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in Materials Science and Technology

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ADVANCED MATERIALS & PROCESSING
FY 94: BY FCCSET

Advanced Materials & Processing

The Fiscal Year 1994 Federal Program in Materials Science and Technology



A Report by the FCCSET Committee on Industry and Technology
To Supplement the President's Fiscal Year 1994 Budget

Cover:

MATERIALS RESEARCH TO APPLICATION

The drawing on the cover is an artist's rendition of the featured theme of the Advanced Materials and Processing Program - Research to Application. It depicts the breadth of the program through a montage of figures drawn to represent examples of emphasis areas. The left side contains illustrations of the research and development effort, from the fundamental (crystal structure), to synthesis-processing (phase diagram, injection molder, metals processing ladle), to environmental concerns (fork composed of biodegradable corn starch). Applications of materials technologies are shown on the right side and include information/communications (transistor cross section, optical fibers), health (MRI image), transportation (automobile, airplane, moon/space exploration) and infrastructure/construction (bridge, roadways). The translation of the R&D to sector beneficiaries is reflected by the optical fiber light pipe that bridges the gap, connecting the left and right sides.

ADVANCED MATERIALS AND PROCESSING

**The Fiscal Year 1994 Federal Program
in Materials Science and Technology**

**A Report by the Committee on Industry
and Technology**

**Federal Coordinating Council for Science,
Engineering and Technology**

Office of Science and Technology Policy

MAY 6, 1993

The Federal Coordinating Council for Science, Engineering, and Technology (FCCSET) was established by statute in 1976 to address science and technology policy issues affecting multiple Federal agencies. The council is chaired by John H. Gibbons, the director of the Office of Science and Technology Policy (OSTP) and the President's science advisor.

The agencies participating in FCCSET, in conjunction with OSTP and the Office of Management and Budget, developed a coordinated strategy in materials science and technology that encompasses long-range goals and priorities to guide Federal programs and activities. The Advanced Materials and Processing Program (AMPP) is one of six FCCSET initiatives focusing on interdisciplinary, high-priority fields of science and technology.

The AMPP was developed under the auspices of the FCCSET Committee on Industry and Technology (CIT). Planning, implementation, and oversight of the AMPP technical program are executed by the Task Group on National Planning of the CIT Working Group on Materials.

**CIT Working Group on Materials (COMAT),
Task Group on National Planning**

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Lyle H. Schwartz, Department of Commerce

Executive Secretary

Samuel J. Schneider, Department of Commerce

Members

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James Eberhardt, Department of Energy
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Michael Rigdon, Department of Defense (IDA)
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John T. Watson, National Institutes of Health
Benjamin Wilcox, Department of Defense (ARPA)

Liaisons/Observers

Cynthia Arnold-McKenna, Office of Science and Technology Policy

Robert Civiak, Office of Management and Budget

Cary Gravatt, Committee on Industry and Technology

Elizabeth Rodriguez, Federal Coordinating Council for Science, Engineering and Technology

COMAT Staff Support

Laura Hanlon, Department of Commerce

Susan Roth, Department of Commerce

EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF SCIENCE AND TECHNOLOGY POLICY
WASHINGTON, D.C. 20506

DRAFT

MEMBERS OF CONGRESS:

I am pleased to forward with this letter "Advanced Materials and Processing: The Federal Program in Materials Science and Technology," prepared by the Committee on Industry and Technology of the Federal Coordinating Council for Science, Engineering, and Technology (FCCSET), to supplement the President's Fiscal Year 1994 Budget.

The economic prosperity, environmental well-being, and quality of life of all Americans are linked to the development of advanced materials and processing technologies. These improved materials and processes can contribute to increased energy efficiency, improved environmental quality, sustained national security, reduced health-care costs, development of information "superhighways", reconstruction of the infrastructure, and production of new transportation vehicles that will carry the Nation into the 21st century.

The Advanced Materials and Processing Program (AMPP) is a coordinated interagency effort to exploit opportunities in materials research and development to meet significant national goals and to extend U.S. leadership in this area. Now in its first year, the AMPP is having strong positive effects. The spotlight on advanced materials and processing has heightened the emphasis on these topics in the participating agencies. The inventory of all active Federal materials R&D programs that was conducted during development of the AMPP not only provided a foundation for the initiative but also continues to serve as a valuable, comprehensive guide to Federal programs for private-sector organizations interested in leveraging their R&D resources. At the technical level, communication and coordination among agencies and with the private sector are increasing, materials R&D has been re-oriented toward AMPP priorities, and collaborative activities are being expanded--with direct benefit to the private sector.

The coordination and integration of the interagency research and development strategy for this Initiative was led very ably by Dr. Lyle Schwartz, Chairman of the AMPP Working Group. He and his interagency colleagues are to be complimented on their work.

John H. Gibbons
Director

DRAFT

TABLE OF CONTENTS

COMMITTEE MEMBERSHIP	i
TRANSMITTAL LETTER	iv
EXECUTIVE SUMMARY	1
1. INVESTING FOR GROWTH	2
2. THE AMPP FRAMEWORK	5
• Goal, Strategic Objectives, Technical Components.	5
Figure 1 - AMPP Framework	6
Figure 2 - Inclusion Criteria	8
• Complementary Programs	9
• Other FCCSET Initiatives	9
• Strategic Accomplishments	11
3. THE FY 1994 PROGRAM	12
• The Budget	12
Table 1 - AMPP R&D Budget by Agency	13
Table 2 - AMPP R&D Budget by Research Component	14
Table 3 - AMPP R&D Budget by Materials Class	15
• The R&D Program: Impact Areas and Technical Milestones	16
Table 4 - Example Applications of Materials Technologies	18
4. AMPP IMPLEMENTATION	29
• Planning: COMAT Task Groups	29
• Execution	30
• Evaluation	32
Table 5 - AMPP Quantitative Measures - Baseline Levels in FY 1992 By Agency	33
5. AGENCY R&D PROGRAMS: LAYING THE FOUNDATION FOR PROGRESS	34
6. APPENDIX	
A. Classes of Materials	56
B. Complementary Programs	58
C. COMAT Task Group Activities	63

[Editors Note: Various Success Stories about AMPP research will be displayed in highlight boxes throughout the text of the booklet as indicated by the notation on individual pages. The text for each Success Story is located at the end of this booklet.]

EXECUTIVE SUMMARY

The Nation's economic prosperity, environmental well-being, and quality of life are linked to the development of advanced materials and processing technologies. Improved materials and processes can contribute to increased energy efficiency, improved environmental quality, reduced health-care costs, development of information "superhighways", reconstruction of the infrastructure, sustained national security, and production of new transportation vehicles that will carry the Nation into the 21st Century.

The Federal government has invested in materials research and development (R&D) for many years, successfully achieving the goals of individual agencies and providing the scientific and educational basis for international pre-eminence in the field. The global competitive challenges of the 1990s, however, demand an expanded effort. A coordinated, interagency approach is needed to increase the effectiveness of the Federal program, by leveraging government research through coordinated planning, and by expanding dialogue and partnerships with industry.

In FY 1994, the **Advanced Materials and Processing Program (AMPP)** will be a \$2 billion Federal program, with additional support from industry for joint projects. The AMPP is an investment in growth, both to meet national goals and to extend U.S. leadership in materials science and technology. The program will exploit new capabilities to design advanced materials and cost-efficient, environmentally conscious processes to meet industrial needs. The program encompasses both basic and applied research, supporting the full continuum of activities required for innovation and application.

The President's FY 1994 budget request for the AMPP is \$2056.4 million, including \$1736.4 million for direct programs and \$320.0 million for construction and operation of the national user facilities. In comparison to budgets for the preceding two years, the request for DOD is substantially lower but requests for most other agencies are higher, reflecting the new effort to balance military and civilian R&D expenditures.

AMPP activities impact seven areas: energy, environment, health and safety, information and communication, infrastructure, national security, and transportation. The program also incorporates a number of general elements emphasized by the Administration, including means for leveraging Federal investment to maximize return, fostering cooperation between government and industry, investing in research to maintain U.S. leadership, helping the private sector gain access to the best technologies and practices, evaluating the extent of public/private cooperation and technology transfer, and improving education and training.

Now in its first year, the AMPP already has had a significant impact. The spotlight on advanced materials and processing has heightened the emphasis on these topics in the 10 participating agencies. Communication and coordination among agencies and with industry is increasing, with direct benefits to the private sector.

1. INVESTING FOR GROWTH

The Nation's economic prosperity, environmental well-being, and quality of life are linked to the development of advanced materials and processing technologies. Improved materials and processes can contribute to increased energy efficiency, improved environmental quality, reduced health-care costs, development of information "superhighways", reconstruction of the infrastructure, sustained national security, and production of new transportation vehicles that will carry the Nation into the 21st Century.

For example:

Billions of dollars in lost energy could be saved through the development of **superconducting materials** suitable for use in electric power lines. Solar energy -- a clean, renewable fuel -- could become economical by virtue of "designer" **photonic materials** synthesized atom by atom for efficient light capture and conversion.

The Earth's protective ozone layer could be preserved through development of new refrigerant materials to replace man-made, ozone-depleting compounds, such as chlorofluorocarbons (CFCs). Pollution could be reduced if consumer products were made of starch-based "bioplastic" **polymers**, which biodegrade in composting operations and thus leave no residues.

Millions of Federal dollars now spent on kidney dialysis could be saved -- and patient quality of life improved -- through development of improved **biomaterials** for artificial kidneys. Public safety could be enhanced if "intelligent" materials were used as sensors to warn of possible structural failures.

Business innovation and training could be enhanced through affordable, high-speed information systems made possible by new **electronic and photonic materials**. Improved chip packaging materials (e.g., **polymers, ceramics**) and packaging strategies could foster continued miniaturization of electronic circuitry.

New industries and jobs could be created through the development and use of highly durable road and bridge materials, such as recycled wastes, **high-strength concrete, polymer-impregnated fibers, and non-corroding metals** -- materials that could save millions of dollars once spent on repairs, energy, and resources.

The Nation's security will benefit from "intelligent" **processing of materials (IPM)**, a computer-based method of automatic control that can reduce costs and improve quality of weapons system components. Through technology transfer, the private sector also can benefit from military innovations such as cost-saving coatings.

The reliability, safety, and fuel efficiency of aircraft and automobiles could be improved through further development of strong-but-lightweight **metal alloys**, **polymers**, and **composites**, as well as fracture-resistant **ceramics** and cost-effective mass production processes.

These are just a few of the important advances the **Advanced Materials and Processing Program (AMPP)** is designed to facilitate.

The Federal government has invested in materials research and development (R&D) for many years, successfully achieving the goals of individual agencies and providing the scientific and educational basis for international pre-eminence in the field. (Examples of past technical achievements are scattered throughout this booklet, designated by red shaded text boxes.) The global competitive challenges of the 1990s, however, demand an expanded effort. A coordinated, interagency approach is needed to increase the effectiveness of the Federal program, by leveraging government research through coordinated planning, and by expanding dialogue and partnerships with industry.

In FY 1994, the AMPP will be a \$2 billion Federal program, with additional support from industry for joint projects. The program is an investment in growth, both to meet national goals and to extend U.S. leadership in materials science and technology. The program encompasses both basic and applied research, supporting the full continuum of activities required for innovation and application.

The AMPP exploits new capabilities to design advanced materials¹ and cost-efficient, environmentally conscious processes to meet industrial needs. This is an era in which materials can be designed to have improved mechanical properties, such as high strength, toughness, and strength-to-density ratios, as well as superior thermal, electrical, optical and chemical characteristics. New materials can provide the basis for entirely new products, and for cheaper, more durable, and more environmentally acceptable versions of conventional products. The translation of materials advances into new products often depends on the development of new or improved processing techniques, to mass produce materials of the required quality economically using environmentally conscious means.

AMPP activities impact seven areas: energy, environment, health and safety, information and communication, infrastructure, national security, and transportation. The AMPP also incorporates a number of general elements emphasized by the Administration, including means for leveraging Federal investment to maximize return, fostering cooperation between government and industry, investing in research to maintain U.S. leadership, helping the private sector gain access to the best technologies and practices, evaluating the extent of public/private cooperation and technology transfer, and improving education and training.

¹ Brief descriptions of the various categories of advanced materials may be found in Appendix A

This document describes the FY 1994 program, the second year of the AMPP. Chapter 2 outlines the program framework. Chapter 3 presents budget data and lists technical milestones that will be used to monitor progress in the impact areas. Chapter 4 outlines implementation plans. Chapter 5 describes the R&D activities of each participating Federal agency.

2. THE AMPP FRAMEWORK

Goal, Strategic Objectives, Technical Components

Success in R&D is measured by both new discoveries and their application. To achieve these objectives, the AMPP provides a framework for strengthening the interfaces between innovation and application, and for enhancing the interaction of all the participants in the technology development enterprise -- in government, industry, and academia.

The AMPP optimizes Federal materials R&D through an interagency strategy, encompassing a research plan and associated funding levels that take advantage of opportunities for significant technical breakthroughs. The AMPP is a goal-driven program based on a planning framework of strategic and technical priorities (see Figure 1).

The **goal** of the AMPP is to improve the manufacture and performance of materials to enhance the Nation's quality of life, security, industrial productivity, and economic growth. To achieve this goal, programs are designed to achieve four **strategic objectives**, which concern broad national needs:

Establish and maintain the U.S. scientific and technological leadership position in advanced materials and processing;

Bridge the gap between innovation and application of advanced materials technologies;

Support agencies' mission objectives to meet national needs with improvements in advanced materials and processing; and

Encourage university and private-sector R&D activities in materials technologies, their applications, and their implementation.

AMPP activities are divided into five **technical components**, each identified as critical to sustained progress in materials science and technology. In order of priority (as determined by internal agency planning based on authoritative outside studies), the components are

- synthesis and processing -- encompassing the creation of new materials and processes, applied R&D to transfer laboratory achievements to pilot plants, and process integration with design and manufacturing requirements;
- theory, modeling, and simulation -- exploiting U.S. leadership in computational techniques to expand quantitative understanding of complex materials and processing technologies;

Figure 1

U.S. ADVANCED MATERIALS AND PROCESSING PROGRAM (AMPP)

GOAL

Improve Manufacture and Performance of Materials to Enhance U.S. Quality of Life, National Security and Industrial Productivity and Economic Growth.

STRATEGIC OBJECTIVES

- A. Establish and Maintain the U.S. Scientific and Technological Leadership Position in Advanced Materials and Processing
- B. Bridge the Gap between Innovation and Application of Advanced Materials Technologies
- C. Support Agencies' Mission Objectives to Meet National Needs with Improvements in Advanced Materials and Processing
- D. Encourage University and Private Sector R&D Activities on Materials Technologies, Their Applications and Their Implementation

PROGRAM COMPONENTS

Research Programs May Consist of One or More Program Components Linked to Achieve a Specific Goal

A. SYNTHESIS & PROCESSING

- 1. Process Integration
- 2. Applied Research and Development
- 3. Basic Research

B. THEORY, MODELING AND SIMULATION

- 1. Application Specific
- 2. Material Specific
- 3. Fundamental

C. MATERIALS CHARACTERIZATION

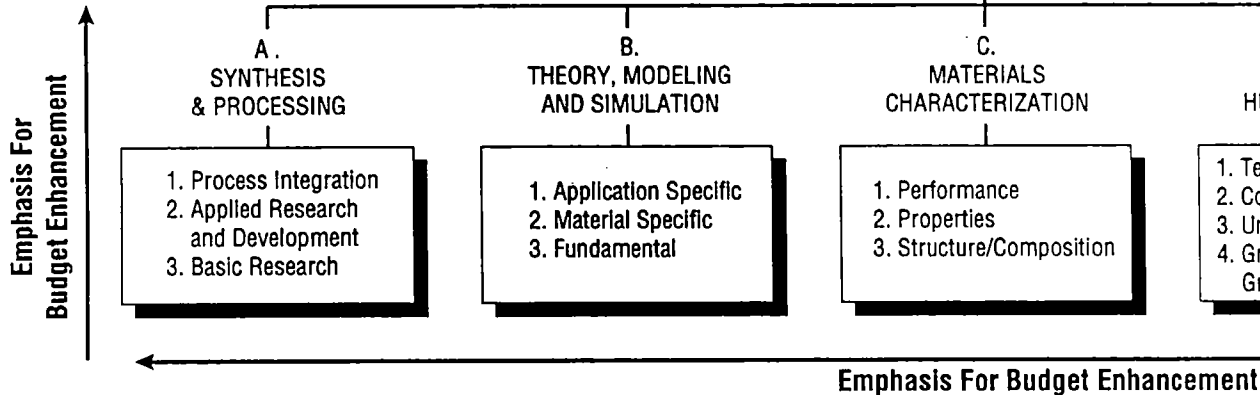
- 1. Performance
- 2. Properties
- 3. Structure/Composition

D. EDUCATION & HUMAN RESOURCES

- 1. Technical Training
- 2. Continuing Education
- 3. Undergraduate Education
- 4. Graduate and Post Graduate Education

E. NATIONAL USER FACILITIES

Photon, neutron and magnet sources



- materials characterization -- focusing on the interrelationships among structure, composition, properties, and performance (basic knowledge critical to the expedient and confident use of new materials);
- education and human resources -- assuring a continued supply of qualified educators and practitioners in the multidisciplinary field of materials science and engineering; and
- major national user facilities -- providing sources of photons, neutrons, and high magnetic fields to characterize the structure and composition of materials.

The AMPP technical program is developed annually by the Committee on Materials (COMAT), a working group of the FCCSET Committee on Industry and Technology (CIT), based on R&D plans submitted by the 10 participating agencies. The plans are evaluated for technical content and adherence to the AMPP framework (inclusion criteria are shown in Figure 2). Program and budgetary oversight is provided by FCCSET (an interagency council of the Office of Science and Technology Policy [OSTP]), and the Office of Management of Budget (OMB).

The 10 participating agencies are:

Department of Commerce (DOC)
 Department of Defense (DOD)
 Department of Energy (DOE)
 Department of Interior (DOI)
 Department of Transportation (DOT)
 Environmental Protection Agency (EPA)
 Department of Health and Human Services (HHS)
 National Aeronautics and Space Administration (NASA)
 National Science Foundation (NSF)
 Department of Agriculture (USDA)

The Federal materials R&D program is carried out in diverse locations, by Federal employees and, through grants and contracts, by researchers in industry, academia, and private research centers. Extensive R&D is conducted in government laboratories operated either by government agencies or by contract with the private sector.

Figure 2

**INCLUSION CRITERIA FOR THE FY 1994 ADVANCED MATERIALS AND
PROCESSING PROGRAM**

Responsiveness: The R&D must contribute significantly to achieving the goal and strategic objectives of the Advanced Materials and Processing Program (AMPP) listed in the planning framework. (See Figure 1).

Scientific/Technical Merit: The R&D must be scientifically/technically sound and of high quality, and must be the product of a scientific/technical planning and review process.

Linkages: The R&D should foster scientific and technical connections between the government and the industrial and/or academic sectors to generate a coordinated interagency plan that increases the effectiveness of the R&D.

Complementary Programs

Efforts to achieve the goal and objectives of the AMPP go beyond the program itself, to include other Federal R&D activities that support materials science and technology but are not incorporated in the crosscut analysis due to incompatibility with the FCCSET planning process. Each of these complementary programs is broad in scope, based on multiple technologies and fields of science, and varied in terms of the level of materials R&D conducted from year to year.

These programs, once funds are allocated, are among the most effective of all Federal efforts in fostering technology development and utilization. Their effect is rapid because they are linked with industry at a late stage in technology development. As such, these programs are a valuable supplement to AMPP activities. Complementary programs include:

Small Business Innovation Research

Advanced Technology Program (DOC)

Enhanced Technology Transfer Program (DOE)

Hatch Act, Cooperative Forestry Research, and Payments to 1890 Colleges and Tuskegee University (USDA)

University Transportation Centers Program (DOT)

Brief descriptions of these programs are provided in Appendix B.

Other FCCSET Initiatives

The AMPP technical programs, and progress toward the program's overall goal and objectives, are complemented and advanced by four other FCCSET crosscut initiatives. Continuing communication and liaison among the appropriate FCCSET planning groups and within agencies will ensure coordination of R&D programs and will avert overlap.

The AMPP and the High Performance Computing and Communications (HPCC) initiative are synergistic through the AMPP technical component in theory, modeling, and simulation, and the HPCC's development of advanced algorithms and computer architectures for scientific computing.

The AMPP and the Biotechnology initiative address common concerns in the processing of materials by biological systems, as well as the production of some biomolecular and biomaterials.

The AMPP component in education and human resources is supported to a significant degree by the Science, Mathematics, Engineering, and Technology Education Initiative.

Finally, the AMPP will be linked closely with the developing initiative in Advanced Manufacturing Technology, which focuses on integration for manufacturing innovation. Synergism and close coordination between these two initiatives will be required for the success of each.

Strategic Accomplishments

The AMPP has had a significant impact on the Federal approach to materials R&D. The spotlight on the topic has heightened the emphasis on advanced materials and advanced processing technologies in the 10 agencies, and the challenge of formulating a coherent Federal program has stimulated interagency communication and coordination. The inventory of all active Federal materials R&D programs conducted during development of the AMPP provided a foundation for the technical program and serves as an invaluable, comprehensive guide to Federal activities for private-sector organizations seeking to leverage their R&D resources.²

At the technical level, materials R&D has been re-oriented toward AMPP priorities. For example, current programs emphasizing synthesis and processing include many developed in close collaboration with the private sector. These include programs in engine materials for high-speed aircraft (NASA), lightweight materials for automotive applications (DOE), X-ray lithography for semiconductor processing (DOD/DOE), precision casting of metal alloys for aerospace (DOC/DOD/DOE), biodegradable materials (USDA), and new liquid crystalline materials for applications in communications (NSF).

In addition, collaborative activities are being expanded, with direct benefits to the private sector. Mechanisms include Cooperative Research and Development Agreements (CRADAs), used extensively by DOC, DOD, DOE, DOI, HHS, and USDA; and new NSF Memoranda of Understanding (MOUs) that establish a framework and guidelines for joint activities involving academia, industry, Federal laboratories, and other Government agencies, both to link university programs more closely with industry and Federal laboratories, and to improve the educational component in materials science and technology.

Perhaps most important, the AMPP generally has been well received by the private sector. Nearly 10,000 copies of the booklet introducing the program have been distributed. Dozens of presentations about the program have been made to various groups, including professional societies, trade associations, and intergovernmental groups. Numerous professional and trade groups have volunteered to help move cooperative activities forward.

Finally, a formal AMPP implementation plan has been developed. The plan incorporates strategies for increasing multi-agency communication, expanding private-sector involvement in the planning process and in the execution of the R&D agenda, and evaluating the success of the program. The plan is described in Chapter 4.

² The inventory is contained in a 211 page document, *Advanced Materials and Processing: The Fiscal Year 1993 Program*. For information on how to obtain this publication, see the inside back cover.

3. THE FY 1994 PROGRAM

The Budget

The President's FY 1994 budget request for the AMPP is \$2056.4 million, including \$1736.4 million for direct programs and \$320.0 million for construction and operation of the national user facilities. In comparison to budgets for the preceding two years, the request for DOD is substantially lower but requests for most other agencies are higher, reflecting the new effort to balance military and civilian R&D expenditures.

Materials R&D is defined broadly here to include any scientific and engineering research on substances in any form, at any stage of preparation, fabrication, manufacture, recycle, or disposal. Program types vary and include activities such as technology development, device or process development, and the gathering or analysis of data on various materials.

The AMPP focuses on activities that may benefit from increased interagency and public/private cooperation. Excluded at agency discretion are classified programs and some unique mission-driven activities, such as the development of magnets for a superconducting supercollider.

The FY 1994 budget continues significant activities in the major AMPP technical priorities -- synthesis and processing, and theory, modeling, and simulation. These two components were emphasized in a major National Research Council study on materials science and engineering that incorporated considerable input from industry. This budget also maintains adequate resource levels to achieve breakthroughs in energy, environment, health and safety, information and communication, infrastructure, national security, and transportation.

Table 1 shows the breakdown by agency of the President's FY 1994 budget request. Data for FY 1992 (actual expenditures or budget obligations) and FY 1993 (budget authorizations as set by Congressional appropriations) are included to illustrate both the change in overall funding and shifts in priorities. Tables 2 and 3 show the budget breakdown for all three fiscal years by materials class and AMPP technical component.³ All budget figures include only focused AMPP programs, not the complementary Federal programs.

³ In Table 3, the "other/non materials specific" category includes a variety of activities not easily classified, such as R&D involving generic testing methods and reference materials, anti-corrosion coatings, paints and lubricants, battery materials, insulation materials, nuclear or fossil fuels, phase diagrams, ores and minerals, textile design, quantum fluids, clays, microgravity science, or comparative risk assessments.

Table 1

AMPP R&D BUDGET BY AGENCY
(Dollars in Millions)

Agency	FY92 \$M	FY93 \$M	FY94 \$M	FY94 CHANGE OVER FY93 \$M
DOC	42.6 (34.1)	48.4 (34.8)	56.7 (42.4)	8.3 (7.6)
DOD*	530.9	557.7	421.7	-136.0
DOE*	862.5 (644.4)	914.0 (682.8)	941.5 (662.6)	27.5 (-20.2)
DOI	25.2	24.9	21.5	-3.4
DOT	11.0	14.9	12.7	-2.2
EPA	3.5	4.5	4.5	0.0
HHS	79.6	85.9	92.9	7.0
NASA	76.3	102.8	131.1	28.3
NSF	265.6 (242.2)	318.5 (291.7)	328.0 (301.2)	9.5 (9.5)
USDA	36.3	37.4	45.8	8.4
TOTAL	1933.5 (1683.5)	2109.0 (1837.4)	2056.4 (1736.4)	-52.6 (-101.0)

Parentheses indicate total funding excluding construction and operating costs for major national user facilities

* Excludes classified research

[Editors Note: This table will be displayed in a combined numerical and bar chart format]

Table 2

AMPP R&D BUDGET BY RESEARCH COMPONENT*
(Dollars in Millions)

Component	FY92		FY93		FY94	
	\$M	Pct	\$M	Pct	\$M	Pct
A. Synthesis and Processing	948.8	49.1	1039.0	49.3	972.4	47.3
B. Theory, Modeling, Simulation	234.3	12.1	262.7	12.5	252.7	12.3
C. Materials Characterization	478.4	24.7	510.7	24.2	486.2	23.6
D. Education/Human Resources	22.0	1.1	25.0	1.2	25.1	1.2
Subtotal	1683.5	87.1	1837.4	87.1	1736.4	84.4
E. National User Facilities	250.0	12.9	271.6	12.9	320.0	15.6
TOTAL COMPONENT FUNDING	1933.5	100.0	2109.0	100.0	2056.4	100.0

* Excludes classified research

[Editors Note: This table will be displayed in a combined numerical and bar chart format]

Table 3

AMPP R&D BUDGET BY MATERIALS CLASS*
(Dollars in Millions)

Materials Class	FY92 \$M	FY93 \$M	FY94 \$M
Bio/BioMolecular Matls	139.8	154.7	172.2
Ceramics	152.1	167.0	159.6
Composites	184.7	226.0	199.7
Electronic Materials	230.5	247.0	220.6
Magnetic Materials	32.0	24.8	26.2
Metals	391.9	391.3	254.7
Optical/Photonic Matls	138.3	154.6	153.3
Polymers	100.7	109.9	122.6
Superconducting Matls	142.7	146.4	133.0
Other/Non Materials Specific	170.8	205.7	194.5
Subtotal	1683.5	1837.4	1736.4
National User Facilities	250.0	271.6	320.0
TOTAL	1933.5	2109.0	2056.4

*** Excludes classified research**

[Editors Note: This table will be displayed in a combined numerical and bar chart format]

The R&D Program: Impact Areas and Technical Milestones

To emphasize the practical applications of materials that could enhance economic growth, environmental well-being, and quality of life, the R&D program for FY 1994 impacts seven areas. Table 4 shows how different types of advanced materials can be applied in each area.

The impact areas cut across agency lines: At least four agencies conduct R&D in each area. This does not mean their activities coincide. It is important to underscore the purpose of the AMPP -- to promote interagency coordination, but not program overlap. The intent is to avert duplication of effort.

The impact areas are interrelated; that is, technical advances in one area can benefit another. For example, improvements in energy efficiency can benefit the environment by reducing pollution, and breakthroughs in information technology can contribute to national security.

The importance of the impact areas is reflected by the economic importance of the related industries. For example, the aerospace, automotive, biomaterials, chemical, electronics, energy, metals, and telecommunications industries had combined worldwide sales of \$1.4 trillion in 1987 and employed 7 million workers. In addition, the chemical and aerospace industries make positive contributions to the U.S. trade balance.

To achieve the President's goals, myriad technical accomplishments will be needed. As an aid in both budgetary planning and program evaluation, specific technical milestones have been established in each impact area. The following pages present selected milestones to be achieved in FY 1994 and thereafter. These milestones can be achieved only if the AMPP is funded at the President's recommended level for FY 1994.

Due to space limitations, the lists of milestones are representative, not comprehensive. Milestones that would be useful in multiple impact areas (e.g., new ceramic fibers for both national security and infrastructure applications) are listed only once.

Although most milestones focus on applications, the AMPP also includes basic research -- the underpinning of technology innovation. Scientists now have the knowledge and tools to synthesize, understand, and exploit highly complex materials, such as nanostructured⁴ materials, "intelligent" materials⁵, biomolecular materials, and new types of magnetic materials. Basic research produces revolutionary surprises that challenge intellectual

⁴ Nanostructured refers to constituents less than 100 nanometers (billionths of a meter) in size.

⁵ This category includes optical, electronic, magnetic, and other types of materials that, by virtue of their sensing capability, will enable diverse technologies to respond dynamically to environmental stimuli.

materials. Basic research produces revolutionary surprises that challenge intellectual understanding of materials and often lead to novel, previously unimagined technologies that meet important needs and/or create new industries.

Table 4
Example Applications of Materials Technologies

ADVANCED MATERIALS TECHNOLOGIES	Energy	Environment	Health and Safety	Information/Communication	Infrastructure	National Security	Transportation
Biomaterials	Catalysts; Low temperature materials processing	Biodegradable plastics; bio-extraction and processing	Artificial organs and tissues	Bioelectronic sensors	Rubber; Greases; Lubricants	Biodegradable food containers; Field medicine containers	Tires; Deicers; Fuels; Lubricants
Ceramics	High temperature chemical processing; Fuel cells; Coal conversion	Nuclear waste storage; Catalytic converters; Wear resistant coatings	Bone/joint implants; Artificial teeth	Electronic packaging	High performance concrete; High temperature insulation	Heat engines; Body and vehicle armor	Low-emission, fuel efficient engines
Composites	Wind turbines; Lightweight structures	Waste storage and processing	Dental restoration; Implants	Printed wiring	Insulating building materials	Lightweight structures for military vehicles	Lightweight aircraft and automobiles
Electronic Materials	Photovoltaic conversion	Hazardous materials sensors	Heart pacemakers; Hearing aids; Safety alarms	Computer chips; Integrated circuits	"Smart" buildings	Communications and data processing; Night vision devices	"Intelligent" highway systems; Advanced electronic cockpits
Magnetic Materials	High strength magnets	Waste separation	Magnetic resonance imaging	Hard disk magnetic storage; Visual/audio displays	Machinery magnets	Railguns	Electric vehicles; Maglev trains
Metals	Energy transmission devices	Corrosion resistant products	Hip implants	Wiring circuits; Transmission lines	Corrosion sensors	Military materiel	Long-life, corrosion resistant, high-temperature aircraft structures
Optical/Photonic Materials	Energy conversion sensors/controls	Pollution detection	Biosensors; Safety control sensors X-ray detectors	Laser systems; Fiber optics; Computer interconnects	Traffic sensors	Lasers; High speed information processing	Intercity rail guides; Fly-by-light aircraft systems
Polymers	Solid state batteries; gas/fluids pipelines	Hazardous waste piping; Chemical separation membrane	Disposal hospital products; Safety protection devices	Liquid crystal light displays	Building products; Adhesives; Pavements	Radar signature devices	Lightweight auto bodies; Flame resistant aircraft interiors; High temperature adhesives and sealants
Superconducting Materials	Energy storage and transmission	Ore deposits mapping	Diagnostic imaging of human body	Supercomputers	Marine propulsion	Electronic warfare	Magnetic levitation trains

Energy

The availability of efficient, affordable, and "clean" energy promotes profits and minimizes waste. New materials and processing technologies could reduce energy costs significantly while conserving resources in the generation, transmission, storage, and use of energy. Materials advances could be applied to enhance energy efficiency in industry, transportation, and buildings (including Federal buildings), and materials R&D in renewable energy could help improve environmental protection.

All classes of advanced materials could have energy applications.

LOCATION FOR SUCCESS STORY #5

Technical Milestones

DOE will conduct studies in FY 1994 to increase the critical currents carried by high-temperature superconductors to more than 10^5 amps per square centimeter over a wire one meter long at -195°C (-380°F) and a magnetic field of at least 1 Tesla. These studies will foster development of superconducting power lines. The stated goals represent benchmark parameters for practical usage; the primary challenge is to process significant lengths of wire with reproducible properties.

DOE will complete cooperative research with industry in FY 1994 assessing the feasibility of commercial production of neodymium-iron-boron magnetic materials by inert gas atomization. These materials, which have high magnetic-field strength, could be used to reduce the size and weight of electric motors in automobiles.

DOE will initiate in FY 1994 the assessment of magnetic multilayers as a means to enhance magnetic anisotropy (i.e., variation in magnetic strength based on orientation of the material). This research could foster advances in transportation. For example, magnetically levitated trains are carried by a magnetic field; the best guideway materials might be those that generate the strongest field in the skyward direction (toward the train).

DOE will characterize and select in FY 1994 functional materials⁶ that show promise for use in lasers, catalysts, high energy/density rechargeable batteries, biosensors, and high-strength, fracture-resistant structural materials for high-temperature, high-pressure environments. Two examples of materials in this category are high-temperature intermetallic alloys and materials with controlled pore size for catalysis.

⁶ Functional materials are those used to accomplish specific functions rather than for their structural or load-bearing properties.

DOE and NSF will continue to support research in FY 1994 and thereafter to identify new classes of superconductors, such as alkali metal-doped fullerenes. The agencies also will pursue theoretical and modeling studies aimed at enabling scientists to predict which materials will exhibit superconductivity.

DOE will develop silicon photovoltaic cells by FY 1995 that exhibit conversion efficiency of 20 percent. This achievement would represent significant progress beyond present efficiency levels of about 15 percent. The goal is to make solar energy economically competitive with other forms of energy conversion; the target level keeps advancing as energy in general becomes more economical.

NSF will support development by FY 1995 of nanophase superparamagnetic composite materials with enhanced magnetic moments, for use in magnetic refrigeration. Nanophase composite particles containing iron and chromium will be prepared and consolidated into composites with the desired magnetocaloric properties. Laser ablation, photolytic dissociation, and pyrolytic processing techniques will be investigated.

Environment

New technologies must be developed to remedy the environmental damage caused by human activities. Waste prevention could be achieved through development of materials that are lighter in weight, less toxic, and more durable than current varieties, and that are produced by efficient and environmentally conscious processes. Recycling, composting, and energy recovery processes also could benefit the environment. Ultimately, the materials cycle⁷ could be transformed into a sequence of infinite re-use through the replacement of some commercial materials, the design of new materials that could be recycled endlessly, and the development of processes with few harmful waste products -- or none at all.

Many advanced materials could benefit the environment, including ceramics, composites, electronic, magnetic, and optical/photonic materials, metals, and polymers.

⁷ The materials cycle includes mining, extraction, and production of raw materials, synthesis and processing, product manufacturing, disposal, and re-use or recycling.

Technical Milestones

EPA will continue development in FY 1994 of environmentally acceptable substitutes for ozone-depleting CFCs and halons used in air conditioning, refrigeration, foam insulation, and fire suppression. Fluoropropanes, fluoroethers, and other chemicals are promising candidates. A key issue is whether these materials are less harmful overall than CFCs and halons; some substitute materials could create new environmental hazards.

DOI will initiate cooperative research with industry in FY 1994 into the recycling of accumulated steelmaking wastes to produce new materials. The intent is to reduce the volume of wastes now stockpiled on site; these wastes can be harmful if, for example, they contain toxic chromium, used to make stainless steel.

DOI will demonstrate in FY 1994 the technology for safe recycling of advanced aluminum alloys and fiber-reinforced aluminum composites, which are used in structures such as aircraft and potentially in automobile frames. At present, these materials cannot be recycled without damaging one or more of the high-valued components. Recycling would lower overall costs for these expensive materials.

DOE and DOI will expand the program on household appliance recycling in FY 1994 to involve industry. The goal is to remove any toxic materials from appliance designs so as to increase the recyclability of these products. Eventually, recyclability is expected to become a design criterion.

USDA will develop mechanical sorting methods in FY 1994 for waste paper and fiber and will establish fundamental properties of recycled fibers in new products and processes. This effort will promote the recycling and re-use of paper and fiber for commercial product applications.

USDA will accelerate the production and application of starch-based biodegradable polymers to have utensils and trash bags on the market in FY 1994. This effort capitalizes on NSF- and USDA-supported studies of alternative processing methods for polyhydroxybutyrate (an advanced polymer) and related renewable materials to achieve lower costs for second-generation biodegradable polymers.

EPA and USDA will initiate the development of low-vapor-emitting materials in FY 1995 for use in indoor or closed environments (e.g., for furniture). These materials could reduce indoor pollution from volatile organic chemicals (VOCs) that pose health risks. Candidate materials include alkyd resin coatings based on hydroxy fatty acid and epoxy fatty acid vegetable oils; performance testing of these coatings, which produce little or no VOCs, will begin in FY 1994.

Health and Safety

The burgeoning cost of health care is among the most pressing issues facing the United States. These costs could be reduced, and overall quality of life maintained or improved, through the development of new biomaterials for biomedical implants (e.g., artificial joints and heart valves, intra-ocular lens implants, and pacemakers). New materials are needed that are more compatible with human tissue and less expensive than are current varieties. Ideally, implants should be designed to last a lifetime rather than the five to eight years characteristic of many current materials and devices.

Quality of life also could be improved by attention to public safety concerns. For example, structures could incorporate sensors made of "intelligent" materials that sense stresses, strains, and corrosion.

A range of advanced materials could have health and safety applications, including biomaterials, biomolecular and optical materials, metals, and polymers.

Technical Milestones

HHS will begin establishing in FY 1994 a national database of the chemical, physical, bulk, and surface properties of biomaterials and medical device implants. The database will be used for systematic assessment of in-service implant performance. The database infrastructure is to be established by FY 1995 through a university-based implant retrieval network and an HHS laboratory.

HHS will initiate by FY 1994 clinical trials with new ocular biomaterials. Two promising types of these materials, perfluorocarbon liquids and ocular drug-delivery materials, are ready for clinical trials. The former materials are likely to help restore eyesight in cases of retinal detachment complicated by noninflammatory disorders. Biomaterials that can provide timed-release drug delivery would obviate the need to administer drugs several times a day.

NSF will support research to exploit in FY 1994 the capability to genetically and biochemically modify natural synthetic pathways in various organisms, in order to synthesize and process novel biomolecular materials. A variety of genetically and chemically modified biopolymers offer great potential as novel materials with desirable optical, mechanical, and electrical properties.

HHS will initiate in FY 1994 research to develop biomaterials that combine with pharmacologic agents to allow controlled drug delivery at specific sites within the body that require long-term, sustained, local administration (of antithrombotic or antihypertensive agents, for example).

DOI will initiate in FY 1994 a cooperative program with industry and user groups to develop transformation-induced plasticity (TRIP) steels as "intelligent" materials to monitor stress/strain fluctuations in structures of significance to worker safety. This effort also will involve development of polymeric and fiber-optic materials that can serve as strain and corrosion sensors in wire rope, pre-stressed concrete, and bridge support cables.

HHS will determine within five years the key structural details in natural nucleation molecules -- such as those in bones and teeth -- and will apply this knowledge to analogue ceramic materials. The goal is to mimic natural processes in the development of ceramics that resist fracture. In addition, studies will be initiated on the long-term stability and efficacy of bioceramic (i.e., biomolecular) coatings for orthopedic implants.

NSF will expand by FY 1995 the range of expression systems used for synthesizing and processing novel biomolecular materials, with the goal of increasing material yields. Current expression systems produce only limited quantities of some novel biomolecular materials. Research is needed to explore the most promising alternatives, primarily yeast, baculo-viral, vaccina, and plant expression systems.

Information and Communication

Advanced information technologies -- computers, databanks, and fiber-optic communications networks -- could help industry, small businesses, schools, hospitals, and others gain access to the best technologies and practices. Information technologies also provide the basis for new business opportunities, promote advanced work concepts such as telecommuting, reduce paperwork, increase the productivity of education and training, and improve the cost effectiveness and efficiency of government.

Advanced materials and processes can enhance the capabilities and reduce the cost of information technologies. Moreover, the use of information technologies to collect and disseminate knowledge about advanced materials and processes can promote economic growth.

Many advanced materials could have information applications, including ceramics; composites; electronic, magnetic, optical/photonic, and superconducting materials; metals; and polymers.

Technical Milestones

DOD will continue in FY 1994 the development of submicron technology to enable reduced feature sizes in electronic components. Short-term goals are a 250-fold increase in number of functions per second, a 10^4 increase in gate-hertz (a measure involving signal switches per second) per cm^2 , and a 500-fold reduction in cost per functional element by 1995.

DOC and DOD will continue in FY 1994 studies to improve understanding of the molecular basis of polymer adhesion, to develop the knowledge base and models that will lead to superior polymer-based bonding technologies for use in adhesives and coatings, polymer-composite materials, and electronic packaging. This work is expected to help improve component reliability under hostile environmental conditions.

DOD will initiate in FY 1994 the assessment of magnetic multilayers and magnetic particles as means to enhance the application of magnetic materials in high-density information storage and magnetic recording. This research could lead to increased storage density and possibly to three-dimensional storage.

DOC will establish in FY 1994 a computerized database service for electronic packaging and interconnect (P&I) technology. Beginning in 1995, this service will provide online information concerning government-sponsored R&D programs, the latest versions of military specifications for P&I, bibliographic background, and names of contacts for further information.

NSF will support in FY 1994 and beyond the synthesis of novel optically nonlinear and luminescent conducting polymers based on new organosilicones. Processing methods will be developed that will yield homogeneous thin films, coatings, and fibers suitable for optical device applications, such as optical modulators and switchable or electroluminescing devices.

DOD and DOE will develop in FY 1994 processing methods for new types of polymer resins (e.g., liquid crystalline polymers) that display inhomogeneous microstructures, and, through cooperative research with industry, these agencies will develop methods for manufacturing printed wiring boards (PWBs) from these polymers. PWBs are critical interconnect technologies that enable full exploitation of advances in electronics.

Infrastructure

Investments in infrastructure promote economic growth and the creation of new jobs. A major challenge is rehabilitation and maintenance of roads, bridges, and other elements of the existing infrastructure, and construction of new facilities with improved performance and durability. A variety of innovations are needed, including new nondestructive methods for assessing the condition of the infrastructure, new materials and methods that lower costs of repair and rehabilitation, and improved materials for construction of new infrastructure facilities.

Most advanced materials could have infrastructure applications, including biomaterials; ceramics; composites; electronic, magnetic, and optical/photonic materials; metals; and polymers.

Technical Milestones

DOC will begin measuring in FY 1994 all parameters affecting the durability of high-performance concrete and will develop a corresponding database. In addition, the agency will identify the technical barriers to exploitation of high-performance concrete and steels posed by building codes and standards and will begin to develop a strategy to overcome those barriers.

DOE will convene by FY 1994 a national conference to finalize R&D plans for high-performance concrete and steel, linking interagency Federal efforts with relevant industry groups. The intent is to develop a long-range R&D program, supported by appropriate resources, to ensure that the technological developments are applied.

NSF will initiate in FY 1994 research on advanced materials for potential use in industrial, residential, road, and bridge construction, as well as systems maintenance. The emphasis will be on development of advanced materials that can extend system durability in hostile chemical and physical environments.

DOT will complete by FY 1995 the Strategic Highway Research Program (SHRP) to realize new specification and testing methods for asphalt and significant breakthroughs in portland cement concrete technology. The new asphalt specifications emphasize performance rather than uniformity. The SHRP-derived developments in portland cement concrete technology include improved screening of aggregates to limit use of materials that do not resist freezing and alkali damage, enhanced protection against chloride-associated corrosion, and improved cathodic protection systems.

In response to a need expressed at a recent government/industry workshop, DOT will establish by FY 1995-96 a national evaluation center to assist innovators in introducing materials and other new products to the highway construction industry.

The center would serve as a one-stop entry to state departments of transportation and to the 39,000 local governments that control the Nation's highways and streets. Recommended products would be available for widespread use; projects rejected for lack of performance data could be referred to interested groups for further R&D. Eventually, the center would be funded by the user agencies.

National Security

Although Federal R&D is being re-oriented to achieve a balance between military and civilian programs, the Nation's security still depends on maintaining a defense that is the best equipped in the world. Advanced materials and processing technologies are essential to the development of advanced weapons systems that can be designed and fielded quickly and affordably. Many of these technologies would be appropriate for dual use -- that is, both military and civilian use.

Most advanced materials could have national security applications, including ceramics; composites; electronic, magnetic, optical/photonic, and superconducting materials; metals; and polymers.

LOCATION FOR SUCCESS STORY #6

Technical Milestones

DOD will demonstrate in FY 1994 the use of thin-film, high-temperature superconducting microwave components (e.g., filters and delay lines) in lightweight, high-performance equipment. These prototypes require much less power than do standard components.

DOD will demonstrate in FY 1994 the performance of superconducting electronic devices and subsystems on an orbiting satellite. This effort involves assessment of new high-temperature superconducting materials designed to carry large electrical currents.

NSF will initiate in FY 1994 university-based research on optical materials suitable for radiation-hardened communication systems. This basic research will expand knowledge and predictive capabilities related to the performance and reliability of these materials.

DOD will demonstrate by FY 1995 the ability to make free-standing diamond or diamond-like electromagnetic transparencies for missiles. These materials would be more resistant to weather effects than are current coating materials.

The DOD/NASA Ceramic Fiber Consortium will develop by the mid-1990s advanced fibers for reinforcing ceramic-matrix composites that can withstand temperatures up to 1650 °C (3000 °F). These materials could offer significant advantages in turbine engines for future military and civilian aircraft, by virtue of reduced costs and improved high-temperature strength, manageability, and resistance to oxidation and to deformation and weakening under heat.

Transportation

Advanced technologies are needed to increase the speed, reliability, and cost effectiveness of transportation while reducing its environmental impact. Aircraft are key U.S. exports; advanced materials and processing methods will facilitate development of high-speed aircraft that are affordable, safe, and environmentally acceptable. Materials advances also are essential to the competitive production of next-generation automobiles that can run on domestic fuels such as natural gas and renewables and produce little or no pollution.

Most advanced materials could have transportation applications, including ceramics; composites; electronic, magnetic, optical/photonic, and superconducting materials; metals; and polymers.

Technical Milestones

DOE will establish in FY 1994 a superplastic-forming⁸ team with academia and automotive and aerospace industry partners. The team will initiate R&D to demonstrate the feasibility of superplastic forming for automotive applications by producing representative complex body parts from aluminum.

NASA and industry partners will continue in FY 1994 the development of high-temperature aluminum alloys, advanced titanium alloys, and polymer-matrix composites for use in future high-speed civil transport (HSCT) aircraft. Plans call for these aircraft to fly at almost 1,600 miles per hour at cruise altitude and to have approximately twice the range and passenger capacity of the Concorde. The key challenges are to develop accelerated testing methods and lifetime-prediction techniques for all these materials. The goal is to achieve accelerated testing for 1/2 of the airframe design lifetime by the end of FY 1996 and for one full lifetime (20 to 30 years) by the end of FY 1999. In addition, real-time thermomechanical testing of the selected materials will be initiated, with a goal of real-time testing for half a lifetime by FY 2001.

⁸ This process involves use of high pressure and/or temperature to make metal "plastic" enough to mold. This approach may be more efficient than the conventional process of stamping out automotive body parts.

NASA and industry partners will begin in FY 1994 the design and fabrication of segments of HSCT combustor liners to be made of ceramic-matrix composites, for verification testing in FY 1995. The team will begin fabrication of intermetallic-matrix composite nozzle subcomponents in FY 1996 and of complete combustor liners in FY 1997. These are the critical components that will enable the development of low-noise, low-emission engines for future HSCT aircraft.

DOC and industry partners will develop, in FY 1994 and thereafter, the technology to manufacture large, complex polymer-composite automobile parts rapidly and inexpensively using the liquid molding fabrication process. Process simulation models, monitoring sensors, and control systems will be used to reduce costs, increase manufacturing speed, and improve part quality.

DOD and DOI will initiate in FY 1994 cooperative R&D with titanium producers and vehicle manufacturers to develop advanced processing technologies that reduce the cost of lightweight titanium for bulk applications. This effort will advance prospects for using titanium in automobiles and other bulk applications.

NASA will develop by FY 1996 materials for lightweight space systems (e.g., thermal radiators, thermal protection systems, multi-layer debris shields) with integral environmental protection. The agency will validate and test the potential of these new materials to achieve 30 percent cost reductions and 40 percent improvements in strength-to-weight ratios of future spacecraft, space power systems, and aerospace propulsion systems.

NASA and industry partners will validate by the late 1990s low-cost polymer-matrix composite materials and fabrication technologies in tests of full-scale wing and fuselage structures. This work will provide the confidence level needed for large-scale application of composites in subsonic commercial aircraft by the turn of the century.

Through large-scale component tests, NASA and industry partners will validate by the 21st century high-temperature engine and airframe materials and processing technologies needed to support an industry decision to proceed with full-scale development of HSCT aircraft.

4. AMPP IMPLEMENTATION

Planning: COMAT Task Groups

Each Federal agency plans its R&D programs independently, seeking technical advice from traditional sources, such as laboratory advisory panels. The AMPP creates new mechanisms for coordinated planning of multi-agency programs in materials science and technology. This synergism will increase the effectiveness of the technical agenda. The long-range goal is to allow government agencies and the private sector to develop a coordinated R&D agenda that is not only technology driven but also goal oriented -- that is, responsive to societal and commercial demands.

The new planning mechanisms are COMAT task groups. Some of these groups have existed for years to meet the technical communication needs of Federal agencies; other groups are new. Each task group focuses on a different material or applications category. These groups vary in purpose and will continue to evolve, but in general they serve as bridges to the private sector and develop research plans to be used for future development of the AMPP. The activities of each task group are outlined in Appendix C.

An agenda will be developed for each technical area encompassing appropriate government activities, subject to funding⁹; these plans will be made available, through the task groups, to the private sector for comments and critique. Task groups will seek input from industrial trade associations, existing R&D consortia, professional societies, and other representatives. Federal agency proposals for future AMPP projects will be measured against the latest versions of these continually evolving agendas.

Coordinated planning of technical programs in air and land transportation vehicles has been under way for some time. During FY 1993, multi-agency planning in cooperation with the relevant private sector groups has been initiated in four technical areas: structural ceramics, infrastructure and construction materials, materials for electronic packaging, and metal casting. The results of these planning exercises will be emphasized in new program directions in FY 1994 and beyond, thereby heightening the emphasis on technology-driven, goal-oriented programs. During FY 1994, joint planning activities will be extended to address additional topic areas.

⁹ Such plans should not be construed as agency commitments to carry out R&D for which funding and other resources are unavailable.

Execution

Execution of the AMPP will be managed decentrally through the line management structure of the participating agencies, with joint planning and execution coordinated, where appropriate, through CIT. Integration of the diverse research projects, and assessment of overall results, are difficult tasks, as materials science and technology is not an homogenous field. Needs and R&D objectives vary, quite legitimately, among the various Federal mission agencies and participating private companies.

In recognition of this diversity, R&D partnerships will be developed, fostered, and evaluated through a variety of different formats. In some cases, the AMPP planning agenda for a technical area will demand R&D coordination beyond that achievable through independent management; in such instances, interagency agreements and other tools will be developed.

Over the past decade, there has been a dramatic increase in the number of mechanisms available for execution of Federal programs. This continuing trend has led to many different types of interactions with the private sector, including the following:

Single Company Interactions

This category includes grants and contracts to a company, personnel exchanges between companies and Federal laboratories or universities, CRADAs or other cooperative agreements, and university involvement through monetary support for programs that emphasize collaborative research with industry.

One interaction of this type is the CRADA signed in 1992 by DOE's Oak Ridge National Laboratory (ORNL) and a corporation that makes thermoelectric elements. Under the agreement, ORNL is to synthesize candidate materials with improved thermoelectric properties and to provide them to the corporation, which will participate in the materials selection process, provide expertise and technical guidance on the materials and concepts, and fabricate elements from the more promising materials for more complete evaluation. Thermoelectric devices convert heat into electricity or electricity to refrigeration.

Multiple Company, Multi-Investigator Interactions

This category includes groups or consortia organized by industry, government, or universities through any of several types of mechanisms: interagency agreements and fund transfers, CRADAs or other cooperative agreements, and/or grants and contracts specifying matching funds.

Examples include Engineering Research Centers, University Research Institutes, industrial consortia such as the U.S. Advanced Battery Consortium (DOE), and AMPP activities such as the Enabling Propulsion Materials program and the Integrated High-Performance Turbine Engine Technology Program (DOD/NASA).

One new interaction of this type is the five-year MOU signed recently by DOD and USDA. The agreement provides for closer coordination in R&D involving food and agricultural sciences, pest management, nutrition, and other areas of mutual interest. Through this MOU, the Advanced Materials from Renewable Resources Program was jointly planned by U.S. Army Natick RD&E Center and USDA's Cooperative State Research Service, and was initiated with \$10 million in FY 1993. This program will make use of renewable resources to develop advanced products of wide application in the defense and commercial marketplaces. Many products will be biodegradable or have tailored lifetimes and will reduce the Nation's dependence on imports from foreign countries. The program covers four product areas: nonstructural materials and systems; fuels, oil, lubricants, surfactants; coating, adhesive, and compound materials; and environmentally compatible processing and monitoring approaches.

LOCATION FOR SUCCESS STORY #8

National User Facilities¹⁰

This category includes major national facilities that provide high-intensity photon, neutron, and magnetic field sources. The interdependency of AMPP activities is most obvious in the use of these facilities. Programs in synthesis and processing, and theory, modeling, and simulation depend on these facilities, which are used for materials characterization by researchers from industry, academia, and government,

Examples include DOE's Cold Neutron Research Facility at the National Institute of Standards and Technology, DOE's National Synchrotron Light Source at Brookhaven National Laboratory, and NSF's National High Magnetic Field Laboratory operated by Florida State University, the University of Florida, and Los Alamos National Laboratory.

A new DOE facility, the Advanced Light Source (ALS) at the Lawrence Berkeley Laboratory, is expected to open in 1993. About \$30 million has been committed by Federal agencies and industry for instrumentation. The research to be carried out at the ALS includes atomic and molecular physics, surface and interface science, structural biology, X-ray imaging, and X-ray lithography. Additional details about the research conducted at ALS and the other facilities may be found in Chapter 5.

¹⁰ For more information about these facilities, refer to the booklet, *Advanced Materials and Processing: The Fiscal year 1993 Program*.

Evaluation

Any new program should be evaluated with specific measures of success. Effectiveness of the AMPP will be judged primarily by success in achieving the technical milestones (some of which were listed in Chapter 3).

In addition, a set of quantitative measures will be used to assess annual increases in cooperation between the government and the private sector. Because cooperation is a concept, rather than an easily measured product, the evaluation process will be somewhat complicated. No single measure can be used; public/private cooperation takes many forms, and interagency collaboration varies in nature due to the unique character of each agency's mission and operating practices.

The quantitative measures of cooperation include:

- number of active CRADAs,
- percent of AMPP funding for joint R&D projects (i.e., total Federal dollars spent on cooperative projects divided by total AMPP spending),
- number of interagency MOUs or similar formal agreements among agencies for activities substantially funded under the AMPP,
- number of licensing agreements (i.e., total number of active licensing agreements on patents held by either the Federal government or contractors operating Federal facilities, derived from activities supported through the AMPP),
- licensing income (i.e., yearly income from licensing agreements described above), and
- number of technical areas for which research agendas have been established jointly by AMPP agencies and the private sector through coordinated planning (task groups).

The measures to be used by each agency, and the baseline figures for FY 1992, are shown in Table 5. The most significant numbers will be future *changes from year to year in each agency's total for each measure*.

Overall evaluation will be handled by the OSTP, through FCCSET, and/or OMB. Periodic reviews of the AMPP and its management will evaluate progress toward meeting the program goal, objectives, and technical milestones and also will assess the appropriateness of these targets.

**Table 5 AMPP Quantitative Measures
Baseline Levels in FY 1992 by Agency**

Category	DOC	DOD	DOE	DOI	DOT	EPA	HHS	NASA	NSF	USDA
No. of CRADAs	42	70	59	10	0	2	8	2	N/A	160
% AMPP Funding for Joint R&D	N/A	N/A	7%	0	0	13%	0	15%	27%	18%
No. of MOUs	1	N/A	3	4	9	1	0	6	0	1
No. of Licensing Agreements	0	13	9	0	0	0	0	3	N/A	60
Licensing Income (\$K)	0	\$71K	N/A	0	0	\$10K	0	N/A	N/A	\$760K
No. of Technical Areas With Joint R&D Agendas	10	N/A	103	2	0	0	0	3	N/A	N/A

N/A indicates that the category is not consistent with the operational mode of the agency or that statistical data for the category is not collected routinely

5. AGENCY R&D PROGRAMS: LAYING THE FOUNDATION FOR PROGRESS

The Federal materials R&D program is designed to achieve the technical milestones described in Chapter 3 and, in the process, to provide the technical and scientific foundation for progress in the seven impact areas. Following is a summary of the materials R&D activities of the 10 agencies involved in the AMPP, including an outline of each agency's orientation within the program framework and approaches to technology transfer.

Additional technical details, as well as the names of individuals to contact for annual reports, may be found in the booklet *Advanced Materials and Processing: The Fiscal Year 1993 Program*. For information on how to obtain this booklet, see the inside back cover.

Department of Commerce (DOC)

Materials R&D is carried out in seven laboratories at the National Institute of Standards and Technology (NIST), principally the Materials Science and Engineering Laboratory (MSEL). The program concentrates on the development of technology and procedures needed to improve material and product reliability, manufacturability, functionality, and cost effectiveness.

AMPP Orientation

NIST activities emphasize three AMPP technical components: synthesis and processing, materials characterization, and the national user facilities. NIST is a linchpin for processing research within the Federal government and thus fosters advances in all impact areas. MSEL has an integrated program in microstructural characterization.

Technology Transfer

NIST has a broad network of delivery systems that support the transfer of scientific understanding, predictive models, measurement methods, reference data and materials, and standards to industrial, academic, and government customers. Delivery modes include published papers and reports, invited lectures, workshops and symposia, patents, the many professional societies and organizations, and negotiated collaboration agreements such as CRADAs.

In addition, the availability of NIST research and testing facilities -- including the Cold Neutron Research Facility -- fosters communication among government, industrial, and academic researchers.

Materials Science and Technology Programs

MSEL has major programs in advanced ceramics, which have applications in electronics, optics, structures, cutting tools, and advanced heat engines; and polymer-matrix composites, which are attractive substitutes for traditional engineering materials such as the steel used in automobiles.

The major barrier to commercialization of advanced ceramics is the difficulty of producing components with desired properties consistently and at reasonable costs. MSEL addresses these issues through measurement-oriented research designed to understand, predict, and control the origins of defects and to enhance the ability of industry to produce reliable components consistently and affordably.

The key technical barriers limiting exploitation of composites include the high cost of fabrication and the present inability to understand and predict long-term performance. MSEL focuses on the technologies required to achieve more rapid, reliable, and cost-effective processing, by continuing the development of advanced sensors for on-line process monitoring, formulating new process simulation models, and implementing on-line process control procedures.

Materials manufacturing activities revolve around "intelligent" processing of materials (IPM) and electronic packaging. IPM, a computer-based concept to control automatically the evolution of microstructure during processing, is an approach to improving the quality of advanced materials while reducing processing costs. Applications under study include processing of metal powders and ceramics, and injection molding of polymers.

NIST also develops measurement tools to determine the optimal properties of materials used in packaging and interconnecting electronic devices, and standards and techniques to support commercial development of functional materials, such as superconducting and magnetic materials.

Additional materials R&D focuses on providing measurement capabilities in the interrelated areas of electronics, opto-electronics, electromagnetics, and electrical engineering; measuring the chemical behavior of materials; developing decision-making criteria concerning construction materials; mathematical modeling; and physics research to support quality control.

New, Expanded, or Planned Programs

The latest areas of emphasis are IPM, materials for electronic interconnects (which protect and cool integrated circuits), and layered ceramic coatings (in which properties vary according to material thickness).

Department of Defense (DOD)

Materials R&D is carried out by the Army, Navy, Air Force, and the Advanced Research Projects Agency (ARPA). The scope of the program is extremely broad, as it is directed at providing future military systems with capabilities not now attainable. New materials technologies are expected to enhance system performance, survivability, and reliability while reducing costs. Where appropriate, dual-use applications of DOD technology are encouraged.

AMPP Orientation

DOD emphasizes the synthesis and processing component of the AMPP but also addresses materials characterization and theory, modeling, and simulation. The R&D program essentially supports national security applications, but advances later may be applied in many, if not all, other impact areas.

Technology Transfer

Where security allows, the results of all DOD science and engineering research programs are disseminated to academia and industry by all the standard methods. The list of high-technology commercial components and systems originally developed through military R&D is extensive. Because DOD constantly pushes the limits of technology, the resulting advances in materials knowledge often benefit the Nation's economy. Contact with academic researchers occurs through hundreds of DOD-supported university research centers.

Materials Science and Technology Programs

To help reduce the size and weight of advanced weapons systems, the Army emphasizes processing and manufacturing of high-strength metals, structural composites, polymers, and ceramics. The program addresses a range of topics, including armor/anti-armor technology, heavy metal penetrators, steels, corrosion, non-destructive evaluation, and specifications and standards as applied to Army mission areas.

The Navy has a comprehensive materials R&D program driven by the salt-water operating environment of its systems, including platforms (e.g., ships and submarines) and weapons systems (e.g., aircraft, missiles, and torpedoes). The program is oriented toward combatting corrosion through use of such techniques as ion-beam-assisted deposition on aluminum to increase pitting resistance.

The Air Force has a comprehensive program to develop low-cost, durable, high-temperature structural materials that weigh less than conventional metals. One example is continuous fiber composites with intermetallic matrices. The emphasis is on optimizing material properties and enhancing processing of components for airframes and engines. Other activities focus on engineering new, high-performance electronic and optical materials for detection and surveillance applications, and on developing laser-hardened materials capable of protecting personnel and systems from laser radiation.

ARPA engages in high-risk R&D that could have an equally high payoff. Areas of emphasis include structural materials, especially composites for advanced systems such as airframes and missiles; electronic materials for high-speed signal processing and infrared imaging; photonic materials for communications, signal analysis, and, eventually, optical computing; and new high-temperature superconductors, for a variety of electronic and magnet/motor applications.

To speed introduction of advanced materials, some ARPA programs focus on inserting new semiconductor, opto-electronic, and structural ceramic materials into fielded weapons systems.

Department of Energy (DOE)

Materials R&D is carried out by numerous DOE offices, principally the Office of Conservation and Renewable Energy, the Office of Energy Research, and the Office of Nuclear Energy. The DOE program is the largest among the 10 agencies involved in the AMPP and is broad in scope, ranging from fundamental studies in condensed-matter physics to development of large-scale materials fabrication technologies.

AMPP Orientation

DOE places roughly equal emphasis on three AMPP technical components: synthesis and processing, materials characterization, and the national user facilities. The program fosters advances in all impact areas.

Technology Transfer

Interaction with industry takes many forms, including direct grants and competitive contracts, collaboration among individual researchers, industrial use of DOE facilities, and agreements such as CRADAs. Literally dozens of companies are involved. The DOE operates 11 national user facilities; nearly 20 percent of the users come from more than 100 companies from all sectors of the economy.

Materials Science and Technology Programs

Industrial technology programs focus on improving equipment to recover energy from waste heat and to provide higher fuel economy. Activities include development of high-temperature materials such as ceramics for industrial heat exchangers, and studies on advanced processing technologies such as microwave processing, plastics recycling, and biobased materials processing.

Ground transportation R&D includes programs devoted to ceramics, battery and fuel cell materials, and lubricants for use with advanced materials such as ceramics in heat engine propulsion systems; lightweight materials for safe, highly fuel-efficient vehicles; fuel system and emission control system materials (e.g., catalysts) that are compatible with alternative fuels; and infrastructure materials such as low-cost construction materials for alternative fuel (i.e., alcohol) production plants, long-lasting roadbed materials such as new forms of asphalt or concrete, or low-cost materials for magnetically levitated train guideways.

Programs in utility technologies address semiconductor and electronic materials that could improve the efficiency of solar energy, and high-temperature and chemical-resistant technologies for use in geothermal energy resources.

Basic energy programs include development of forefront analytical instruments used to probe the behavior and structure of matter, and exploration of properties and other phenomena in materials of importance to DOE, including polymers, semiconductors, superconductors, magnetic materials, metals, and ceramics. Research in magnetic fusion, intended to help assess the feasibility of fusion energy, addresses such topics as reduced activation in steels and vanadium alloys, hydrogen embrittlement, stress corrosion, and radiation effects on ceramic insulators.

Programs in nuclear energy address materials for atomic-vapor-laser isotope separation and materials required for the development of coated particle fuels, heat exchanger tubing, and other applications. Applied technology activities related to reactor systems focus on such topics as evaluation of core materials. In addition, applied materials programs for DOD and NASA power systems focus on such topics as thermoelectric materials and devices, and high-temperature heat source materials.

Other programs are devoted to improving materials for a variety of uses. Efforts to increase the magnetic field strength of magnetic materials could lead to applications such as smaller and lighter electric motors for cars. The development of advanced processes (e.g., high-energy beam welding) for combining dissimilar materials, such as ceramics and metals, could have applications in advanced heat engines, such as in welding turbocharger rotors to the drive train shaft. Finally, multiple breakthroughs could result from synthesis and processing of nanometer-scale materials, which are expected to have unusual electronic, optical, mechanical, surface, magnetic, and energy storage and transfer characteristics.

New, Expanded, or Planned Programs

The latest emphasis is on synthesis and processing of materials for photovoltaic applications, materials for corrosive environments, catalytic materials, magnetic materials, artificially nanostructured materials, conducting and superconducting polymers, materials for radiation environments, structural polymers, and polymeric and organic superconducting materials.

Other key topics include advanced techniques for near-net-shape fabrication of ceramic components; advanced techniques for welding and joining; basic research on tribology; high-temperature, load-bearing structural ceramic-matrix composites; lightweight transportation materials; ceramics manufacturing; and modeling and computation.

Department of Interior (DOI)

Materials R&D is carried out through the Bureau of Mines (BOM). The program addresses environmental and conservation issues related to both engineered and commodity materials that meet national security and economic needs. The BOM resolves problems arising throughout the materials cycle.

AMPP Orientation

The program concentrates on the synthesis and processing component of the AMPP and fosters advances in all impact areas.

Technology Transfer

The achievements of the BOM materials program are transferred to the private sector through joint program planning and cooperative research. Joint research is carried out through CRADAs and MOUs. Specific CRADAs have been established dealing with topics such as platinum automobile exhaust catalysts, fine particle technology, high-nitrogen steels, and titanium processing and fabrication. In addition, BOM utilizes exhibits, open industry briefings, seminars, workshops and demonstrations, patent licensing, films, and special publications.

Materials Science and Technology Programs

The BOM minerals program addresses problems in extraction, refining, and recycling of metals and nonmetallic minerals. Research topics include physical and chemical separations, process automation and control, and grinding technology. A general goal is to develop new, environmentally sound approaches for extraction and processing.

Other activities focus on recovering valuable commodities from minerals, concentrates, and discarded mine and other wastes; of special interest are minerals the Nation must import in large quantities, such as cobalt, chromium, and platinum. Related programs concern advanced processes for recycling scrap materials, and the processing of waste materials for reuse or recycling.

The BOM materials program seeks materials to substitute for those derived from insecure sources, or that are hazardous (e.g., lead, chromium, cadmium). Another objective is to reduce life cycle costs associated with the protection of workers and the public from toxic substances and structural hazards. One activity in this area involves the development of "intelligent" structural materials to protect workers; of particular interest are hoist ropes with internal sensors to warn of impending failure.

Efforts to conserve resources by extending the service life of major commodity materials include basic research to characterize materials and to improve their performance. Topics of interest include localized corrosion in metals and ceramics, fracture of brittle materials, and the development of computer models for predicting the service life of materials.

Programs to lower the costs and to enhance the properties of commodity materials involve production of low-cost titanium for use in ground vehicles, nitrogen alloying of steels, and processing of nanostructured materials. Advances in these areas would create many new applications for advanced materials that would promote U.S. economic growth.

New, Expanded, or Planned Programs

Activities are being expanded in several topic areas, including low-cost titanium, "intelligent" materials for worker safety, and "clean" technologies for processing and for reducing quantities and toxicity of discharges to the environment. In addition, a new program on infrastructure materials is planned, focusing on detection and prevention of degradation, environmental protection and recycling of wastes associated with crushed-stone operations and construction demolition, and raw materials (aggregate) processing.

Department of Transportation (DOT)

Materials R&D is supported by three DOT modal administrations: the Coast Guard, the Federal Aviation Administration (FAA), and the Federal Highway Administration (FHWA). Projects generally are directed at specific transportation applications.

AMPP Orientation

DOT concentrates almost entirely on the materials characterization component of the AMPP. The program fosters advances in three impact areas: environment, health and safety, and infrastructure.

Technology Transfer

Virtually all R&D results are disseminated broadly because, due to the nature of its activities, DOT must coordinate its programs with state and local governments and the various transportation industries. In addition, DOT operates programs that complement the AMPP by linking industrial and university research with the department's R&D programs.

Materials Science and Technology Programs

The Coast Guard emphasizes applied R&D in support of its primary missions -- marine safety, enforcement of laws and treaties, national security, and marine and environmental protection. Programs include the development of improved steels and composite materials for ship construction, fire-resistant ship materials, chemicals for oil spill cleanup and mitigation, and corrosion-resistant aircraft materials.

The FAA conducts materials R&D in two areas: aircraft safety and system security. The former program includes development of advanced materials and processes to improve aircraft structures, propulsion systems, and control and electrical systems. The program also is concerned with protecting aircraft and occupants from crash impacts, fire, and adverse atmospheric and environmental events. System security R&D involves the development of advanced materials to ensure that aircraft can survive various types of explosive threats.

LOCATION FOR SUCCESS STORY #10

The FHWA concentrates on materials for pavement and highway structures. The program includes development of new construction materials, including waste and hazardous materials; improvement of conventional materials; and exploration of the properties and performance of both existing and new materials. Materials under study include high-strength concretes, advanced asphalts and portland cements, composites, fiber-reinforced plastics, and adhesives.

New, Expanded, or Planned Programs

The primary areas of emphasis will continue to be pavement and structures technology and aircraft safety technology.

Environmental Protection Agency (EPA)

The EPA develops new and improved materials and processes that could benefit the environment. Materials R&D is carried out by two laboratories: the Risk Reduction Engineering Laboratory (RREL), and the Air and Energy Engineering Research Laboratory (AEERL).

AMPP Orientation

The program concentrates on the materials characterization component of the AMPP and fosters advances in four impact areas: energy, environment, health and safety, and infrastructure.

Technology Transfer

The missions of both laboratories assume close interaction with industry. It is expected, for example, that the RREL will foster the commercialization of improved and innovative technology in collaboration with industry. AEERL also collaborates with industry and trade associations in developing and demonstrating advanced technologies. Mechanisms include CRADAs and licensing agreements.

LOCATION FOR SUCCESS STORY #11

Materials Science and Technology Programs

RREL programs in waste management concentrate on advanced processes, such as recycling of materials and waste treatment technologies, that could reduce the environmental and health risks related to materials. The laboratory also develops and maintains databases on the capabilities of treatment technologies, and on the risk profiles of materials and products. An AEERL program to reduce indoor chemical pollution includes evaluation of new materials that could reduce consumption of organic chemicals during the production and manufacture of furnishings. Related efforts are devoted to developing low-emission solvents, adhesives, and finishes, and to developing, validating, and promoting methods for evaluating sources of indoor pollution.

Other activities address pollution from industrial processes. The goal is to synthesize improved calcium-based sorbents for controlling sulfur dioxide emissions. Calcium, the active ingredient, is combined with other materials to enhance capture efficiency and cost

effectiveness. The new sorbents are pre-crystalline, ceramic-like materials.¹¹ These advanced materials are tested in an in-house pilot plant. Related efforts are underway to develop advanced processes for reducing nitrogen oxide and chlorinated organic emissions.

Another AEERL priority is to identify and to evaluate environmentally acceptable substitutes for ozone-depleting refrigerants such as CFCs. Most of the substances under investigation will be used as heat-transfer fluids. Characteristics such as flammability, oil miscibility, and acute inhalation toxicity are being studied. Related activities test the compatibility of the new compounds with alternative refrigeration cycles.

A program in fire protection is evaluating new classes of chemicals as possible substitutes for Halon-1301, a flooding fire-extinguishing agent and explosion suppressant used in indoor Alaskan oil and gas operations. A number of chemical classes are under investigation.

New, Expanded, or Planned Programs

The general area of emphasis is evaluation of environmentally benign materials and processes, and development of related tools such as comparative risk assessments, pollution prevention guidelines, and life cycle analysis. Comparative risk assessments will be extended to include advanced materials such as gallium arsenide, a compound semiconductor expected to be important in information and communications.

¹¹Most EPA programs cannot be classified readily according to the materials taxonomy defined in the AMPP. In the budget, most of the agencies' materials R&D is classified in the "other" materials category

Department of Health and Human Services (HHS)

Materials R&D is carried out by 12 units of the National Institutes of Health (NIH) and by the Food and Drug Administration (FDA). The program focuses on improving biomaterials and biomolecular materials for use in medical device implants.

AMPP Orientation

The HHS program is related to three AMPP technical components, primarily synthesis and processing but also theory, modeling, and simulation, and materials characterization. In keeping with AMPP priorities, HHS is working to bridge the gap between innovation and the practical application of advanced materials. For example, projects are guided by the advice of non-Federal advisory committees to focus on the most useful biomaterials.

Technology Transfer

Communication with academia and industry is extensive. Most NIH materials research is conducted by outside investigators through grants and contracts, which may include arrangements for commercialization of promising implants. The results of grant-supported research are discussed widely at public meetings and published in technical and medical journals. In addition, the NIH has an Office of Technology Transfer to handle all patent policy issues and to implement CRADAs, patent licenses, and other activities such as education and special conferences.

Materials Science and Technology Programs

The NIH program on orthopaedic implants focuses on improving devices such as total joint (i.e., hip and knee) replacements. An important concern is optimization of the bone/material interface to form a more permanent attachment than can be achieved using cement.

Dental R&D focuses on developing improved materials for fillings, bonding agents, sealants, adhesive coatings and cements, and intra-oral prostheses. NIH also supports the NIST dental laboratory, a private association developing new amalgams. Development of ocular materials is supported by materials chemistry research. Studies of polymer chemistry help produce substances for ocular bandages, fluid replacements, and controlled drug delivery systems, and general materials chemistry research supports development of ocular implants and lenses.

Research concerning the blood system includes development of improved vascular grafts; a hybrid organ capable of delivering insulin or other treatments through genetically engineered cells; an improved temporary or permanent artificial lung; and artificial blood substitutes consisting of organic and inorganic compounds.

To help predict the performance of materials, basic research explores biological responses, such as coagulation and inflammation, occurring at tissue/material interfaces. Other studies with multiple practical applications address molecular-based biosensors, absorbable polymers, and blood vessel regeneration systems.

The program in neurological rehabilitation emphasizes biomaterials for high-charge-density electrodes, insulating thin-film protection of implanted integrated-circuit electrodes, and micromachining of multiple electrode arrays. Other biomaterials R&D for preventing, diagnosing, and treating diseases concentrates on controlled drug delivery systems such as microencapsulated vaccines.

To help predict the reliability of implant devices, the FDA develops measurement methods, fundamental understanding of the mechanical behavior of materials, and databases on device reliability.

New, Expanded, or Planned Programs

The latest areas of emphasis include development of a new generation of orthopaedic implants; new materials for restoring back teeth; new synthetic polymers to prevent and treat ocular diseases; genetically enhanced cardiovascular implants (i.e., hybrid organs); neural prostheses; new artificial kidney membranes and access devices; and microencapsulated vaccines. In addition, NIH is considering developing an advanced biomaterials laboratory and a comprehensive national database to be used in assessing the in-service performance of biomaterials and biomedical implants.

National Aeronautics and Space Administration (NASA)

NASA engages in a broad range of basic and applied materials and processing R&D. Applications include general aviation aircraft, high-performance military fighters and rotorcraft, subsonic commuter aircraft, supersonic commercial transports, hypersonic and re-entry vehicles, launch vehicles, satellites, and interplanetary spacecraft.

AMPP Orientation

The program emphasizes three AMPP technical components: synthesis and processing; theory, modeling and simulation; and materials characterization. Activities foster advances in two impact areas: national security and infrastructure.

Technology Transfer

The primary mechanism for technology transfer is close coordination and cooperation with the U.S. aerospace industry in planning and conducting R&D in aeronautics and space. In addition, a well-established Technology Utilization Program fosters liaisons with industry and produces several publications, including the monthly NASA Tech Briefs and an annual Patent Abstracts Bibliography.

NASA actively reaches out to academia through a network of 10 university-affiliated Industrial Applications Centers and 9 University Space Engineering Research Centers; and to industry and small businesses through its network of 12 Centers for the Commercial Development of Space.

Materials Science and Technology Programs

The aeronautics program focuses on development of advanced materials and processes for engine and airframe structures. Advanced metals and polymer-matrix composites (PMCs) offer promise for reducing the cost, increasing the performance, and improving the damage tolerance of commercial and military airframe structures. Low-cost processes under study for PMCs include automated fiber placement, automated textile processes such as weaving and stitching, and alternate energy sources such as microwave curing. **LOCATION FOR SUCCESS STORY #12**

Materials development for turbine engines focuses on high-temperature PMCs, metallic/intermetallic (MMCs/IMCs), and ceramic-matrix composites (CMCs) that could improve engine performance, decrease fuel consumption, and lower noise and emissions. Hypersonic vehicles such as the National Aero-Space Plane require actively cooled IMCs and carbon-carbon composites and durable, oxidation-resistant coatings.

Space research addresses synthesis and processing of space-durable materials for advanced launch systems, space platforms, spacecraft, and re-entry vehicles. Materials of special interest include carbon-carbon composites, ceramics, and CMCs for thermal protection systems, and lightweight metals, MMCs, and PMCs for lightweight cryogenic tanks.

Thermoelectric materials and new materials for photovoltaic cells and arrays are being developed to reduce the weight and improve the efficiency of nuclear and solar power sources. These technologies will be used in future planetary science missions and in solar-electric propulsion systems for orbital transfer and interplanetary exploration.

New, Expanded, or Planned Programs

New programs emphasize technology development for future high-speed aircraft. Propulsion materials development will progress from feasibility demonstration to design and fabrication of subcomponents for simulated engine testing. Airframe materials R&D will focus on development of low-density titanium alloys and high-temperature aluminum alloys and PMCs, with an emphasis on long-term durability at elevated temperatures, and on development of accelerated test methods.

Engineering research is devoted to developing advanced processes for producing large quantities of new, high-quality materials. The objective is to increase knowledge and predictive capabilities related to the effects of processing variables, microstructure, and the environment on material properties and performance. Materials under investigation include ceramics, electronic materials, metals, polymers, and composites.

NSF also emphasizes biomolecular materials. This research explores synthetic routes to new materials that can serve as sensors or transducers, as well as biological synthesis by bacteria and other organisms of polymers or other new materials, through the introduction of synthetic DNA. A new area of study is tissue engineering, which involves developing living tissue equivalents of skin, bone, blood vessels, cartilage, and bone marrow.

New, Expanded, or Planned Programs

NSF is expanding its efforts in all AMPP components. One activity involves the design, synthesis, and processing of complex new materials with predictable and controlled properties. A second involves the development of computer models and simulations to predict the physical and chemical properties and performance of new materials before they are synthesized. A third activity focuses on materials characterization. A fourth involves expansion of undergraduate course and curriculum development, augmentation of support for research experiences for undergraduate students, and enhancement of the faculty internship-in-industry programs by including the Combined Research-Industrial Sabbatical Program (CRISP).

Department of Agriculture (USDA)

Materials R&D is carried out by the Forest Service (FS), the Agricultural Research Service (ARS), and the Cooperative State Research Service (CSRS). The program focuses on the use of renewable, non-food agricultural materials and their derivatives in industrial processes and products.

AMPP Orientation

Most of the R&D is related to the synthesis and processing component of the AMPP, with some effort devoted to materials characterization. The program fosters technical advances in five impact areas: energy, environment, security, health and safety, and infrastructure.

Technology Transfer

Transfer of knowledge is an integral part of all USDA activities because the agency's sole purpose is to benefit producers and consumers of agricultural products, various industries, states, and the Nation as a whole. The FS Forest Products Laboratory and the four ARS utilization laboratories are using the CRADA process to facilitate transfer of technologies developed in-house to the private sector. The Alternative Agriculture Research and Commercialization (AARC) Center works directly with the private sector at the point of commercialization of industrial uses of agricultural products, with considerable emphasis on advanced materials. The CSRS, for example, participates in a nationwide agricultural research network, the State-Federal Partnership, which includes state universities and industry.

Materials Science and Technology Programs

A major FS program concentrates on improving the performance of wood-based materials. This effort includes development of high-performance synthetic composites (e.g., fiber-reinforced cement) from wood, wood fibers, and other materials; and biopulping research to support development of both advanced processes (e.g., bleaching and recycling of paper) and products.

Basic research enhances prospects for designing wood-based materials for specific uses. Wood is composed of three types of polymers that form a lightweight but strong composite matrix. This complex matrix connects the fibers and is the basis of wood's unique mechanical and physical properties. Studies are carried out to explore the relationships among the chemical components, the fibers, and the physical properties.

Related efforts are devoted to reducing environmental damage resulting from the use of chemicals and high temperatures for the conversion of wood into products. This R&D addresses pulping processes, the production of new chemicals, and the preservation of wood using non-traditional methods. For example, pulping is less polluting when the wood is treated with selected wood-decaying fungi before mechanical pulping.

ARS concentrates on developing commercial products from agricultural crops and wastes, both to find uses for surplus crops and to find useful new plants to replace surplus production. The commodities of primary interest have been corn, soybeans, and wheat.

Starch can be combined with other types of polymers to produce plastics with unusual properties, such as biodegradability. At present, cornstarch is combined with various materials to produce chemicals for such applications as starch-encapsulated herbicides, a product that reduces the typical herbicide losses and environmental impacts.

Other ARS activities focus on bioconversion¹² of soybean oil into new chemicals, with the aim of reducing the need for imported oils. These oil-derived substances can be used in cosmetics, lubricants, coatings, and other products. Hulls, fibers, and corn cobs also could be turned into chemicals or fuels through bioconversion. In addition, studies on combustion chemistry are underway to improve prospects for the use of vegetable oils as fuels.

Major CSRS projects address the following topics: natural rubber and resins derived from domestic guayule plants for use in aircraft and truck tires, for protective coatings, and paints; crambe and rapeseed oils for use in fluids, oils, and nylon; and kenaf, an annual nonwood fiber plant, for use in newsprint and other paper products; and taxol from ornamental *Taxus* shrubs for use as a cancer-fighting agent.

New, Expanded, or Planned Programs

The latest emphasis is on three topics: transferring the results of publicly funded research into commercial development of industrial products using agricultural materials; paper and wood recycling to alleviate the landfill crisis; and the development of bioplastics.

¹² Bioconversion refers to the chemical reactions caused by natural enzymes found in plants or microorganisms.

National User Facilities

These facilities, supported by DOC, DOE, and NSF, are made available to thousands of industrial, academic, and government researchers. There are several types:

Synchrotron light sources provide photons and X-rays for structural and spectroscopic studies of materials such as metals, ceramics, polymers, and various biological materials. Projects range from fundamental studies to proprietary industrial activities such as the development of X-ray lithography technology for advanced semiconductor integrated circuits. Six facilities are available, offering the strongest beams in the world; one new facility is scheduled to open in 1993, and one more is under construction.

Neutron sources can give precise information on the positions and motions of individual atoms in materials; they are useful for studying radiation effects, and magnetic properties. Five facilities are available, offering the most intense continuous beams in the world and the Nation's highest peak neutron flux. A new cold neutron facility, when completed, will provide research capabilities now available only in Europe and Japan. The design of another facility was completed in 1992.

High-magnetic-field laboratories are the premier sites for magnet design and development. Research using high magnetic fields contributes significantly to the basic understanding and development of materials such as semiconductors, superconductors, and magnetic materials. An existing facility offers the world's highest steady-state magnetic fields. Another facility, a collaborative effort involving the state of Florida, academia, and a national laboratory, is under construction.

APPENDIX A

Classes of Materials¹³

Biomaterials and biomolecular materials - include diverse materials that are compatible with human tissues and/or mimic biologic phenomena, as well as materials made from products of biological origin. Traditional materials in this category include dental fillings and crowns. Advanced materials are made from metals, ceramics, and polymers; applications range from artificial hearts to ultra-tough ceramic tank armor modeled on the molecular structure of abalone shells, and biodegradable plastics for use in packaging and fast-food containers.

Ceramics - include materials made from nonmetallic inorganic minerals. Ceramics are noted for their light weight, hardness, corrosion resistance, and tolerance to high temperatures. Spark-plug insulators are a traditional example. Advanced ceramics are used for thermal coatings and in structures of high-temperature engines.

Composites - include combinations of two or more materials, usually reinforced ceramic, metal, or organic-matrix materials. These materials combine the most useful properties of each component. Fiberglass is a traditional composite, composed of glass fibers in epoxy or polyester matrices. Advanced composites have both structural and non-structural applications and often are used in air and land vehicles.

Electronic materials - include active materials, such as semiconductors, that transmit signals by way of electrons. These materials are processed to form elements in circuitry. Current electronic technology is based on silicon. A newer material is gallium arsenide. This class also includes metals, ceramics, and polymers used in electronic wiring, interconnections, and packaging.

Magnetic materials - include metallic, organic, or ceramic-based materials in which electron "spins" are arranged in certain structures, such that the materials either attract or repel each other, depending on their orientation. When magnets are moved relative to a coil of wire, an electrical field is generated. Iron metal is a traditional magnet. The much stronger iron-rare earth alloy magnets are among the advanced varieties.

¹³ The AMPP focuses on *advanced* materials. For purposes of this report, "advanced" refers to the most recent evolutionary developments within a materials class or an applications category. Following are brief descriptions of the various types of materials (both traditional and advanced).

Metals - include ductile, strong structural materials, high-temperature, and corrosion resistant alloys, and electrical conductors. Traditional metals include commodity alloys of elements such as iron or aluminum. Advanced metals tailored for specialty applications are predominantly lightweight aluminum alloys and high-temperature/high-strength intermetallics.

Optical/photonic materials - include materials that control the transmission of light, materials used for light sources, such as lasers, and materials used to switch and modulate light. Glass in numerous forms, from window panes to optical fibers, continues to be an important material. Compound semiconductors, such as gallium arsenide, and complex structures made from such materials play an important role in modern communications systems.

Polymers - include a variety of large molecules consisting of long chains of repeating molecular units. Polymers are noted for unique combinations of properties and have a range of applications, from plastic containers to liquid crystal displays. Plastic wrap is a traditional example; polyimides are advanced, high-temperature polymers used for electronic packaging and aircraft skins.

Superconducting materials - include materials that carry electrical currents with no resistance. Some metals and alloys exhibit this characteristic only at temperatures near absolute zero. Advanced varieties, including oxides, organics, and some intermetallics, superconduct at much higher temperatures.

APPENDIX B

Complementary Programs

Small Business Innovation Research (SBIR)

This government-wide program originated with the Small Business Innovation Development Act of 1982 (Public Law 97-219). It is intended to stimulate domestic small businesses, to make use of small businesses to meet Federal R&D needs, to increase private-sector commercialization of innovations derived from Federal R&D, and to foster and encourage participation by minority and disadvantaged persons in technological innovations.

Awards are made in three phases: Phase I includes up to \$50,000 for evaluation of proposals; Phase II includes up to \$500,000 over two years to cover most of the R&D; Phase III, which involves commercialization, is not funded through SBIR but rather uses other sources of capital, such as corporate resources.

Materials-related projects are selected using specific evaluation criteria listed in each agency's program solicitation. Projects are funded based on independent reviews by a variety of representatives from government, universities, and the private sector.

Following are summaries of each agency's SBIR program in AMPP-related technologies, citing baseline data for FY 1992. The dollar figures represent totals for all awards in the stated category.

DOC/NIST made 2 phase II awards. Contact: Bruce Mattson, NIST, Building 221, Room B-252, Gaithersburg, Md. 20899. Telephone: (301) 975-6501.

DOD made numerous Phase I and Phase II awards for a total of \$50 million. Contact: Horace J. Crouch, Director of Small and Disadvantaged Business Utilization, The Pentagon, Room 2A340, Washington, D.C. 20301. Telephone: (703) 614-1151.

DOE made 73 Phase I and new Phase II awards for a total of \$13.3 million, and 23 Phase II awards for continuing projects (\$11.5 million for up to 2 years). Project topics range from basic research into the properties, behavior, synthesis, and characterization of materials to R&D involving advanced concepts in energy-related fields. Annual abstracts of DOE's SBIR awards may be obtained by calling Kay Etzler: (301) 903-5867.

DOT made 9 Phase I awards (\$450,000) and 3 Phase II awards (\$450,000 over 2 years). Projects emphasize energy-efficient materials developed using recycling technologies and improved materials to extend the life of structures and pavements and to reduce maintenance costs. Contact: George Kovatch, SBIR Program Office, DTS-22, DOT Research and Special Programs Administration, John Volpe National Transportation Systems Center, 55 Broadway -- Kendall Square, Cambridge, Mass. 02142-1093. Telephone: (617) 494-2756.

EPA does not support materials-related R&D through the SBIR program.

HHS made 39 Phase I awards (\$1.7 million) and 25 Phase II awards (\$4.7 million). SBIR biomaterials projects include development and evaluation of implants such as pediatric cochlear implants, improved breast prostheses, finger joint prostheses, and hybrid artificial organs. Many projects address biocompatibility and infection-free materials. Contact: H. Kreitman, Office of Extramural Programs, Building 31, Room 5B44, Bethesda, Md. 20892. Telephone: (301) 496-1968.

NASA made 35 Phase I awards (\$1.75 million) and 12 Phase II awards (\$5.88 million over 2 years). Contact: Harry Johnson, Code C, NASA Headquarters, Washington, D.C. 20546. Telephone: (202) 488-2442.

NSF made 94 Phase I awards (\$4.7 million) and 15 Phase II awards (\$3.4 million). Many Phase I awards focus on advanced electronic materials. Research topics range from low-leakage gallium phosphide for physics applications (e.g., particle detectors) to silicon flat-panel displays for computer applications. Contact: Donald Senich, Room V-502, 1110 Vermont Ave., N.W. Annex, Washington, D.C. 20005. Telephone: (202) 653-5202.

USDA made 1 Phase I award (\$50,000) and 2 Phase II awards (\$440,000). Projects focus on development of biodegradable oils from oil seed crops for use in cosmetics, oil additives, and lubricants. Contact: Charles Cleland, USDA-CSRS, Suite 320-G Aerospace Center, Washington, D.C. 20250-2200. Telephone: (202) 401-4002.

Advanced Technology Program (DOC)

Through technology development grants, this program helps single businesses or joint industry ventures carry out R&D on precompetitive, generic technologies. Awards to individual firms are limited to \$2 million over three years; industry covers at least half of the costs. The program currently supports 60 projects, including 50 initiated in FY 1992. About one third of the projects involve materials, including composites, ceramics, polymers, and metals.

Contact:

John Gudas
A402 Administration Bldg.
National Institute of Standards and Technology
Gaithersburg, MD 20899
(301) 975-3214

Enhanced Technology Transfer Program (DOE)

This program was initiated in response to the National Competitiveness Technology Transfer Act of 1989, which was intended to help realize the benefits of DOE's significant R&D budget (over \$6.2 billion in FY 1991) by delivering the results into commercial use. The Enhanced Technology Transfer Program was launched formally in January 1991.

As part of this program, DOE has improved the accessibility of its laboratories and other facilities and has expanded outreach efforts to inform the private sector and the public about DOE resources and the many ways to make use of them. A general information package on DOE and its facilities is available from the office listed below.

Contact:

Roger Lewis
Department of Energy
1000 Independence Ave. SW
Washington, DC 20585
(202) 586-5388

Hatch Act, Cooperative Forestry Research, and Payments to 1890 Colleges and Tuskegee University (USDA)

Through these three authorities, the USDA participates with states and other sources of funding to encourage and assist the state institutions in the conduct of agricultural research through the state experiment stations, in the District of Columbia, and in the U.S. territories by approved schools of forestry, the 1890 land grant institutions and Tuskegee University, colleges of veterinary medicine and other eligible institutions. A portion of these funds, as determined by a formula, is used for R&D in advanced materials based on agricultural products.

Contacts:

(Hatch Act:)

Edward M. Wilson
Aerospace Center, Room 330K
Department of Agriculture
Washington, DC 20250
(202) 401-4329

(Cooperative Forestry Research:)

Colien Hefferan
Aerospace Center, Room 329F
Department of Agriculture
Washington, DC 20250
(202) 401-4425

(Payments to 1890 Colleges and Tuskegee University:)

McKinley Mayes
Aerospace Center, Room 329C
Department of Agriculture
Washington, DC 20250
(202) 401-5620

University Transportation Centers (DOT)

The objective of this program is to advance U.S. technology and expertise in the many disciplines that contribute to surface transportation, through education, research, and technology transfer at university-based centers of excellence. The program encompasses 10 regional centers and five national centers.

Each center is managed by a lead university and its activities are organized around a particular theme; the number of universities involved in each center ranges from two to 12. More than 400 research studies were initiated during the first four years of operation. The research is providing innovative solutions to problems such as urban congestion, rural accessibility, air quality, special needs of the elderly and disabled, and safety.

Contact:

**William Brown
Federal Highway Administration, HHI-20
6300 Georgetown Pike
McLean, Virginia 22101-2296
(703) 285-2512**

APPENDIX C

COMAT TASK GROUP ACTIVITIES

Certain AMPP technical areas will benefit from joint planning through COMAT task groups. To qualify for joint planning, a technical area (1) either should be of significant interest to several agencies or should call for a change in the size, scope, or direction of the R&D agenda; (2) should be ready for exploitation; and (3) should be the primary focus of existing private-sector groups (e.g., trade associations, professional societies, R&D consortia, major research centers) that gather industry input and, ideally, are involved in coordinated R&D planning.

Four topics are targeted for emphasis in FY 1993 through scheduled planning activities with industry: electronic packaging materials, infrastructure/construction materials, metal casting, and structural ceramics.

No single planning mechanism or strategy will suit all technical areas, but workshops may be a common format. Such workshops, organized by either interagency or private-sector groups and planned by both sectors, will focus on a realistic time frame (e.g., 3-10 years), will limit the number of participants (to promote dialogue), and will produce a written public document, which may be published by private sector participants and open to critique and improvement.

Following are brief descriptions of each COMAT task group and its activities, including written reports. For information about the current availability of task group reports, call Samuel Schneider at NIST: (301) 975-5657.

Biomaterials and Biomolecular Materials

The purpose of this task group, organized in 1991, is to coordinate Federal research in biomaterials and biomolecular materials, to identify relevant issues and concerns, and to bring them to attention of COMAT. The group focuses on R&D involving materials that have the best chance for wide generic application by industry and can thus play an important role in the Nation's competitiveness. Priority is given to research involving cooperation with industry.

The group has held several meetings and has outlined goals, technical milestones, and challenges. Although opportunities remain diffuse in this emerging field, an extensive research network already exists. The various NIH biomaterials programs interact with industry, and USDA has established links with academia and industry in forest products and agriculture research. The task group expects to conduct planning activities in 1993.

Contacts:

H. Hollis Wickman
Division of Materials Research
National Science Foundation
1800 G Street NW
Washington, DC 20550
(202) 357-9787

Daniel Kugler
Department of Agriculture
14th Street & Independence Avenue
342 Aerospace Center
Washington, DC 20250-2200
(202) 401-6861

Composites

This task group was organized in 1991. Its purpose is to coordinate Federal research in composites, to identify relevant issues and concerns, and to bring them to the attention of COMAT.

The group held its first meeting with industry in November 1992. More than 20 representatives from DOD, NASA, and the major U.S. aerospace companies and materials associations attended the meeting, which was sponsored by the National Center for Advanced Technologies (NCAT). The proceedings are to be published by NCAT for submittal to COMAT.

Much of the discussion at the meeting centered around the issue of standards for materials, processes, testing, and quality. Materials suppliers and aerospace companies agreed that objectives should include standardization of test methods, specifications, criteria, and processes for developing design allowances. Also considered was a specific proposal for developing the processes and mechanisms for standardization of composite materials.

Another topic of discussion was the development of standard methods for design and analysis of engineered materials, from the atomic level to completed structures. Participants generally agreed that government-funded development of integrated analysis tools for engineered materials would help foster application of the technology and could revolutionize the design and analysis of composites.

Contacts:

Jerome Persh
ODDRE/Advanced Technology
The Pentagon, Room 3D1089
Washington, DC 20301-3080
(703) 695-0005

Steve Moran
NASA Headquarters
Federal Building 10B, Room 607
600 Independence Ave., SW
Washington, DC 20546
(202) 453-9344

Electronic and Photonic Materials

The purpose of this task group is to coordinate Federal R&D activities in electronic materials, to assemble a group of experts knowledgeable of trends and problems in electronic materials, to provide leadership in the thoughtful identification of issues and recommendations that can be advanced through FCCSET, and to inform COMAT about task group activities.

Five agencies are involved: DOC, DOD, DOE, NASA, and NSF. Recent activities have included the development of position papers outlining challenges in the electronics and photonics field.

In addition, workshops and symposia have been sponsored by one or more Federal agencies and industry groups to assess the status and direction of important research areas. Recent topics have included epitaxy¹⁴, interfaces, defects, and processing of electronic and photonic materials; and atomic layer epitaxy.

¹⁴ Epitaxy is the growth of a crystalline substance on a crystalline substrate.

Contacts:

LaVerne Hess
Division of Materials Research
National Science Foundation
1800 G Street NW
Washington, DC 20550
(202) 357-9789

Sven Roosild
DARPA
1400 Wilson Blvd.
Arlington, VA 22209-2308
(703) 696-2235

Environment, Safety, and Health

This group is at the organizational stage. Its purpose is to coordinate the environmental, safety, and health aspects of materials mining, processing, synthesizing, manufacturing, and use; to identify relevant issues and concerns; and to bring them to the attention of COMAT.

This task group is expected to become active in 1993. One important activity will be the definition of a critical technology taxonomy for environmental R&D.

Contact:

Alfred Galli, RD-681
Office of Environmental Engineering and Technology Demonstration
Office of Research and Development
Environmental Protection Agency
401 M Street SW
Washington, DC 20460
(202) 260-2583

Infrastructure/Construction

This task group was established in 1992 to coordinate and stimulate Federal research on infrastructure-related materials, to identify issues and concerns, and to bring them to the attention of COMAT. The ultimate goal is to optimize the design of structures using high-performance materials, to demonstrate the construction and testing of prototypes, and to provide assistance in technology implementation.

The initial emphasis will be on fostering advances in state-of-the-art concrete and steel, and on demonstrating the effective use of these technologies in construction and rehabilitation. In the future, other infrastructure materials will be addressed and assistance will be provided in the application of new infrastructure technologies.

The task group has identified the major Federal agencies involved in infrastructure, has encouraged participants to share information on their progress, and has produced a draft working paper outlining challenges and opportunities in the field as well as current and planned programs. About 16 agencies are developing a program to address R&D needs and technology transfer; the program will be reviewed at a workshop in the spring of 1993.

The task group also has established a partnership with the private sector. A working paper was written concurrently with a private-sector report developed through Civil Engineering Research Foundation (CERF), an affiliate of the American Society of Civil Engineers (112,000 members). The forthcoming CERF report, which defines research studies in high-performance concrete and steel, was developed by technical committees in coordination with the American Concrete Institute (20,000 members) and the American Iron and Steel Institute (1,200 individual and 47 company members).

Contact:

Thomas J. Pasko, Jr.
Federal Highway Administration
6300 Georgetown Pike
McLean, Virginia 22101-2296
(703) 285-2034

**LOCATION FOR
SUCCESS STORY #15**

"Intelligent" Processing of Materials

This task group evolved from a pre-existing COMAT working group. Its purpose is to coordinate materials processing research among Federal agencies, to identify relevant issues and concerns, and to bring them to attention of COMAT. The group focuses on processing research that has the best chance for wide generic application by U.S. industry and thus can advance the Nation's global competitiveness. Priority is given to cooperative research with industry.

In 1986 and 1987, the working group held two workshops, co-sponsored with industry, to further the concept of "intelligent" processing. More recently, the working group proposed and helped develop the concept as a top priority of the AMPP.

The topic of the next meeting is the new Consortium on the Casting of Aerospace Alloys, which involves NIST, industry, and academia. NIST and the Aerospace Industries Association sponsored two workshops in 1992 that attracted representatives of aircraft manufacturers, jet engine producers, casting companies, universities, NASA, DOI, NSF, and two national laboratories. The consortium's start-up plan focuses on "intelligent" casting of aerospace alloys.

Contact:

H. Thomas Yolken
Materials Science and Engineering Laboratory
National Institute of Standards and Technology
Gaithersburg, MD 20899
(301) 975-5727

Lightweight Materials for Ground Vehicles

The first organizational meeting of this task group is scheduled for early 1993. The objective of the group is to effect, through interagency collaboration on lightweight materials R&D, the formation of industrial partnerships among domestic materials suppliers, the "Big Three" automobile manufacturers (General Motors Corp., Ford Motor Co., and Chrysler Corp.), and U.S. aircraft manufacturers.

The ultimate goal is for these partnerships to develop new, lost-cost synthesis, processing, and manufacturing technologies that will enable automakers to increase use of lightweight materials on a cost-competitive basis without compromising passenger comfort and safety. Aircraft manufacturers are expected to benefit from the automobile industry's experience with mass production techniques in the effort to lower costs and to remain competitive in the international marketplace.

Contact:

James Eberhardt, CE-34
Office of Transportation Materials
Department of Energy
1000 Independence Ave. SW
Washington, DC 20585
(202) 586-9837

Metal Casting

This task group initiated interagency coordination of advanced metal casting R&D. Its primary objectives include implementation of the DOE Metal Casting Competitiveness Act of 1990 (Public Law 101-425), which calls for a program to perform and promote R&D on issues related to the technology competitiveness and energy efficiency of the U.S. metal casting industry.

Metal Casting Research Institutes have been established at universities and other institutions in regions where the industry is concentrated. Research is underway in the following priority areas, which were established after the DOE Metal Casting Industrial Advisory Board held public meetings with industry leaders and top researchers:

- dimensional control of castings;
- clean cast metal technologies;
- computer-integrated processing methods for productivity and quality improvements;
- aluminum furnace optimization;
- process improvements for lightweight components of aluminum, magnesium, and thin wall; and
- mitigation of environmental hazards arising in waste streams and emissions.

Also participating in the program are working groups of experts from the industries that are major users of metalcasting products, including automotive, aerospace, and heavy machinery and equipment companies.

Contact:

David Pellish, CE-231
Department of Energy
Forrestal Building
Washington, DC 20585
(202) 586-6436

Nondestructive Inspection/Evaluation (NDI/E)

The purpose of the group is to coordinate Federal research in NDI/E, to identify relevant issues and concerns, and to bring them to the attention of COMAT. Overall Federal funding for NDI/E programs in FY 1992 was approximately \$55 million.

The largest R&D program is carried out by DOE. Topics include digital analysis, sensor development for process control, eddy current inspection of aluminide coatings, development of NDE tests, and laser-generated acoustics for in-process control of welding.

The DOD program includes R&D on smart sensors, PC-based systems, analytical techniques for materials characterization, neural networks for the classification of defects and flaws, NDE of composite materials for aircraft, and improving NDE reliability. The Nondestructive Testing Information Analysis Center (NTIAC) maintains a literature database containing more than 45,000 documents with about 200 new items added per month.

DOT focuses on NDE related to aircraft and bridge safety. NASA emphasizes development of quantitative NDE (QNDE) technologies. Ongoing and planned efforts include detection of cracks and corrosion in airframe structures, detection of surface contamination, NDE of batteries, QNDE inspection methods for the National Aero-Space Plane. DOC develops advanced NDE technologies as part of a major program in "intelligent" processing. The NSF program focuses on NDE for infrastructure renewal.

Contact:

Jerome Persh
ODDRE/Advanced Technology
Room 3D1089
The Pentagon
Washington, DC 20301-3080
(703) 695-0005

Polymeric Materials

This task group is being organized. Plans for 1993 include information exchange among Federal agencies involved in polymer research; initial contacts with industry, professional societies, and other representatives from the private sector; and development of plans for a workshop at which the research needs of the private sector can be identified.

Contact:

Norbert M. Bikales
Division of Materials Research
National Science Foundation
1800 G Street NW
Washington, DC 20550
(202) 357-9787

Structural Ceramics

This task group evolved from a COMAT working group established 18 years ago and is linked to the Interagency Coordinating Committee on Structural Ceramics. The purpose of the group is to facilitate communication and coordination among the Federal programs in structural ceramics (i.e., ceramics for mechanical load-bearing applications at temperatures above 1000 °C [1830 °F]). A total of 23 offices in six agencies (DOC, DOD, DOE, DOI, NASA, and NSF) are involved.

The group holds an annual meeting at which R&D managers report on their activities. This information exchange often leads to interagency collaboration on specific projects. One example is the Integrated High-Performance Turbine Engine Technology (IHPTET) Initiative, a collaborative effort of the three DOD military services and NASA.

The task group also encourages interaction with industry. IHPTET steering committee meetings, for instance, are attended by representatives from the seven prime engine contractors. These companies are entering into a cost-sharing research agreement with the government to establish a consortium, which will develop ceramic fibers to meet IHPTET needs. Research proposals will be solicited from the materials research community.

In addition, communication has been established with the U.S. Advanced Ceramics Association.

The task group recently developed a plan that identifies future needs and opportunities in monolithic ceramics and structural ceramic-matrix composites. The report identifies common elements in the various Federal programs and attempts to integrate and balance R&D needs. The report is available for review by industry.

Contact:

Robert Gottschall, ER 131
Division of Materials Science
Office of Basic Energy Sciences
Department of Energy
Washington, DC 20585
(301) 903-3428

Superconductivity

This task group evolved from a pre-existing COMAT subcommittee, chartered in 1988 to coordinate Federal programs in superconductivity and to focus on long-term, high-risk basic research in superconducting materials that have the best chance for wide generic application. The interest in this area was sparked by the discovery of superconductivity in copper oxide perovskites at temperatures above that of liquid nitrogen.

The subcommittee has produced annual reports describing Federal activities in superconductivity, compilations that have been useful in tracking the government's focus and investment in the field. These reports have been of considerable interest to Federal agencies in setting budget priorities, and to the private sector.

The most recent report, covering the five years through 1992, reveals increasing Federal procurement of low-temperature superconducting devices (principally magnets for a superconducting supercollider and other components for particle accelerators), moderately declining support for research in low-temperature superconductors, and steady support for research in high-temperature superconductivity.

The first high-temperature superconducting devices -- including wires and superconducting quantum interference devices (SQUIDs) -- now are entering the marketplace, and the Navy plans to fly such devices on a space flight in 1996. Recent research has led to substantial improvements in current-carrying capabilities and mechanical properties of such components, as well as in fabrication processes.

Contact:

W.T. Oosterhuis, ER-132
Division of Materials Science
Office of Basic Energy Sciences
Department of Energy
Washington, DC 20585
(301) 903-3426

University Issues

This is a new task group established to handle duties that include the dissemination of information on budgets, scientific trends and needs, changes in agency policies, and new Federal activities; the identification of technical areas that require enhancement; and responses to special requests by COMAT.

The task group may be asked to develop reports and recommendations on topics such as usage of national facilities; the development of instrumentation; emerging areas of research; coordination of agency activities; interagency collaboration; interactions among universities, industry, and national laboratories; and databases.

The task group is organizing a workshop to be held in the spring of 1993 involving universities, industry, and government laboratories.

Contacts:

David L. Nelson
Division of Materials Research
National Science Foundation
1800 G Street NW
Washington, DC 20550
(202) 357-9787

Richard Kelley
Division of Materials Science
Office of Basic Energy Sciences
Department of Energy, ER-13
Washington, DC 20585
(301) 903-3426

To obtain a copy of this document - send request to:

Committee on Industry and Technology/COMAT
c/o National Institute of Standards and Technology
Room B309, Materials Building
Gaithersburg, MD 20899

[Phone: (301) 975-5655]

For additional information about the importance of materials to society, the science and engineering of materials, and the origins of the AMPP, request the booklet *Advanced Materials and Processing: The Federal Program in Materials Science and Technology*. For detailed information about AMPP technical programs (the inventory of Federal materials R&D), request the publication *Advanced Materials and Processing: The Fiscal Year 1993 Program*.

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SUCCESS STORIES

SUCCESS STORIES

The Following "Success Stories" will be Displayed in Highlight Boxes Placed in Various Sections of the Budget Booklet Text as Indicated by Specific Page Locations

#1. Bridge Coating Process Creates a New Industry

A coating process developed by DOT and DOC for bridge reinforcing bars has extended the life of bridge decks while spawning a thriving new industry. The epoxy coating system was developed to remedy corrosion of steel reinforcing bars, a problem exacerbated by the application of de-icing salts during winter. Since the coating system was developed, the fusion-bonded coating industry has grown to include 17 firms with 34 plants in North America, and production in 1989 reached an estimated \$260 million. Experience indicates that the coated bars provide protection for more than 20 years. Additional protection may be needed in unusually corrosive environments such as Florida, so R&D continues to find even better materials and to enhance quality control of the coatings. Stainless steel is too expensive; alternatives under evaluation include vapor deposition of silicon and titanium coatings.

[PLACEMENT: PAGE 2]

#2. New Polymers May Enhance Safety of Contact Lenses

New polymers designed through HHS research may reduce the incidence of eye infections related to artificial lenses. The most severe complication of contact lens wear is infection by a bacterium, *Pseudomonas aeruginosa*, which adheres to lens deposits and causes inflammation and sometimes blindness. These and other microorganisms can cause similar complications with intraocular lenses, notably after cataract surgery, which is performed more than 1.5 million times each year in the United States. Research by HHS and an industry partner recently identified new materials, the poloxamers (Pluronic®), that may prevent adherence by microorganisms. These inert, non-toxic, water-soluble polymers already are used as food additives and in pharmaceutical preparations. Researchers discovered that varying the size of "blocks" of molecules in these polymers -- and thereby changing the molecular weight -- enhanced the materials' properties. The poloxmers of high molecular weight significantly inhibited bacterial attachment to lenses in vitro. Studies of clinical applications are underway.

[PLACEMENT: PAGE 5]

#3. Simulation Models Streamline Design of Lightweight Car Parts

Process simulation models developed by DOC are improving prospects for the use of polymer composites in automobile frames. Lightweight yet strong, polymer composites resist fatigue and corrosion, can be made into complex shapes, and could reduce the weight of automobile structures by as much as 50 percent. Current fabrication technology, however, is too expensive and/or slow to make composites competitive, and the most promising advanced processing technique, liquid molding, requires extensive trial-and-error adjustment. (In this process, the reinforcing fiber is shaped and placed in a mold. A pre-polymer is injected into the mold; this resin then is polymerized to form the rigid matrix.) The DOC simulation models speed up the design and installation processes by enabling technicians to optimize mold temperatures, location of injection ports, and other variables. Validation and refinement of the models is handled by the Industrial Automotive Composites Consortium, which is fabricating and testing a number of full-scale parts; modeling has improved the efficiency of the fabrication and testing procedures.

[PLACEMENT: PAGE 11]

#4. New Refrigerants May Help Preserve the Ozone Layer

Human health and ecosystems worldwide stand to benefit from new, environmentally benign refrigerant chemicals developed through EPA research. A number of private companies are considering commercialization of these chemicals, which could be used in refrigeration, heat pumps, insulation, and fire-extinguishing systems. One chemical could be a long-term replacement for refrigerants used in the estimated 65,000 large air-conditioning systems (i.e., low-pressure chillers) now in service in the United States. Another new chemical may be used to retrofit nearly 950 shipboard refrigeration and air-conditioning systems. The new chemicals were identified by EPA and industrial and academic partners in a program directed at reducing emissions of man-made ozone-depleting compounds, such as chlorofluorocarbons (CFCs). Stratospheric ozone depletion and the resulting increase of UV-B radiation is a worldwide concern. The EPA is collecting additional data on the properties of the new chemicals and validating their performance.

[PLACEMENT: PAGE 12]

#5. New Process Creates Novel Properties in Ceramic Engine Parts

An "intelligent" manufacturing process developed by DOE and an industry partner can produce ceramic engine parts with more than four times the tensile strength, some five times the reliability, and much greater resistance to weakening under heat than previous ceramic materials -- a combination of properties heretofore unknown. The new material, which could enable the development of ultra-efficient, high-heat automobile engines, is silicon nitride with 4 percent yttrium. Prototype turbine rotors made of these ceramics have been tested successfully for more than 300 hours at full design speed and temperatures (1370 °C [2500 °F]). The manufacturing method involves applying statistical process control and in-process

nondestructive inspections to identify and minimize or eliminate sources of flaws introduced during processing of components. This process, an important step toward overcoming the major drawback of ceramics -- the tendency to crack -- is expected to be equally effective for improving other materials and processes.

[PLACEMENT: PAGE 19]

#6. Low-Cost Steels Could Save Billions

Advanced steels developed by DOD and industrial and academic partners have saved the Navy some \$140 million in ship construction costs so far, and savings from wider application could amount to hundreds of millions annually. The High Strength, Low Alloy (HSLA) steel was developed through innovative metallurgy and steel-plate processing technologies. The HSLA plate is less expensive than traditional steel plate and also significantly cheaper to weld, yielding a combined savings of up to \$4,000 per ton. Moreover, because the HSLA steels incorporate carbon rather than costly alloy materials, these steels reduce dependency on imported materials such as chromium and cobalt. Private industry and other government agencies have shown considerable interest in adapting the Navy's steel technology for other uses. Applications under investigation include offshore oil platforms, pressure vessels for boilers, highway bridges, railway cars, and military tank-recovery vehicles.

[PLACEMENT: PAGE 26]

#7. Prospects Improve for Titanium Car Engines, Medical Implants

A new process developed by DOE and DOI, now being commercialized, could revolutionize production of titanium, a lightweight and corrosion-resistant metal now used in aerospace applications. Aerospace-grade titanium is expensive -- \$20 or more a pound -- but the new plasma quench reaction process could lower costs, thereby paving the way for new applications such as standard-production automobile engines and medical implants. The process also would reduce energy usage indirectly, by enabling the development of lightweight products. The innovative aspect of the new process involves the method of recovering titanium from a hot gas. A titanium compound is superheated to the plasma phase, in which the atoms, usually titanium and chlorine, break apart. The mixture then is flash cooled ("quenched") quickly to a fine powder, before the atoms recombine; the quenching technique involves expanding the plasma into a cold chamber. A company has been formed in Idaho to commercialize the process, which in the future could be used to produce other high-value materials. Ongoing efforts to boost production rates involve industry and academia.

[PLACEMENT: PAGE: 29]

#8. Advanced Commercial Products Developed from New Crop

New high-performance products, including biodegradable lubricants, have been developed from agricultural crops and now are being commercialized through joint R&D by USDA and private-sector partners. The products include advanced lubricants (transmission fluid treatments, gear oils, and biodegradable cutting oils), engineering plastics, and processing aids. The lubricants were developed through the collaborative efforts of the private sector and a USDA-managed consortium of universities, government laboratories, and private companies. The products were made with oils high in erucic acid derived from industrial rapeseed and a new crop, crambe. Production of crambe has increased from no commercial acreage in 1989 to a projected 60,000 acres in 1993.

[PLACEMENT: PAGE 31]

#9. Polymer-Based Coating Reduces Costs and Pollution

A polymer-based coating developed by DOD to replace the standard multi-layer paint system for aircraft and industrial applications is expected to save some \$25 million annually in time and materials costs and to reduce hazardous emissions and toxic wastes. UNICOAT was developed through use of theoretical and statistical models to blend state-of-the-art polymers, corrosion inhibitors, and opacifying fillers. Because no precedent existed for this technology, the research focused on determining and understanding the physical, surface, and electrochemical properties needed for the successful performance of a self-priming topcoat. By eliminating the need for a primer, UNICOAT substantially reduces hazardous emissions and toxic wastes; the coating won the EPA Administrator's 1992 Award for Pollution Prevention. It also saves time and money: The traditional paint system required separate applications of primer, sealant, and topcoat. The new coating has been approved for Navy aircraft, and studies are planned to develop formulations for other applications, such as ground equipment and ships.

[PLACEMENT: PAGE 34]

#10. New Concrete May Lead to Safer Bridges

A new concrete developed at an NSF-supported academic research center is 13 times stronger than the best materials in existing U. S. bridges, a development that may lead to safer bridges. The new concrete has a strength of 730.8 MPa (106,000 psi). By comparison, the highest design strength in an existing bridge is 55.1 MPa (8,000 psi) in the East Huntington Bridge in West Virginia; the more typical level for U. S. bridges is 34.4 MPa (5,000 psi). (Stronger concretes have been used to armor pavements and to reduce column sizes in tall buildings.) Even small increases in the design strength of bridges can have significant benefits. Studies indicate that, when the typical design strength is doubled to 68.9 MPa (10,000 psi), bridge weight can be reduced by one third, span lengths can be increased by one third, or the number of supporting girders can be cut in half. Before high-performance concrete can be exploited fully, however, additional R&D is needed to explore the durability of efficiently designed concrete structural members, and to assure adequate

ductility of the materials. Studies continue to evaluate new bridge designs and to develop construction procedures that assure bridge safety.

[PLACEMENT: PAGE 43]

#11. Recycled Wastes May Help Reduce Pollution-Control Costs

An inexpensive method of preparing sorbents for air pollution control could save billions of dollars in pollution-control costs while providing for re-use of industrial waste materials. The EPA's ADVACATE process has been licensed for use in coal-fired boilers and utility grids in the United States, and an agreement may be forthcoming to install the system in some Polish power plants. The process involves reacting calcium slurry with the silica component of an industrial waste, such as fly ash, glass, or sludges from mineral processing. The resulting calcium silicate gels may be integrated into pollution control schemes for inexpensive control of sulfur oxides and acid vapors. Continuing research is exploring the use of other industrial wastes and development of other applications for ADVACATE such as for control of air toxins (e.g., mercury, dioxin). In an effort to eliminate the waste stream entirely, researchers also are exploring the possible use of spent sorbents in commercial products, such as insulation and low-strength concrete materials.

[PLACEMENT: PAGE 45]

#12. New Alloy Developed for Lightweight Turbine Blades

An advanced alloy developed by NASA and an industry partner holds promise for reducing the weight and increasing the performance and fuel efficiency of future commercial aircraft engines. Today's state-of-the-art turbine blades are made from nickel-based superalloys, solidified from molten liquid into single crystals. These heavy materials cause high stresses in rotating components. Nickel aluminide (NiAl) alloys are attractive replacement candidates due to their oxidation resistance, low density, and high thermal conductivity; however, these materials also tend to weaken and deform at high temperatures. A new NiAl alloy being developed through NASA research contains small amounts of hafnium and silicon, which appear to have a positive synergistic effect on the alloy. Scanning electron micrographs have revealed microstructural changes during heat treatment, resulting in smaller grains and a more homogeneous material. The material meets goals for high-temperature strength for next-generation turbine blades.

[PLACEMENT: PAGE 49]

#13. New Display Technology Could Reduce Instrument Cost, Weight

NSF-supported researchers have invented a new liquid crystal technology for flat-panel displays that is expected to reduce the power needs, cost, and weight of portable instruments and computers. The new technology, which does not require power-draining backlight, represents a breakthrough in reflective, front-lit displays. Colors are produced by light reflection off crystal planes rather than by light-absorbing filters. Good contrast and brightness are achieved under ambient light conditions without polarizers, so the displays can

be manufactured on common, lightweight substrates such as plastic. The display also has full memory, retaining images without electronic refreshment; this advance could lead to new types of products and could reduce the cost of drive electronics for some applications. The invention resulted from the discovery that textures of liquid crystals with helicoidal structure can be stabilized by the dispersion of polymers, which create small textured domains adjacent to stabilizing surfaces. The intensity of reflected light is controlled by adjustments in the density of domains containing the reflecting planes, relative to other domains. A prototype device using the new display technology has been constructed with a small company.
[PLACEMENT: PAGE 58]

#14. "Intelligent" Process Improves Quality of Jet Engine Blades

An "intelligent" method of processing expensive metal alloys, now being commercialized through an AMPP consortium, is saving millions of dollars while improving the quality of jet engine turbine blades. The DOC, DOE, and four industrial partners improved the uniformity of the alloy material by enhancing process control and the associated measurement technology for metal powder atomization. In this process, high-pressure gas is used to blow apart a stream of molten metal into tiny droplets, which are solidified and collected (and later reheated and shaped into turbine blades). Ideally, the particles should be uniform in size; this would ensure a consistent rate of solidification and thus a uniform solid microstructure (i.e., no defects). Until now, commercial processes depended on trial and error to achieve optimal conditions, as well as expensive sieving of the particles; even then, 50 to 70 percent of the particles had to be discarded or remelted. One consortium partner already reports cutting both scrap rate and gas usage by 50 percent using the new process, while producing better material.

[PLACEMENT: PAGE 63]

#15. Metal Spray Forming Process Could Benefit Many Industries

A unique process for producing reduced-cost machinery components, developed by DOD and industry and university partners, is expected to revolutionize fabrication of metallic parts, both military and commercial. The "intelligent" metal spray forming process employs sensors to control automatically the fabrication of asymmetric, near-net-shape (i.e., requiring no machining) components. Spray forming can save 20 to 50 percent of fabrication costs while reducing component weight and enhancing performance. The advance is significant for the Navy, which traditionally has relied on difficult and expensive processes to shape the high-strength, corrosion-resistant alloys needed for military equipment. Metal spray forming, developed initially for seawater piping in submarines (the process saves some \$3 million per submarine), until now had been limited to symmetrical components, and processing adjustments had to be made by trial and error. The "intelligent" process has attracted the interest of many U.S. manufacturers in the aerospace, aluminum, farm equipment, and other industries.

[PLACEMENT: PAGE 67]

#16. "Designer" Irregularities Prepare Superconductors For Space

Processing research by DOE and industry has revealed that "designed" irregularities can increase substantially the current-carrying capability of high-temperature superconductors, thus making these materials attractive for space applications. It has been difficult to tailor high-temperature superconductors to carry high levels of electrical currents reliably.

However, scientists have found that by irradiating single crystals of yttrium-barium-copper-oxide ("1-2-3") superconductors with energetic ions of tin, they can produce linear columns of highly irregular material. The effects are striking. For example, when a magnetic field is aligned with the columnar defects, the critical current at -196 °C (the boiling temperature of liquid nitrogen -- warm in comparison to the space environment) exceeded 10^5 amp/cm^2 in a field of 4.5 Tesla (100,000 times the Earth's magnetic field). That electrical current level is sufficient for practical use. (The critical current must be high enough that the electric energy is used efficiently, and that the field generated by the current itself does not suppress the superconductivity). The Naval Research Laboratory plans to fly prototype high-temperature superconducting devices on a space flight in 1996.

[PLACEMENT: PAGE 72]