, U.S. DEP'T OF INTERIOR, MINERAL COMMODITY SUMMARIES (1986) [hereinafter SUMMARIES] (U.S. Gov't Printing Office No. 1986-606-275).

[8] *Id.* at 2. (Minerals exceeding 90%: columbium, manganese, mica, strontium, bauxite, cobalt, platinum group metals and tantalum) (minerals exceeding 50% include: potash, chromium, tin, asbestos, barite, zinc, nickel, tunsten, silver, mercury, cadmium and setinicum).

[9] *Id.* at 38-39.

[10] *Id.* at 98-99, 118-19.

situation provides more than enough cause for alarm. A 1985 report by the Office of Technology Assessment[11] identified thirteen strategically vulnerable materials, whose supply is relatively limited, all of which are essential to the United States' economy. These include such industrial materials as platinum (for catalytic converters), cobalt (essential for high-temperature turbine blades for aircraft as well as industrial magnetics and machine tooling), chromium (stainless steel and high-temperature alloys for use by chemical and aerospace industries) and manganese (for high strength steels and basic steel production) seventy percent of which are produced in Africa or the Communist bloc.[12]

Concerns such as these eventually lead to the passage of the National Materials and Minerals Policy, Research and Development Act of 1980,[13] which set the stage for defining our national materials policy in broad terms. The law was seen at that time (and continues to be seen today) as providing a balance between the nation's needs for energy and our concern for the environment. This balance is stated in the legislation:

> The Congress declares that it is the continuing policy of the United States to promote an adequate and stable supply of materials necessary to maintain national security, economic well-being and industrial production with appropriate attention to a long-term balance between resource production, energy use, a healthy environment, natural resources conservation, and social needs.[14]

The statute required that the President report to the Congress within one year of enactment with a plan for implementation of this policy.[15] I should mention at this point that the 1980 act was not seen by Congress as a panacea for materials issues, but rather as a first step toward dealing with these concerns.[16]

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[11] OFFICE OF TECHNOLOGY ASSESSMENT REPORT, STRATEGIC MATERIALS: TECHNOLOGIES TO REDUCE U.S. IMPORT VULNERABILITY (1985) [hereinafter TECHNOLOGY REPORT] (OTA-ITE-249).

[12] SUMMARIES, *supra* note 7, at 34-35, 38-39, 98-99, 118-19.

[13] National Materials and Mineral Policy, Research and Development Act of 1980, [hereinafter Materials Act] 30 U.S.C. §§ 1601-1605 (1980).

[14] 30 U.S.C. § 1602.

[15] 30 U.S.C. § 1604.

[16] 125 CONG. REC. H1152 (daily ed. Dec. 3, 1979) (debate on H.R. 2743, Materials Policy, Research and Development Act of 1979).

During the Reagan Administration a cabinet-level Natural Resources and Environment Council was formed. This development led to a flurry of activities and departmental reports,[17] and eventually a response[18] to the Congressionally mandated plan for carrying out the 1980 law. Unfortunately no monies or real specifics were provided by the Administration. Eventually, the Presidents' Council was abolished, having done little or nothing about the problems identified. Meanwhile, the health of many of our basic materials industries—steel, copper, aluminum, and others—floundered in the uncertain economic and technological environment of that time which further exacerbated our materials import problems.

The Congress, frustrated by the inactivity concerning the 1980 Act, and increasingly perturbed by the erosion of our basic materials industries, passed follow-up legislation that was signed by the President on July 31, 1984. The National Critical Materials Act of 1984[19] established a three-member National Critical Materials Council within the Executive Office of the President.[20] The Council was designed as the focal point of the legislation in order to provide advice and recommendations on materials issues to the President and Congress.[21] In addition, the Council was mandated to establish a national Federal program plan for advanced materials research and development.[22] Let us turn to the question of *advanced materials*.

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[17] Among examples: a short lived (1982-83) research program with NASA's Office of Aeronautics and Space Technology research on substitute materials for strategic materials (chromium and cobalt); the Bureau of Mines was reorganized in 1981 to improve its capacity to assess international mineral supplies; R. REAGAN, NATIONAL MATERIALS AND MINERALS PROGRAM PLAN AND REPORT TO CONGRESS (April 5, 1981); creation of the Minerals Management Service within the Dep't of Interior in 1981; and directives to U.S. negotiation at the 3rd U.N. Conference on Law of the Sea regarding deep sea mineral resources.

[18] R. REAGAN, NATIONAL MATERIALS AND MINERALS PROGRAM PLAN AND REPORT—MESSAGE FROM THE PRESIDENT OF THE UNITED STATES, 128 CONG. REC. H1412 (daily ed. April 5, 1982).

[19] National Critical Materials Act of 1984 [hereinafter cited as Minerals Act of 1984], Pub. L. No. 98-373, 98 Stat. 1248 (codified at 30 U.S.C. §§ 1801-1810 July 31, 1984).

[20] Materials Act of 1984, 30 U.S.C. § 1802 (1984).

[21] Materials Act of 1984, 30 U.S.C. § 1803 (1984).

[22] Materials Act of 1984, 30 U.S.C. § 1804 (1984).

ADVANCED MATERIALS

Starting in the early 1980s, materials experts within and outside the government became increasingly aware of the growing importance of new advanced materials.[23] These advanced materials, including new structural ceramics, polymeric composites, and new metallic alloys hardly known before 1980, are the key to the success of the high technology of the 1990s and beyond. Perhaps the most familiar class of advanced materials are the new superconductors. The discovery of a new class of "high temperature" superconductors in January 1986 by Swiss researchers George Bednorz and Alex Muller[24] went virtually unnoticed until Japanese researchers led by Koichi Kitazawa of the University of Tokyo announced verification of their discovery at a Boston meeting late that same year.[25] In January of 1987, a few months later, Dr. Paul Chu of the University of Houston and Dr. Mik Wu of the University of Alabama in Huntsville had discovered related ceramic compounds with critical temperatures above that of liquid nitrogen (a balmy temperature of—300 °F).[26] The discovery triggered a worldwide race to obtain even higher temperature superconductors that continues to this day. Suddenly materials were making national headlines, including major articles in *The Wall Street Journal*,[27] *The New York Times*,[28] *The Washington Post*[29] and elsewhere. *Time Magazine*[30] trumpeted the beginning of a new industrial revolution, pointing to potential major improvements in microelectronics and computers, electrical power generation, and its storage

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[23] *See Hearings Before the House Comm. on Science and Technology*, 97th Cong., 2d Sess. (1982); *Hearings Before the House Comm. on Science and Technology*, 98th Cong., 1st Sess. (1983); *Hearings Before the House Comm. on Science and Technology*, 99th Cong., 1st Sess. (1985); *Technology Report*, *supra* note 9; OFFICE OF TECHNOLOGY ASSESSMENT REPORT, ADVANCED MATERIALS BY DESIGN (1988) [hereinafter MATERIALS REPORT] (OTA-E-352).

[24] *See* G. BEDNORZ & A. MULLER, LEITSCHRIFT FUR PHYSIK B (1986).

[25] Meeting with Materials Research Society in Boston, Mass. (Dec. 4, 1986).

[26] 58 P. CHU & M. WU, PHYSICAL REVIEW LETTERS 908 (1987).

[27] Wall St. J., July 9, 1987, at A1, col. 1.

[28] N.Y. Times Magazine, Aug. 16, 1987, at 29.

[29] Wash. Post, May 17, 1987, at 29.

[30] Lernonick, *Wiring for the Future — The Superconductivity Revolution*, TIME, May 11, 1987 at 64-75 (cover story).

and transmission, advanced scientific and medical diagnostic equipment, "mag-lev" trains and other advanced transportation systems, as well as yet unknown applications of advanced materials.

Even the normally staid National Academies of Sciences and Engineering[31] were no less enthusiastic. To quote from their report of September, 1987:

> The recent discovery of Superconductivity at temperatures up to 95 K is one of the more important scientific events of the past decade . . . a door has been opened to the possibility of superconductivity at temperatures at or above room temperature. Such a development would represent a truly significant breakthrough, with implications for wide spread applications in modern society.[32]

Perhaps of even greater significance, in 1987 Bednorz and Muller were awarded the Nobel Prize in physics, an accolade normally reserved for decades after a discovery has been made. While the potential for these new superconductors remains enticing, let me inject some concerns expressed by policy makers, including myself, that need thoughtful examination.

One major concern is how to sustain a long term commitment to a critical materials policy. It is is not realistic to expect more *Time Magazine* cover stories to continue the enthusiasm. Even the most optimistic experts suggest[33] that the real applications of these materials will not be forthcoming for at least several years, and more likely a decade or longer. Thus, the economic payoffs will be long-term and uncertain, while the interim research will be extremely costly, especially in these times of budget and trade deficits. America has not always had a good record for maintaining technological programs beyond comparatively short periods. If we are in a race, then we must under-

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[31] The National Academies of Science and Engineering in Wash., D.C. were chartered by Congress in 1863 as a private, nonprofit organization to further science and engineering for the public welfare.

[32] Briefing on high-temperature superconductivity, National Academy Press, in Washington, D.C. (Sept. 1987).

[33] *See Superconductivity: Hearings Before the House Comm. on Science, Space, and Technology*, 100th Cong., 1st Sess. 187-93 (1987) [hereinafter *Superconductivity Hearings*].

stand that our policy and programmatic strategies for these new superconductors should emulate a marathon, not a sprint.

Stable funding is the essential complement to a long-term commitment. (See Table I, following footnote 65). Table I shows the estimated funding by the federal government in superconductivity research for fiscal years 1987 and 1988. This table shows that in little over one year high temperature superconductivity research and development grew from almost zero to almost $100 million! The problem is that these monies were "reprogrammed" or taken by federal agencies from other worthwhile research programs. Whereas this policy might be (and in this case I believe it is) justifiable in a short-term, emergency situation, it would be irresponsible to continue shortchanging other research efforts in future budget cycles. Instead, we need to provide *new* monies for the superconductivity research while providing adequate funding for other important scientific areas.

While it seems reasonable to formulate a national program, the Reagan Administration appears to resist such ideas. Each of the major agencies—Energy, Defense and Commerce—have embarked on their own programs, independent of each other. In lieu of a single program of action, at present there are several programs. The Department of Defense has the most programs.

Now that the initial first flurry of activity has settled down, it is imperative that we establish an overall national effort. Ideally, this would involve important private as well as public sector groups, including appropriate industry, university researchers, and nonprofit research organizations, who could carry out long-term plans. We must avoid the pitfall of allowing the fragmentation of superconductivity efforts to continue. Currently, the independent programs in the Departments of Energy, Defense and Commerce represent a national program but there are no overall national objectives and guidelines.

ADVANCED CERAMICS

Advanced ceramics present another material class of considerable interest. We normally think of ceramics as being very brittle, which causes them to fail under certain conditions. Scientists have greatly improved the strength of ceramic materials. This resistance to failure, combined with the inherent properties of high wearability, heat and electrical insulation, and high resistance to chemical attack make these materials ideal for high-temperature, low friction, advanced heat engines for cars, trucks, or even jet aircraft. Such advanced heat engines are expected to operate at temperatures exceeding 2,500°F and will require little or no water for lubrication.[34] They will also weigh a fraction of normal metallic engines. Such properties will allow for much higher fuel economy, and use of a variety of fuels (including methanol, diesel, gasoline and even liquid hydrogen), with little or no pollution. Other uses for the new materials include bio-materials for human implants, cutting tools, filters, wear resistant parts, and various electrochemical devices (such as fuel cells). Economic studies have shown that by the year 2000 these advanced structural ceramics could contribute tens of billions of dollars to our gross national product and potentially create hundreds of thousands of new jobs.[35]

COMPOSITES AND OTHER ADVANCED MATERIALS

Two other advanced groups of materials should be mentioned—polymeric composites[36] and rapidly solidified, alloyed materials.[37] These materials have particular interest to our aeronautics and astronautical sectors for both defense and commercial application. Light weight, high strength, polymeric composites, (essentially "super" plastics)—as the "Voyager" flight demonstrated[38]—open new areas of improved flight performance. They make entirely new subsonic and supersonic air-

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[34] MATERIALS REPORT, *supra* note 23, at 61.

[35] *See id.* at 64. *See also* L. JOHNSON, A. TEOTIA & L. HILL, A STRUCTURAL CERAMIC RESEARCH PROGRAM: A PRELIMINARY ECONOMIC ANALYSIS (March 1983) (Argonne National Laboratory Report # ANL/CNSV-38).

[36] *See* MATERIALS REPORT, *supra* note 23, at 730. Polymeric composites consist of polymer-based materials such as expoxies, polymides and liquid crystal polymers with various metallic or ceramic added for mechanical reinforcement. *Id.* at 76.

[37] Rapidly solidified, alloyed materials are primarily metal alloy systems, including iron, titanium and aluminum which are cooled from the molten state at such high rates of heat extraction so as to produce metastable, "amorphous," non-crystalline materials. Appropriate processing allows for producing various materials with controllable properties not possible through normal, thermodynamically stable processing.

[38] *See supra* note 2 (The *Voyager* was constructed entirely of polymeric composite materials for its strength and light weight characteristics.).

craft possible such as the F-18 and the Stealth bomber. In space, these materials will be the key to any development of large structure programs, including the Space Station, the Strategic Defense Initiative and future interplanetary missions.

Rapidly solidified, alloyed materials—the so-called "metallic glasses" which are formed by cooling molten liquid metals by up to a million degrees per second[39]—allow us to combine elements and compositions normally considered impossible. Their superior high-temperature strengths and corrosion resistance make these materials prime candidates for use on the Administrations' proposed Aerospaceplane. In fact, it would not be possible to build structures in space without these materials.

BASIC MATERIALS—THE SMOKESTACK INDUSTRIES

A national materials policy cannot ignore our basic materials industries—the so called "smokestack industries"—steel, aluminum, copper, and others. Just as we would not feed our children a diet consisting only of highly enriched desserts and candies, our nations' economic health cannot be sustained or balanced solely with high technology industries. Rather, our nation's capacity to continue building, manufacturing, and providing the full spectrum of essential goods and services requires the hearty "meat and potatoes" component of our national diet provided by these basic materials industries.

The problems and some of the potential solutions of these smokestack industries can be illustrated by the steel industry. Official statistics in 1977 showed that 396 steel companies employed almost 450,000 people and produced roughly $42 billion in products.[40] By 1985, only 100 companies remained, with employment standing at roughly half that of eight years earlier.[41] Direct imports of steel increased from fifteen to twenty-two percent between 1981 and 1985; if we consider indirect imports of steel products, as well, this import reliance would exceed

[39] NATIONAL RESEARCH COUNCIL, SCIENCE AND TECHNOLOGY - A FIVE YEAR OUTLOOK 305 (1979) (ISBNO-7167-1141-9).

[40] DEP'T OF COMMERCE, CRITICAL MATERIALS REQUIREMENTS OF THE U.S. STEEL INDUSTRY (March 1983) (U.S. Gov't Printing Office # 1983-380-997/5054).

[41] SUMMARIES, *supra* note 7, at 78-79.

forty percent.[42] A 1980 Report from the Congressional Office of Technology Assessment[43] listed these problems of the steel industry: obsolete plants and production facilities (most are vintage World War II), dumping by foreign competitors, high labor costs, high costs of federal regulations, improper management, and world production exceeding actual demand. The same Office of Technology Assessment report suggested that an investment of $3 to $5 billion annually over a decade would be required to modernize our steel industry.[44]

To the credit of our domestic industry, major investments have occurred. Close to $13 billion have been invested since 1980, despite financial losses of more than $9.3 billion.[45] These investments, coupled with the shut down of marginal facilities, have improved steel industry productivity by more than fifty percent.[46] Unfortunately, our international competition in Japan and Europe has also improved productivity during this period, eclipsing United States productivity by roughly twenty percent.[47]

These investments by United States industry to improve productivity are important but more must be done. The Federal Government has funded a modest $5 million, through the Department of Energy, to examine possible energy savings in steel production. However, further efforts, could include:

- The establishment of an advanced steel processing research program to focus on such areas as continuous casting of thin strip, use of levitated, containerless processing, development of high-strength-high-carbon superplastic steels, direct iron making, and advanced casting technologies.

- The introduction of artificial intelligence and robotics, integrated with advanced processing technologies, can lead to a restructured modern, basic materials industry, by strong cooperative efforts between industry and the federal government.

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[42] *Id.* at 78.

[43] OFFICE OF TECHNOLOGY ASSESSMENT REPORT, TECHNOLOGY AND STEEL INDUSTRY COMPETITIVENESS (June 1980) [hereinafter STEEL REPORT] (OTA M-122).

[44] *Id.* at 3.

[45] *Advanced Manufacturing Materials and International Competitiveness: Proceeding of the 9th Biennial Conference of National Materials Policy, August 4-7, 1986,* PUBLISHED FEDERATION OF MATERIALS SOCIETIES 149 (1986) [hereinafter *Proceedings*].

[46] STEEL REPORT, *supra* note 43.

[47] *Id.*

- The establishment of programs to use existing, yet idle, steel production facilities for resource recovery and recycling and the conversion of hazardous industrial wastes to benign substances through high temperature incineration in steel blast furnaces.

INTERNATIONAL CONCERNS

A. Japan and Advanced Materials

Japan is one of the nations which has long recognized the importance of advanced materials. As the Executive Vice President of Japan's NEC Corporation, Dr. M. Uenohara recently noted: "One who can control materials also can control technology."[48] Japan has evidently followed that motto. Since 1981, it has embarked on a ten-year national research program in advanced ceramics, an effort designed to help Japan dominate the lucrative international market estimated by some as tens of billions of dollars.[49] It is not clear how much the Japanese are investing in this particular effort, but it is clear that the activities are well coordinated and extensive.[50] The design of this program closely resembles that of their other long-term activities of previous years in photovoltaics and energy conservation.[51] Although direct government funding appears relatively modest, approximately $10 to $15 million per year, industry funding has been estimated at between $100 to $300 million per year.[52] Over sixty industrial companies have been identified in the ceramics program, the companies operating through a special engineering research association. Even if the lower figure of $100 million is

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[48] M. Venohara, Remarks at the Summary Talk at the High-Tech Materials Exhibition (May 20-23, 1987) (held in Tokyo, Japan).

[49] *Id.*

[50] *Superconductivity Hearings, supra* note 33, at 193 (Testimony of Dr. Kent Bowen, of M.I.T.).

[51] In 1980, Japan's Minister of International Trade & Industry (MITI) announced a number of national efforts to focus on advancing a number of high technology areas: these included photo voltaices, artificial intelligence, and structural ceramics, among others. Energy conservation had been identified by MITI as another area of national interest in previous years. Each of the programs have durations of about ten years.

[52] NAT'L MATERIALS ADVISORY BD. OF THE NAT'L RESEARCH COUNCIL, HIGH TECHNOLOGY CERAMICS IN JAPAN (1984) (NMAB-418, Nat'l Academy Press, Wash., D.C.).

accurate, this would mean that there has been an investment of over $1 billion in the ten year span by the Japanese.

The Japanese program in ceramics focuses heavily on the engineering aspects of these materials and relies, when necessary, on the basic research results from the United States and elsewhere. Their current program would make it quite easy to move quickly into the applications side of the new ceramic, superconducting materials. It should also be noted that more sizable investments can be anticipated in this area given the worldwide interest in the new ceramic superconductors.

In contrast to Japan, the United States has no national advanced materials program effort. We have been slow to act, providing only intermittent funding for advanced ceramics research, and not providing long-term direction or priorities. In analyzing the President's recent budgets,[53] approximately $60 million can be identified as targeted toward advanced structural ceramics. However, these funds are spread out among the Departments of Defense, Energy, Commerce, NASA and NSF, and divided among numerous programs and agency divisions. While informal communication does take place between the various agencies, the annual appropriations review within the executive branch takes place in isolation, with each agency scurrying to protect its own programmatic slice of the budget pie as it argues individual budgets with OMB.

Unfortunately, there is a similar lack of coordination, planning, and priority-setting in the evaluation of other research areas in the estimated $1.5 billion we spend on federal materials research and development. These research areas include polymeric composites, photovoltaics, advanced metals processing, and others. Meanwhile, France, Germany, the United Kingdom and others appear to have taken their cue from Japan and have initiated major advanced materials collaborations. No similar effort exists in the United States.

B. Materials Vulnerability

A 1986 study by the Bureau of Mines examined the economic impact of a 100 percent interruption of our chromium supplies

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[53] EXECUTIVE OFFICE OF THE PRESIDENT, OFFICE OF MANAGEMENT AND BUDGET, BUDGET OF THE U.S. GOV'T 1989 (1988) (U.S. Gov't Printing Office) [hereinafter BUDGET].

from southern Africa. The study projected losses of more than $15 billion and close to 450,000 jobs over a three year period in the United States in the event that these supplies were cut off.[54]

Europe, Japan, and other western countries would be even more severely affected by the loss of chromium imports. I emphasize that this impact is only for one element, chromium, important to our chemical and aerospace manufacturing industries. The collective impact of an embargo on several strategic materials could be globally devastating. One solution may be to promote development of alternate sources of critical minerals such as chromium or manganese. For example, Brazil continues to explore the potential of its chromium and maganese reserves. Guyana and Venezuela[55] could provide alternative sources of bauxite for the manufacture of aluminum, or they might even provide the processed metal itself. The Pacific rim countries could serve as future sources[56] of cobalt and the rare earth minerals such as yttrium, lanthanum and cerium of potential importance to the new ceramic superconductors. However, if we are to use any of these countries as alternate sources, we must exert some national leadership and set appropriate priorities to avoid potential disaster.

Unless we are careful, the situation for advanced materials could be as serious as that with the basic minerals.[57] For example, the new, high temperature, superconducting materials are made from yttrium, barium, and other "rare earth" materials, and copper oxides. The major sources of these "rare earths" and yttrium are China, Australia and elsewhere.[58] There are domestic sources of these materials, but presently they are not commercially viable. Of greater concern is that the largest domestic source of these minerals is located in the desert areas of southern California.[59] This land currently is being considered for

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[54] BUREAU OF MINES, U.S. DEP'T OF INTERIOR, SOUTH AFRICA AND CRITICAL MATERIALS (July 1986) (Open File Report No. 76-88).

[55] SUMMARIES, *supra* note 7, at 8-9, 18-19 (Guyana has a reserve base of bauxite of about 900 million metric tons and Venezuela about 350 million metric tons.).

[56] Includes Australia, New Caledonia, the Philippines as well as China, Malaysia, India and Thailand.

[57] *Proceedings*, *supra* note 45, at 149.

[58] SUMMARIES, *supra* note 7, at 127, 177.

[59] *Id.* at 126, 176.

inclusion in a new wilderness park, which would make the minerals inaccessible for industrial development. Regarding advanced composites, we are most entirely dependent on foreign source for PAN (*p*oly*a*crilo*n*itrile) fiber material essential to many of the "super" plastics. It is estimated that it will cost billions of dollars to build the necessary domestic facilities to provide these fibers,[60] a difficult proposal in these tight economic times. Again, leadership and priorities are necessary to chart our course for the future.

NEW MATERIALS—NEW PROBLEMS

Just as we were slow to learn that environmental costs must be included in determining the full costs of using basic materials, we have also been slow to recognize this problem with the advanced materials. Unlike most metals, plastics, composites, and others do not degrade readily. As land becomes more valuable, landfills, the method of choice for much waste disposal, is no longer a viable alternative. In addition, plastic in municipal waste is expected to rise over 15.5 million tons by the year 2000.[61] Obviously, we must look to recycling technologies. In addition, plastics present special problems including separation from other nonmetallic waste, the chemical complexity of the plastics themselves, storage and processing technologies, and toxicity. If we choose not to deal with these problems, and assuming the increased use of these materials in new products, we will find ourselves eventually buried in these "advanced materials."

FEDERAL ROLE

Let me offer a few thoughts about the Federal role in promoting critical materials—advanced or basic.

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[60] *National Critical Materials Council: Hearings Before the Subcomm. on Transportation, Aviation and Materials of the House Comm. on Science, Space, and Technology*, 100th Cong., 1st. Sess. (1987).

[61] LEAVERSUCH, *Industry Begins to Face Up to the Crisis of Recycling*, 64 MODERN PLASTICS 3, Mar. 1987, at 44, 45.

A. Policy

There is growing recognition among national policy makers of the importance of materials to our economy and to our security. The President has appointed members to the National Critical Materials Council,[62] the organization within the White House mandated to focus on this important issue. The Council must now take steps to carry out its responsibilities. In the area of materials alone, topics which must be addressed by the Council include superconductivity, the steel and copper industries, South Africa, the stockpile, and hazardous wastes. These topics must compete with all the other issues calling for the attention of the President and his advisors. An important role for the Council will be to help sort out the President's priorities on these diverse topics. In addition, further steps must be taken to bring the private sector into the policy process, possibly as an advisory group to the Council.

B. Research

We now spend about $1.5 billion for federal materials research and development efforts.[63] These programs are scattered over fifteen major departments and agencies, and suffer from little or no coordination or planning. The private sector investment was about $4.3 billion in 1977;[64] current private sector investment is unknown. Among the present issues of concern in research are:

- The need for a national program in advanced materials research and development with appropriate priorities.
- An appropriate balance between basic and applied research. Our government currently remains heavily committed to supporting basic work, while our international competition promotes application oriented research and development.

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[62] *See* National Critical Materials Act of 1984, 30 U.S.C. § 1801 (1984) (as required by 30 U.S.C. § 1802, a three-member National Critical Materials Council was first appointed by President Reagan in Nov. 1985).

[63] BUDGET, *supra* note 53.

[64] COMM. ON MATERIALS OF THE FED. COUNCIL FOR SCIENCE AND TECHNOLOGY, INVENTORY AND ANALYSIS MATERIALS LIFECYCLE RESEARCH AND DEV. IN U.S. INDUS. 1977 (April 1979) (Office of Science and Technology Policy, Executive Office of the President).

- The problem of transferring technology from our federal labs to commercial applications.
- The national security need to protect the export of advanced materials technology balanced with the need for scientific openness and information exchange.

C. *Education*

We need to develop a generation of engineers who have broad, hands-on experience. There is too much overall emphasis on theory and on early specialization (ceramics versus materials engineers) with little or no focus on industrial processing. Perhaps most telling is the fact that Japan produces more engineers per capita than the United States[65] and that most of Japan's corporate leadership has engineering or other technical degrees. We, on the other hand, produce far more lawyers than engineers, and it is rare when a chief executive officer has more than an inkling of technical expertise.

D. *Advanced Processing*

Advanced processing, that is using our improved understanding of knowledge systems, artificial intelligence and robotics to

[65] NAT'L SCIENCE FOUND. AND DEP'T OF EDUCATION REPORT, SCIENCE AND ENGINEERING EDUCATION FOR THE 1980'S AND BEYOND (1980) (NSF 80-78).

Table 1

*Federal Funding for High Temperature Superconductivity**
(Millions of Dollars)

	FY 87	*FY 88 Estimate*
Department of Defense	24.0	33-50
Department of Energy	12.5	27.2
National Science Foundation	11.3	15.0
NASA	0.8	3.7
NBS/DOC, other	1.1	2.8
TOTAL	49.7	82-98

* Source: Author's compilation from Administration's budget request for fiscal year 1989.

name a few, is the key to both the advanced as well as the basic materials industries. Although this seems rather obvious in the case of advanced materials, it has only begun to be recognized in relation to the basic industries. Development of the new superconductor for practical applications depends almost entirely on developing processing-technologies to produce materials with the engineered properties required. Similarly, advances in productivity of basic materials (steel, aluminum, copper) requires tremendous development in the advanced processing of these materials. Development of such processing will require long-term commitments by both industry and the government in both collaborative as well as independently funded programs.

CONCLUSIONS

To conclude, our current critical materials situation is a result of three to four decades of benign neglect. Improvements in materials will not occur overnight. We have taken some steps to correct this situation. Within the federal government we have the institutional framework (the National Critical Materials Council, for instance) to develop and to implement that policy. We must now take actions to make these institutions work.

Additionally, steps must be taken to increase joint industry-government efforts in basic and advanced materials technology development. These cost-sharing programs will provide a built-in means to insure that we are working on the right issues, while at the same time allowing for efficient translation of the research benefits to commercial products.

On the bright side of our materials position, the importance of these critical materials is increasingly being recognized by the nation's leaders, public and private. We must invest resources as well as make commitments to the long-term if we are to maintain a healthy minerals/materials industry into the next century.