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Reports on Current
European/Middle Eastern Science

a focused issue:

MATERIALS RESEARCH IN EUROPE

a report

by M.J. Koczak

Office of Naval Research European Office

TELEPHONE: 44-71-409 + ext.

TELEX: (900) 7402119 ONRE UC **FAX: 44-71-724-7030/723-1837**

OMNET: ONR.EUROPE **MILNET: ONREUR@ONREUR-GW.NAVY.MIL**

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U.S. Mail Address
PSC 802 Box 39
FPO AE 09499-0700

U.K. Address
223/231 Old Marylebone Road
London NW1 5TH

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The European Science Notes Information Bulletin (*ESNIB*) 92-01 focuses on Materials Research in Europe. Europe is orchestrating a union of educational, corporate, and government research centers, as well as technical societies motivated by the 1992 deadline. Although there has been cooperation in the past, realization that the union is near has catalyzed more vigorous activities. Via partnerships in research and materials development, a *quid pro quo* can be established with the European Community. The ties can be most easily established at four parallel levels: (1) government/government, (2) university/university, (3) defense agency/defense agency, and (4) industry/industry. The materials research field can be a model for this program since the research direction at the basic research level is clear, the community is relatively small, and the contacts are well established.

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This publication is approved for official dissemination of technical and scientific information of interest to the Defense research community and the scientific community at large.

Commanding Officer ..... CAPT John M. Evans, USN
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Editor ..... Ms. Connie R. Orendorf

This special issue of ESNIB has been compiled by Dr. Michael J. Koczak. Dr. Koczak was the Liaison Scientist for Materials in Europe and the Middle East for the Office of Naval Research European Office.

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Materials Research in Europe

by Michael J. Koczak. Dr. Koczak was the Liaison Scientist for Materials for the Office of Naval Research European Office. Dr. Koczak was on sabbatical leave from Drexel University, Philadelphia, Pennsylvania, where he is a Professor of Materials Engineering.

Executive Summary

Purpose

The development of materials research in Europe is considered here in light of the scientific, technical, economic, and political changes that are altering the nature of Europe. This study is organized to examine initially the cooperative European Community (EC) programs. The introductory synopsis portrays the changes in the EC materials efforts, contrasts the programs with efforts in the U.S., identifies the significant programs, and cites initiatives that should be implemented. The national materials programs of the larger European countries are discussed. The report should serve as a resource to identify the general program themes and the individual materials-related laboratories[1].

Over the past 2 years, the climate of change in the European countries has been evolutionary if not revolutionary. The EC has emerged as a major economic force with a centralized structure. The exact nature of the cooperation will continue to develop and reshape the framework of the EC. The new independence of the Eastern and Middle European countries has provided for an unprecedented entree into the science base and technological developments that remained obscure for 50 years. The center of gravity of materials science is shifting toward mainland Europe with the United Kingdom (U.K.) finding it difficult to maintain leadership in ferrous metallurgy, composites, microelectronics, and fibers.

With the reunification of the Federal Republic of Germany (FRG), the advanced technology of the West has joined with the dormant infrastructure of the East. This union leaves an unresolved question about the German science base because of the economic burden of reunification.

The science base in France continues to be strong as a result of the of benefits government support of a semiautonomous research laboratory and industrial infrastructure.

Several scientific and technological points highlight the difference in the European science and technology base versus the U.S. and Japan. Historically, the Europeans have developed their science with the tradition of a well-developed, long-standing, educational structure. In many aspects, the university system is superior to the U.S. since it provides for a greater educational focus to the student in a particular science or engineering field. The European advanced degree is a research degree and highly specialized in a narrow area.

An Oxford, Cambridge, or the Grand Écoles (France) degree bestows upon the student an elite diploma and a rapid route to the best companies, laboratories, and educational establishments within Europe. The perception from an industrial and academic viewpoint is that the second tier of students; i.e., those applying to less notable universities, are not motivated to enter basic and applied sciences in sufficient numbers to support the science and technology base. With an economic recession, in the student's view, the viability of a career in technology may be questioned and they may seek a more secure career path; i.e. business, law, insurance, medicine. Many U.K. students are seeking employment on the continent and are being linked to multinational projects. The combined effects of a limited number of entry undergraduate level students, consolidation of departments, reduced science funding, and the departure of top students for continental employment and training will clearly affect future U.K. science developments. The European universities in general have facilities at an intermediate level of equipment and support with reasonable ties to industry. There are some exceptional universities that are extremely well funded and are tightly linked to the electronics and the materials companies.

In contrast, the diversity of the U.S. educational s.ructure provides for more independent movement for career development. At the undergraduate level, demographics will result in a reduction of entry level undergraduates into the pipeline for the next 2 years. At the graduate degree level, U.S. educational training provides for greater breadth in terms of course content. In defense of American universities, they provide a more

[1]Information was acquired from professional meetings, personal interviews, and publications. Budgetary information shown was the most current available to the author at the time of writing.

general education. Often, this is required by accreditation guidelines. However, American universities should give an international perspective by requiring language and other training, to include international perspectives on business and technology.

The American academic researcher is relatively well endowed with better facilities and a closer link to industry than universities in Europe. In the U.S., technologies are nurtured in the universities and transferred to industry. In contrast in Europe (as in Japan), some of the best materials research is conducted not at universities, but in industry or government-related laboratories; i.e., Max Planck Institutes (Düsseldorf, Stuttgart), Frauenhofer Society for Applied Sciences (Würtzberg, Bremen, Freiberg, Aachen) in the FRG, CNRS[1] laboratories in France, and MITI[2] facilities in Japan. Access to U.S. academic research remains relatively open to all. However, the perception is growing that access to European academic, EC, and Japanese national programs by American scientists is becoming more restrictive and is addressed on an *ad hoc* basis, which may be interpreted that no formal protocal exists for rapid research dissemination which is vital in a technological society.

The current European scientist is well versed in the international arena. His American counterpart may not be as well informed. Although not critical for scientific communication, being multilingual certainly facilitates technological cooperation in Europe. With several cooperative EC programs, the interactions among European scientists have been strengthened. Current EC modifications to the professional engineer status will require knowledge of two languages before certification is granted.

In the U.K., the privatization of government laboratories has focused attention away from basic research to a closer link to the commercial sector. In general for Europe and Japan, there is a strong focus on nondefense-related industrial competitiveness, with a triad vision; e.g., U.S. versus Japan versus Europe. Each element of the triad has focused on the emerging technologies that will make it respectively competitive on the more global marketplace throughout the next century. The identifying and implementing basic science is critical to the development of advanced technologies for the next century.

This report is a window that the reader should open to seek further information concerning materials-related efforts in Europe. Although the view certainly is far from complete, it provides an overview of the diversity and depth of materials activity in Europe.

[1]Centre National de la Recherche Scientifique
[2]Ministry of International Trade and Industry

Comparison with Materials Technology in the United States

France and the FRG have highly centralized research and technology with a network of semi-independent laboratories and nongovernmental research societies. The research at the institutes focuses on applied or developmental research activities; i.e., microelectronics, information, and materials. The CNRS organization in France is associated with the Ministry of Education and is involved with more basic research activities. The French government has taken a proactive technology stance with regard to industrial technologies with regard to transportation; i.e., rail (TGV), air (Airbus Industries) and space (Ariane), and electronic (Thomson). These national programs and companies (Airbus Industries, SEP) are subsidized to promote technologies vital to the national goals. The Max Planck Societies in the FRG are similar. The materials strength of the EC can be considered significant in the following basic sciences and technologies:

- Ferrous alloys - Sweden, FRG, France, U.K.
- Aerospace design and manufacturing - France, FRG, U.K., the Netherlands, Italy
- High-performance aluminum alloys - France, U.K.
- Titanium alloy developments - U.K.
- Optical fibers - France, the Netherlands
- Polymer composite materials - U.K., France, Italy, the Netherlands
- Structural ceramics - France, FRG
- Ceramic composites - France
- Materials synthesis - France, FRG
- Manufacturing systems - Sweden, FRG
- Instrumentation - U.K., FRG
- Marine structures - U.K., Norway, France.

For naval and marine considerations, ship design based on glass-reinforced composites and offshore oil platforms has supplied a basis for materials selection and design from a marine environment and fire hazard control viewpoint.

It is tempting to see Europe as a whole and integrate the individual basic research and advanced technologies into a manufacturing system. How effective this will be in the future remains an open question. The EC efforts certainly seek to unify and harmonize the differences. The translation of these basic research directions into advanced manufacturing is certainly more directed than in the U.S. Traditionally, the U.S. has sought to maintain a free market outlook. For fear of being linked with cartels, individual groups conducted independent activities. Faced with the international competition from the EC and Japan, one wonders if this view remains a relic of the 1950s. The precompetetive intercountry research groups that work jointly with the aerospace,

manufacturing, and automotive sectors have special advantages in the research and developmental process. They have managed to team together in finessing the patent and market-share questions by organizing generic research programs which develop participating companies and individually exploit or jointly license to outside parties with mutual agreement of the research partners. The model EC research contract could serve as a guideline to American precompetitive programs.

Conclusions

A strong base materials science and related technologies industry is prospering within Europe. Also, it is being nurtured by the EC materials and manufacturing programs as well as selected national programs. The focus is on developing the sciences and technologies related to the commercial sector with a special focus on the aerospace sector and manufacturing competitiveness. Program emphasis is aimed at the small to medium enterprises in design, manufacture, and quality assurance.

Several European companies have capabilities as materials producers, equipment, and product manufacturers; e.g., ASEA, Mannesman. Materials research funding will continue to receive special attention with the primary stimulus being derived from the EC. Europe is looking inward, via the EC, and considering relations with the EFTA and Eastern European countries. Programs with the U.S., particularly bilateral, can be effective with individual research institutes and universities. However, multilateral agreement, especially with industrial partners, may be more difficult to orchestrate.

Outstanding European Programs

The following European programs are highlighted for their basic research activities and technology developments. The activities should be followed as world leaders in science and manufacturing technology. In addition, certain programs are vehicles for materials and systems orchestration. For instance, European national and international programs in space; i.e., Hermes, Columbus, HOTOL, Sanger; transportation; i.e., TGV, Airbus; and defense; i.e., EFA, accelerate materials developments and manufacturing expertise. Although several of the programs may not reach fruition, they build national and scientific enthusiasm and promote a national spirit coupled with appreciation of technology from school age to senior citizens. The focus in the national programs is toward the development of a more competetive industrial edge with a transition of the research to consumer products; i.e., EURAM, BRITE, and EUREKA programs.

Advanced Technologies

AIRBUS - Aerospatiale (France), British Aerospace (UK), CASA (Spain), MBB, Dornier (FRG), Fokker (Netherlands)

HERMES - European Space Agency (ESA), SEP, ONERA

EC and National Research Programs

BRITE/EURAM - Over 400 materials-related programs in materials developments, manufacturing, design and quality assurance

EUREKA - Concerted manufacturing program to enhance the competitiveness of European industries

COST - Nationally funded cooperative programs directed to powder metallurgy, advanced casting, materials for power generation, light alloys, and thermochemical and thermophysical data

Research Direction of National Materials Programs - SERC, CNRS, and program plans for the Max Planck and Frauenhofer Institutes.

Centers of Excellence for Key Technologies

From an individual laboratory basis, the centers cited are perceived as outstanding in the key areas. This is primarily the author's perception based on visits, interactions, and discussions (see Table 1).

Table 1. Centers of Excellence for Key Technologies

Nonferrous Alloy Developments

- Pechiney Recherches - Voreppe, France
- ALCAN - Banbury, England
- RWTH - Aachen, FRG
- RAE - Farnborough, England
- Norsk Hydro - Porsgrunn, Norway
- University of Sheffield - Sheffield, England
-

High-Temperature Metallic Materials

- ONERA - Chatillon, France
- Birmingham University - Birmingham, England
- Max Planck Institute - Dusseldorf, FRG
- Rolls Royce - Derby, England
- IMI Titanium - Witton, England
- SNECMA - Evry, France
- MTU, Munich, FRG.

Ceramics and Ceramic Matrix Composites

- GEC Alsthom - Stafford, England
- Saint Gobain Recherche - Aubervilles, France
- CNRS - University of Bordeaux, Bordeaux, France
- Hoechst - Frankfurt, FRG
- SEP - Saint Medard en Jalles, France
- Technical University of Hamburg - Hamburg, FRG
- Max Planck Institute - Stuttgart, FRG
- Rhone Poulenc - Aubervilliers, France.

Polymer Matrix Composites

- Akzo International - Arnhem, the Netherlands
- BP International - Sunbury on Thames, England
- ICI - Wilton, England
- Aerospatiale - Suresnes, France
- MBB - Munich, FRG
- Courtaulds - Coventry, England
- Dornier - Friedrichshcafen, FRG
- BASF - Ludwigshafen, FRG
- Fiat Centro Ricerche - Torino, Italy.

Universities with Notable Materials Programs

- Birmingham University - Birmingham, England
- University of Bordeaux - Bordeaux, France
- Cambridge University - Cambridge, England
- Catholic University - Leuven, Belguim
- Delft University - Delft, the Netherlands
- Ecole des Mines de Paris - Armines, France
- Ecole Superieure des Mines des Paris - Evry, France
- Imperial College - London, England
- Oxford University - Oxford, England
- RWTH, Aachen University - Aachen, FRG
- Technical University of Hamburg - Hamburg, FRG
- Technion - Hafia, Israel.

Materials Research in Europe

Introduction

New materials research in the European Community (EC) has developed at several levels. The research has matured to the establishment of individual and multinational programs. Future EC needs and directions have been analyzed and actions initiated. As result, it was decreed that European materials policy is required and should be integrated into an overall European economic policy. This includes the related effects of raw materials, semifinished products, and consumer and defense articles. A separate European research program in defense-related research termed EUCLID include research areas of modern radar technology, silicon microelectronics, composite material and structures, modern avionics, electric guns, artificial intelligence, signature manipulation, optoelectronic devices, solid-state lasers, underwater technologies, and human factor simulations. As a result of EC planning efforts in Brussels, there has been an upsurge in coordinated industry, academic, and government research similar to Japan's Ministry of International Trade and Industry (MITI) programs with an outlook to future industries. The EC industry-to-government interactions have paralleled the German models. A comparison of the European community, vis-à-vis Japan and the U.S., indicates a larger gross national product (GNP) and population base (see Table 2). In addition, a large pool of talented scientists is available with significant research budgets. With the approach of *1992*, a unification of industrial and science policy is being formulated. A triad competitive (EC versus Japan versus U.S.) vision has been developing to protect and take advantage of the significant internal EC markets and develop strengths in competitive key technologies; i.e. aerospace, materials, information sciences, and biotechnology.

Table 2. World Comparison of Gross National Products

	Europe	U.S.	Japan
Population	340 M	246 M	122 M
R&D Budget	$ 56 B	$ 88 B	$ 34 B
Number of scientists	500 K	700 K	435 K
GNP	$5,580 B	$5,165 B	$2,800 B

*Source: OECD, 1988

As part of these actions, there is the associated development of an infrastructure to coordinate and orchestrate national and international cooperation and competition. The diffusion of the research knowledge goes directly to the national economic units and commercial sectors with the transfer of the research market to a commercial market. Several key questions involve the scope of these efforts upon the science, technology, and manufacturing efforts of the U.S. Significant issues and imponderables include:

- Transition of research efforts into technology
- Role of the newly industrialized Eastern European countries
- Participation of European Free Trade Association (EFTA) members; e.g., Sweden, Norway
- Role of Japan and U.S. industrial effort in the EC.

Coordinated European Community Programs

The summary highlights the materials developments and organizations primarily within the EC and Eastern Europe. The significant multinational research efforts within the EC are highlighted under the framework of the European Research in Advanced Materials (EURAM), Basic Research in Industrial Technologies for Europe (BRITE), and European Research Coordination Agency (EUREKA) programs. In addition, the EC has addressed educational and vocational needs by committing resources to exchanging researchers within the EC and to student exchange and training programs. The diversity of the advanced graduate research between France, the Federal Republic of Germany (FRG), the U.S., and the U.K. is depicted in Figure 1. The age of a student is shown in various countries with the appropriate degree path to a doctorate. Wide differences exist; i.e., the U.S. Ph.D. candidate graduate student is required to take course and candidacy examinations developing a broad base of knowledge. In contrast, a post M.S. graduate student pursuing a Ph.D. in the U.K. is focused on a research theme and the course requirements are optional and often not required.

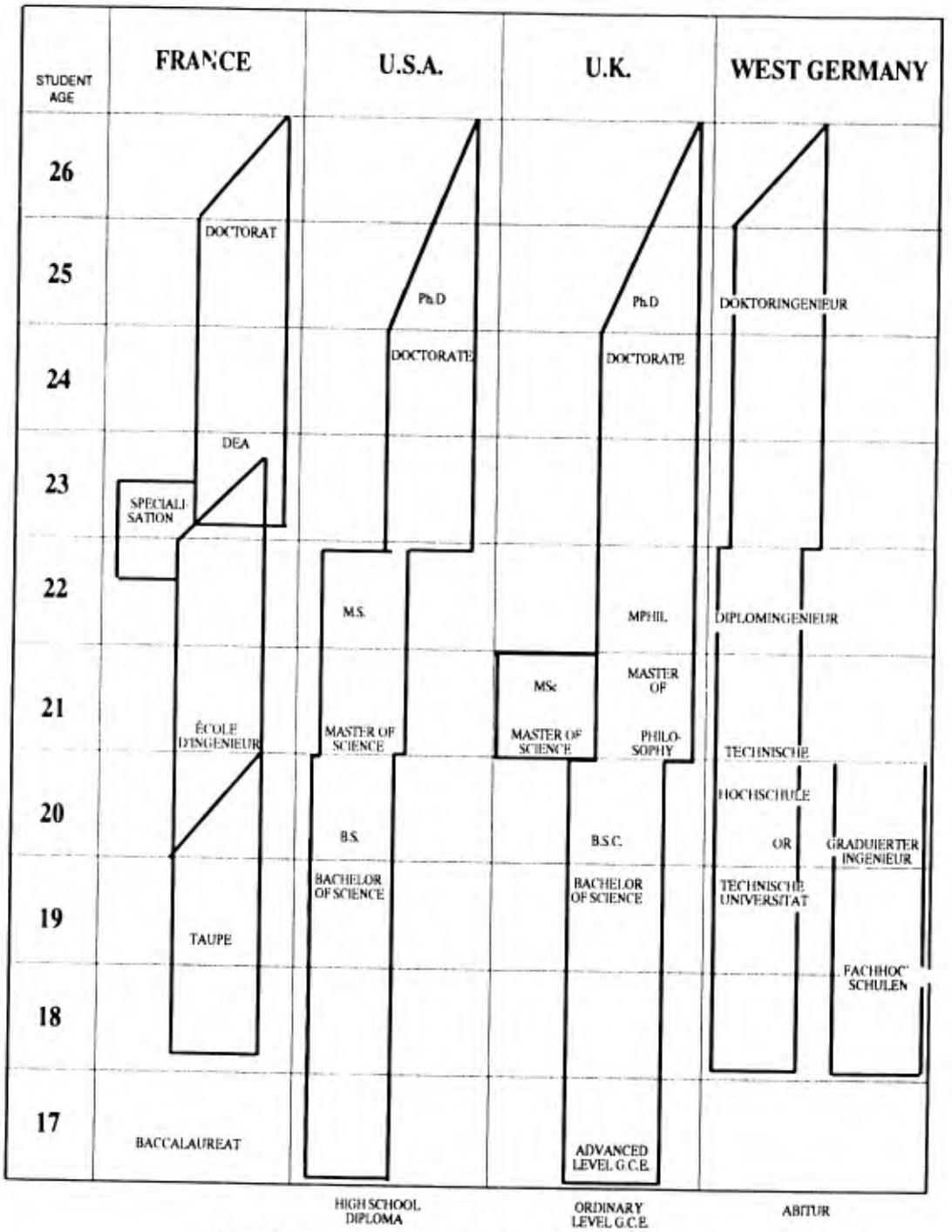


Figure 1. Correspondence between advanced study programmes

The source materials for the survey involve documentation from the following sources:

- Advanced Materials - Policies and Technological Challenges OECD (1990), *ISBN* 92-64-13255-4
- Industrial Revival Through Technology - OECD, *ISBN* 92-64-13103-5
- The World of Learning, Europa Publications, 40th Edition (1990)
- The International Research Centers Directory (1988-1989) D. Smith, ed., Gale Research Company (1988)
- International Cooperation and Competition in Materials Science and Engineering, NIST, *NISTIR* 89-4041, (1989)
- Materials Research Centres, Second Edition, Longman Group U.K., (1986)
- Focus on Materials Science, A Dedicated Issue, *ESNIB* 89-02 by Louis Cartz, (1989).

The goal of unification of the EC is clearly on track, with certain countries taking a strong leadership position; e.g., France and the FRG, in promoting community programs. The group of 12 may be joined in the future by EFTA countries (i.e., Norway, Sweden, Finland). Switzerland, as well as the former Warsaw Pact countries, may become associate or full members. The incorporation of additional members appears to be a democratic procedure with the definition of a federation of states being a critical issue. France and the FRG have established leadership positions in their process. Although daily obstacles are addressed, a remarkable degree of progress has been achieved and monetary union will cement the relationships with the U.K. remaining as a reluctant partner. Incorporating particularly less-developed economies will pose economic and cultural challenges and strains upon the existing EC infrastructure. The delicate balance of majority rule and minority rights is being formulated and will continue to progress.

Background - European Cooperation in Research

The impact of 1992 on materials research has had overtures with several multinational research programs. Previous cooperation in research activities has created European programs in the aerospace commercial sector with the development of the Airbus, Ariane, and Hermes. In addition, several other multinational programs; i.e., EC--BRITE, EURAM, EUREKA, EUCLID, have been generated to accelerate development of advanced technologies and to create original devices for commercialization. Program outlines can be obtained from EC offices in Brussels, Washington, or New York (see Summary). In addition, the EC has an annual conference termed BRITE-EURAM days which highlight program achievements. However, specific program details must be obtained with the consent of the individual research partners. Many of the program details are emerging in research papers by academic and industrial partners. However, there is no formal dissemination protocol. A first tier of programs was initiated during 1984-1987, a second "program-cadre" for the 1987-1991 time frame, and a third in 1990. The Framework budgets are detailed in Tables 3 and 4. These cooperative, interdisciplinary programs seek to consolidate research institutes, academic laboratories, and industrial partners with a cooperative, jointly funded, and highly leveraged research program. The creative and evolutionary nature of these programs has catalyzed several research efforts in materials science and has forged EC links throughout the manufacturing sector. The research programs will be highlighted and the research program in EURAM-BRITE have been detailed in an EC publication (see Summary). The long-term impact to EC competitiveness is difficult to judge. However, national programs have been established and are seen by some U.S. industrialists as a threat to their market share, particularly in Europe. In contrast, U.S. multinational companies with production bases in Europe view the developments as an opportunity to participate in EC-sponsored research.

Table 3. Current Framework Program Budgets (1987-91)

	MILLION ECU	$	%
Quality of Life			
• Health	80		
• Radiation protection	34		
• Environment	261		
TOTAL	375	450	6.9
Towards a Large Market and as Information and Communications Society			
• Information technologies	1,600		
• Telecommunications	500		
• New services of common interest (including transport)	125		
TOTAL	2,275	2,730	42.3
Modernization of Industrial Sectors			
• S&T for manufacturing industry	400		
• S&T of advanced materials	220		
• Raw materials and recycling	45		
• Technical standards, measurement methods, and reference materials	180		
TOTAL	845	1,014	15.6
Exploitation and Optimum Use of Biological Resources			
• Biotechnology	120		
• Agro-industrial technologies	105		
• Competitiveness of agriculture and management of agricultural resources	55		
TOTAL	280	336	5.2
Energy			
• Fission: nuclear safety	440		
• Controlled thermonuclear fusion	611		
• Non-nuclear energies and rational use of energy	122		
TOTAL	1,173	1,408	21.7
S&T for Development	80		1.5
Exploitation of the Seabed and Use of Marine Resources			
• Marine science and technology	50		
• Fisheries	30		
TOTAL	80	96	1.5
Improvement of European S&T Cooperation			
• Stimulation, enhancement and use of human resources	180		
• Use of major installations	30		
• Forecasting and assessment and other back-up measures (including statistics)	23		
• Dissemination and utilization of S&T research results	55		
TOTAL	288	345	5.3
GRAND TOTAL	5,396	6,475	100

Source: EC

Table 4. New Framework Program Budgets (1990-94)

	MILLION ECU	%
Enabling Technologies		
• Information and communications technologies		
Information technologies	1,352	
Communications technologies	489	
Development of technological systems of general interest	380	
TOTAL	2,221	39
• Industrial and materials technologies		
Industrial and materials technologies	748	
Measurement and testing	140	
TOTAL	888	16
Management of Natural Resources		
• Environment		
Environment	414	
Marine S & T	104	
TOTAL	518	9
• Life sciences and technology		
Biotechnology	164	
Agricultural and agro-industrial research, including Fisheries	333	
Biomedical and health research	133	
Life sciences and technologies for developing countries	111	
TOTAL	741	14
• Energy		
Non-nuclear energies	157	
Nuclear fission safety	199	
Controlled nuclear fusion	458	
TOTAL	814	13
Management of Intellectual Resources		
• Human capital and mobility		
Human capital and mobility	518	
TOTAL	518	
GRAND TOTAL	5,700[1]	100

[1]Including 60 million ECU for the dissemination and exploitation and 550 ECU million for the Joint Research Center.

Source: EC

This development of materials science in the EC is crosslinked and united with an interlocking network of university, industry, and government cooperation. The feasibility and responsiveness of the linkages in research action will determine future success. The cooperation can be viewed in two forms: (1) the development of a cooperative research funding and manufacturing base and (2) the more unified cooperation of the educational programs and technical materials' societies. In the former category, BRITE was spawned in 1985, a second round of projects were generated in 1988, and a third in 1990. Specifically in materials science, several technical areas have been targeted with a EURAM program. Fields of study within the 1986-1989 timeframe concerned were:

- Primary raw materials
- Secondary raw materials
- Wood as a renewable resource
- Advanced materials (EURAM).

Under the EURAM programs, several priority themes have been selected in four major technical areas with specific priority themes (see Table 5 and Additional Reading).

Table 5. EURAM Major Technical Areas

Advanced Materials Technologies
- Metallic materials and metallic matrix composites
- Materials for magnetic, optical, electrical, and superconducting applications
- High-temperature nonmetallic materials
- Polymers and organic matrix composites
- Materials for specialized applications; e.g., biomaterials, packaging, and civil engineering materials

Design Methodology and Assurance for Products and Processes
- Quality, reliability, and maintainability in industry
- Process and product assurance

Application of Manufacturing Technologies
- Advanced manufacturing practices for specialized industrial purposes; e.g., tooling, design methodology, integrated design, and production
- Manufacturing processes for flexible materials; e.g., clothing, footwear, composite, and packaging materials

Technologies for Manufacturing Processes
- Surface techniques
- Shaping assembly and joining
- Chemical processes; e.g., optimization of reactions, selectivity, membranes, and catalysis
- Particle and powder processes

Source: EC

In the realm of metallic alloys, emphasis is placed upon Al, Ti, Mg alloys, electrical contact and magnetic materials, coatings, tooling materials, and development of thin wall castings. For engineering ceramics, the studies include property optimization, metal ceramic interfaces, ceramic composites, and high-temperature behavior. Within the area of composite materials, studies on metal and organic systems have been addressed.

A second research effort entitled BRITE has an initial time span from 1985-1989 with the application of manufacturing technologies to several industries; e.g., aerospace, automotive, chemistry, metals, and textile. There are materials aspects to the BRITE program that incorporate polymers and composites production techniques for flexible products. Also, concerns include reliability, wear, membrane science, CAD/CAM (computer-aided design/-manufacturing) laser technology, and joining techniques.

In addition to the BRITE/EURAM programs, cooperation between European laboratories has been spurred by the STIMULATION program for combining research capabilities of two or more laboratories. In addition, the European COST program was established. A joint research center (JRC) program has established concerted programs at four locations in the materials area: (1) JRC Geel, Belgium, (2) JRC Ispra, Italy, (3) JRC Karlsruhe, FRG, and (4) JRC Petten, the Netherlands (see *ESNIB* 89-02).

In a separate EUREKA program, there are several materials-related programs with joint multinational participation spanning an initial 2- to 5-year period. Tables 6a and 6b highlight impact of EUREKA technology and projects in new materials, respectively. Emphasis is placed on developing improved materials; e.g., advanced composites, ceramics, continuous casting of sheet steel and aluminum, and materials for transportation systems. Apart from the research activities, several education programs are actively being implemented and are highlighted in Table 7. A significant segment of the EC budget in Table 2 focused on the key technology areas of the aerospace industry to include aerodynamics, structures materials, acoustics, computational modeling, airborne systems, propulsion, and design technology. The materials systems involve development of light alloys (Al-Li), composites, and high-temperature materials (C-C, SiC-SiC).

Summary

At this point, Europe is orchestrating a union of educational, corporate, and government research centers, as well as technical societies motivated by the 1992 timetable. Although there has been cooperation in the past, a realization that the union is nearing has catalyzed more vigorous activities. The next Framework Program has been defined at a budget of 700 million European Currency Units (ECU) over a 4-year period (see Table 7). In certain cases, corporate mergers of European companies are creating facilities and expertise comparable to research laboratories abroad; e.g., GEC, Siemens, and Plessey; MBB and Mercedes Benz. As a result, the corporations appear enthusiastically to be seeking international, particularly European partnerships to create and/or expand their position in the EC. They are also particularly wary of the internationalization of their technological industrial base by U.S. and Japanese interests. Companies with production capabilities pose difficult questions in terms of being a domestic producer or a foreign competitor.

Table 6a. Impact of EUREKA Materials Technology

	Aerospace	Land Transport	General Engineering	Bio Engineering
Ceramics	●	●	● ○	●
Polymer composites	● ○	● ○	○	●
Metal matrix composites	●	● ○	● ○	
Reinforced ceramic	●	● ○		●
Carbon/carbon	●	●		●
Rapid solidification	●		○	
Powder metallurgy	●	● ○	● ○	
Precision casting			● ○	
Superplastic forming/ diffusion bonding	●		●	
Automation	●	●	●	
Non-destructive evaluation			● ○	

● Industry sectors on which new materials technology will have impact

○ Scope of EUREKA projects

Source: EUREKA Secretariat

Table 6b. Eureka Projects in New Materials

Project Number	Project Name	Cost (ECU millions)	Duration (months)
Application Field			
EU 33	Composite ceramics in axial flow gas turbins	11.3	72.0
EU 47	Ceramics for diesel engines	8.0	72.0
EU 138	Coatings for advanced technology	3.0	76.0
EU 220	Hardening of road/building material process via optimization of natural phenomena: diagenesis and lateritisation	3.75	36.0
EU 272	Advanced sandwich panel	1.3	36.0
EU 281	Generation of pumps for fluids with adverse lubricating properties: application to fuel centrifugal pumps	1.0	48.0
EU 291	Very large optical telescopes	11.4	60.0
EU 338	New soft coating materials for heavy duty slide bearings	3.6	36.0
EU 388	Specification and development of an isolating electrical mineral coating on metal support	1.0	36.0
EU 433	Improved plastic pipe systems	3.0	36.0
EU 544	Low-cost brushless axial flux motors with a high energy rubber bonded rare earth permanent rotating magnet	2.0	36.0
EU 549	Metal matrix composites used as friction materials for trucks and cars	1.6	48.0
EU 669	Low-cost brushed axial flux DC motors with high energy pressed rare earth permanent magnets	4.5	36.0
Fabrication and Design Technology			
EU 13	Car structure using new materials	60.0	36.0
EU 29	Development of new materials for car engines	12.0	60.0
EU 30	High pressure sub-sea pipe from high performance fibres	4.0	60.0
EU 42	Light materials for transportation systems	2.9	60.0
EU 206	Process for direct casting of very thin metal strips and new products obtained	24.0	72.0
EU 264	Compact reinforced composite	1.6	39.0
EU 269	Design of aluminum structures under fatigue loading	2.6	48.0
EU 318	Casting of aluminum parts with aluminum inserts	0.8	24.0
EU 332	Joining of metals and ceramics by ion beam techniques	1.1	42.0
EU 337	Steels with high static dynamic and fatigue strength for automotive applications	6.8	54.0
EU 352	Technologies for industrial production of molded parts made from synthetic rubber from organic silicon compounds	3.5	36.0
EU 369	Hot melt laminating	1.5	30.0
EU 442	Advanced ceramic materials for aluminum electrolysis technology: ceramic non-consumable anodes replacing carbon	20.4	48.0
EU 468	European Structural Composites Group - development of a practical design code for the construction industry	2.0	57.0
EU 469	Powder metallurgy of high-nitrogen steels	3.4	60.0
EU 541	Development of a welding system for polypropylene film by thermocontact	5.0	36.0
EU 558	Material optimization for a structural automotive innovative concept	51.2	36.0
EU 575	Medium pressure die casting	1.9	48.0
EU 612	Assessment of fracture behaviour of joints in high-strength, low-alloy structural steels using high-efficiency welding	1.7	36.0
EU 616	Development/demonstration of resin transfer molding process for the mass production of structural composite components	4.2	46.0
Development of New Materials			
EU 96	Superconducting wires and magnets for very high field applications	8.0	51.0
EU 107	Production of percursors for high performance ceramic materials by wet chemistry	1.1	42.0
EU 183	Polymer fibres	5.0	55.0
EU 445	Aluminum matrix composites	5.6	36.0
EU 627	Shoe upper material project	1.3	30.0
EU 658	European high-temperature fibres (definition phase)	0.2	8.0
Material Testing Equipment			
EU 22	Automated system for neutronography	19.0	64.0
EU 525	Ultrasonic images of system interfaces (definition phase)	2.2	12.0
Other Materials-Related Projects			
EU 39	Gas proportional scintillation counters	4.0	84.0
EU 602	Non-polluting passivation compounds	0.7	36.0
EU 613	The corrosion of copper tubes in soft waters	0.4	36.0

Courtesy of T. Kekkonen, EUREKA Technical Development Cente (TEKES)

The materials position and research strategy of the U.S. has apparently not crystallized with regard to the EC. The choices are:

1. Ignore the situation and carry on business as usual
2. Allow the major multinational corporations to develop and strengthen their linkages to the EC research community
3. Forge research programs to the manufacturing and market sectors, establish contacts, reinforce the existing ties, and develop a joint research and development linkage to the EC programs.

Via joint partnerships in research and materials development, a *quid pro quo* can be established with the EC. The ties can be most easily established at four parallel levels: (1) government/government, (2) university/university, (3) defense agency/agency, and (4) industry/industry. Although more difficult, the cross linkages; e.g., defense agency/university and /industry, certainly should be pursued and should provide for a more international and talented research base and facilities. The materials research field can be a model for this program, since the research direction at the basic research level is clear, the community is relatively small, and the contacts well established. The international linkages in materials are well established with chemical companies; i.e., BP, BASF, Shell, ICI, Mobil, Dupont; metal production companies; i.e., Pechinney, ASEA, with joint multinational partnerships. As an initiative, parallel research efforts are being undertaken in the EC and the U.S. There is a clear need for rapid dissemination of the basic research studies. The leaders of the major programs should establish duplicating efforts.

From a corporate market perspective, a three- or four-fold competition is foreseen between in the U.S., EC, Japan, and the newly industrialized countries. The multinational companies; e.g., IBM, DuPont, Ford, General Motors, already have a presence in Europe and probably feel secure in their research and marketing positions and will not be excluded from the 1992 developments. Companies that have marketed in the U.S. and Europe, but without European domestic content, are in peril; i.e., the range of companies in the small- to middle-size company that cannot afford a position in Europe. These innovative companies have a market potential and should seek joint manufacturing and research linkages.

Further information of the BRITE/EURAM programs can be obtained from the European Communities offices in:

Washington
2100 M Street NW, Suite 707
Washington, D.C. 20037
Tele : (202) 862-9500

Table 7. EC Educational Programs

Program	Participation	Objective
PETRA	Young people in vocational training following full-time compulsory education. 154 training initiatives in 1989. 200 youth projects.	Support, with a community added value; the implementation of the Council decision of the vocational training of young people.
IRIS	Women in vocational training. 71 projects in 1989.	Develop the access of women to vocational training.
CEDEFOP	Decision makers, practicians, social partners involved in initial and continuing vocational training.	To assist the commission in the promotion and development of vocational training and in-service training.
EUROTECNET	Young people and staff of enterprises in training. 135 demonstration projects in 1989.	Dissemination of innovations in the area linked to new technologies.
EURYDICE	Education officials.	Develop information on the education systems and on EC activities in the education field.
ARION	Education policy makers and experts. 3,200 study visits since 1978.	Improve mutual understanding of the education system.
LINGUA	Pupils and teachers from secondary and higher education.	Improve language training for the EC citizens.
Education of Migrant Workers' Children	Primary and secondary schools with migrant children. 15 pilot projects in 1988.	Improve the integration of migrant children at all levels of the education systems.
ERASMUS	Students in higher education. Participation of 4,300 students and 1,500 higher education institutions in the first phase.	Increase the mobility of students in higher education in the EC and add a European dimension to their initial training.
COMETT	Students in higher education and staff from enterprises participating in 1987/1988. 1,320 projects and 2,400 students.	Stimulate university-industry cooperation to improve high-level training linked to new technologies.
Youth for Europe	Young people from 15 to 25 years old. Participation in the first phase: 80,000.	Improve, develop, and diversify young peoples' exchanges in the EC.
Exchanges of Young Workers	Young workers or job seekers of 18 to 28 years old. Participation in 1987/1988: 7,000.	Offer training or work experience for young people in another member state.

Source: The International Herald Tribune, Oct. 4, 1989.

Telex: 64 215 EURCOM NW
FAX : 429-1768

New York
Suboffice of the Washington Office
3 Dag Hammarskjöld Plaza
305 East 47th Street
New York, NY 10017
Tele : (212) 371-3804
Telex: 012 396 EURCOM NY
FAX : 758-2718

Brussels
Production and Materials Technology
Tele: 235.59.60

Materials Research
Tele: 235.52.90

Aeronautics R&D (see Table 8)
Tele: 235.40.55

Commission of The European Communities
Directorate General for Sciences
BRITE/EURAM Program
Research and Development XII/C
200 Rue de la Loi, B-1049
Brussels, Belgium
Tele: 32-2-235-1111.

Individual National Programs in Europe

In addition to the joint EC programs, the national materials policies and actions are considered about materials research in Denmark, Finland, France, the FRG, Greece, Ireland, Italy, the Netherlands, Norway, Sweden, Switzerland, and the U.K. In addition, a list of the materials-related universities and laboratories in Austria, Belgium, Israel, and Poland are detailed in Appendix D.

Reference

Focus on Materials Science, a Dedicated Issue, 1989. *ESNIB* 89-02:39.

Additional Reading

XII/289/88-EN Division C-4, Materials Technology EURAM (1986-1989) Project Synopsis

BRITE: Basic Research in Industrial Technologies in Europe (Project Synopses 1985 and 1987).

Table 8. Aerospace Research Programs

Topic	Project Head	Number of Partners	Total Cost (million ECUs)	EC Funding (million ECUs)
Aerodynamics				
Experimental studies of supersonic flow phenomena	Aeritalia	14	2,565	1,522
Study of laminar flow	MBB	24	9,539	5,074
Aerodynamic rotor/fuselage interaction in helicopters	Agusta	14	2,447	1,423
Generation of block meshes for computational methods	BAe	14	3,335	1,814
Validation of computer codes	Dornier	16	3,146	1,693
Optimization method for aerodynamic configuration	AMD-BA	9	1,638	981
Top-down approach to solution of Navier-Stokes equations	VKI	5	621	413
Design method for rotor blades	MBB	12	2,007	1,057
Contribution to European supercomputer network project	ONERA	8	800	400
Acoustics				
Active noise control in aircraft (ASNACA)	Dornier	22	3,601	1,745
Research in the area of external noise from rotors	MBB	10	3,074	1,695
Acoustic fatigue and damage tolerance	AMD-BA	14	2,937	1,459
Onboard systems and equipment				
Effects of future technologies on cockpits (FANSTIC)	Aerospatiale	14	3,690	1,904
Optical data transmission	MBB	13	2,620	1,330
New concepts for optical sensors in aeronautics (NOSCA)	Thomson-CSF	5	1,161	587
Monitoring of helicopter utilization and condition	Westland	6	1,667	834
Software for integrated modular avionics (IMAGES)	Aerospatiale	16	2,719	1,439
Electric servocontrols	CASA	19	2,273	1,101
Anti-icing protection for civil aircraft (CAPRI)	BAe	13	1,664	953

Source: EC BRITE/EURAM

Denmark

The Danish government funds materials research through the Council of Technology, the Danish Technical Research Council (DTRC), and the Danish Natural Science Research Council (DNSRC). The Danish governments contribution to basic research is an estimated 1.25 percent of the gross national production (GNP), or 7,700 million Krone ($727.1 million). The balance of the budget is estimated at 55 and 45 percent to the private and public sectors, respectively. The 1985 budget is detailed below with regard to physics, chemistry, and materials (see Table 9). Advanced materials has been a focus of the Ministry of Education with a 5-year program of 300 million Krone, ($44.1 million) were placed into advanced materials with the topics and budgets detailed in Table 10. Composites, engineering ceramics, surfaces, and thin films are emphasized in materials educational efforts.

Table 9. 1985 Denmark Budget in Physics, Chemistry, and Materials

Area	Topic	Budget U.S. $ (million)
Basic	Physics (solid state)	3.5
	Chemistry (synthesis, structural chemistry)	2.4
Applied	Materials	4.2

Source: OECD 1990

With the encouragement of Danish industry, an ambitious 5-year program has been jointly funded by the Council of Technology, DTRC, and DNSRC for research, education, development, and technology transfer. Five centers will be established in polymer-based composites, powder metallurgy, advanced engineering ceramics, surface technology, and boundary layer/thin film technology. The 5-year budget initiated in 1988 is provided in Table 11. The RISO National Laboratory has an active materials effort and is a focus of international cooperation and conferences.

Table 10. 1985 Ministry of Education 5-Year Program Budget

Topic	Budget	Percent
Magnetic materials	73.5	3
Engineering ceramics	338.2	12
Composites	750	25
Plastic shaping	103	4
Durability	235.3	8
Materials characterization	323.5	11
Surfaces, thin films	764.7	26
Organic conductors	44.1	2
Metals, semiconductors	73.5	3
Synthesis, structures	191.2	6
TOTAL	2,897	100

Source: OECD 1990

Table 11. 1988 Materials Funding: 5-Year Program

Source	Funding U.S. $ (million)	Percent
Council of Technology	46.2	60
Danish Technical Research Council	18.5	24
Danish Natural Science Research Council	10.8	16
TOTAL	75.5	100

Source: OECD 1990

Table 12 provides information about Danish materials-related research institutes.

Table 13 provides information about Danish materials-related research centers.

Table 12. Danish Materials-Related Research Institutes

Research Institute	Address	Tel/FAX
Niels Bohr Institute, University of Copenhagen	Blegdamsveg 17, DK-2100 Copenhagen Ø	31 421616/31 421016
Forsøgsanlæg Risø (Riso National Laboratory)	POB 49, DK-4000 Roskilde	45 42 37 12 12/ 45 42 36 06 09
The Technical University of Denmark, Department for Metallurgy	Building 204, 100 Lundtoftevej, 280 Lyngby	Unknown

Table 13. Danish Materials-Related Research Centers

Research Center	Address	Telephone
Danmarks Ingeniorakademi (DIA) (Engineering Academy of Denmark)	Bygning 101, DK-2800 Lyngby	02 88 22 22
Forsøgsanlaeg Risø (Risø National Laboratory)	P.O. Box 49, DK-4000 Roskilde	02 37 12 12
Korrosionscentralen ATV (Danish Corrosion Centre)	Park Allé 345, DK-2600 Glostrup	02 63 11 00
Svejsecentralen (Danish Welding Institute)	Park Allé 345, DK-2600 Glostrup	02 96 88 00

The leadership of the materials efforts are seen at Risø National Laboratory which serves as a focus for international conferences in mechanical behavior and structures of materials. In addition, the Neils Bohr Institute and the Technical University of Denmark are very well regarded.

National and international research budgets can be obtained from the following references:

Advanced Materials, Policies and Technological Challenges. OECD, 1990
2 rue André Pascal
75775 Paris, Cedex 16 France

International Cooperation and Competition in Materials Science and Engineering. NIST, 1989, NISTIR 89-4041
Gathersburg, MD

EC Research Funding, A Guide to Applicants. Commission of European Communities, 1990
Brussels, Belgium

Finland

In 1986, funding of materials in Finland was estimated at 60 million Finnmarks ($12 million). The research programs are organized by the Technology Development Center (TEKES) for applied research and development, and for fundamental research by the Academy of Finland. The leadership of TEKES and EUREKA National Program Chairman advisor are Heikki Kotilaine and Temo Kekkonen, respectively, during 1991 and 1992. Emphasis has been placed on materials related to the design and construction industry; e.g., mechatronics, powder metallurgy, advanced ceramics, polymer composites, laser, and arctic techniques. Helsinki University of Technology has positioned itself to serve as a venue for East-West materials conferences and a conduit for technology transfer. The MAT-TECH conferences over the past 2 years have linked the Eastern European materials community with scientists from the West. Professor Lilius has served as the organizer for the last two MAT-TECH conferences and hopes to place Finland as an appropriate venue for East-West materials exchanges.

Table 14 provides information about Finnish materials-related societies and research institutes.

Table 15 provides information about Finnish materials research centers.

Table 14. Finnish Materials-Related Societies and Research Institutes

Societies and Research Institutes	Address	Tel/FAX
Rakenteiden Mekaniikan Seura (Finnish Society for Structural Mechanics)	Rakentajanaukio 4, 02150 Espoo	Tel: 451-3067/Unknown
Suomen Teknillinen Seura STS r.y. (Engineering Society in Finland-STS)	Ratavartijankatu 2, 00520 Helsinkii	Unknown
Merentutkimuslaitos (Finnish Institute of Marine Research)	FOB 33, Lyypekinkuja 3A, SF-00931 Helsinkii	Tel: (0) 331044/ FAX: (0) 331376
Valtion teknillinen tutkimuskeskus (Technical Research Center of Finland)	Vuorimiehentie 5, SF-02150 Espoo	Tel: (358-0) 4561/ FAX: (358-0) 460419
Helsinki University of Technology, Department of Materials Science & Engineering	SF-02150 Espoo	Note: Contact Professor Lilius
The University of Oulun, Department of Mechanical Engineering	SF-90570 Oulu	Unknown
Tampereen Teknillinen Korkeakoulu	Pyynikintiez, 33230 Tampere 23, P.O. Kettunen P	Unknown

Table 15. Finnish Materials-Related Research Centers

Research Center	Address	Tel/FAX
Metallurgical Research Centre	P.O. Box 60, SF-28101 Pori 10	Tel: 939 26 211/Unknown
Institute of Naval Architecture and Aircraft Engineering, Light Structures Laboratory	Puumiehenkuja 5A, SF-02150 Espoo	Tel: 90 451 2709/Unknown
Mechanics of Deformable Solids, Strength of Materials Laboratory	Otaniemi, Otakaari 1, SF-02150 Espoo	Unknown
Teknillinen Korkeakoulu, Helsinki University of Technology, Department of Mining and Metallurgy	Otaniemi, Otakaari 1, SF-02150 Espoo	Tel: 90 460 144/Unknown
Valtion Teknillinen, Tutkimuskeskus, VTT (Technical Research Center of Finland)	Vuorimiehentie 5, SF-02150, Espoo 15	Tel: 90 4561/Unknown

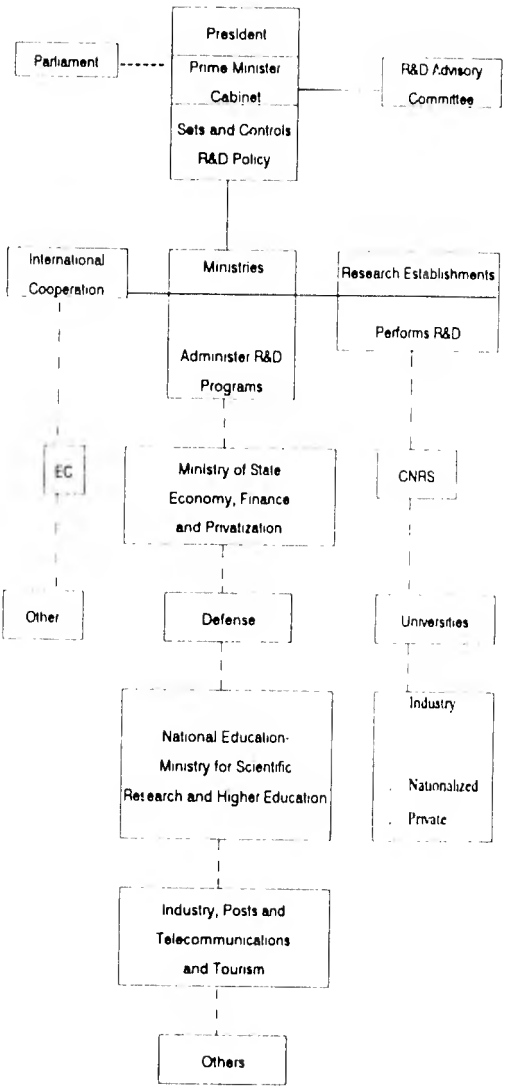
France

The national laboratories and industries of France have very significant strengths in advanced materials. The transportation, defense, and aerospace industries utilize the French technological developments to include alloy and ceramic composites for advanced systems. Notable research-oriented companies include Rhone Poulenc (ceramics, fibers), SEP (high-temperature materials C/C, SiC/SiC, C/SiC), Aerospatiale (aerospace structures), Pechinney (nonferrous alloys), and SNEMA (gas turbine). The strong role of the French government shaped an industrial policy and is significant with several key materials-related industries partially state owned and subsidized; e.g., SEP, Airbus. The French government has established a national laboratory system that is tied to universities and independent government laboratories; i.e., CNRS[1]. The organization of research budgets of the French research establishment is detailed in Figure 2 and Table 16. In 1987, the materials-related budget was approximately $1 billion. The majority; e.g., 75 percent, was industrial.

Table 16. 1988 French Public Research and Development Budget

	Millions of Francs
Ministry of Research and Higher Education	
Research section	21,425
Higher education (research)	1,653
University research	7,440
Other ministries	9,190
Annex to the telecommunications budget	
Electronics research	2,268
Space (appropriations only)	4,762
Research in telecommunications	5,004
Other research	2,250
Research tax credit	1,600
Contribution to EEC research	1,353
Total civil R&D budget	56,945
Defense R&D budget	33,219
Total government expenses for R&D	90,164
National Center for Scientific Research (CNRS)	8,955
Atomic Energy Agency (CEA)	6,654
National Space Agency (CNES)	5,425
National Agronomy Research Institute (INRA)	2,187
Aeronautics Research Program	2,486
Electronics Research Program	2,098
National Health and Medical Research Institute (INSERM)	1,608
National research for cooperation and development (ORSTOM and CIRAD)	1,236
Institute for Oceanographic Research (IFREMER)	797
Fund for Research and Technology (FRT)	930
National Research and Development Agency (ANVAR)	784
Foreign Affairs Department R&D	801
Total budget for major research agencies	33,961

Source: Fast 1987



Source: Allen 1975; Background notes - France 1988

Figure 2. The research organization of France

Tables 17 and 18 provide information about French materials research sector funding (1987-92) and summary of materials science and engineering, respectively.

In addition, there are several governmental agencies which are involved in materials efforts (see Table 19).

[1]Centre National de la Recherche Scientifique

Table 17. 1987 French Materials Research Sector Funding

National program	New materials priorities
New materials	Traditional materials with new applications Composites Ceramics Superconductors
Technology and production engineering	Mechanical engineering, optics Product design Electrical engineering
Electronics and information technology	Advanced microelectronics

Research sector funding	Percent
Industry	75
Government - civil	17
Government - military	8

Source: Cotto 1988

In 1988, the Ministry of Research and Higher Education (MRES) began coordinating a materials research mobilization program termed IDMAT National Materials Program. The goal was to unify the various factions in materials research with greater cooperation between industry and research. A research and technology fund (FRT) was established amounting to $30 million with the aims presented in Table 20.

Under the IDMAT programs, new materials received $10 million, technology and production engineering received $11.7 million, and electronics and information technology received $13.3 million. A stimulus was also provided to assist small to medium enterprises and industries (SME, SMI). Through sponsorship of CNRS and FRT, there have been materials-related topics supported without direct government funds (see Table 21).

Table 22 provides information about French materials-related societies and institutes.

As detailed in Table 18, the French government has at the research, educational, and industrial levels sponsored and invested in research. They have made national commitments to the aerospace and transportation industries. For example, their success in high-temperature materials is notable (e.g., carbon-carbon, SiC-SiC, C-SiC) and made with national investments in SEP and the space program. France appears to be the driving force in European science and technology (S&T), particularly in the materials and aerospace-driven markets. Particularly notable is the composites materials development at the University of Bordeaux which seeks to position itself as a leader in France as well as Europe.

Table 18. Summary of French Materials Science and Engineering

Summary

- 700,000 materials related industry employment (1987)
- Industrial activity: $70 billion
- Materials R&D budget (1987): $1.4 billion
- Public research budget - $286 million
  - Civilian - $200 million
  - Military - $86 million
- Corporate R&D budget - $857 million
  - Research - $286 million
  - Development - $571 million.

National program to activate the development of materials (I.D. Mat Program)

1982 - Material Report (MRES)
- State of the art and potentialities
- Materials development

1986-1992 - I.D Mat Program

Objectives:
- Give a status to the field of materials science and engineering
- Stimulate the cooperation between
  - Different disciplines (chemistry, physics, mechanics)
  - University-industry (education, access to large physics equipment)
  - Different industrial sectors (synthesis, processing, assembly)
- Try to coordinate the action of the different government agencies and ministries.

Area of interest

- Generic area
  - Structure and constitution laws
  - Aging and transient regimes
  - Interfaces
  - Synthesis.
- Mutation of traditional materials
- Advanced composites (MMC, CMC, OMC)
- Engineering polymers
- Advanced ceramics
- High-performance metallic alloys
- Electronic materials
- New building materials.

1987-1988 - Ministry of Research and Higher Education (MRES) 11 national programs
- New materials (mutation of traditional materials, composite ceramics, superconductors)
- Biotechnology
- Manufacturing
- Transportation - civil engineering
- Molecular engineering.

The instruments of these programs

- Education

  7 "Pôles FIRTECH matériaux" ERC

  Research training of engineers in field of interest for industry
  - Advanced materials
  - Metallurgy
  - Synthesis and processing
  - Mechanics and materials
  - Surface - interface and composites
  - Mechanical engineering of materials
  - Increase the number of engineers with research experience.

Source: Cotto 1988

Table 19. French Materials-Related Government Agencies

ARNT	Association Nationale de la Recherche Technique
ANVAR	Agence Nationale de Valorisation de la Recherche
PIRMAT	Programme Interdisciplinaire Recherche Materiaux
CNRS	Centre National de la Recherche Scientifique
DGA	Delegation Generale pour l'Armement
DRET	Direction des Recherches Etudes et Techniques
CESTA	Centre d'Etude sur les Sciences et les Techniques
ETCA	Etablissement Technique Central de l'Armement
CMCM	Centre Mecanique Chimie Materiaux
CTME	Centre de Techniques et Moyens de Mesures et d'Essais
ONERA	Office National d'Études et de Recherches Aéronautiques.

Table 20. Priority Areas of French Materials Research

- "Use of industrial research training conventions to stimulate research training for senior staff in industry
- Contributions to the EUREKA program
- Support for transfer of know-how and technology from government laboratories to private industry with equal cooperation from the regions and states
- Implementation of national programs for priority areas of research."

Table 21. French Nongovernment-Funded, Materials-Related Activities

GRECO	Coordinated Research Groups
CRITT	Regional Centers for Innovation and Technology Transfer
GIS	Groupements d'Interdet Scientifique.

Table 22. French Materials-Related Societies and Institutes

Societies and Institutes	Address	Tel/FAX
Société Française de Métallurgie, Immeuble Élysées La Défense	Cedex 35, 92072 Paris La Défense	(1) 47-67-88-71/ (1) 47-67-85-77
Centre National de la Recherche Scientifique (CNRS)	15 quai Anatole France, 75700 Paris	(1) 47-53-15-15/ (1) 45-51-73-07
Laboratoire de physique des matériaux	1 Place Aristide Briand, 92190 Meudon	45-34-75-50/Unknown
Laboratoire des propriétés mechaniques et thermodynamiques des matériaux, Université de Paris-Nord	Ave Jean-Baptiste Clément, 93430 Villetaneuse	48-21-61-70/Unknown
Laboratoire de cristallographie	BP 166X, 38042 Grenoble Cedex	76-88-10-00/Unknown
Laboratoire d'études des propriétés électroniques des solides	Ave des Martyrs, BP 166X, 38042 Grenoble Cedex	76-96-98-37/Unknown
Laboratoire de mécanique et d'acoustique	31 chemin Joseph Aiguier, 13402 Marseille Cedex 9	91-22-40-00/Unknown
Laboratoire d'ingénierie des matériaux et des hautes pressions, Centre universitaire Paris Nord	Ave Jean-Baptiste-Clément, 93430 Villetaneuse	49-40-34-47/Unknown
Centre d'études de chimie métallurgique	15 rue Georges Urbain, 94400 Vitry	46-87-35-93/Unknown
Laboratoire de chimie du solide, Université de Bordeaux I	351 cours de la Libération, 33405 Tallence Cedex	56-80-84-50/Unknown
Laboratoire des matériaux organiques	BP 24, Autoroute Lyon-Vienne, Echangeur de Solaize, 69390 Vernaison	78-02-13-44/Unknown
EUROPARC	3 ave Léonard-de-Vinci, 33600 Pessac	56-87-06-80/Unknown
Chimie et biochimie macromoléculaire (ENS)	allée d'Italie, 69365 Lyon Cedex 07	72-72-83-60/Unknown
Polymères thermostables et leurs applications (IFP CEMOTA)	69390 Vernaison	78-02-20-77/Unknown
Physique et chimie des matériaux, Université de Nantes (ISITEM)	2 rue de la Houssinière, 44072 Nantes Cedex	40-37-30-37/Unknown
Centre Nationale d'Etudes Spatiales	2 place Maurice Quentin, 75001 Paris	Unknown

Societies and Institutes	Address	Tel/FAX
Institut Max von Laue-Paul Langevin (ILL)	156x, 38042 Grenoble Cedex	Tel: 76-48-71-11/Unknown
Université d'Aux Marseille III, Faculté des Sciences et Techniques Saint Jerome, Laboratoire de Metallurgie - UA 443	Case 511, Sv. Escadrille Normandie Niemen, 13397 Marseille Cedex 13, entre Defauts dans les Solides	Unknown
École Superieure de Fonderie, Establissement privé d'Enseignement, Technique supérieur reconnu par l'Etat	44 Avenue de la Division Lederc, 92310 Sevres	Unknown
Institut des Sciences de la Matière et du Rayonnement, Université de Caen	14032 Caen Cedex	Unknown
École Centrale des Arts et Manufactures (Ecole Centrale de Paris)	Grande Voie des Vignes, 92295 Chatenay-Mallabry Cedex	Unknown
Université Blaise Pascal	34 Avenue Carno, 63006 Clermont-Ferrand	Unknown
Institut National Polytechnique de Grenoble, École Nationale de Physique de Grenoble, Laboratoire de Genie Physique et Mecanique des Materiaux	Domaine Universitaire-B.P. 46, 38402-Saint Martin d'Heres Cedex	Unknown
Université de Limoges, U.E.R. des Sciences, Laboratoire de Ceramiques Nouvelles	123, Avenue A. Thomas, 87060 Villeneuve d'Ascq Cedex	Unknown
École Catholique d'Aris et Metiers, Service Metallurgie et Materiaux	40, montee Saint-Barthelemy, 69321 Lyon Cedex 1	Unknown
École Centrale de Lyon, Laboratoire de Metallurgie, Physique Materiaux	36 Av. Guy de Collongue, B.P. 163, 69131 Ecully	Unknown
Institut des Sciences de l'Ingenieur de Montpellier, Filiere Materiaux	2 Place E. Bataillon, 34060 Montpellier Cedex	Unknown
École Nationale Superieure d'Electrochimie et d'Electrometallurgie (Institut National Polytechnique de Grenoble)	B.P. 75, 38402 Saint-Martin-d'Heres	Unknown
Université de Nancy I (Vandoevre), Department des Sciences et Techniques des Materiaux-Metallurgie, Institut des Sciences de l'Ingenieur Parc Robert Bentz	54500 Vandoeuvre	Unknown
École Nationale Supérieure de Mécanique	1 rue de la Noe, 44072 Nantes Cedex	Unknown
Université de Paris-Sud, Centre d'Orsay	91405 Orsay Cedex	Unknown
Conservatoire Nationale des Arts et Métiers, Paris, Laboratoire de Métallurgie	292 rue Saint-Martin, 75141 Paris Cedex 03	Unknown
École Nationale Supérieure de Chimie de Paris, Laboratoire de Métallurgie Structurale	11 rue Pierre et Marie Curie, 75237 Paris Cedex 05	Unknown
École Nationale Supérieure des Mines de Paris, Centre des Materiaux	BP 87, 91003 Evry Cedex	Unknown
École Nationale Supérieure des Techniques Avancées	32 Boulevard Victor, 75015 Paris	Unknown

Societies and Institutes	Address	Tel/FAX
Université de Reims, Faculté des Sciences, Moulim de la Housse	B.P. 347, 51062 Reims Cedex	Unknown
Institut National des Sciences Appliquées, Rennes, Laboratoire de Métallurgie et	20 Avenue des Buttes de Coesmes, 35043 Rennes Cedex	Unknown
Université de Rouen, Faculté des Sciences et des Techniques, Groupe de Metallurgie Physique, Unite Associe au CNRS no. 808	B.P. 118, 76134 Mont Saint Aignan, Cedex	Unknown
Institut National Supérieur de Chimie Industrielle de Rouen (INSCIR), Laboratoire des Recherches Metallurgiques	B.P. 08, 76130 Mont Saint-Aignan	Unknown
École Nationale Supérieure des Mines, Saint-Etienne	158, Cours Fauriel, F 42023 Saint-Etienne Cedex	Unknown
École Nationale Supérieure des Arts et Métiers, Talence, Esplande de l'Université	33405 Talence	Unknown

Research training centers have been established under the FIRTECH which specializes in the following areas: advanced materials (Bordeaux); electronic materials (Grenoble); metallurgy (Lille); materials manufacturing and processing (Nancy); mechanical engineering and mechanics (Strasbourg); computer-aided manufacturing (Toulouse). In addition, the "grande écoles;" i.e., The École des Mines, supplies France with a cadre of talented engineers. Notable are the materials center in Evry, the materials forming center in Sophia Antipolis, and the École des Mines in Paris.

France has taken an initiative with GEC in funding a lagging French electronics and semiconductor industry. Europe has traditionally been weak in semiconductors, software development, consumer electronics, and data processing. France appears to be stimulating its industry in these consumer related areas. Details of French support for S&T are available from:

National Science Foundation (NSF)
Europe Office
Embassy of the United States
2, avenue Gabriel
75382 Paris, France

In addition, information concerning joint exchange between France and the U.S. is available from:

Scientific Mission
Embassy of France
4101 Reservoir Road, NW
Washington, D.C. 20007-2176
Tel: (202) 944-6247

The embassy also provides a newsletter on French Advances in Science and Technology (FAST). Joint bilateral programs between CNRS and NSF allow for cooperative programs with U.S. and French researchers. For information, contact:

NSF
Division of International Programs
1800 G Street, NW
Room 1208
Washington, D.C. 20550
Tel: (202) 357-7554

The Federal Republic of Germany

The newly reunified Federal Republic of Germany (FRG) has a strong position in advanced materials. The traditional strengths of German science and technology are endowed in ferrous metallurgy, heavy manufacturing, materials-processing equipment, and ceramics. The organization of the former West German Federal Ministry of Research and Technology is detailed in Table 23. There are several renowned institutes with world-class strengths in fundamental and applied research; i.e., Max Planck Institutes in Stuttgart and Düsseldorf and Frauenhofer Institutes in Würtzberg, Bremen, Freiburg, Saarbrüchen, and Aachen (see Tables 23 and 24). The Max Planck Institutes serve a fundamental research and educational and graduate research/educational role while the Frauenhofer Institute and larger research centers are focused on developmental and applied technologies. Among these are specialized materials laboratory divisions in nuclear, aerospace, and materials processing, (i.e., JRC[1] Julich, DLR[2]- Cologne, Max Planck Institute [see Table 25]), as well as selected institutes in surface science, plasma physics, radiochemistry, and nuclear materials (see Figure 3). Research expenditures by industrial sector in the FRG has been a mix of corporate and government investments. The major sectors for industrial research investment have been electrical, construction, chemical, and automotive. The chemical sector investment in research has not been matched by their relative share of profits (see Table 25).

Table 23. Organization of FRG Federal Ministry of Research and Technology

Administration, Basic Principles of Research and Technology Policy

- Initial assessment office
- Administration, finance, principles of research and technology policy
- Interdisciplinary questions of research sponsorship and research installations
- Infrastructure.

Basic Research, Research Coordination, International Cooperation

- Basic research, research coordination
- International and intra-German cooperation.

Energy, Biology, Ecology

- Nuclear energy, energy research program
- Biology, ecology, fossil, and renewable energy sources.

Information and Production Technologies, Living and Working Conditions, Specialized Information

- Information and production technologies, support for innovation
- Living and working conditions, specialized information.

Aerospace, Raw Materials, Earth Sciences, Transportation

- Aerospace
- Materials research, earth sciences, transportation.

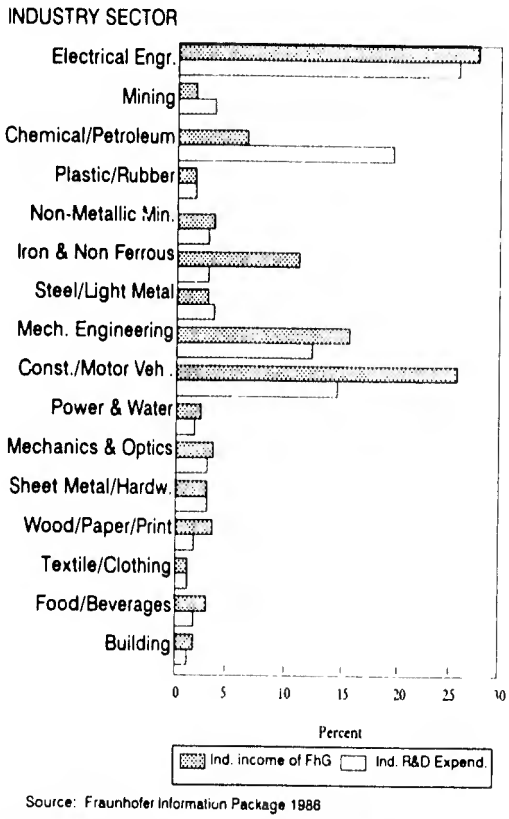
Source: Ronayne 1984

Table 24. Characteristics of the FRG Research and Development Facilities

	Education	Fundamental Research	Applied Research	Development	Introduction Into Market
Universities	◐	●	O		
Max Planck Gesellschaft Society for Advancement of Sciences		◐	O		
Grossforschungseinrichtungen Large-Scale Research Centers		●	◐		
Fraunhofer Gesellschaft for the Advancement of Applied Research		O	●	●	O
Industries			●	◐	◐

● **Primary research focus**
O **Secondary research focus**
Source: Fraunhofer 1986

[1] Joint Research Center
[2] Deutsche Foschunstatt fur Luft und Raumfahrt



Source: Fraunhofer Information Package 1988

Figure 3. Origin of Industrial Income of Fraunhofer Institute (FhG) & Industrial R&D expenditures

Funding in materials research is orchestrated by the Federal Ministry of Research and Technology (BMFT) on a 4-year cycle with a strong emphasis in advanced materials under the Materials Forschungs Program (MATFO) efforts. Under the MATFO, for 1985-94, a budget of 1.1 billion Deutsche Marks (DM) ($785 million) has been authorized. The government contribution in the BMFT programs is averaging 50 percent with the balance of industrial funding. The program and funding levels of 1986 BMFT programs are detailed in Table 26.

The structural ceramics program has been designated into four areas, representing 1986 budgets:

1. Development of materials and processes - $16.8 million
2. New powder production processes - $5.4 million
3. Development of processes for prototypes - $43.7 million
4. Joining of ceramics - $2.4 million.

Notably, FRG industries have contributed significantly, representing approximately 50 percent of the budgeted program funds.

The second area of materials research has been the development of powder metallurgy processes. This can be represented in semidense parts for the automotive and commercial sector; e.g., small appliance and fully dense components for high-performance structural applications, aerospace structural, and engine

Table 25. FRG Government-Funded Materials-Related Research Institutes

Institutions		Activities in materials science
Frauenhofer Society for Applied Science	Institute for Research in Silicates, Würtzberg	New nonmetallic, anorganic materials (including Sol-gel process)
	Institute for Applied Materials Research, Bremen	Composites: metal-metal, metal-plastic, surface layers, interfacial bonding techniques
	Laboratory for Durability Measurements of Industrial Materials, Darmstadt	Measurements of life-long durability and mechanical resistence of composites metallic and nonmetallic materials
	Institute for Mechanical Testing of Materials, Freiburg	Mechanical and technological characterization of materials, behavior of structural material under static and cyclic loading, determination of fracture behavior.
	Institute for Nondestructive Testing, Saarbrücken	Development and preparation of new/improved techniques for nondestructive evaluation of new materials (ceramics, composites)
	Institute for Production Technology, Aachen	Technique for high speed production of materials (for ex. with lasers)
Max Planck Society for Promotion of Science	Institute for Research on Iron, Düsseldorf	Metallurgical processing techniques, materials science and technology
	Research Institute of Solid-State Materials, Stuttgart	Optical, electrical, magnetic and mechanical properties of nonmetallic, crystalline and glassy materials

Institutions		Activities in materials science
Nuclear Science Research Center, Jülich	Fritz-Haser Institute, Berlin	Microstructure evaluation of polymers with x-ray lithography
	Institute for Materials Science, Stuttgart	Research on metallic, powder metallurgical, and ceramic materials
	Institute for Plasma Physics, Garching	Surface science of metallic materials
	Institute for Polymer Science, Mainz	Interdisciplinary research (physics, chemistry, materials science) for characterization and synthesis of neon (including electrical conducting) polymers
	Institute for Research in Dynamics, Göttingen	Surface science
	Institute for Reactor Materials	Development and testing of high temperature metallic and ceramic materials; coating, composites
	Institute for Solid State Research	Research on properties of solid materials, crystal growth, material development of metallic materials (lattia defects and radiation damage, phase transformations and critical phenomena) mechanical (and electrical) properties of (doped) polymers
	Institute for Plasma Physics	Analysis of materials for fusion reaction technology
	Institute for Surface Science and Vacuum Physics	Applied research in surface and vacuum physics
Institute for Reactor Science and Technology, Karlsruhe	Institute for Applied Nuclear Physics/Institute for Neutron and Solid State Physics	Interface and microstructural research
	Institute for Radiochemistry	Basic science in surface chemistry
	Research Institute for Materials and Solid State Reactions	Research and development of specific materials (multi-phase ceramic and metallic materials (with respect to high wear resistance. High temperature deformation of metallic materials
	Institute for Nuclear Materials	Material reliability (life time durability) low temperature mechanical properties of polymers
Research Center, Geesthact	Institute for Physics	Development and characterization of materials for marine environments as well as high temperature materials, analysis of brittle behavior of nuclear steel containers under pressure
German Airspace Research, Center	Materials Research, Institute for Materials Science	Development of high temperature and light weight materials; production of metallic, ceramic, and composite materials
Hahn-Meitner Institute for Nuclear Research, Berlin	Nuclear Chemistry and Reactor Technology	Radiation damage in solid state materials (life long durability prediction)
	Radiation Chemistry	Interface processes and energy conversion, photo chemical analysis on polymers

applications. The areas of research emphasize the latter high-performance market to include:

- New powder production and processing techniques - $7.2 million
- Aluminum, magnesium, and titanium-based alloys - $13.8 million
- Copper, iron nickel, cobalt-based, and mechanically alloyed heat-resistant alloys - $21 million
- Materials with graded structures that allow for tailored properties over a large temperature or stress gradient - $ 3 million.

Table 26. BMFT Research Funding - 1986

Topic	Funding U.S. $(million)	Percent BMFT
High-performance structural ceramics	87.8	51
Powder metallurgy	50	61
High-temperature and special purpose metals	73.9	61
High-performance polymers	95.6	53
Composite material	107.2	52
Tribology	16.7	77
TOTAL	431.2	56

Source: BMFT 1986

The FRG has traditionally been very strong in the powder processing area with the research efforts at Max Planck, Stuttgart, and commercial powder metallurgy efforts at Sintermetalwerk-Krebsoge. The emphasis on high-performance alloys seeks to extend their expertise into the full density high-performance materials systems.

The third area of developments includes more traditional areas of study with the improvement and development of metallic and special purpose materials. The areas involve:

- Intermetallic phases - $4.7 million
- High-tensile strength light alloys - $5 million
- Superalloys - $10.6 million
- Protective coatings - $7.7 million
- Materials for special purposes - $10.7 million.

In the polymers and composites materials sectors, two efforts have been orchestrated. For high-performance polymers, four areas have been defined for evaluation.

- Polymers with high strength - $17.3 million
- Polymers with unique properties; i.e., copolymers, alloys, blends - $15 million
- Polymers with special electrical, magnetic, and optical properties - $34.8 million
- Polymers as information carriers - $1.5 million.

The composite materials research activity has been devoted to

- Improved fiber developments - $6.7 million
- Polymer matrix composites - $34 million
- Metal and ceramic matrix composites - $18.8 million
- New composite structures - $2.3 million.

The combined efforts in polymers and composite structures reflects a $130 million research investment. The strong FRG chemical industry (e.g., BASF) and automotive and aerospace companies (e.g., BMW, MBB, Dornier) will be the benefactors of the investment in composites research. The future interest in the aerospace sector reflects the interest in high-performance composite structures.

The final area of interest is tribology; i.e., wear applications, including

- Fundamentals of tribology - $1.6 million
- Materials and lubricants - $9.7 million
- Tribotechnology of machinery components - $1 million
- Industrial applications - $0.5 million.

These efforts reflect the strengths of German industry in the developing improved processing and manufacturing equipment and the needs for improved materials to enhance elevated temperature performance and wear resistance, therefore system reliability.

In addition to the private and academic institutions, there are Max Planck Societies that promote research in specialized areas. In many cases, these are elite and autonomous organizations that receive guidance from their director. The director is empowered with a strong mandate to define the research goals of the institute and the resources to implement the programs. As a consequence, strongly independent research establishments have mandates to initiate and carry out long-term exploratory research programs. A selected list of some of these institutes is detailed in Table 27.

The Deutsche Forschungsgemeinschaft (DFG) grants for the society institutes can be considered in categories for ongoing as well as focused research efforts, and special interdisciplinary efforts.

There will certainly be a re-examination of research directions, certainly the defense aerospace-related sector and the question of the development of the European fighter EFA. With the reunification of the German Democratic Republic (GDR) and the FRG, and a possible restructuring of NATO, the motivation to develop high-performance materials for a shrinking defense market will certainly be reflected in a smaller commitment. The resulting need to improve the economy and infrastructure of the former GDR may result in a reallocation of resources and very difficult decision on the allocation of technological research investment. Large research facilities in the former GDR portion may duplicate in equipment and personnel the efforts in the former FRG. As a result, a certain degree of downsizing of the overall FRG and GDR research cadre is underway.

With regard to the former GDR, there are institutes and universities that have maintained research programs and will be incorporated into the larger infrastructure of the western sector (see Table 28).

Table 27. Staff and Budget of FRG Advanced Materials Institutes - 1986

Organization	Institute	Staff	Budget U.S. $ (million)
Max Planck Society	Max Planck Institute for Metals Research, Stuttgart	337	7.7
	Max Planck Institute for Polymer Research, Mainz	125	6.0
	Max Planck Institute for Solid-State Research, Stuttgart	287	N/A
	Max Planck Institute for Iron and Steel Research, Dusseldorf	N/A	N/A
Fraunhofer Society	Fraunhofer Institute for Applied Materials Research, Bremen	93	2.4
	Fraunhofer Institute for Materials Mechanics, Freiberg	69	6.4
Science Centers	Aerospace Materials Research Institute (DLR), Cologne	86	N/A
	Nuclear Research Center (KFA) Julich GKSS, Geesthacht	297	N/A
Special Institutes	Heinrich-Heinz Communication Center, Berlin	N/A	N/A
	Bremerhaven Marine Research Institute	N/A	N/A
Federal Institutes	Länder Institute Federal Institute for Materials and Research Testing (BAM)	N/A	N/A
	Federal Physics and Technology Institutes, Berlin, Brunswick	N/A	N/A

Note: $1.00 = 1.86 DM (1987)

Table 28. Institutes and Universities with Research Programs

- The Academy of Sciences
- Institute for Polymer Chemistry - Teltow Seehoff
- Institute for Technical Chemistry - Leipzig
- Institute for Technology of Fibers - Dresden
- Physics, Nuclear Sciences and Materials Research - Berlin
- Institute for The Physic of Materials Processing - Berlin
- Ernst Moritz Ardnmt University of Greifswald - Greifswald
- Humboldt University of Berlin - Berlin
- Karl Marx Stadt Technical University - Karl Marx Stadt
- Dresden Technical University - Dresden
- Central Welding Institute - Halle Saale

The reunification requires difficult decisions with regard to the viability and longevity of the GDR Academy of Sciences, as well as the institutes and universities.

Table 29 provides information about FRG materials-related societies and institutes.

Table 29. FRG Materials-Related Societies and Institutes

Societies and Institutes	Address	Tel/FAX
Deutsche Gesellschaft für Luft und Raumfahrt eV (DGLR), (German Society for Aeronautics and Astronautics)	5300 Bonn 2, Godesberger Allee 70	0228 376726/0228 374755
Deutsche Gesellschaft für Metallkunde, (Metallurgy)	6370 Oberursel, Adenauerallee 21	Unknown/Unknown
Deutsche Gesellschaft für Zerstörungsfreie Prüfung eV (DGZfP), (non-destructive testing)	1000 Berlin 45, Unter den Eichen 87	030 8114001/030 8114003
Deutche Glastechische Gesellschaft eV, (German Society of Glass Technology)	D-6000 Frankfurt a.M. 1, Mendelssohnstr. 75-77	069 74 90 88/Unknown
Deutsche Keramische Gesellschaft eV, (German Ceramic Society)	5000 Cologne 90, Frankfurterstr. 196	02203 69069/02203 69301
Deutscher Verband für Material Forschung und Prüfung eV (DVM), (materials testing)	1000 Berlin 45, Unter den Eichen 87	030 811 30 66/ 030 811 93 59

Societies and Institutes	Address	Tel/FAX
Deutscher Verband für Schweisstechnik eV, (German Welding Society)	4000 Düsseldorf, Postfach 2725, Aachener Str. 172	0211 15759-0/0211 1575950
Verein Deutscher Eisenhüttenleute, (German Iron and Steel Institute)	4000 Düsseldorf 1, Sohnstr. 65	0211 6707-0/Unknown
Alexander von Humboldt-Stiftung, (Humboldt Foundation)	D-5300 Bonn 2, Jean-Paul-Str. 12	0228 833-0/0228 833199
Max-Planck-Gesellschaft Zur Förderung Der Wissenschaften eV, (Max Planck Society for the Advancement of Science)	8000 Munich 1, Postfach 647, Rezidenzstr. 1A	089 21081/Unknown
Max-Planck-Institut für Festkörperforschung, (solid state)	7000 Stuttgart 80, Heisenbergstr. 1, Postfach 800665	0711 68601/Unknown
Max-Planck-Institut für Kernphysik, (nuclear physics)	6900 Heidelberg 1, Saupfercheckweg 1, Postfach 103980	06221 5161/Unknown
Max-Planck-Institut für Metallforschung, (metallurgy)	7000 Stuttgart 1, Seestr. 92	0711 20951/Unknown
Max-Planck-Institut für Polymerforschung, (polymer research)	6500 Mainz Jakob-Welder-Weg 11, Postfach 3148	06131 393521/Unknown
Fraunhofer-Institut für Bauphysik	7000 Stuttgart 80 (Vaihingen), Nobelstr. 12	0711 68 68 03/ 0711 6868395
Hahn-Meitner-Institut Berlin GmbH	1000 Berlin 39 , Glienicker Str. 100	30 80091/30 80092181
Kernforschungszentrum Karlsruhe GmbH (Nuclear Research Center)	7500 Karlsruhe 1, Weberstr. 5, Postfach 3640	07247-821/Unknown
Arbeitsgemeinschaft Industrieller Forschungsvereinigungen eV (AIF)	5000 Köln-Marienburg, Bayenthalgürtel 23	(0221) 376800/ (0221) 3768027
Battelle-Institut eV, Forschung, Entwicklung, Innovation	6000 Frankfurt a.M., Am Römerhof 35	(069) 7908-0/Unknown
Bundesanstalt für Materialforschung und-prüfung (Federal Institute for Materials Research and Testing)	1000 Berlin 45, Unter den Eichen 87	Unknown/Unknown
Deutsche Forschungsanstalt für Luft- und Raumfahrt eV (DLR) (German Aerospace Research Establishment)	5000 Cologne 90 (Porz), Box 906058, Linder Höhe	(02203) 601-0/ (02203) 67310
Forschungsinstitut für Edelmetalle und Metallchemie (precious and rare metals)	7070 Schwäbisch Gmünd, Katharinenstr. 17	(07171) 62054/Unknown
Forschungsinstitut für Internationale Technische und Wirtschaftliche Zusammenarbeit der RWTH Aachen (FIZ) (Research Institute for International Technical and Economic Co-operation of Aachen University of Technology)	5100 Aachen, Henricistr. 50	(0241) 84071-73/Unknown

Greece

The smaller southern tier European Community (EC) countries; i.e., Greece, Portugal, and Spain, have not had a significant investment in research. However with the EC initiatives in Brussels under EURAM[1], BRITE[2], and ESPIRIT[3], their participation is encouraged and often required. As a result, young scientists and researchers in these countries are receiving recognition, support, and encouragement. In Greece, early specific efforts in materials research was initiated in a general program in 1979 termed EPET (National Program for Research and Technology). The program had a focus in polymer matrix composite structure with aramid, glass, and carbon fiber reinforcements.

An industrial research development program (PAVE) under the auspices of the General Secretary for Research and Technology (SGRST) assisted industrial-sponsored research efforts with 30-percent supplemental funding (70 percent of the required budget). Although relatively modest by contrast to major industrialized programs, the total PAVE program received $1.3 million in government support with areas of interest in polymer matrix composites, metals, refractory ceramics, corrosion, ores, and construction materials. To develop the scientific personnel and university structure, a PENED program was initiated with a total 1987 budget of $3.9 million. Materials efforts received $529,000. From the university viewpoint, three research institutes were conceived with selected materials-related efforts:

1. University of Crete - structural polymers, laser applications, microelectronics, surface treatments
2. University of Patras - high-temperature materials, III-V compounds, semiconductors
3. University of Thessalonika - chemical engineering and high-temperature processes.

In an attempt to link the university and industrial research sectors, two organizations were formed:

1. MIRTEC - (industrial research and metals engineering) focused on metallurgical and heat treatment research for small to medium enterprises
2. CERTEC - (development of ceramics and refractory materials) aimed at the refractory market.

Table 31 provides information about Greek materials-related societies and institutes.

As with many of the newly industrialized countries with limited resources, Greece is trying to establish a modest research base. As a member of the EC, these less-developed countries are encouraged and are active participants in the materials-related programs. As a result, the Greek research infrastructure should prosper particularly at the new universities of Crete, Patras, and Thessalonika.

Table 31. Greek Materials-Related Societies and Institutes

Societies and Institutes	Address	Tel/FAX
Helliniki Epitropi Atomikis Energhias (Greek Atomic Energy Commission)	POB 60228, 153 10 Aghia Paraskevi, Athens	651-31-11/Unknown
"Demokritos" National Center for Scientific Research	POB 60228, 153 10 Aghia Paraskevi, Athens	(01) 6513111/6519180
Institouton Geologikon kai Metalleutikon Ereunon (Institute of Geology and Mineral Exploration)	70 Messoghion St., 115 27 Athens	(01) 7798412/7752211

[1]European Research in Advanced Materials
[2]Basic Research in Industrial Technologies for Europe
[3]European Strategic Programme for Research and Development

Table 30 provides information about FRG materials-related universities.

Table 30. FRG Materials-Related Universities

Materials-related universities	Address	Tel/FAX
Bergakademie Freiberg, Department of Metallurgy	Akademie Strasse 6, 92 Freiberg	Unknown/Unknown
Technische Hochschule Karl-Marx-Stadt	Strasse der Nationen 62, 901 Karl-Marx-Stadt	Unknown/Unknown
Technische Universität Berlin	Strasse des 17. Juni 135, 1000 Berlin 12	Unknown/Unknown
Technische Universität Clausthal, Institute of Materials Engineering	Adolf-Romer-Str. 2A, 3392 Clausthal-Zellerfeld	Unknown/Unknown
University of Hannover, Institute of Materials Science	Applestrage 11a, 3000 Hannover 1	Unknown/Unknown
Universität Karlsruhe, Institut für Werkstoffkunde	Kaiserstr. 12, D-7500 Karlsruhe 1	Unknown/Unknown
Institut für Metallforschung der Westfalischen Wilheims-Universität	Domagkstrasse 75, 4400 Münster	Unknown/Unknown
Rheinisch-Westfalische Technische Hochschule Aachen (Technical University Aachen)	D-5100 Aachen	Unknown/Unknown

In summary, the German scientific base has developed with an interdependent infrastructure with established linkages with industry and research facilities. These programs have served as a model for the European community.

Ireland

The funding of research in Ireland is financed by the Department of Industry and Commerce in two agencies:

1. Irish Science and Technology Agency (EOLAS)
2. Industrial Development Authority (IDA)

The merger of two organizations resulted in EOLAS--National Board for Science and Technology (NBST) and the Industrial Research and Standards (IIRS).

Similar to Greece and Portugal, Ireland has a relatively small population and not a large basis of former research funding from government or industry. Nevertheless, with EC funding, major universities; i.e., Trinity College, Dublin, and The University of Limerick with established efforts in materials, should benefit. Ireland should also benefit from U.S. investment, having a well-educated and literate work force coupled with a relatively low labor cost. Consequently, many multinational companies are looking to Ireland as a potential site for manufacturing operations within the EC. In addition, the talented student labor pool will seek employment within the EC and the U.S. The University of Liverpool has historically sought talented students for their graduate programs. Ireland appears to be in a position to export its mathematicians, scientists, and engineers. The question remains open whether a sufficient industrial and research base can be established to support the educated graduates from several excellent universities.

Italy

Italy's research base has been defined by several key areas (see Table 32). Based on need for economic competitiveness, several future key technologies have been defined for funding (see Table 33, *ESNIB* 88-08:5). In the early 1980s, Italy's materials initiative consisted of two programs relating to fine chemistry and metallurgy.

Table 32. Italian Public Sector Research in Key Areas (1987)

	Amount		Percent
	lire (billion)	$ (million)	
Mathematics	133.5	101	2.1
Physics	755.6	570	11.9
Chemistry	312.8	236	4.9
Biology and medicine	910.6	687	14.4
Geology and mining	134.4	101	2.1
Agriculture	463.8	350	7.3
Nuclear energy	443.2	334	7.0
Space	720.8	544	11.4
Engineering and technology	1141.7	862	18.0
Interdisciplinary	538.0	406	8.5
Other	782.6	591	12.4
Total	6337.0	478	100.0

Source: OECD 1990

Table 33. New Italian Finalized Projects (1987-1992)

Projects	Amount $ (million)
Telecommunications	60
Robotics	52
Electro-optical technologies	41
Fine chemicals	74
New materials	65
Cryogenic technologies	3
Enterprise "internationalization"	8
Information systems and parallel computers	49
Biotechnology	65
Building technologies	89
Total	506

Source: OECD 1990

By 1985, they had added a program on devices and materials for solid-state electronics (microwave and optoelectronic applications, SENSORS). More recently, areas of focus include:

- Superconductivity and cryogenic technologies - superconducting materials, instrumentation, superconducting devices
- Fine chemistry - specialty and high-performance polymers, membrane technology
- Fine chemistry - special materials, biotechnologies, special materials for advanced technologies (fine ceramics, composite materials, electronic and magnetic materials).

The materials program budget is detailed in Table 34.

Table 34. Materials Programs in Italy (1986-90)

Topic	Budget $ (million)	Percent CNR
Devices and materials for solid state electronics	29.7	21
Sensing devices	15.0	11
Superconductor and cryogenic materials	54.0	42
Fine chemistry - polymers	17.0	14
Fine chemistry - biotechnology, specialized materials	192.5	
Special materials for advanced technologies - composites, ceramics	115.7	78

Source: OECD 1990

The National Center for Research (NCR) coordinates national research efforts. Areas of focus involve microelectronics, transport, telecommunications, and biomedical technologies. A metals-related program involves topics for materials for chemical and power generation processes ($16 million) and materials for aerospace industries ($13 million). A summary of governmental funding for materials research activities for 1980-88 is provided in Table 35.

Table 35. Government Research and Development Funding for Materials (1980-88)

Topic	Total Budget $ (million)	Percent Government
Fine chemistry -1	3.6	65
Metallurgy	5.3	78
Electronic devices and materials	44.8	70
Superconductor/cryogenic technologies	54.0	42
Fine chemistry -2 polymers	17.0	14
Special materials for advanced technologies	115.7	29
Iron metallurgy, power generation, aeronautical materials	29.2	75
Total	269.5	75

Source: OECD 1990

Apart from the direct funding of research efforts, governmental regulations have facilitated advanced industrial technologies via loan subsidy, capital, and research investments; i.e, Law 1089/1968. A second law stimulates the development of materials and new processes through the financing of technological innovation; i.e., Law 49/1982.

Universities with specialties in materials science and technology include the Universities of Parma and Trento and the Polytechnic School of Milan in collaboration with the Universities of Trieste, Pisa, Turin, and Genoa. The University of Pisa is leading a consortium of universities for polymer research. Apart from the governmental and university laboratories, materials efforts are centered in at the Joint Research Center (JRC) Ispra and the central research facility of Fiat.

Table 36 provides information about Italian materials-related societies and institutes.

Table 36. Italian Materials-Related Societies and Institutes

Societies and Institutes	Address	Tel/FAX
Federazione delle Associazioni Scientifiche e Techniche	Piazzale R. Morandi 2, 20121 Milan, Italy	(02) 783051/(02) 784236
Associazione Italiana di Aeronautica e Astronautica	Via Po 50, 00198 Rome, Italy	(06) 8845894/Unknown
Associazione Italiana di Metallurgia	Piazzale R. Morandi 2, 20121 Milan, Italy	(02) 791132/(02) 784236
Associazione Nazionale di Ingegneria Nucleare	Piazza Sallustio 24, 00187 Rome, Italy	(06) 486415/Unknown
Consiglio Nazionale delle Ricerche (CNR) (National Research Council of Italy)	Piazzale Aldo Moro 7, 00185 Rome, Italy	49931/4957241
Istituto per l'Interscambio Scientifico (Institute for Scientific Interchange)	Viale Settimo Severo 65, 10133 Turin, Italy	(39-11) 6502679/Unknown
Istituto di Ingegnaria Nucleare, Centro di Studi Nucleari Enrico Fermi (CESNEF) (E. Fermi Center for Nuclear Studies)	Via Ponzio 34/3, 20133 Milan, Italy	2360388/Unknown
Istituto Nazionale di Fisica Nucleare (INFN) (National Institute of Nuclear Physics)	CP 56, 00044 Frascati, Rome, Italy	Unknown/Unknown
Centro Fusione e Applicazioni Laser (Fusion and Laser Applications Laboratories)	CP 65, 00044 Frascati, Rome, Italy	Unknown/Unknown
Centro Informazioni Studi Esperienze (CISE) (Center of Information, Studies and Experiments)	Via Reggio Emilia 39, CP 12081, 20134 Milan, Italy	(39-2) 2167-1/Unknown
Centro Sperimentale Metallurgico SpA	Via di Castel Romano, 00129 Rome, Italy	Unknown/Unknown
Comitato Nazionale per la Ricerca e lo Sviluppo dell'Energia Nucleare e delle Energie Alternative (ENEA) (National Commission for Nuclear and Alternative Energy Sources)	Viale Regina Margherita 125, 00198 Rome, Italy	Unknown\Unknown
Istituto Nazionale per Studi ed Esperienze di Architettura Navale (National Institute of Naval Architecture Studies and Experiments)	Via Corrado Segre 60, 00146 Rome, Italy	5563634/Unknown
Universitá degli Studi, Ferrara	44100 Ferrara, Italy	Unknown/Unknown
Universitá degli Studi, Milano	21 Via G. Venezian, 20133 Milan, Italy	Unknown/Unknown
Politechnico di Torino, Istitute di Chimica, Generale e Applicata di Metallurgy	Carso duca degli Abruzzi 24, 10129 Torino, Italy	Unknown/Unknown
Centro di Ricerca e di Sviluppo nell'Impiego degli Elastomeri-Cerisie, Research and Development Centre for the use of Elastomers	Via Privataa Cadore 13, 20098 San Giuliano Milanese, Milano, Italy	02 9880443/9880975

Societies and Institutes	Address	Tel/FAX
Centro di Studi Chimico Fisici di Macromolecole Sintetiche e Naturali (Physical Chemistry of Synthetic and Natural Macromolecules Research Centre)	c/o Istituto Chimica Industriale, Università Via Pastore 3, 16100 Genova, Italy	010 515016/Unknown
Centro di Studio per la Chimica dei Plasmi del CNR Plasma Chemistry Research Centre del CNR	c/o Dipartimento di Chimica, Università Via Amendola 173, 70126 Bari, Italy	080 396210/Unknown
Centro di Studio per la Chimica e Tecnologia dei Composti Metallorganici degli Elementi de Transizione Chemistry and Technology of Transitional Metallo-Organic Coumpounds Research Centre	Facoltá Ingegneria, c/o Istituto Chimica Industiale, Via Marzolo 9, 35100 Padova, Italy	049 35205/Unknown
Centro di Studio per la Cristallografia Strutturale Structural Crystallography Research Centre	c/o Istituto Mineralogia, Università Via Bassi 4, 27100 Pavia, Italy	0382 36689/Unknown
Centro di Studio per la Termodinamica ed Elettrochimica di Sistemi Salini Fusi e Solidi Research Centre for Thermodynamics and Electrochemistry of Molten and Solid Saline Systems	c/o Istituto Chimica Fisica, Università Viale Taramelli, 27100 Pavia, Italy	0382 27082/Unknown
Centro Sperimentale Metallurgico SpA (CSM) Experin ental Metallurgical Centre	CP 10747, Via di Castel Romano, 00129 Roma, Italy	06 64951/Unknown

The materials research has a strong industrial base in manufacturing and polymer chemistry. The universities of note include the University of Parma, University of Trento, Polytechnic School of Milan, as well as the Universities of Trieste, Pisa, Turin, and Genoa. These locations have established postgraduate research programs. Information concerning Italy's strong materials programs in ceramics can be obtained from the University of Genoa; wear and polymer composites from the University of Pisa; cryogenic materials from the National Group for Materials Structures, ENEA; surface analysis from the Institute Ricerche Donegani. The National Center of Research and the ENEA have major research programs and participate in several BRITE-EURAM, ESPRIT, EUREKA, and cost programs. Although not as publicized as French and German scientific activities, the chemistry, manufacturing, design, and cryogenic materiais research activities are notable.

The Netherlands

In 1986, the Netherlands Parliament focused on materials via a policy paper. The document highlighted the knowledge of and working with new materials and their application's present major problems. As a result, an advisory group was assembled (AGM) and developed a materials technology program via the Ministries of Economic Affairs, Education, and Science. The goals of the directives were: "to actively increase the awareness of advanced and improved materials and their properties and applications" and "increase the availability of advanced materials in the Netherlands." In 1987, technology development programs were established in information technology, materials technology, biotechnology, and medical technology. The program provides not only research efforts but also coordinates the linkage to industry with demonstration projects and business-oriented incentives (PBTS). The 1987 budget for materials technology for the Ministry of Economic Affairs and the Ministry of Education and Science is detailed in Table 37.

Table 37. Materials Technology Program

Area	Ministry of Economic Affairs		Ministry of Education and Science
	1987	1988	1987 - 1990
Industry	27.5	25	
University research institutes	13	5	5.8
Information	0.5	1	
Education and other		1	5.2
Total	41	32	11

Above amounts represent $ million
Source: OECD 1990

The business-oriented programs (PBTS) had a 1987 budget of $26.5 million with $25.3 million dedicated to research projects and the balance to feasibility awards. The sectors involved surface, joining, and binding technology, material evaluation for manufacturing, and metals substitution. A second effort involved innovation-oriented programs (IOP) aimed at strategic research efforts. Of the nine programs initiated, four are materials related in the areas of membrane technology, polymer composites, technical ceramics, metallic materials, and recycling of nonferrous metals. The budgets reflect a 2- to 7-year research program and projected budgets for the specific time periods (see Table 38).

Table 38. IOP Programs in Advanced Materials

Topic	Time Period	Budget U.S. Million dollars
Membrane technology	1984-91	12.9
Polymer composites	1985-88	6.0
Technical ceramics	1985-92	14.8
Metals	1988-96	16.2
Stimulation Programs		
Catalysis	1986-88	1.0
Paint	1984-90	1.0
Biosensors	1984-87	2.5
Recycling non-ferrous	1987-89	1.0

Source: OECD 1990

The Netherlands government has established special programs and centers in metals, ceramics, and polymers. The metals area has been addressed by the Advanced Metal Science Foundation (SGM) which has received a budget of $3.4 million for 1986-90 to establish a center at the Technical University of Twente in metals research, design, and engineering. A second center in ceramics research was established at the National Center for Ceramics Research (ECN) with initial funding of $2.35 million.

A national center in polymers is under the direction of the Netherlands Polymer Technology Foundation (PAN) which received $1.2 million from the Ministry of Economic Affairs. In addition to the area of traditional alloys, initiatives have been pursued at universities (i.e., ECN appears to be an umbrella organization with several laboratories having ECN affiliation, similar to U.S. DOE laboratories, TNO[1], PEO[2]) in high-temperature superconductivity.

Table 39 provides information about Dutch societies and institutes.

Table 40 provides information about Dutch materials-related research centers.

The Dutch materials research effort is very significant considering the physical size and population of the country. Materials research at Shell, Philips Electronics, and AKZO is world class and these are major industrial companies. Delft University is one of the finest schools of science and engineering in Europe with strength in aerospace materials and transition to airframe applications. In addition, the universities at Eindhoven and Groningen have material efforts. However, they are located in the ceramics and applied physics departments,

[1]The Netherlands Organization for Applied Scientific Research
[2]Phillips Electronics Organization

Table 39. Dutch Societies and Institutes

Societies and Institutes	Address	Tel/FAX
Koninklijke Nederlandse Chemische Vereniging (Royal Netherlands Chemical Society)	Burnierstraat 1, 2596 HV The Hague, the Netherlands	070 469406/Unknown
Nederlandse Natuurkundige Vereniging (Netherlands Physical Society)	POB 5451, 1007 AL Amsterdam, the Netherlands	020 5738808/Unknown
Koninklijk Instituut van Ingenieurs (Royal Institute of Engineers in the Netherlands)	POB 30424, 2500 GK The Hague the Netherlands	070 3919900/070 3919840
Nederlandse Organisatie voor Toegepast-Natuurwetenschapp elijk Onderzoek (TNO) (Netherlands Organization for Applied Scientific Research)	POB 297 2501 BD The Hague, (Juliana van Stolberglaan 148 2595 CL The Hague) the Netherlands	070 496500/Unknown

TNO divides 32 research institutes, departments, and committees into eight divisions:

Institutes, Departments, and Committees	Address	Tel/FAX
Hoofdgroep Maatschappelijke Technologie TNO (Technology for Society)	POB 342 , 7300 AH Apeldoorn, the Netherlands	Unknown/Unknown
Hoofdgroep Bouw en Metaal TNO (Construction and Metal Research)	POB 49, 2600 AA Delft, the Netherlands	Unknown/Unknown
Hoofgroep Industriele Produkten en Diensten TNO (Industrial Products and Services)	POB 67, 2600 AB Delft, the Netherlands	Unkown/Unknown
Hoofdgroep Technisch-Wetenschappelijke Diensten TNO (Technical Scientific Services)	POB 214, 2600 AE Delft, the Netherlands	Unknown/Unknown
Hoofdgroep Defensieonderzoek TNO (National Defence Research)	POB 208, 2501 CE The Hague, the Netherlands	Unknown/Unknown
Stichting Ruimteonderzoek Nederland (SRON) (Space Research Organization Netherlands)	Beneluxlaan 21, 3527 HS Utrecht, the Netherlands	30 927145/Unknown
Laboratorium voor Ruimteonderzoek (Laboratory for Space Research)	Beneluxlaan 21, 3527 HS Utrecht, the Netherlands	030 937145/030 945783
Laboratorium voor Ruimteonderzoek (Laboratory for Space Research)	POB 9504, 2300 RA Leiden, the Netherlands	071 275817/071 275819
Laboratorium voor Ruimteonderzoek (Laboratory for Space Research)	POB 800, 9700 AV Groningen, the Netherlands	050 634074/050 634033
National Instituut voor Kernfysica en Hoge Energie Fysica (NIKHEF) (National Institute for Nuclear Physics and High Energy Physics)	Section K, Kruislan 409, POB 41882, 1009 DB Amsterdam, the Netherlands	020 2929444/020 5925155
Stichting voor Fundamenteel Onderzoek der Materie (FOM) (Foundation for Fundamental Research on Matter)	Van vollenhovenlaan 659, POB 3021, 3502 GA Utrecht, the Netherlands	030 923211/030 946099
FOM-Instituut voot Atoom- en Molecuulfyusica (FOM Institute of Atomic and Molecular Physics)	Kruislaan 407, POB 41883, 1009 DB Amsterdam, the Netherlands	020 946711/020 6684106
FOM-Instituut voor Plasma-Fysica (Institute of Plasma-physics)	Rijnhuizen, Edisonbaan 14, POB 1207, 3430 BE Nieuwegein, the Netherlands	03402 31224/03402 31204
Nuclear Accelerator Institute (KVI)	Zernikelaan 25, 9747 AA Groningen, the Netherlands	050 633600/050 634003

Institutes, Departments, and Committees	Address	Tel/FAX
Centre for Submicrontechnology (CST)	Lorentzweg 1, POB 5046, 2600 GA Delft, the Netherlands	015 782600/015 783251
Nationaal Lucht- en Ruimtevaartlaboratorium (NLR) (National Aerospace Laboratory)	Anthony Fokkerweg 2, 1059 CM, Amsterdam, the Netherlands	020 5113113/020 178024
Netherlands Energy Research Foundation (ECN)	Scheveningseweg 112, The Hague, Research Centre, 3 Westerduinweg, Petten (NH), POB 1, 1755 ZG Petten (NH), the Netherlands	Unknown/Unknown
Eindhoven University of Technology, Center for Technical Ceramics, Laboratory for Physical Chemistry	P.O. Box 513, 5600 MB Eindhoven, the Netherlands	Unknown/Unknown
Technische Hogeschool Delft Interdisciplinary Department of Materials Science	Postbus 5025, 2600 GA Delft, the Netherlands	Unknown/Unknown
Rijksuniversiteit Groningen Department of Applied Physics	Nijenborgh 18, 9747 AG Groningen, the Netherlands	Unknown/Unknown

Table 40. Dutch Materials-Related Research Centers

Research Centers	Address	Telephone
Akzo Naamloze Vennootschap (produces chemicals and fibers)	P.O. Box 186, Velperweg 76, 6800 LS Arnhem, the Netherlands	085 664433
Centrum voor Microelectronica TNO (CME-TNO) (TNO Centre for Microelectronics)	Postbus 67, 2600 AB Delft, the Netherlands	015 569330
Instituut TNO voor Bouwmaterialen en Bouwconstructies (IBBC-TNO) (TNO Institute for Building Materials and Building Structures)	Postbus 49, 2600 AA Delft, the Netherlands	015 138222
Interuniversitair Reactor Instituut (IRI) (Interuniversity Reactor Institute)	Mekelweg 15, 2629 JB Delft, the Netherlands	015 784870
Kunststoffen- en Rubberinstituut TNO (KRI-TNO) (Plastics and Rubber Institute TNO)	Postbus 71, 2600 AB Delft, the Netherlands	015 569330
Metaalinstituut TNO (MI-TNO) (Metal Research Institute TNO)	Postbus 541, 7300 AM Apeldoorn or Laan van Westenenk 501, 7334 DT Apeldoorn, the Netherlands	055 773344
Nationaal Lucht- en Ruimtevaartlaboratorium (NLR) (National Aerospace Laboratory)	Postbus 126, Delft 2600 AC, the Netherlands	015 788014
Hoofdgroep Bouw En Metaal TNO (BM-TNO) (Division for Building and Metal Research)	Postbus 541, Laan van Westenenk 501, 7300 AM Apeldoorn, the Netherlands	055 773344
Philips Gloeilampenfabrieken (electronics)	P.O. Box 80 000, 5600 JA Eindhoven, the Netherlands	Unknown
Shell Internationale Research Maatschappij BV (Shell International Research Company)	Postbus 162, Carel van Bylandtlaan 30, 2501 AN's-Gravenhage, the Netherlands	070 773174

Research Centers	Address	Telephone
Stichting Nederlands Instituut voor Lastechniek (Netherlands Institute for Welding)	Laen van Meerdervoort 2b, 2517 AJ 's-Gravenhage, the Netherlands	070 600937
Technische Hogeschool Delft (Delft University of Technology)	Postbus 5, 2600 AA Delft, the Netherlands	015 789111
Materials Handling Laboratory	Postbus 5034, Mekelweg 2, 2600 GA Delft, the Netherlands	015 786704
Interdisciplinary Department of Metals Science and Technology	Postbus 5, Julianalaan 134, Delft, the Netherlands	015 789111

respectively. A network of national laboratories; i.e., TNO, ECN, helps maintain a national laboratory structure in microelectyronics, polymers, and building materials. The NLR specializes in aerospace. An important feature of the Belgian and Dutch scientists is their spirit of cooperation which reflects and materializes in a natural desire for joint research efforts. Consequently, despite the small physical size, the centrally located Benelux countries have extremely active joint programs and are linked to numerous EC programs.

Norway

Materials research in Norway is strongly linked to its export position in nonferrous alloys and strengths in hydroelectricity, gas, and oil. The institutes conducting strong research programs in Norway include: The Norwegian Institute of Technology (NTH), The University of Oslo, The Center for Industrial Research-Oslo and SINTEF[1]-Trondheim. The Norwegian Council for Scientific and Industrial Research (NTNF) had selected materials technologies as a priority effort with the following themes:

- Processing of light metals and polymers
- Materials and materials technology for the offshore industry
- New processing approaches for state-of-the-art materials.

In light of these objectives, metallic programs were established in aluminum and magnesium alloys, metal matrix composites, and continuous fabrication techniques. For polymeric materials, areas of interest included polymers and polymer composites, offshore applications, and process simulations. Marine applications were emphasized with the application of concrete to marine environments as well as steel and titanium. The application of materials to offshore technology also required the understanding of reliability, quality assurance, welding, fatigue, and corrosion. Similar to naval and marine structures, the offshore industry and platform developments serve as an important testbed for materials development. They emphasize welded steel structures, polymer composites, and fire-resistant materials and designs. The ceramics program emphasized powder technology, coatings, fuel cells, and structural ceramics.

The 1988 NTNF budget in materials is detailed in Table 41.

Table 41. NTNF Materials Budget for 1988

Topic	Budget $ (million)
Light metals	3.0
Polymers	1.4
Ceramics	0.9
Concrete	0.8
Mechanical engineering	2.3
Equipment	1.0
Total	9.4

Source: OECD 1990

Table 42 provides information about Norwegian materials-related societies and institutes.

Table 42. Norwegian Materials-Related Societies and Institutes

Societies and Institutes	Address	Tel/FAX
Kongelige Norske Videnskabers Selskab, Det (Royal Norwegian Society of Sciences)	Trondheim, Norway	Unknown/Unknown
Norsk Kjemisk Selskap (Norwegian Chemical Society)	POB 1107-Blindern, 0317 Oslo 3, Norway	00472 455531/Unknown
Norges Tekniske Vitenskapsakademi (Norwegian Academy of Technical Sciences)	Trondheim, Norway	Unknown/Unknown
Institutt for Energiteknikk (Institute for Energy Technology)	POB 40, 2007 Kjeller, Norway	47 6 80 60 60/47 6 81 63 56
Norsk Undervannsteknologisk Senter A/S (Norwegian Underwater Technology Centre)	POB 6, 5034 Ytre Laksevåg/Bergen, Norway	475 34 16 00
Norwegian Marine Technology Research Institute A/S (MARINTEK)	POB 4125 Valentinlyst, 7002 Trondheim, Norway	47 7 595500/47 7 595776

[1]Foundation of Scientific and Industrial Research

Societies and Institutes	Address	Tel/FAX
Skipsfartsøkonomisk Institutt (Institute for Shipping Research) Norwegian School of Economics and Business Administration	Helleveien 30, 5035 Bergen-Sandviken, Norway	5 95 90 00/5 25 88 74
Universitetet I Trondheim, Norges Tekniske Hogskole, Department of Metallurgy (NTH)	7034 Trondheim - NTH, Norway	Unknown/Unknown

Table 43 provides information about Norwegian materials-related research centers.

Table 43. Norwegian Materials-Related Research Centers

Research Centers	Address	Telephone
Norges Teknisk- Naturvitenskapelige Forskningsråd (NTNF) (Royal Norwegian Council for Scientific and Industrial Research)	Sognsveien 72, Postboks 70, Tåsen, N-0801 Oslo 8, Norway	02 237685
Norsk Hydro AS	Bygdoy Allé 2, Oslo 2, Norway	02 432100
Senter for Industriforskning (SI) (Center for Industrial Research)	Forskningsveien 1, Postboks 350, Blindern, N-0314 Oslo 3, Norway	02 452010
Stiftelsen for Industriell og Teknisk Forskning SINTEF) (Foundation of Scientific and Industrial Research)	Strindveien 2, N-7034 Trondheim, Norway	07 592480

In Norway, the major materials research efforts are located in the NTH and SINTEF in Trondheim. The abundance of hydroelectric power has resulted in a strong materials effort in aluminum at Hydro Aluminum, Norsk Hydro, and Elkem. As a maritime nation, interests are linked to naval and offshore structure as well as underwater technology; i.e., MARINTEK, Norwegian Underwater Technology Center. There are also common needs in offshore oil platforms and naval structures in the areas of reliability, corrosion protection, fire- and smoke-resistant materials, and welding, as well as inspection of submersed steel structure. An effort to glean and transition the technology of the North Sea oil-related companies and countries to naval application is an important technology transition area and worthy of pursuit. Of particular note is the area of fire-resistant, lightweight composite (i.e., glass fiber, reinforced polymer) applications to piping and fire resistant structural shapes (e.g., panels, accommodation), modules, and ship structures (e.g., rescue vessels).

Sweden

Traditionally, Sweden has had a strong interest in metals and a particularly strong steel industry with additional strengths in the automotive, engine, and aerospace sectors. Funds are involved from the Ministries of Education, Industry, Defense, and Energy. A national board for technical development (STU) has a major influence on the directions of cooperative research institutes (CRI). In addition, technical universities receive funds from the central government as detailed in Table 44.

Table 44. Government Funds for Swedish Technical Universities

Material Areas	Universities	CRI
Metals	3.6	12.8
Polymers	1.7	2.6
Fine ceramics	0.3	0.7
Surface Treatments	2.2	3.7
Total	6.8	19.8

Above amounts represent 1985 $ million.
Source: OECD 1990

Research funds for the technical universities and the cooperative research institutes is a blend of several sources, including the National Swedish Board for Technical Development, National Science Research Council, industry, and the National Council of Universities and Colleges. Industrial support is directed at the CRIs, while the National Council of Universities and Colleges does not support the CRIs. The commercial strength of the metals industry in Sweden has attracted a disproportionate, larger number of scientists in this area.

Table 45 provides information about Swedish materials-related institutes and societies, and Table 46 provides information about Swedish materials-related universities.

Historically, Sweden has held a world leadership position in quality ferrous products; i.e., Sandvik AB, Höganäs AB as well as manufacturing and tooling capability ASEA Research and Innovation, Bofors-Åkers AB. These capabilities have fostered a quality automotive and aerospace sector; i.e., Volvo, SAAB. At this point Sweden is an EFTA member and has not joined the EC. As a result, it can participate in COST and EUREKA programs, but not BRITE-EURAM activities. Of particular note are the efforts in three EUREKA programs on:

1. Advanced ceramic gas turbines - No. EU 33
   11.3 MECU - 72 mo.
2. Ceramics for diesel engines - No. EU 47
   8 MECU - 72 mo.
3. Coating for advanced technologies - No. EU 138
   3 MECU - 76 mo.

Companies such as Volvo (Sweden), SEP (France), Coat (Sweden), Inco (U.K.) among others are cooperating. The research developments and viability of the ferrous, automotive, and aerospace sectors are being challenged by separate EC programs where Sweden has been included in research activity and participation. The viability of these national industries may be incorporated into a multinational company in the future.

Table 45. Swedish Materials-Related Institutes and Societies

Institutes and Societies	Address	Tel/FAX
Kungl. Vetenskapsakademien (Royal Swedish Academy of Sciences)	Box 50005, S-104 05 Stockholm, Sweden	08-150430/08-155670
Svenska fysikersamfundet (Swedish Physical Society) Department of Radiation Sciences Uppsala University	Box 535, S-75121 Uppsala, Sweden	Unknown\Unknown
Swedish Institute of Space Physics	POB 812, S-981 28 Kiruna, Sweden	0980 122-40/0980 154-65
Flygtekniska Försöksanstalten (FFA) (Aeronautical Research Institute of Sweden)	Box 11021, S-161 11 Bromma, Sweden	08 7591000/08 253481
Institutet för Metallforskning (Swedish Institute for Metals Research)	Drottning Kristinas väg 48, S-114 28 Stockholm, Sweden	08 24 33 30/08 723 04 23
Statens Provningsanstalt (Swedish National Testing Institute)	POB 857, S-501 15 Boras, Sweden	4633 16 50 00/ 4633 13 55 02

Table 46. Swedish Materials-Related Universities

Universities	Address	Telephone
Chaolmers Tekniska Hogskola (Chalmers University of Technology) School of Mechanical Engineering	HS-41296 Gothenburg, Sweden	Unknown
Linkoping Institute of Technology Faculty of Technology	S-581 83 Linkoping, Sweden	Unknown
Technical University of Lulea Division of Mineral Processing	S-951 87 Lulea, Sweden	Unknown
Royal Institute of Technology School of Metallurgy & Materials Science	S-100 44 Stockholm, Sweden	Unknown
ASEA Research and Innovation	S-721 83 Västerås, Sweden	21-10 00 00
Bofors-Åkers AB	S-150 31 ÅKers Styckebruk, Sweden	0159 302 60
Chalmers Tekniska Högskola (Chalmers University of Technology) Engineering Metals Department Polymeric Materials Department	S-412 96 Göteborg, Sweden	031-81 01 00
Höganäs AB, Metallurgy Division	Box 501, S-263 01 Höganäs, Sweden	042 380 00
Institutet för Metallforskning (IM) (Swedish Institute for Metals Research)	Drottning Kristinas väg 48, S-114 28 Stockholm, Sweden	08-24 33 30
Kungliga Tekniska Högskolan (KTH) (Royal Institute of Technology)	S-100 44 Stockholm, Sweden	08-787 00 00
MEFOS-Stiftelsen för Metallurgisk Forskning (MEFOS-Foundation for Metallurgical Research)	Box 812 S-951 28 Luleå, Sweden	0920-556 40
Sandvik AB	S-811 81 Sandviken, Sweden	026-26 00 00
Stockholm Universitet (Stockholm University)	Universitetsvägen 10, S-106 91 Stockholm, Sweden	08-16 20 00
Svenska Silikatforskningsinstitutet (Swedish Institute for Silicate Research)	Box 5403, S-402 29 Göteborg, Sweden	031-16 23 18

Switzerland

Support in Switzerland for research and development is directed via National Research Programs (PNR). The focused 5-year programs (a materials theme in 1976 with PNR 7) was directed to the study of metallurgy, metallic glasses, and corrosion with a budget of $3.2 million. A second materials program, PNR 19, was imitated in 1984 with the study of

- Electronics, sensors, amorphous metals, superalloys (alloys for gas turbine applications, powder metallurgy, and composite materials)
- Biomedical materials, polymers (colloids, adhesives, membranes, multi-film polymers, and polymer matrix composites)
- Engineering ceramics (ceramic composites, powder processing, refractory coatings).

The funds for these efforts is divided approximately 25 percent to industry, with the balance divided among technical institutes and universities. Switzerland's research in materials has strong university groups at Neuchâtel, Lausanne, and Zürich. Industrial laboratories involving Batelle-Geneva, Alusuisse, Brown Boveri, and, of course, IBM also have made significant contributions to materials developments.

Table 47 provides information about Swiss materials-related societies and institutes.

The Université de Neuchâtel, Institute of Structural Metallurgy, Eidgenössische Technische Hochschule Lausanne, and the École Polytechnique Fédéral Zürich have noted materials programs. In addition, Brown Boveri Forschungszentrum, Battelle Centres de Recherche de Genéve, and Alusuisse have strong materials research efforts.

Table 47. Swiss Materials-Related Societies and Institutes

Societies and Institutes	Address	Tel/FAX
Schweizerische Akademie der Technischen Wissenschaften/Académie Suisse des Sciences Techniques Swiss Academy of Engineering Sciences: Postfach	8034 Zürich, Switzerland	Unknown/Unknown
Schweizerischer Nationalfonds zur Förderund der Wissenschaftlichen Forschung/Fonds national suisse de la recherche scientifique Swiss National Science Foundation	Wildhainweg 20, 3000 Bern, Switzerland	031 24 54 24/031 23 30 09
Schweizerische Gesellschaft für Mikrotechnik/Association Suisse de Microtechnique: c/o VSM	Kirchenweg 4, 8032 Zürich, Switzerland	01 384 48 44/Unknown
Université de Lausanne Institut de Physique Experimentally Faculté des Sciences	CH-1015 Lausanne, Switzerland	Unknown/Unknown
Université de Neuchâtel Institute of Structural Metallurgy	Bellevaux 51, 2000 Neuchâtel, Switzerland	Unknown/Unknown
Eidgenossische Technische Hochschule Zürich Abteilung fuer Werkstoffe	CH-8092 Zürich, Switzerland	Unknown/Unknown
Battelle Centres de Recherche de Genève (Battelle Geneva Research Centers)	7 Route de Drize, CH-1227 Carouge Genève, Switzerland	022 43 98 31/Unknown
Brown Boveri Forschungszentrum (Brown Boveri Research Center)	CH-5405 Baden, Switzerland	056 84 84 11/Unknown

Societies and Institutes	Address	Tel/FAX
École Polytechnique Fédérale de Lausanne/Eidgenössische Technische Hochschule Lausanne/Politecnico Federale di Losanna (EPFL) (Swiss Federal Institute of Technology, Lausanne)	CE Ecublens, CH-1015 Lausanne Vand, Switzerland	021 47 11 11/Unknown
Materials Department	34 Chemin de Bellerive, CH-1007 Lausanne, Switzerland	Unknown/Unknown
Eidgenössische, Materialprüfungs- und Versuchsanstalt/Laboratoire, Féderal d'Essai des Matériaux et Institut de Recherches/Laboratorio Federale di Prova dei Materiali ed Istituto Sperimentale (EMPA) (Swiss Federal Laboratories for Materials Testing and Research)	Überlandstrasse 129, CH-8600 Dübendorf, Switzerland	01 823 55 11/Unknown
Eidgenössische Technische Hochschule Zürich/École Polytechnique Fédérale Zürich (ETHZ) (Swiss Federal Institute of Technology, Zürich)	Rämistrasse 101, CH-8092 Zürich, Switzerland	01 256 22 11/Unknown
Schweizerische Aluminium AG (Alusuisse) Forschung und Entwicklung	Bad Bahnhofstrasse 16, CH-8212 Neuhausen am Rheinfall, Switzerland	05 32 02 21/Unknown
Structural Metallurgy Institute	Avenue de Bellevaux 51, CH-2000 Neuchâtel, Switzerland	038 25 28 15/Unknown

United Kingdom

The overall structure of research and development in the United Kingdom (U.K.) is complex. Under the authority of the Department of Education and Science are the Science and Engineering Research, the Medical Research, National Environmental Research, and the Social Science Research Councils. The Department of Trade and Industry (DTI) administers National Laboratories under its purview; e.g., National Physical and National Engineering Laboratories. The Ministry of Defense (MOD) has funding authority over the several entities, including the Royal Aerospace Establishment (RAE) and the Admiralty Research Establishment (ARE). These laboratories have now been merged into the Defence Research Establishment (DRE). The MOD research funds, 50 percent of the total of British government funds for research, are directed primarily to its laboratories and industry. By comparison, educational institutions receive 2 percent. In an effort to privatize these establishments, the MOD laboratories are becoming independent. Similarly, Harwell has successfully changed from a government laboratory to a position in which it competes with industry and universities for national and European Community (EC) research funds. The newly created DRE will compete for funds as an independent research entity with industry, academia, and other privatized laboratories.

One of the prime sources of funds for university research in the U.K. is the Science and Engineering Research Council (SERC). In addition, DTI and the MOD support academic research centers. The areas of funding in structural materials for DTI involve composite materials, engineering ceramics, rapid solidification, near net shaping methods, surface/joining technology, and product assurance with a funding level of $22 million in 1987/88. The SERC operates on a commission structure and incorporates seven research areas shown in Table 48.

Within each of these areas, there are coordinators at the SERC Swindon office, as well as typically academic researchers who formulate the programs. In an effort to enhance the linkage between university and industry, a program termed LINK was established. There are LINK programs in addition to the SERC research grants in these specific areas. A LINK steering committee accelerates commercialization of research efforts. The public and commercial sectors contribute equally to the funding. The LINK programs are in the six areas shown in Table 49.

Table 48. SERC Research Areas

1. Ceramic and inorganic materials
2. Medical engineering and sensors
3. Metals and magnetic materials
4. Molecular electronics
5. Superconductivity
6. Polymers and composites
7. Semiconductors.

Table 49. LINK Programs

1. Structural composites
2. Molecular electronics
3. Nanotechnology
4. Advanced semiconductor materials.
5. Molecular sensors
6. Technology for analytical and physical measurements.

Under a SERC program, five interdisciplinary research centers have been established; Table 50 lists those centers.

Table 50. SERC Interdisciplinary Research Centers[1]

1. Superconductivity - Cambridge University
2. Surface science - Liverpool and Manchester Universities
3. Semiconductor materials - London University
4. High-performance materials - Birmingham University and University College of Swansea
5. Polymer science and technology - Leeds, Bradford, and Durham Universities.

[1]For further information, contact Materials Science and Engineering Commission, Science and Engineering Research Council, Polaris House, North Star Avenue, Swindon SN2 1BR, U.K.

Table 51 provides information about U.K. materials-related societies and institutes.

Table 51. U.K. Materials-Related Societies and Institutes

Societies and Institutes	Address	Tel/FAX
Institute of Ceramics: Shelton House	Staffordshire ST4 2DR, England	0782 23116/Unknown
Institute of Metals	1 Carlton House Terrace, London SW1Y 5DB England	071 839 4071/071 839 2289
Institution of Chemical Engineers	165-171 Railway Terrace, Rugby CV21 3HQ England	Unknown/Unknown
Institution of Mechanical Engineers	1 Birdcage Walk, London SW1H 9JJ England	071 222 7899/Unknown
Institution of Mining and Metallurgy	44 Portland Place, London W1N 4BR England	071 580 3802/071 436 5388
Plastics and Rubber Institute	11 Hobart Place, London SW1W 0HL, England	071 245 9555/071 823 1879
Welding Institute, Head Office and Research Station: Abington Hall	Cambridge CB1 6AL, England	0223 891162/Unknown
Science and Engineering Research Council (SERC)	Polaris House, North Star Avenue Swindon SN2 1ET, England	0793 411000/0793 411400
Department of Trade and Industry Research Establishments		
National Engineering Laboratory	East Kilbride, Glasgow G75 0QU Scotland	03552 20222/03552 36930
National Physical Laboratory	Teddington, Middlesex TW11 0LW England	081 977 3222/Unknown
Ministry of Defence Research Establishments		
Admiralty Research Establishment	Portsdown, Portsmouth, Hampshire England	Unknown/Unknown
Admiralty Research Establishment (Marine Technology)	Teddington, Middlesex TW11 0LN, England	01 977 3231/Unknown
Admiralty Research Establishment	(Portland) Southwell, Portland, Dorset DT5 2JS, England	0305 820381/Unknown
Aeroplane and Armament Experimental Establishment	Boscombe Down, Salisbury, Wiltshire, England	
Chemical Defence Establishment	Porton Down, Salisbury, Wiltshire SP4 0JQ England	0980 610211/Unknown
National Remote Sensing Center, Space Deptartment Royal Aerospace Establishment	Farnborough, Hampshire GU14 6TD England	0252 541464/0252 375016
Royal Aerospace Establishment	Farnborough, Hampshire GU14 6TD, England	Unknown/Unknown
Royal Signals and Radar Establishment	Malvern, Worcestershire WR14 3PS England	Unknown/Unknown
BHRA Fluid Engineering Centre	Cranfield, Bedford MK43 -AJ, England	0234 750422/Unknown

Table 52 provides information about U.K. materials-related universities.

Table 52. U.K. Materials-Related Universities

University	Address	Tel/FAX
University of Bath, School of Materials Science	Claverton Down, Bath, Avon BA2 7AY, England	0225 61244/Unknown
University of Birmingham, Department of Metallurgy and Materials	P.O. Box 363, Birmingham R15 2TT, England	(021) 472-1301/Unknown
Brunel, The University of West London, Department of Materials Technology	Uxbridge, Middlesex UB8 3PH, England	Unknown/Unknown
University of Cambridge Department of Materials Science and Metallurgy	Pembroke Street, Cambridge CB2 3QZ, England	(0223) 334300/Unknown
Imperial College of Science and Technology, Department of Materials	Prince Consort Road, London SW7 2BP, England	(071) 589 5111/Unknown
University of Leeds, Department of Metallurgy, Houldsworth School of Applied Science	Leeds, West Yorkshire LS2 9JT, England	(0532) 431751/Unknown
University of Liverpool, Department of Materials Science and Engineering	P. O. Box 147, Liverpool L69 3BX, England	(051) 709-6022 or 794-2000/Unknown
University College, Department of Materials Engineering, University College of Swansea	Singleton Park, Swansea SA2 8PP, Wales	(0792) 295243/Unknown
University of London, Queen Mary College, Department of Materials	Mile End Road, London E1 4NS, England	(081) 980-4811/Unknown
City of London Polytechnic, Department of Metallurgy and Materials Engineering, Sir John Cass School of Science and Technology	Whitechapel High Street, London E1 7PF, England	(071) 283-1030
University of Newcastle upon Tyne, Department of Metallurgy and Engineering Materials, Physics and Metallurgy Buillding.	Newcastle upon Tyne, NE1 7RU, England	(091) 328511/Unknown
University of Nottingham, Department of Metallurgy and Materials Science	University Park, Nottingham NG7 2RD, England	(0602) 506101/Unknown
University of Oxford, Department of Metallurgy and Science of Materials	Parks Road, Oxford OX1 3PH, England	Unknown/Unknown
University of Sheffield, School of Materials Division of Ceramics, Glass, and Polymers	Elmfield, Northumberland Rd., Sheffield S10 2TZ, England	(0742) 768555 x 6087/Unknown
Sheffield City Polytechnic, Department of Metals and Materials Engineering	Pond Street, Sheffield S1 1WB, England	Unknown/Unknown
University of Strathclyde, Department of Metallurgy	Colville Building, North Portland Street, Glasgow G1 1XN, Scotland	(041) 552-4400/Unknown
University of Surrey, Department of Materials, Science, and Engineering	Guildford, Surrey GU2 5XH, England	(0483) 800800/Unknown
University of Wales, Cardiff, Department Metallurgy and Materials Science	Newport Road, Cardiff CF2 1TA, Wales	Unknown/Unknown
University of Wales, University College of Swansea, Department Metallurgy and Materials Technology	Singleton Park, Swansea SA2 8PP, Wales	Unknown/Unknown

The state of research in the U.K. is at a watershed period. The privatization of public sector laboratories; i.e., AEA-Harwell and the DEA, has created enhanced competition for an apparently smaller amount of government- and industry-sponsored research. The universities have undergone an enhanced scrutiny with regard to their research productivity and a consolidation of university departments may be required. Questions have been raised concerning the utility of SERC-funded programs, in particular programs in superconductors, surface science, and electronics. Although the quality of basic research remains high, the U.K.'s microelectronics, semiconductor production capacity and industry has waivered and the utility of the government-funded research in this sector is questioned.

The U.K. traditionally has had a strong academic position in physical and mechanical metallurgy and more recently in composite materials. The universities have produced excellent graduates who migrated and supported technology development in the U.S. and now to the EC. The U.K. will continue to be a source of excellent research talent. However, the viability of the industrially related materials efforts is in question. The materials research activities at major companies such as ICI, BP, British Steel, ALCAN, Courts, and Rolls Royce have had world leadership positions. The center of gravity shifted with the integration of the EC. The reluctance of British participation in the EC has not excluded the U.K. from an active role. However, it has allowed France and the FRG to assume a more dominant decision-making role in the future development of the EC. The implication to materials research and manufacturing has not crystalized. Nevertheless, there is a transition of internal government funding (e.g., SERC) to external funding (e.g., EC BRITE-EURAM, LINK programs) for academic research. Also the availability of research results of laboratories and universities with programs linked to the EC and industry is restricted. These restrictions and discrimination is apparently more prevalent. It appears that there is a general trend to more industrially related programs of a 5-year horizon. The ability to sustain long-term research of a 10-year vision is questioned, and only with EC contributions can it be maintained.

From a personnel perspective, with budget cuts in university funds, staffing is being reduced. Many academics are opting for early retirements and many active research groups may fail to sustain their viability. The new breed of researchers in the U.K. (as well as the U.S.) is actively seeking funding and collaboration at an international level.

Appendix A

Selected Materials-Related Organizations in Austria, Belgium, Israel, Iceland, Ireland, Poland, Portugal, Spain

Organization	Address
Austria	
Institut für Metallkunde und Werkstoffprofung, Montanuniversitut	A-8700 Leoben
Belgium	
Université Libre de Bruxelles	C.P. 165, Avenue F.-D. Roosevelt 50, B-1050 Bruxelles
Université de Liege, Faculté des Science Appliquées, Service de Métallurgie et Sidérurgie	Rue Armand Stévart, 2 (Bâtiment C1), B-400 Liege
Katholieke Iniversiteit Leuven, Faculty of Engineering, Dept. of Metallurgy and Materials Engineering	de Croylaan, 2, B-3030 Heverlee-Leuven
Université Catholique de Louvain, Faculté des Sciences Appliquées Département des Sciences des Matériaux et des Procédés	Place Sainte Barbe, 2, 1348 Louvain-la-Neuve
Israel	
Technion Israel Institute of Technology, Materials Engineering Department	Technion City, Haifa, 32000 Israel
Iceland	
Learned Societies	
Visindafélag Íslendinga (Icelandic Scientific Society) University of Iceland	Reykjavik
Research Institutes	
Rannsóknarád Ríkisins (National Research Council)	Laugaveg 13, Reykjavík
Hafrannsóknastofnunin (Marine Research Institute)	
Idntæknistofnun Íslands (Technological Institute of Iceland)	
Ireland	
University of Dublin, Manufacturing Engineering	Parsons Building - Trinity College, Dublin, 2, Ireland
University of Limerick, Material Engineering and Industrial Chemistry	Limerick, Ireland
Poland	
Politechnika Czestochowska	Deglera 35, 42 200 Czestochowa
Politechnika Slaska Im W. Pstrowskiego	ul. Krasinskiego 8, 40-017 Katowice
Politechnika Krakowska	al. Planu 6-letniego 10 A, 31-864 Krakow adres korespondencyjny: ul. Warszawska 24, 31-155 Krakow
Akademia Gorniczo - Hutnicza Im. Stanistawa Staszica	Mickiewicza 30, Krakow
Politechnika Wroclawska	Wybrzeze Wyspinaskiego 27, Wroclaw 2
Warsaw University of Technology Institute of Materials Science and Engineering	Narbutta 85, 02-524 Warsaw
Portugal	
Universidade Technica de Lisboa, Higher Technical Institute	Rua do Quelhas 6, Lisbon
Spain	
Universidad de Barcelona, Dpto. de Ingeniería Química y Metalurgia	Avda. Diagonal no. 647, 08028 Barcelona
Universidad Complutense de Madrid, Departamento de Ciencia de los Materiales, Facultad de Química	Ciudad Universitaria, 28040 Madrid
Escuela Técnia Superior de Ingenieros de Minas Departamento Metalurgia y Materiales	Independencia, 13, Oviedo 33004

Appendix B

Acronyms Used in this Publication

AGM	Advisory Group
ARE	Admiralty Research Establishment
BMFT	Federal Ministry of Research and Technology
BRITE	Basic Research in Industrial Technologies for Europe
CAD/CAM	Computer-Aided Design/-Manufacturing
CERTEC	Development of ceramics and refractory materials
CNRS	Centre National de la Recherche Scientifique
COST	Cooperation on Science and Technology
CRI	Cooperative research institutes
DFG	German Research Association
DLR	Deutsche Foschungstatt für Luft und Raumfahrt
DNSRC	Danish Natural Science Research Council
DRE	Defense Research Establishment
DTI	Department of Trade and Industry
DTRC	Danish Technical Research Council
EC	European Community
ECN	National Center for Ceramics Research
ECU	European Currency Unit
EFTA	European Free Trade Association
EPET	National Program for Research and Technology
ESPRIT	European Strategic Programme for Research and Development
EURAM	European Research in Advanced Materials
EUREKA	European Research Coordination Agency
FRG	Federal Republic of Germany
FRT	Research and technology fund
GEC	British General Electric Company
GNP	Gross National Product
IOP	Innovation-oriented programs
JRC	Joint Research Center
MATFO	Materials Forschungs Program
MIRTEC	Industrial research and metals engineering
MITI	Ministry of International Trade and Industry
MRES	Ministry of Research and Higher Education
MOD	Minister of Defense
NCR	National Center for Research
NTH	Norwegian Institute of Technology
PAN	Polymer Technology Foundation
PAVE	Research development program
PBTS	Business oriented programs
PEO	Phillips Electronic Organization
PNR	Swiss National Research Programs

RAE	Royal Aerospace Establishment
R&D	Research and Development
RTD	Research and Technology Development
SERC	Science and Engineering Research Council
SGRST	General Secretary for Research and Technology
SINTEF	Foundation of Scientific and Industrial Research
S&T	Science and Technology
STU	Board for Technical Development
TEKES	Technology Development Center
TNO	The Netherlands Organization for Applied Scientific Research
U.K.	United Kingdom

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