MASTER

Final Report

Review of the Management of Materials Research and Development in the Department of Energy

September 30, 1979

Published December 1979

950 6581
U.S. Department of Energy
Office of Energy Research
Office of Program Analysis

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

MASTER**Final Report**

Review of the Management of Materials Research and Development in the Department of Energy

September 30, 1979

Published December 1979

by

Materials Working Group

for

Department of Energy
Research and Development Coordination Council

**U.S. Department of Energy
Office of Energy Research
Office of Program Analysis
Washington, D.C. 20585**

FOREWORD

Management of materials science and engineering is a critical element in the technology development sequence. To gain an understanding of how materials are actually managed within the various parts of DOE and to recommend possible changes, a Materials Working Group of senior technical staff members was set up as one of the activities of the Research and Development Coordination Council within the Office of Energy Research.

950 6581

This report gives the findings of this Working Group and sets forth recommendations, chiefly of a management nature, to improve the handling of materials R&D within DOE. I believe the report provides valuable insights into the special role of materials in the development of new energy technologies and contains a wealth of detailed information on the management processes by which materials problems are currently handled. The recommendations are all under active consideration.

I would like to record my appreciation to those involved in the preparation of this report.

A large, stylized handwritten signature in black ink, consisting of a large loop and a horizontal stroke.

John M. Deutch
Under Secretary

Research and Development Coordination Council
Materials Working Group
and Supporting Personnel

Members

Dr. William D. Jackson, ER - Chairman
Dr. Howard Feibus, RA
Cdr. Frank W. Hughes, DP - from October 1978
Dr. James Mayo, ET
Col. H. C. McClammy, DP - deceased October 1978
Dr. J. Michael Power, CS
Dr. Donald K. Stevens, ER
Dr. Robert Wood, EV

Executive Secretary

Dr. Robert J. Mackin, Jr., ER

Organizational Representatives

Dr. Louis C. Ianniello, Chmn., EMACC
Robert E. Rosenthal, RDCC Staff
Dr. James J. Steckert, PE

Sub-Working Group

Mr. Robert Butenhoff, EV
Dr. James J. Eberhardt, CS
Mr. Eugene E. Hoffman, ET/RRT
Mr. Linus M. Raring, ET/FR
Dr. Robert Reeber, ET/DGE
Mr. Walter S. Scheib, Jr., ET/W
Mr. Robert H. Steele, ET/NR
Mr. Ray D. Walton, Jr., ET/W
Dr. Klaus M. Zwilsky, ET/OFE

Table of Contents

Part 1

	<u>Page</u>
I. Introductory Comments	1
II. Issues, Approach and Scope	1
III. Findings	3
IV. Recommendations	7

Part 2

I. Introduction	1
II. Role of Materials in Research, Development and Demonstration	3
III. Definitions	5
IV. DOE Concerns Relating to Materials	8
V. Materials R&D Activities in DOE - Overview and Perspective	11
VI. Findings and Conclusions	17
1. Programs and Projects -	17
Adequacy of Problem Identification, Coverage and Emphasis	
A. Project and Program Mechanisms for Assuring Coverage	
B. Mechanism to Assure Appropriate Level of R&D	
C. Conclusions	
2. Technology Base -	22
Timeliness in Identification of Materials Problems	
A. Mechanisms for Assuring Early Problem Identification and Attention	
B. Procedures for Factoring in Environmental and Commercialization Considerations	

C. Use of Basic Scientists in Defining Problems for R&D	
D. How Well the System is Working	
E. Conclusions	
3. Basic Sciences -	28
Effectiveness of Linkage Between Activities in the Division of Basic Energy Sciences (BES) and Technology Development Programs	
A. How BES Materials Program Supports Technology Development	
B. Energy Technology and other Development and Demonstration Organizations View of Support Received from BES Materials	
C. Conclusions	
4. Data, Information and Experience Exchange -	33
Degree to Which this is Organized and Productive Throughout DOE	
A. Information Exchange Mechanisms and Measures of Adequacy of Their Performance	
B. Documentation that Identifies Sources of Expertise	
C. How Well the System is Working	
D. Conclusions	
5. Coordination with other Agencies and Organizations -	38
Nature and Utility	
A. Mechanisms of Coordination	
B. Data on Whether the Coordination is Adequate and In Most Effective Form	
C. Conclusions	
6. Balance of Effort -	44
Budget Categorization Amongst Universities, Industry, DOE Laboratories	
A. Criteria for Determining Appropriate Locations for R&D Elements	
B. Criteria Bearing on Balance	

- C. Mechanisms that Determine Existing Assignments
- D. How Well the Existing Balance of Effort Serves DOE
- E. Conclusions

List of Appendices

	<u>Page</u>
A-1 Memorandum Establishing Materials Science Task Force	50
A-2 Terms of Reference for R&D Coordination Council Materials Committee	51
A-3 Basic Research in DOE, October 11, 1978	53
B-1 Selected References on Energy-Related Materials R&D Problems	55
C-1 Critical Materials Problems in Energy Systems	57
C-2 The Fusion Reactor Materials Program	61
D-1 Coverage of Materials Problems in Defense Programs	66
D-2 Existing Reactor Research Technology Division Management Policies and Procedures Related to Materials and Guidance Concerning Their Effectiveness	76
D-3 Coverage of Materials Problems in Fossil Energy	86
D-4 Materials Management in Energy Technology Advanced Systems	89
D-5 Approach for Improved Coordination in the Research and Development of Materials for Energy Conservation and Solar Applications	92
D-6 Materials Aspects of Resource Applications Programs	106
D-7 Environmental Program Policies and Conservation Related to Materials	109

Part 1

Summary of Activities,
Findings and Recommendations

Part 1

Summary of Activities, Findings and Recommendations

I. Introductory Comments

On August 1, 1978, the Under Secretary of the Department of Energy (DOE) requested a review of the status of materials science and engineering within the Department. The objective of this review was to develop recommendations which would assist in the formulation of an effective policy for materials science and engineering within DOE. This has been undertaken during the months September 1978 - January 1979; the results are presented to the Director of Energy Research in this two-part report.

Part 1 of the report summarizes the background to the commissioning of the report, the issues considered, the approach taken by the Working Group responsible for its preparation and the limitations placed on the study. The findings and recommendations are also set forth in Part 1. Part 2 provides a treatment of some of the philosophical aspects of materials work as it relates to the energy field, presents a perspective on materials activities in DOE, gives data on DOE materials activities, and gives information on the management processes involved. The findings of the Working Group are also included in Part 2 along with the pertinent data and information from which they are derived. For convenience, the specific recommendations are repeated in identical form at the end of Part 2. Appendix material provides a range of supporting background information.

The review was conducted by the Materials Working Group set up by the Director of Energy Research within the structure of the Research and Development Coordination Council (RDCC). The relevant memoranda establishing the Working Group are included as Appendices A-1 and A-2.

II. Issues, Approach and Scope

The Working Group received its terms of reference in the form of six general issues which cover basic and applied activities, problem identification and problem solving, information dissemination, management techniques and resource utilization. The issues, as established by the Working Group, are stated as follows:

1. Adequacy of identification and coverage of, and emphasis on, materials problems in R&D programs and projects, including major energy systems acquisition projects;
2. Timeliness in identification of materials problems which are judged to be critical to future energy systems from both performance and economic viewpoints or to be potentially important to a number of programs and/or projects;
3. Effectiveness of linkage between the basic and applied materials activities in the Division of Basic Energy Sciences (BES), the R&D programs and the technology development projects;
4. Degree to which there is organized and productive exchange of materials data, information, and experience between R&D programs throughout the Department;
5. Nature and utility of coordination with other Federal and state agencies, nongovernment organizations and nondomestic activities; and
6. Budget categorization of balance of effort among universities, industry, DOE Laboratories and Centers, and other Government research centers.

At the outset of its activities, the Working Group recognized that an adequate inventory of materials work within DOE is compiled annually by the Energy Materials Coordinating Committee (EMACC) and the 1978 Annual Report* issued by this ad hoc group served as a major data base. Additional information is provided by the Topic Area Reports prepared by EMACC on an annual basis, the most recent* issue being for 1978. It was further recognized that compilations of materials problems faced by DOE and its predecessor agencies were available from several sources and a partial listing appears as Appendix B-1. The report entitled, "Materials Sciences Overview, Parts I and II" (ERDA 77-76/2, August 1977) is particularly pertinent in this regard. Accordingly, the Working Group concluded that it could most effectively contribute to the management aspects of materials science and engineering (hereafter referred to as "materials R&D" and elected to make its primary responsibilities:

1. the identification of the mechanisms by which DOE manages its materials R&D; and
2. the preparation of recommendations by which these can be made more effective. It was encouraged to pursue this objective by the original formulation of the six issues with which it had been provided (Appendix A-2).

The procedure followed was to formulate for each issue a number of questions designed to illuminate the issue and to acquire data bearing on these questions. This approach was aimed at:

1. identifying existing management policies and procedures; and
2. uncovering problem areas in the management of materials R&D.

Subsequent analysis was aimed at summarizing the findings and developing options for corrective measures judged to be necessary.

The philosophical aspects of materials R&D were discussed at some length and the consensus emerging from this aspect of the activities of the Working Group appears in Part 2 along with a formal definition of materials R&D. The definition adopted is consistent with the emphasis on the management of materials R&D in the DOE programs associated with energy supply and conservation. The Working Group necessarily had to place limitations on the scope of its activities. Issues which were not addressed include the technical quality of existing programs (including realism of technical goals for applied programs), optimal overall organization of the DOE materials effort, priorities among technologies in materials R&D, allocation of projects and activities to industry, universities and national laboratories and appropriate DOE response to emerging national goals for materials management.

III. Findings

The Working Group, within the scope previously defined, considered the six issues as they relate both to the areas of responsibility of individual Assistant Secretaries and to DOE as a whole. The pervasive and multi-faceted character of materials activities require careful

handling and all of the issues are interrelated from both technical and managerial viewpoints. Data and information on DOE materials activities and management procedures obtained primarily by a sub-working group, which was set up for this purpose, with the membership indicated earlier. The Working Group used this material to develop a set of findings which could be identified with the various issues set forth above. The group then drew up a list of recommendations based on these findings and applicable, at least to some extent, to all of the issues. The data and information assembled to justify the findings and support the recommendations are to be found in Part VI.

Issue #1. Adequacy of identification and coverage of, and emphasis on, materials problems in R&D programs and projects, including major energy systems acquisition projects.

1. The Working Group observes that R&D programs within DOE have originated in agencies of quite diverse management traditions. These programs are now faced with requirements and challenges new to many of them, and the traditional approaches are meeting these challenges with varying degrees of effectiveness. Materials considerations often appear not to be addressed until late in a project.
2. The Program and Project and Management System (PPMS) promises to provide the kind of management control hitherto lacking, and the Working Group strongly endorses its thorough implementation. However, even this system appears not to contain a requirement for formal design reviews that would include materials considerations to insure design and technology integrity. The PPMS does not yet appear to have been applied extensively at the program and project level.
3. A key to the success of the military programs conducted by the Department appears to be the continuous, fully integrated involvement of materials experts from initial system design through development, production and operational evaluations. These programs also benefit from procedures that insure that the management system operates as a closed loop and incorporates feedback from users in the engineering design.

4. The low level of materials R&D in Energy Technology (ET) is a matter of special concern. A recent policy memo by the Assistant Secretary for Energy Technology to the Director of Energy Research (ER) entitled, "Basic Research in ET", and dated October 11, 1978, (Appendix A-3), addresses the need to support additional research (all aspects) within ET and specifically proposes additional funding allocations within ET for research related to the fossil program. Assuming that a portion of these funds will be applied to materials R&D, this policy can be used as a vehicle to improve the support of materials R&D within ET.
5. The conduct of materials R&D intended to support longer range objectives has no spokesman or point of accountability within the organizations of the several Assistant Secretaries responsible for materials R&D nor is there a focal point for activity integration within DOE. Its fragmented and uncoordinated character make it vulnerable as a prime candidate for cutbacks under budget pressures.

Issue #2. Timeliness in identification of materials R&D problems which are judged to be critical to future energy systems from both performance and economic viewpoints or to be potentially important to a number of programs or projects.

1. A number of ad hoc studies and workshops have identified numerous technologically critical materials R&D problems. Presentations to EMACC have described the problems of current concern to most of the technology development programs. There is as yet no systematic means of assuring that these needs are reflected in program plans.
2. There is no formal mechanism for coordinating the materials research in ET and ER with the many types of requirements that must be met in a commercially produced operational system. The Resource Managers, recently appointed in Conservation and Solar Applications (CS) and Resource Applications (RA) to guide technology efforts towards commercialization are apparently expected to perform this function. However, it is unlikely that this will be done effectively since planning review requirements have not been made an integral part of the PPMS in CS and RA. In contrast, this action has been taken in Environment (EV).

Issue #3. Effective linkage between the basic and applied materials activities in BES and the technology development projects and programs.

1. The BES Materials Program serves the Department well in terms of research results and other products of a basic research activity.
2. The coupling of this basic effort to the development programs requires that these individual programs devote resources to basic and applied materials R&D. A basic materials program should not be expected to solve all of the problems encountered in a development program, but it can provide valuable assistance if the individual development program has the requisite technical, management and budget resources properly to carry out the required applied research and development.
3. The policy announced in the October 11, 1978, memo, "Basic Research in ET" referred to above, could go far toward improving the linkage between BES/Materials and the program offices of ET as it is implemented.

Issue #4. Degree to which there is organized and productive exchange of materials data, information and experience between R&D programs throughout the Department.

1. The EMACC is the only organized DOE internal vehicle for the exchange of materials R&D information, data and experience at the "grass roots" (i.e., project manager) level. EMACC evidently serves a needed function within DOE although the Working Group received varying opinions as to its present usefulness.
2. The EMACC would be of greater benefit to the Department and perform more consistently if it were given an official role and position in the DOE with corresponding resources with a charter somewhat broader than that currently being used on an ad hoc basis.

Issue #5. Nature and utility of coordination with other Federal and state agencies, nongovernment organizations and nondomestic agencies.

1. The dis-establishment of COMAT, the FCCSET Committee on Materials causes concern in that it is very likely to reduce the effectiveness of interagency coordination and interaction.

2. The Group found that much informal contact between agencies nevertheless exists (meetings, working groups, etc.). Varying opinions as to the effectiveness of these activities were again received, attesting to the general lack of formal coordinating mechanisms for energy and energy-related materials R&D.

Issue #6. Budget categorization of balance of effort among universities, industry, DOE laboratories and centers, and other government research centers.

1. The Group limited its treatment of the matter of balance between national laboratories, universities and industry to the gathering and analysis of budget data.
2. A budget breakdown based on the data received suggests that the funding distribution to the three sectors is, a priori, reasonable in the light of policies and management attitudes of predecessor agencies. A considered judgment on this point would require a detailed definition by DOE of the roles of these classes of institutions, including the socio-technical relationships and in-depth reviews of the outcome and character of the materials R&D being currently undertaken and planned for the future in each of the three classes.

IV. Recommendations

Based on the foregoing conclusions and the data and analysis presented in Part 2, the Working Group puts forward the following recommendations which to some degree relate to the foregoing issues and findings.

1. The detailed implementation of the Program and Project Management System (PPMS) should include explicit provisions for the handling of materials issues within the context of both major systems acquisitions and technology development programs. This requires the inclusion of materials development requirements in program and project plans and the institution of design reviews at stipulated milestones to insure overall technology readiness. These design reviews should explicitly include consideration of the adequacy of specified materials and fabrication methods, and employ appropriate materials expertise on the review board.

2. Establishment and maintenance of a materials R&D component within the DOE technology base is considered to be essential to insure an adequate engineering design basis for the acquisition of major systems, to enable technology development programs to proceed with reasonable expectation of success, and to explore upgraded or alternative approaches for growth potential of energy systems selected for development and/or commercialization. The responsibility for this must lie with each Assistant Secretary involved with R&D.
3. The vitality of basic materials research activities judged supportive of long-range goals of the Department of Energy should be fostered by a substantial and critical commitment of support by the Department. A significant increase of funding in this area appears to be warranted by both program needs and by perceived scientific opportunities.
4. The Energy Materials Coordination Committee (EMACC) should continue to operate and be formally established for materials coordination within the structure of the RDCC. A formal charter for EMACC should be established with its primary function to be the dissemination of technical and program information. Membership should be at the project manager level and be mandated for the Offices and/or Divisions, as appropriate, with materials responsibilities.
5. The importance of having a formal means of communications among Government agencies on all aspects of materials dictates that the Committee on Materials (COMAT) should be reconstituted on a formal basis with full DOE participation and support. Appropriate representation to this effect should be made by DOE to the Office of Science and Technology Policy.
6. The Controller should be instructed to include the specific identification of materials budget information in program plans and budget calls. This process should be initiated with the FY 80 Program Plans and the FY 81 budget. It is further recommended that the question of balance of funding among various organizations responsible for R&D be considered by a group with a broader charter than the present Working Group when the effects of current program management decentralization are understood and reliable budget data becomes available.

7. The management of materials activities in R&D requires two specific actions by the appropriate Assistant Secretaries: (1) implementation of the October 11, 1978, memorandum referred to above with explicit allocation of a materials R&D budget; and (2) establishment in each Program Office of an organizational unit responsible for materials oriented technology base activities and the oversight of materials R&D in accordance with Recommendation 1 above. This function could be included in an organizational unit devoted to technology base activities.
8. To complement these R&D actions, the Assistant Secretaries for Resource Applications and Conservation and Solar Applications should also make organizational arrangements which insure that materials issues receive timely attention.

Part 2

Perspectives, Methodology and Data Base

Part 2

Perspectives, Methodology and Data Base

I. Introduction

The realization of new technologies and the further refinement of those for which a significant body of engineering experience already exists is self-evidently dependent on engineering design successfully meeting the system requirements with materials of the required characteristics and available on a basis which makes the resultant system competitive in marketplace terms. Consequently, the discipline which may be described as materials science and engineering has a critical role in the engineering design process as it determines the feasibility of physical realization with the mechanical, thermal, chemical, electrical and other conditions which the system requirements impose.

Recognizing that these considerations are of special concern to the Department of Energy (DOE), the Under Secretary requested a review of the status of materials science and engineering within the Department. This has been undertaken during the past few months (September 1978 - January 1979) and the results are presented to the Director of Energy Research in this report which is in two parts.

Part 1 of the report summarizes the background to the commissioning of the report, the issues considered, the approach taken by the working group responsible for its preparation and the limitations placed on the study. The findings and recommendations are also set forth in Part 1. Part 2 provides a treatment of some of the philosophical aspects of materials work as it relates to the energy field, presents a perspective on materials activities in DOE, gives data on DOE materials activities, and information on the management processes involved. The findings of the working group are also included in Part 2 along with the pertinent data and information from which they are derived. For convenience, the specific recommendations are repeated in identical form at the end of Part 2. Appendix material provides a range of supporting background information.

The review was conducted by the Materials Working Group set up by the Director of Energy Research within the structure of the Research and Development Coordination Council (RDCC). The relevant memoranda establishing the Working Group are included in Appendices A-1 and A-2.

The terms of reference of the Working Group were established in the form of six issues which it was directed to address. These issues are restated here for convenience; the approach taken and the scope offered by the Working Group are outlined in Part 1 and discussed below. The issues as slightly reformulated by the Working Group are:

1. Adequacy of identification and coverage of, and emphasis on, materials problems in R&D programs and projects, including major energy systems acquisition projects;
2. Timeliness in identification of materials problems which are judged to be critical to future energy systems from both performance and economic viewpoints or to be potentially important to a number of programs and/or projects;
3. Effectiveness of linkage between the basic and applied materials activities in the Division of Basic Energy Sciences (BES), the R&D programs and the technology development projects;
4. Degree to which there is organized and productive exchange of materials data, information, and experience between R&D programs throughout the Department;
5. Nature and utility of coordination with other Federal and state agencies, nongovernment organizations and nondomestic activities; and
6. Budget categorization of balance of effort among universities, industry, DOE Laboratories and Centers, and other Government research centers.

Based on the extensive literature on energy-related materials problems (Appendix 1) and information (Part 1, p.2) compiled by the Energy Materials Coordinating Committee (EMACC), the Working Group concluded that it could most effectively contribute to the management aspects of materials science and engineering (hereafter referred to as "materials R&D") and elected to make its primary responsibilities:

1. the identification of the mechanisms by which DOE manages its materials R&D and
2. the preparation of recommendations by which these can be made more effective.

The Working Group had to place limitations on the scope of the study. Issues which have not been addressed include the technical quality of existing programs (including realism of technical goals for applied programs), optimal overall organization of the DOE materials effort, priorities among technologies in materials R&D, and appropriate DOE response to emerging national goals for materials management.

II. Role of Materials in Research, Development and Demonstration

The successful achievement of "first-of-a-kind engineering" is a creative process which is heavily dependent on the individuals involved and which always carries a degree of risk. Recognizing these are fundamental considerations, it is useful to observe that there are three driving forces in the process of technology development and that each has its influence on materials work. These are:

1. The "top down" systems engineering effort in which a system concept is first established, conceptual design work is undertaken, and specifications are established, at least tentatively, for the individual subsystems and components and also for their performance when operated in a fully integrated mode.
2. The research and exploratory development activities through which the basic data needed to support the feasibility of the process are obtained and the preliminary engineering work is conducted to provide a reasonable basis on which the design work may be undertaken.
3. Engineering design itself in which the requirements derived from (1) and the data obtained from (2) are, if possible, combined to achieve a full or subscale realization of the process under conditions which are acceptable relative to the perceived commercialization requirements.

The order in which these activities may be undertaken is not fixed, though, there is a comforting logic in proceeding in the order 1-2-3. There are, however, sufficient examples of other sequences (e.g., solid state devices were developed from basic investigations and only once they became available was their full systems potential realized) to indicate the need for a flexible viewpoint on the creative process involved.

The materials aspects of engineering design have evolved in a manner which yields a perspective on its current position in the "first-of-a-kind engineering" process. During the 19th century evolution of technology, the strength of materials was considered as a critical factor and a sufficient factor of safety was built into engineering design to guard against failures observed in the utilization of earlier versions of the particular class of machine or structure involved. Although this approach generally sufficed, warning of the limitations imposed by it was already evident in such spectacular failures as the 1880 collapse of the Tay Bridge in Scotland as a result of the specification of cast iron welding of the girders in an otherwise sound design.

The increasing performance demands of the 20th century technology, exemplified by aircraft development, rendered inadequate a reliance only on factors of safety. A fuller understanding of the fundamental properties of materials already available, or capable of near-term development, and the detailed character of the stress environment in which they were required to serve became the prerequisites for successful engineering design. (The catastrophic fatigue of the fuselage of the jet-engined Comet passenger aircraft is directly attributable to disregard of these considerations.)

A further stage has now been reached in that new systems in the exploratory development phase have been shown to have materials requirements so significantly beyond existing experience that successful design realization can only follow from some materials "breakthrough". For example, the higher temperatures required by fundamental thermodynamic considerations to increase heat engine conversion efficiencies imply materials requirements beyond the current state-of-the-art.

In parallel with this engineering design evolution, materials science has emerged as a powerful discipline with an ever-increasing capability to analyze materials at both the basic structural and macroscopic levels and with impressive successes in predicting the properties and

behavior of materials and their device applications (e.g. solid state devices). The insight gained into materials to facilitate their incorporation into the engineering design process is increasingly valuable as materials requirements become more stringent and new concepts in energy systems can be expected to arise directly from materials science and engineering.

The foregoing considerations, rather than the particular materials problems of specific technologies under development and/or demonstration by DOE, have led to the primary thrust of this report being to identify if, in the judgment of the Working Group which authored it, the DOE management procedures and allocation of resources are adequate to the circumstances. The allocation of resources to create an environment in which new concepts arise involves much broader issues than those which are properly covered in a review of materials science and engineering. Accordingly, this report is mainly concerned with management aspects of materials from the maintenance of an adequate basic effort to the successful realization of a particular system as a viable process in the marketplace. Treatment of the allocation of resources issue is limited to an account of the current DOE situation, including the best available budget data for programs and DOE laboratories.

III. Definitions

A problem which arises in discussing materials is the lack of a common understanding of the boundaries implied by the term. Accordingly, for purposes of this study, the Working Group set forth and utilized the following definition:

"Materials Research & Development includes all basic research, applied research, and development on all substances--solid, liquid, or gaseous--used in the generation, conversion, storage transmission or conservation of energy. Natural substances and their formations related to energy systems are included as are materials production processes and by-products of energy systems. Fuels are included to the extent that knowledge of their properties and structure is needed in systems development or systems analysis."

The Group recognized that materials activities break down into two major categories:

1. Basic or generic activities which are not directly connected with any specific design application but are generally directed towards materials synthesis, mechanisms or structures or correlations of these physical and chemical properties. These activities have as their main purposes: (a) advancing the state of knowledge; (b) checking the validity of published data and extending such data; (c) training materials scientists and advanced students.
2. Applied activities under program or project support. In these, work is directed towards a specific design application where the design functions and environment are understood within reasonable limits. Work may include synthesis, properties determination, test evaluation, fabrication studies, mechanistic studies, post-test analyses and combinations of all of these. Major emphasis is placed on test evaluation to establish in a credible manner the design acceptability of material candidates for the intended application. This category includes the pursuit both of base line and backup activities within the context of the design of the particular system involved.

These categories can be related to the overall technology process as illustrated in Figure 1 which utilizes the DOE method of classifying the several development stages. In this figure, the successive stages of system development are characterized, from conception through engineering development and the associated materials activities are described. It also shows the changing nature of the materials effort from research into engineering. Where the particular development has its origin in a Government facility or university, this change is accompanied by a growing involvement of industry as work progresses towards the engineering development stages.

MATERIALS/DESIGN RELATIONSHIPS

Figure 1

IV. General DOE Concerns Relating to the Materials Review

The Working Group identified a number of observations and concerns relating to materials R&D which involves a crosscutting scientific and engineering area. These provide part of the backdrop against which the materials activities must be viewed, affords useful insights into some of current DOE practices and gives guidance for the development and application of any new materials R&D policies. They include:

1. A widely held view that many energy technologies are materials limited and accordingly, there is a need for special emphasis on an effective materials R&D program. For instance:
 - a. Fusion faces well known materials problems that may become program limiting as soon as scientific feasibility is demonstrated.
 - b. The performance of liquid metal fast breeder reactor fuel elements is limited by radiation-induced swelling and limited end-of-life ductility in the reference 20% cold-worked 316 stainless steel being developed for cladding and duct applications.
2. A high-level managerial concern that currently operating management systems are unable to provide assurance that there are not hidden materials problems within one or another technology development program which will emerge as fundamental obstacles very late in the development cycle. For instance:
 - a. Although stress corrosion cracking is a materials hazard under study for half a century, cracks found in commercial boiling water reactors caused all 23 of these reactors in the U.S. to be shut down in 1974 for inspection. During 1978, there have been reports of cracks in large-diameter pipes of operating reactors in Germany, Japan, and the U.S.
 - b. Localized corrosion has been found to be a serious problem in the Niland 10-MW geothermal thermal-loop facility and in operating New Zealand plants.

3. A key attitude on the part of engineering managers from several program areas is that a separately established materials program per se is inappropriate and that only a materials activity conducted as an integral part of a specific program or major subdivision is compatible with effective management. Associated with this attitude is the view that the involvement of materials is crucial in all stages of the design and development process. Great importance is attached to continuity of involvement by the same materials group through all stages of technology development, but it is recognized that continued involvement of a single materials group is difficult to achieve when a program is passed from one element of the Department to the next, and with a progressively greater proportion of the implementation management transferred to industry.
4. The 1978 Technology Base Review (submitted July 1978 and covering more than materials) found that, if the fusion program is excluded, DOE's allocation of funds to the Exploratory Development phase of the RD&C spectrum is well below national proportions and also below the corresponding investment by innovative sectors of industry. Closer examination of program content suggests (according to the Review) that this apparent imbalance in DOE's R&D allocations reflects a broad gap between DOE's basic research programs and the Department's development programs. The Review gives statistics which reveal, among other things that, "no applied research is identified in the development programs to support such key technologies as coal liquefaction, photovoltaics, and batteries. There is an implied assumption that such efforts will be conducted by ER. An examination of the ER activities suggests that they are very strongly oriented toward the basic science end of the research spectrum." The review acknowledges that "to at least some extent, the major gaps perceived in the DOE technology base activities may reflect...inadequacies in the information base." Subsequent data reveal that this is not the case and that, in fact, there are serious deficiencies and FY 79 cut-backs in technology base activities.
5. A survey by the Energy Materials Coordinating Committee (EMACC) of seven selected topical materials areas summarized over 250 projects currently being sponsored by DOE in those areas (reference: EMACC 1977-78 Annual Administrative Report). The very pervasiveness of

materials issues and problems and their intimate relationship to engineering and systems considerations make it impracticable to give precise figures on the volume of materials R&D. For instance, many component development problems can be considered to be dominated by materials engineering considerations, but in this case, it is impractical to break out the materials R&D effort as an independent budget item and only estimating is possible.

6. The Report of the OSTP Working Group on Basic Research in the DOE (S. Buchsbaum, chairman, June 1978) contains a number of general conclusions and recommendations that relate closely to the issues the present Working Group was assigned to address. This reinforces the assertion, made elsewhere in this report, that the problems for this study are specializations of larger problems of DOE R&D programs. The following observations do not refer to the materials area explicitly, but they clearly apply to it as evidenced by the large number of suggestions for materials research made in the OSTP Report section "Research Needs and Opportunities."

"There is a lack of balance in the DOE programs between research on the one hand and development, engineering and demonstration programs on the other. This stems in large measure from a pre-occupation with certain near-term programs and neglect of longer term fundamental work that is vital to the DOE mission. The dearth of research is especially evident in the solar and fossil fuel programs."

The OER programs alone do not and should not fill the total needs of the DOE for basic research."

V. Materials R&D in DOE - Overview and Perspective.

The materials research and development effort of DOE is one of the largest in the Federal Government and has been estimated at \$330 million for FY 1978. It is carried out in twenty-two divisions with about a dozen of these having major size programs. Materials research specific to an energy technology is primarily conducted by the program having responsibility for the technology, whereas, fundamental research underpinning either single or multiple technologies is conducted primarily in the Division of Materials Sciences of the Office of Energy Research.

A materials coordinating committee has been in existence since before ERDA was formed and has served as the focal point for discussion of mutual problems and exchange of programmatic and technical information. The committee consists of representatives from the various materials programs and meets monthly. This committee is now called the Energy Materials Coordinating Committee (EMACC). Data compiled by EMACC describe major DOE technical programs and interests in the areas of structural ceramics, alloy development, nondestructive evaluation, corrosion, joining of materials, reactor fuel and cladding development, elastomers, catalysts, radiation effects, superconductivity, cement and concrete, and alternate materials. These topics have been surveyed by EMACC, and listings of ongoing programs in these areas have been compiled in topical reports. In addition, EMACC compiles an annual summary of materials research and development programs underway - the latest report covering the FY 1978 period (EMACC Annual Technical Report, DOE/US-0003). This report briefly describes the technical content of each programs, gives information on the funding levels, and identifies DOE contacts where further information may be obtained. In Table I, the funding levels for each of the various programs represented on EMACC are given for the years FY 1978 and FY 1979. The FY 79 figures are estimates as of October 1, 1978. Since that date, several ET projects have been terminated or reduced.

In many cases, no separately identified materials program exists. Rather, it is part of a project or technology base program. Therefore, the exact levels of effort is subject to interpretation. Nevertheless, since the two years were estimated by the same individuals, the trend should be fairly accurate.

For FY 1979, the effort in materials R&D represents about 3.0% of the DOE total budget authority or about 7.8% of the DOE R&D budget. Table V shows the corresponding figures for other agencies. Of the total materials R&D effort, about 19% is devoted to fundamental research and the rest is applied to various technologies. Table II shows the materials budget by energy technology and the corresponding total technology budget. (Fundamental research and environmental research supported by OER and EV have been omitted.)

Table I - Materials R&D by DOE Program

<u>Program</u>	DOE <u>ORGANIZATION</u>	Operating Budget (M\$, B/A)	
		<u>FY 78</u>	<u>FY 79</u>
Materials Sciences.....	ER-BES.....	64.0	70.0
Advanced Systems and Materials Pro- duction.....	ET-FISSION....	4.6	6.2
Reactor Research and Technology.....	ET-FISSION....	39.0	35.7
Nuclear Power Development.....	ET-FISSION....	10.4	9.8
Naval Reactors.....	ET-	35.0	38.0
Fusion Energy.....	ET-MAGNETIC...	9.3	10.5
Coal Conversion.....	ET-FOSSIL....	6.5	7.4
Magnetohydrodynamics.....	ET-FOSSIL....	3.5	3.0
Fuel Utilization.....	ET-FOSSIL....	20.0	22.0
Electric Energy Systems.....	ET-	2.5	2.3
Energy Storage.....	ET-	5.9	5.9
Solar Technology.....	ET-SOLAR	23.2	51.0
Geothermal Energy.....	ET	4.5	5.5
Nuclear Waste Management.....	ET	1.0	1.0
Military Application.....	DP	78.6	78.6
Laser Fusion.....	DP	5.0	5.0
Biomedical and Environmental Research...	EV	1.0	1.0
Environmental Control Technology.....	EV	0.1	.1
Industrial Energy Conservation.....	CS	1.0	1.0
Buildings and Community Systems.....	CS	5.0	5.0
Transportation.....	CS	6.0	6.0
Solar Applications.....	CS	6.0	5.0
Total.....		332.1	369.8

The FY 1978 EMACC Annual Technical Report lists, in general, the contractors performing the various materials R&D tasks. All types of institutions are involved to some extent, including other government laboratories, not-for-profit organizations, industry, and educational institutions in addition to the DOE laboratories. Research is supported both in response to requests from DOE and in response to unsolicited proposals. Table III gives the approximate distributions by performer for the total FY 1978 materials R&D budget of 332.1M\$. The table is only an estimate.

Table II - FY 1979 Materials R&D by Percent of Technology Program

<u>Program</u>	Operating Budget (M\$, B/A)		
	<u>Technology</u>	<u>Material</u>	<u>%</u>
Fission	709	51.7	7.3
Naval Reactors	264	38.0	14.4
Magnetic Fusion	233	10.5	4.5
Coal	597	32.4	5.4
Solar Technology	263	51.0	19.4
Geothermal	153	5.5	3.6
Nuclear Waste	158	1.0	0.6
Inertial Confinement Fusion	104	5.0	4.8
Conservation	814	12.1	1.5
Solar Applications	152	5.0	3.3
Military Applications	1196	78.6	6.6
Electric Energy Systems	38	2.3	6.1
Energy Storage	<u>56</u>	5.9	10.6
	4737		

For the fundamental research program (included in the above tabulation), the distribution of funds is easily determined from the EMACC Annual Technical Report, and the corresponding percentages are: Universities - 35.6%, Laboratories - 64.4% (Note: less than 1% in industry and other).

Table IV lists the funding in Materials at selected DOE laboratories for FY 1978, based on data provided by the Laboratories. (Note: KAPL and BETTIS, the two Naval Reactor dedicated contractors, are not included).

Table III

	<u>M\$ (B/A)</u>	<u>FY 1978</u> <u>%*</u>
Universities (including about 10.5M\$ at LBL and Ames)	36.5	11.0
DOE Laboratories (except for above)	194.5	58.6
All Other (industry, not-for-profits and other Gov't Labs.)	<u>101.1</u>	<u>30.4</u>
Total	332.1	100.0

Recognizing the special reasons for conducting R&D for Defense Programs and Naval Reactors mainly in DOE laboratories, and subtracting the appropriate figures, results in

University	17%
DOE Laboratories	36%
Industry	47%

for the strictly nonmilitary materials efforts of DOE in Fiscal Year 1978.

* The above percentages have been prepared from estimates made by the materials staff of the various Technology Programs. EMACC is presently updating these figures for FY 1979.

An important source of information on the current basic research program is the report Materials Sciences Program, Fiscal Year 1978, Office of Basic Energy Sciences (DOE/ER-0013, dated September 1978). In addition to a brief profile of each of 422 projects, the report contains statistical tables of support (a) by region of the country, (b) by academic department or laboratory division, (c) by DOE Laboratory vs. University, (d) by named DOE laboratory, and (e) by selected areas of research. It also contains indices of investigators (sorted by laboratory of university), materials, phenomena, technique, and physical or chemical environment.

Table V - FY 1978 Operating Levels (M\$)

<u>Laboratory</u>	<u>Total DOE Support</u>	<u>DOE Materials Support</u>	<u>Non-DOE Support</u>	<u>Non-DOE Materials Support</u>
Ames	11.6	5.8	0.7	0.3
ANL	203.2	24.5	12.1	3.1*
BNL	94.7	10.5	8.6	2.4*
LBL	76.7	5.6	26.6	0
LLL	273.0	16.4	56.0	2.2
LASL	254.6	21.6	35.0	1.0
ORNL	186.2	18.7	57.4	4.0*
PNL	95.0	18.0	25.0	7.0
Sandia	328.4	29.4	71.4	3.2
Morgantown	34.0	0.5	0	0
Pittsburgh	20.0	0.5	0	0
HEDL	135.0	26.0	1.0	1.0*

*Mostly Nuclear Regulatory Commission

TABLE VI - MATERIALS R&D IN OTHER AGENCIES (FY-1979)

<u>Agency</u>	<u>Materials R&D</u> <u>\$M</u>	<u>All R&D</u> <u>\$M</u>	<u>Total Budget</u> <u>\$B</u>	<u>Materials R&D</u> <u>All R&D</u>
NSF	63.7 ⁽¹⁾	261 ⁽¹⁾	0.917	24%
DOD	141 ⁽²⁾	2500 ⁽²⁾	126.	6%
NASA	53	3305	4.371	1.6%
DOI	121 ⁽³⁾	161 ⁽³⁾	4.5	75%
DOC	11.0 ⁽⁴⁾	86 ⁽⁴⁾	2.685	13%

(1) Division of Materials Research and Mathematical, Physical Sciences & Engineering Directorate (respectively)

(2) 6.1, 6.2, 6.3A

(3) Bureau of Mines (other \$48M is for helium program)

(4) National Bureau of Standards - direct appropriation

VI. Findings and Conclusions

This section deals with each of the issues in turn. The procedure followed by the Working Group was to develop a series of questions appropriate to each of the six issues. In the following sub-sections, the issue is restated and the questions considered by the various DOE organizational units represented on the sub-Working Group are underlined. The material supplied by the organizational units is given in Appendices D-1 through D-7 and this, together with the data appearing in the preceding section, was used as the basis for the analysis and discussion presented below. The conclusions of the Working Group, as given in Part 1, are repeated with each issue considered. As noted in the Introduction, the questions are the natural ones that arise in appraising an R&D management system.

1. Programs and Projects - Adequacy of Problem Identification, Coverage and Emphasis

Issue #1. Adequacy of identification and coverage of, and emphasis on, materials problems in R&D programs and projects, including major energy systems acquisition projects.

A. Project and Program Mechanisms for Assuring Coverage

Question. In projects and programs what mechanisms are employed for assuring that significant materials problems have been identified and covered?

In large measure, this issue emerges as a special example of a broader concern for management assurance of technological advancement according to plan and system technological readiness at each decision point in an RD&C program.

The needed assurance cannot be gained through the present Management Review and Control Document (MRCD) process. In FY 1978, at least, the control milestones generally relate to incompletely defined goals, making it possible (in principle) to report a given milestone as met despite significantly inadequate performance or inadequate testing. Moreover, materials requirements seldom appear explicitly in MRCD's.

The Fusion Program faces extraordinary long-term materials challenges. Accordingly, its Materials and Radiation Effects Branch of the Office of Fusion Energy works closely with the Systems and Design Study Programs to define and update materials requirements. The Branch carries out a very broadly based R&D program guided by a Program Plan that is keyed to the milestones of the overall Magnetic Fusion Energy Development Plan. The Materials Plan, which includes implementation management, contains enough ideas of potential value for planning by other technologies of the materials R&D efforts, that it is described in some detail in Appendix C-2.

Nuclear waste management (ETW) programs involve primarily the selection and adaptation of developed materials for specific uses. These programs appear highly decentralized. Materials requirements are identified by field office/contractor organizations, and Headquarters then relies on them to meet these requirements as part of their overall responsibilities for program implementation. There is not an evident systematic Headquarters follow-up to assure adequate performance.

Fossil Energy projects, by and large, build upon the materials technology base of existing industries. Materials problems are nevertheless at the core of certain programs, and the management approach recognizes this.

For instance, Project Managers in Fossil Energy are directly charged with the responsibility to identify, define, and address material and fabrication problems which impair the substitution of coal and oil shale for imported oil and high cost natural gas. Status and program reviews concentrate on these issues. Both individual DOE Headquarters engineers and outside organizations are assigned specific responsibilities in carrying out the purposes of the project. For example, the Illinois Institute of Technology has been assigned the job of systematically evaluating candidate low cost materials for coal liquefaction and gasification duty. ORNL regularly investigates the material aspects of equipment failures or malfunctions in coal conversion pilot plant operation. Other examples as well as further descriptions of the management approaches of the different programs in Fossil Energy are given in Appendix D-3.

Advance Systems (Solar, Geothermal, Electric and Storage Systems) are as diverse in management policies and practices as in technologies. Even the individual areas have internal differences. Appendix D-4 outlines the management systems and the involvement of materials experts.

CS, RA, and EV likewise have a variety of management approaches, as would be expected, but in general seeming not to reflect the high concern for materials integrity that is at the heart of this issue. Their interests and concerns (which will be discussed more fully under other issues) are discussed in Appendices D-5, D-6, and D-7, respectively.

The above paragraphs and the corresponding appendices describe a broad variety of management philosophies and practices. The several materials problems cited in the Introduction and others that have been cited in informal conversations (and, thus, represent unevaluated data) suggest that many program areas are now faced with challenges different from their traditional ones and that their traditional management approaches may be inadequate. In crude terms, the present energy program has moved them from a largely cost-limited environment into a schedule-limited environment with an accompanying escalation of technological performance goals. The concern expressed in the Report of the OSTP Working Group on Basic Research in the DOE (cited in Section I) that "new technology programs are being conducted as if near-term success were assured" supports this view. The emergence of an agency-wide DOE management policy, thus, offers a best hope for providing an effective reorientation to meet the concerns underlying this issue.

The source documents that define departmental policy in this area are IMD 0203, Department of Energy Policy and Program Planning Systems (PPPS); IMD 0207, DOE Major System Acquisitions; and the Under Secretary's policy memorandum of May 31, 1978, "Program and Project Management System (PPMS) for DOE Outlay Programs."

The ET documents that define that Assistant Secretary's policies and procedures for implementing the PPMS were only signed off in August 1978 and corresponding CS and RA documentation has not yet been signed off. Hence, the PPMS system is not yet being applied at the program/project level. This is a matter for concern.

The above documents (and their ET counterparts) have been reviewed for the effectiveness with which they deal with assuring technology readiness (including materials). The finding is that they provide a good general framework for dealing with it but do not in themselves specify unambiguously what is required to provide genuine management assurance of technological readiness at key decision points. Terms such as "state-of-the-art assessment" and "risk assessment" permit a broad range of interpretations as to criteria to be applied and means for their accomplishment.

One element apparently missing from these directives is the requirement for and definition of formal design reviews at various stages. In such reviews, as carried out by other agencies, boards of disinterested experts probe for weaknesses and oversight in design and testing. A formal requirement for this type of activity, including the requirement for materials specialists' participation, minimizes the possibility that significant materials selection errors will occur.

It should be emphasized that the PPMS, while imposing certain firm principles (e.g., "accountability", "management feedback") should still permit the broad range of management styles required by the varying levels and modes of industry and/or DOE Laboratory involvement, varying degrees of management decentralization, and differing commercialization settings. It is as applicable to the technology base as it is to acquisition projects. There is clearly a need for widespread management training activities to assure its uniform interpretation and its acceptance at all management levels.

B. Mechanism to Assure Appropriate Level of R&D.

Question. What mechanisms exist to assure that an appropriate level of materials R&D is undertaken to support development projects?

The data on problem areas cited in Section 2-IV suggest that effective mechanisms have not existed up to now. The Technology Base Review, conducted by ER for the RDCC, is designed to expose weaknesses in the program and has done so in gross terms for the FY 1980 budget. A policy memo, Assistant Secretary for Energy Technology (ASET) to Director, Office of Energy Research, Basic Research in DOE, dated October 11, 1978, describes corrective action to be undertaken by the ASET in terms of ET internal policy

guidance and a request for additional technology base funds. A more extensive technology base assessment is just now being organized which should provide more detailed and revealing information. A prerequisite for a quantitative technology base assessment is that materials problems of the various programs and corresponding requirements for R&D be explicitly spelled out—which is the subject of Issue #2.

C. Conclusions

1. The Working Group observes that the R&D programs within DOE have originated in agencies of quite diverse management traditions. These programs are now faced with requirements and challenges new to many of them, and the traditional approaches are meeting these challenges with varying degrees of effectiveness. Materials considerations often appear not to be addressed until late in a project.

2. The PPMS promises to provide the kind of management control hitherto lacking, and the Working Group strongly endorses its thorough implementation. However, even this system appears not to contain a requirement for formal design reviews that would include materials considerations to insure design and technology integrity. The PPMS does not yet appear to have been applied extensively at the program and project level.

3. A key to the success of the military programs conducted by the Department, appears to be the continuous, fully integrated involvement of materials experts from initial system design through development, production and operational evaluations. These programs also benefit from procedures that insure that the management system operates as a closed loop and incorporates feedback from users in the engineering design.

4. The low level of materials R&D in Energy Technology (ET) is a matter of special concern. A recent policy memo by the Assistant Secretary for Energy Technology to the Director of Energy Research (ER) entitled, "Basic Research in ET", and dated October 11, 1978, addresses the need to support additional research (all aspects) within ET and specifically proposes additional funding allocations within ET for research related to the fossil program. Assuming that a portion of these funds will be applied to materials R&D, this policy can be used as a vehicle to improve the support of materials R&D within ET.

5. The conduct of materials R&D intended to support longer range objectives has no spokesman or point of accountability within the organizations of the several Assistant Secretaries responsible for materials R&D nor is there a focal point for activity integration within DOE. Its fragmented and uncoordinated character make it vulnerable as a prime candidate for cutbacks under budget pressures.

2. Technology Base - Timeliness in Identification of Materials Problems

Issue #2. Timeliness in Identification of Materials Problems Which Are Judged to be Critical to Future Energy Systems From Both Performance and Economic Viewpoints or to be Potentially Important to a Number of Programs and/or Projects.

A. Mechanisms for Assuring Early Problem Identification and Attention

Question. What mechanisms exist at each level of the organization for assuring early identification of, and attention to, potential critical materials problems?

To give an example of the scope of this issue, a list of current critical materials problems in energy systems, collected by EMACC, is presented in Appendix C-1. Near-term and long-range materials technology problems have been well assessed in the following documents and those listed in Appendix B-1. These identify critical problems and suggest priority ordered R&D programs to attack them.

1. "Materials Technology in the Near-Term Energy Program, Report of the Ad Hoc Committee on Critical Materials Technology in the Energy Program to the Science Advisor to the President," National Academy of Sciences, September 1974. The period 1975-1985 was considered.

2. "A Federal Look at the Needs for Energy-Related Materials Research and Development, Volume 1: Near Term Energy Program" (ERDA 76-28V1 preliminary version) prepared by the Energy Task Group, Committee on Materials (COMAT), Federal Council for Science and Technology, August 1976. The intent of this report was to specify and to set priorities on the materials R&D efforts needed to meet the objectives of the then current National Energy Plan. The planning horizon again was 1985, but the objectives were taken to include some specific milestones in programs with a longer term payoff.

3. "Materials Sciences Overview, Report of a Series of Workshops Recommending Future Directions in Energy-Related Basic Materials Research," (ERDA-77-76/1-2, dated August 1977) organized and reported by L. C. Ianniello et al, Materials Sciences Program of the ERDA Division of Basic Energy Sciences. Nine workshops involved a total of 380 scientists and engineers and addressed promising research areas as well as critical needs. Overviews of each energy technology and of conservation were presented at each workshop. This was a highly productive and pertinent exercise.

4. "The Fusion Reactor Materials Program Plan" (DOE/ET-0032/1, -2, -3, -4, dated July 1978) prepared by task groups under the direction of Materials and Radiation Effects Branch, Office of Fusion Energy. A brief description of this plan is presented as Appendix C-2.

The Working Group has not made a systematic attempt to list all such planning documents. There very likely are others pertaining to specific technical areas, but these alone provide a very broad coverage. The BES Materials Sciences Program, in part working through EMACC, is continually active in seeking new and updated problem descriptions to guide its program in addition to the milestone series of workshops (report 3, above). It has held many topical workshops on problem areas of energy technology, and its staff attend meetings and reviews held by the applied materials programs. Two innovations of the Program are Research Assistance Task Forces, set up to bring scientific assistance to explicit applied problems (e.g., cannister materials) (e.g., surfaces). The outlay program addresses generic problem areas rather than specific problems.

The Fusion Reactor Materials Plan is the result of a very broadly based and effective effort in near- and long-range problem identification and systematic R&D planning. Very importantly, the Fusion Materials and Radiation Effects Branch has also published six bulletins giving assessments of problem areas and suggested solutions. Task groups have been appointed and are actively leading the R&D programs of the Fusion Materials Plan. Materials problems defined during fusion systems studies are iterated with materials people both at DOE and in the field.

The Development Requirements Specifications (DRS) documents used by RRT to address specific development needs (see Issue #1) form a systematic vehicle for identifying and characterizing materials problems.

Fossil energy projects typically represent advanced derivatives of existing industrial materials technologies. In these, the materials problems are regularly identified and are generally associated with near-term incremental advances in the state-of-the-art.

B. Procedures for Factoring in Environmental and Commercialization Considerations

Question. How does the Department insure that environmental and commercialization considerations are factored into materials R&D requirements?

The following is extracted from a more complete EV statement of materials related program policies and concerns (Appendix D 7).

Environmental planning and review requirements are an integral part of the Program and Project Management System for DOE Outlay Programs.

Of special note are those requirements which relate to the National Environmental Policy Act (NEPA), and the development and preparation of Environmental Development Plans (EDP) and Environmental Readiness Documents (ERD). The purpose of these documents is to assure that health, environmental and safety considerations are identified and dealt with at appropriate decision points throughout the energy RD&C cycle.

The principal environmental requirements and their intersection with the Program and Project Management System are illustrated in Figure 2. The figure provides a representation of how environmental activities and their documentation work to support the removal of barriers and identification of uncertainties that must be considered within the technology movement to commercialization, production or operation.

EV has a formal responsibility for developing mechanisms, in close cooperation with other DOE offices, for the preparation of Environmental Development Plans (EDP). The policy, responsibilities and procedures for the EDP system are set forth in DOE Order No. 5420.1, a copy of which is attached to Appendix D-7. EDP's were conceived and prepared as basic documents for planning and managing environmental

PRINCIPAL ENVIRONMENTAL REQUIREMENTS IN THE PROGRAM AND PROJECT MANAGEMENT SYSTEMS

Figure 2

requirements of energy technology development including aspects of development related to materials. Approximately 33 EDP's covering the major energy technologies have been prepared. These EDP's are updated annually to assure that all potential problem areas are considered so that appropriate steps can be taken to remove or control environmental barriers to eventual commercialization. In addition, Environmental Readiness Documents (ERD) have been prepared for projects proposed for near-term commercialization.

The recent Commercialization Task Force (CTF) activities have provided a means for factoring commercial (and other) considerations into new technology program planning. How the findings of the CTF reports will be reflected in formal program planning and control documents remains unclear. As indicated in Appendix D-5 from CS, there appears to be no formal means of coordinating the materials research done by ET and ER, for instance, with the materials requirements of CS. Appendix D-5 outlines a proposed "Materials Coordination System," suggested by CS as an approach to assuring all relevant materials considerations are formally brought to bear at each stage of developmental projects carried out under the Program and Project Management System. It calls for the earliest materials input to appear in program plans including those for technology base activities.

Recently, it has been announced that as an implementing follow-on the Commercialization Task Force reports, Resource Managers will be appointed to lead the selected Energy System Acquisition Projects (ESAPs). They will be given authority over the elements of the ESAPs in all Assistant Secretary offices ("matrix approach"). They should, therefore, be in a position to promulgate requirements and see that they are met.

C. Use of Basic Scientists in Defining Problems for R&D.

Question. How are the skills and insights of basic scientists such as those supported by BES used in defining materials problems in a format that will promote the most promising R&D programs toward their solution?

All four documents cited above were developed by groups containing almost a full spectrum of relevant scientific disciplines along with applied scientists and engineers working in the important

energy technologies. The further topical workshops, the Research Assistance Task Forces, and other activities of the Materials Sciences Program to bring technology problems to the attention of the Basic Energy Sciences community are continuing efforts along these lines.

D. How Well the System is Working

Question. What data bear on how well the system is working?

The listed documents are good evidence of effective problem identification. The Fusion Reactor Materials Program Plan displays the development and initial implementation of effective R&D plans toward problem solution in the fusion area.

Whether the various other programs aimed at near- and intermediate-term commercialization are effectively addressing all relevant problems, will probably first be known from reviews of their Energy System Acquisition Project Plans.

Attempts to stimulate technology base activities by use of development-project materials needs statements have met with mixed success. This is an aspect of the "linkage" problem, the subject of Issue #3.

E. Conclusions

1. A number of ad hoc studies and workshops have identified numerous technologically critical materials R&D problems. Presentations to EMACC have described the problems of current concern to most of the technology development programs. There is as yet no systematic means of assuring that these needs are reflected in program plans.

2. There is no formal mechanism for coordinating the materials research in ET and ET with the many types of requirements that must be met in a commercially produced operational system. The Resource Managers, recently appointed in Conservation and Solar Applications (CS) and Resource Applications (RA) to guide technology efforts toward commercialization are apparently expected to perform this function. However, it is unlikely that this will be done effectively since planning review requirements have not been made an integral part of the PPMS in CS and RA. In contrast, this action has been taken in Environment (EV).

3. Basic Sciences - Effectiveness of Linkage Between Activities in the Division of Basic Energy Sciences (BES) and Technology Development Programs

Issue #3. Effectiveness of Linkage Between the Basic and Applied Materials Activities in BES, the R&D Programs and the Technology Development Projects.

The word "linkage" can be used in three different senses relevant to this issue:

1. The transfer of basic research results into applications.
2. Availability of BES scientists to respond to programmatic needs for guidance and/or participation in problem solving tasks.
3. Continuity of effort between basic research and research specifically supporting technology development.

The information-flow aspects of "linkage" are covered under Issue #4.

A. How BES Materials Program Supports Technology Development

Question. How does the BES Materials Sciences Program Support the Technology Development Projects and programs?

The basic Materials Sciences Program is not only concerned with present problems or perceived problem areas but also aims to provide the foundation for the solution of unforeseen problems and the basis for new developments which may not have an application for many years. How effective this latter aspect of the program is can only be assessed by looking to past achievements. One such examination was done and the results published in the report, "Applications of Fundamental Materials Research." Part of the justification for doing basic materials research lies in the justification for doing basic research itself. The history of the transfer of basic research to actual use for energy applications shows important examples of success - witness the present nuclear reactors providing electrical energy, which all started with research aimed at understanding the basic structure of matter. In the materials field the interaction is more intimate and on a day-to-day basis, since all structural components of energy systems require knowledge of how materials behave.

The transfer of basic research results into actual application occurs on a number of levels including the ability of experts to consult on new and unpredicted phenomena (see discussion under Issue #4); the training of materials scientists who can apply novel techniques to help solve industrial problems; the development of new techniques and instrumentation; and the understanding of materials phenomena which is incorporated into the design of new energy systems. It is well known, however, that basic research results do not flow in a simple manner from the laboratory to commercialization, and the results are often used in unpredictable or diffuse ways. Progress in the area of design of materials to meet engineering requirements is being made in a number of energy areas, including: pressure vessels for fossil and nuclear plants, cladding for nuclear fuel, superconducting coils for fusion reactors and solar photovoltaic cells. Several good examples of the application of materials science in the design of actual materials for energy systems can be cited which have grown out of this program. Design of materials for future plants may be of even more significance in view of the safety, environmental and critical materials shortages envisioned.

BES is active in soliciting technological problems to serve as guides to important areas of research for both universities and National Laboratories. This has been discussed under Issue #2. BES insists that the National Laboratories analyze the technologies, identify areas needing basic research attention and reflect this in the 189 forms. Such suasion is not applied to university supported research, although the problem areas are made known to the proposers through such documents as the Materials Sciences Overview Workshops, reports of workshops on specific problem areas (e.g., stress corrosion cracking, polymers, etc.).

B. Energy Technology and Other Development and Demonstration
Organizations View of Support Received from BES Materials

Question. How do ET and other technological organizations view the support they receive from BES Materials?

The Defense Programs Office acknowledges that BES "has been a major contributor to basic research of interest to defense programs."

Magnetic Fusion Energy appears to enjoy very good linkage with BES/Materials in all three senses of the word. A statement on this subject attests to the good interaction, the historic organizational ties, workshops, strong funding in fundamental radiation damage, and beneficial research support in several other technical areas. It should be emphasized that the Materials Sciences Division provides fundamental research in areas of applicability to the fusion program rather than solutions to specific problems. Although informal cooperation is excellent, no formal mechanisms for collaboration exist, and contributions of the Materials Science Program activities responsive to the needs of MFE are determined by the staff of the Materials Science Division. However, the two divisions fund complementary programs at the same contractor location. Preliminary results suggest that the most effective cooperation has been achieved at ORNL where individuals within the same group are working on complementary problems. Section II of the Fusion Reactor Materials Program Plan, "Damage Analysis and Fundamental Studies" was drawn up with major input from contractors of the Materials Sciences Program. It serves as a document in which guidance is provided to independent researchers on the needs of the fusion program.

The Office of Naval Reactors (NR), with more immediate and narrowly defined needs, finds less usefulness in BES research products. This is in part because these products relate to such idealized materials that they are seldom relevant to the alloys or other specific materials with which NR must deal. Moreover, NR finds it difficult to identify from the BES task descriptions (in the annual program book for instance) many materials studies with possible applicability to their programs. NR relies primarily on applied research, mostly empirical, by their dedicated contractors for their materials needs. They have not made a recent expression of their needs to BES.

There is a perception, at least in parts of ET, that the BES materials research is in areas primarily relevant to magnetic fusion, advanced weapon systems, and advanced LMFBR fuel and materials problems. The Working Group has not developed systematic data on this, but it should be noted that this program had its origins in the Atomic Energy Commission and at the time was restricted by law to areas related to nuclear energy. With the activation of the Energy Research and Development Administration in 1975, the responsibilities of this

were automatically broadened to cover all energy technologies, but without a commensurate increase in funding. As a result of progressive reorientation of projects and reprogramming of funds, the staff of the Materials Sciences Program analyzes its FY 1979 program in terms of activities of fundamental interest to the technologies as follows:

Conservation	11.5%	(e.g., turbine blade materials)
Fossil	11.1%	(e.g., erosion, catalysis)
Solar	7.7%	(e.g., photovoltaic materials)
Geothermal	1.8%	(e.g., pipescaling)
Fission	7.4%	(e.g., radiation damage)
Fusion	9.2%	(e.g., hydrogen and helium effects)
Environment and Safety	2.1%	(e.g., fly ash phenomena)
Multi Technology	23.7%	(e.g., stress corrosion cracking)
Long Term	<u>25.5%</u>	(e.g., magnetic structure of solids)
TOTAL	100%	

*Down from 48% prior to 1975.

In this analysis, the term "Multitechnology" refers to research that is important to two or more technologies; for example, superconductivity that is important to magnetic fusion, underground power transmission, electric energy storage, and advanced motors and generators (conservation). "Long term" designates research of a fundamental nature that is not related in an obvious way to any currently perceived energy problem area; for example, studies of the phonon structure of solids using neutrons from research reactors as the investigative tool. (The DOE Materials Science Program supports close to 100% of all U.S. basic research in the field of neutron diffraction and neutron scattering because the most powerful U.S. neutron sources for research purposes are located at DOE installations.)

Where BES-supported research scientists are co-located organizationally and especially physically with technology development personnel, useful two-way information flow exists and the groups

support each other effectively. Examples at ORNL have been cited by RT and Magnetic Fusion Energy.

There has been a reluctance in some parts of ET to fund basic and even some applied research, especially during the past year. The memo of October 11, 1978, cited earlier, gives policy guidance that should correct this. Accordingly, this report will not attempt to detail the previous situation or the rationale given for it. As regards that Issue #3, the most important statement in the memo is:

"I am pleased that your (ER) and my (ET) view is consistent with the view expressed by the Office of Science and Technology Policy (OSTP) Committee on Basic Research in DOE, chaired by Sol Buchsbaum. The essential feature of this consistent view is that research -- work undertaken under the budget categories "basic and applied research" (6.1) and "exploratory development," (6.2) -- must be an integral part of the ET technology programs."

Adding significant technology base activities in ET should, along with other benefits, encourage the linkage with BES. The people engaged in those activities will be in a position to respond to the immediate needs of systems developers and will, in their own work, encounter the kinds of fundamental problems to whose solutions BES programs can contribute. The required linkage cannot, however, be expected to develop without the dedication of qualified technical personnel to this critical management function.

The University Coal Research Program, now in an early planning stage, could enhance the linkage both by the nature of the research itself and by the fact that a great fraction of fossil research up to now has been carried out by industry - with no support from or other linkage to BES/Materials.

C. Conclusions

1. The BES materials Program serves the Department well in terms of research results and other products of a basic research activity.

2. The coupling of this basic effort to the development programs requires that these individual programs devote resources to basic and applied materials R&D. A basic materials program should not be expected to solve all of the problems encountered in a development program, but it can provide valuable assistance if the individual development program has the requisite technical, management and budget resources properly to carry out the required applied research and development.

3. The policy announced in the October 11, 1978, memo, "Basic Research in ET" referred to above, could go far toward improving the linkage between BES/Materials and the program offices of ET as it is implemented.

4. Data, Information and Experience Exchange - Degree to Which this is Organized and Productive Throughout DOE

Issue #4. Organized and Productive Exchange of Materials Data, Information and Experience Between R&D Programs Throughout the Department.

A. Information Exchange Mechanisms and Measures of Adequacy of that Performance

Question. What information exchange mechanisms exist? What are the measures of adequacy of their performance?

The Energy Materials Coordinating Committee (EMACC) has been briefly described in Section III. This unofficial committee, which is supported by the Director of Energy Research, is the Department's major agent for coordinating Headquarters personnel administrative interactions, especially the planning of new programs. Its range of action is somewhat limited by its unofficial status.

According to its "unofficial" terms of reference the purposes of the EMACC are:

1. Achieve more effective coordination of all materials research and development.

2. Assure optimum use of DOE's existing expertise in the field of materials research and development.

3. Evaluations: The EMACC shall identify areas for increased emphasis or areas of opportunity as the need arises (upon motion of a member, with his Division manager's prior concurrence); or respond to requests from Department higher management.

4. Reporting: The EMACC shall prepare and circulate minutes of each meeting. Its members shall report on its activities to Division Directors; it may bring certain matters to the attention of still higher levels of management.

The EMACC endeavors to perform a broad range of functions:

1. Technical seminars, programmatic information exchange, and problem discussions at meetings.

2. Topical reports.

3. Overview data on DOE materials program - not accessible through budget documents.

4. Interlock with external (e.g., DOD) materials committees.

5. Annual Technical Report.

6. Annual Administrative Report.

7. Solicitations of problem lists from technology areas.

The various DOE divisions differ in their participation and in the degree to which they find these activities useful to them. The positive ones are very positive, indeed, and offer examples of concrete benefits of the interactions.

Generally, participation by the nonnuclear technologies has been spotty at best. As a result, surprises sometimes occur. For instance, it was only in November 1978 that several interested EMACC members became aware of a \$43M program in ceramic engine work in its second year under sponsorship by CS (which is not an active EMACC supporter). The ceramic research work being conducted under this program well exceeds that going on elsewhere in the Department and promises to influence a number of programmatic decisions in ET.

Close coordination among national laboratories, universities and industry is achieved in a number of ways. First, research results are published in the open literature, and the whole system of scientific "rewards" is based on achieving new results and not duplicating research elsewhere. To enhance this openness, annual information meetings are held at all the major laboratories where other laboratories, universities and industry are invited. At the Headquarters level, publications are prepared and widely distributed on an annual basis summarizing the work underway throughout the Materials Sciences Program. In addition, topical meetings are held (e.g., solar-related materials research) and workshops are held (e.g., stress corrosion cracking) which bring together researchers from all sectors of the program. Research results are also discussed at technical society meetings - this is encouraged. The Laboratories each have review committees comprised of distinguished scientists from industry and universities which report to the Director of the laboratory on quality and on possible overlap with other research.

The Materials Sciences Program conducted an overview of the total program in 1977 by means of a series of nine workshops. A total of 380 scientists and engineers participated - from the National Laboratories (37%), Universities (33%), Industry (15%), DOE (8%) and other laboratories (7%). Reports of the workshops (cited under Issue #2) have been published, widely distributed and are available. Sections of the reports have appeared in technical journals and the entire set will appear in the international journal, Materials Science and Engineering. The workshops provided another mechanism for focusing on priorities. Their recommendations are key factors in assigning the areas which will receive emphasis in the Materials Sciences Program. Both basic researchers and technology representatives were present at these workshops. Unnecessary duplication was not found to be a significant problem. Instead, the lack of appreciation of the materials problems in energy systems is a persistent theme.

Defense Programs participates in EMACC and in the Hydrogen Energy Coordinating Committee (HECC), a spin-off of EMACC. The limitations imposed by Classification constrain DP in its ability to reciprocate the benefits from the knowledge it receives concerning other programs and technologies. The DP statement of views and observations (Appendix D-1) describes the modes of information exchange within DP activities.

In the Reactor Materials Branch of NR, it is found that because of the nature of the work, the information exchange activities are tied more closely to the commercial reactor industry than to other parts of DOE. Thus, the NR organization receives all reports from the Electric Power Research Institute (EPRI) (along with relevant published literature) and finds these at least as useful as the publications coming from other parts of DOE. NR does publish information (mostly internally); for instance, there have been 250 technical reports on the Light Water Breeder Reactor (LWBR). These are listed in the LWBR Environmental Impact Statement.

Materials information generated under RRT programs is documented and distributed in the form of progress and topical reports required as specific milestones in the control document (189a) for each program. These documents are distributed both within and outside DOE in accordance with the guidance given in TID-4500-R66, Standard Distribution for Unclassified Scientific and Technical Reports, September 1977.

The Fusion Materials Program publishes quarterly and/or biannually reports in each of four task areas. These reports contain contributions from each contractor working in a specific task area such as alloy development, for instance. Thus, a single report summarizes progress in a given task area on a periodic basis.

The Fusion Materials Program also participates in the Nuclear System Materials Handbook sponsored by RRT and managed by HEDL and is currently making plans for issuing preliminary evaluated data sheets for the Fusion Program similar to those now being used for the nuclear programs. It has been suggested from time to time that this handbook, which provides evaluated data for design purposes on a variety of materials through a series of working groups which collect and analyze such data and prepare it for review by other experts in the field, be expanded to become an Energy Systems Materials Handbook for use by all energy technologies throughout DOE.

A second project of a similar nature is the ongoing Data Storage and Retrieval System (DSRS) at ORNL for mechanical property data on commonly used materials. This capability likewise could be expanded to serve all of DOE.

In Fossil Energy, Geothermal and Naval Reactors, information exchange occurs primarily with industry--with corresponding advantages claimed (see Appendix D-3). FE distributes a quarterly newsletter (based largely on contractor progress reports) and containing advanced information regarding materials performance.

B. Documentation that Identifies Sources of Expertise

Question. Are specialized sources of materials expertise identified in documentation that is available across the organization?

The annual Materials Sciences Program Summaries identify several hundred principal investigators. Where there is a need for some specific expertise, the EMACC could perform an effective search function.

C. How Well the System is Working

Question. What data indicate how well the system is working?

Only anecdotal data have been collected, but it is possible to use these to establish a positive evaluation despite the presence of some negative attitudes toward the value of EMACC.

There appears to be a fair correlation between attitudes toward EMACC's value and attendance at its meetings. There is one instance of a nonattending organization initiating a search for materials information that had in some measure just been published by EMACC.

It is clear the EMACC would enjoy broader participation and be of more use to the Department if it were given an official role and position in the DOE and if its charter were broadened somewhat. It plays a useful role in assembling department-wide data about materials R&D for use by management. However, EMACC cannot serve as a substitute for the dedication of full-time technical management personnel, especially in Energy Technology.

D. Conclusions

1. The EMACC is the only organized DOE internal vehicle for the exchange of materials R&D information, data and experience at the "grass roots" (i.e., project manager) level. EMACC evidently serves a needed function within DOE although the Working Group received varying opinions as to its present usefulness.

2. The EMACC would be of greater benefit to the Department and perform more consistently if it were given an official role and position in the DOE with corresponding resources with a charter somewhat broader than that currently being used on an ad hoc basis.

5. Coordination with Other Agencies and Organizations - Nature and Utility

Issue #5. Coordination with Other Federal and State Agencies, Non-Government Organizations and Non-Domestic Agencies.

There is considerable Congressional interest in Federal materials R&D coordination as exemplified by recent GAO and OTA reports (by the Comptroller General, Report to the Congress, "Management of Federal Materials Research Should be Improved," EMD-78-41, July 14, 1978) and bills now before Congress. Some of the Congressional concerns include:

1. Present and future materials inventory relative to national needs.

2. Large economic impact of certain general materials problems such as corrosion.

3. Materials as a very large component of the Federal R&D effort and one difficult to assess.

4. Vast amounts of materials data and a corresponding need to assure its availability to meet technical needs and to forestall unnecessary experiments to reacquire it.

The Working Group investigation has been mainly directed at coordination in the sense of information flow and assurance of nonduplication.

Information to be exchanged among agencies take three major forms:

1. Technical - R&D results: Mostly accomplished through professional society meetings, journals, and exchange of technical progress reports.
2. Technical - Problems: Requires specialized workshops which join people having problems (technologists) with people who have potential solutions (researchers).
3. Programmatic: Meets the requirements of those with program management responsibilities. Its purpose is to look for duplication (seldom found), commonalities among research problems where one agency may be of assistance to another, and manifest aspects of program management.

A. Mechanisms of Coordination

Question. What mechanisms of coordination exist?

The senior official organization for interagency information exchange on materials matters has been COMAT, the Committee on Materials of the Federal Council for Science, Engineering and Technology (FCCSET). COMAT was established in 1975 as a successor to ICM (the Interagency Council on Materials reporting through the NAS/NRC to the President's Science Advisor 1969-1973) and the CCMRD (Coordinating Committee for Materials Research and Development of the Federal Council for Science and Technology 1959-1969). COMAT was disestablished on June 30, 1978, as an official body of FCCSET by letter from F. Press, FCCSET to T. A. Henrie, Chairman, COMAT, dated June 30. The reason given was to strengthen the role of FCCSET by focusing "its attention on significant national, scientific and technical issues cutting across Government departments and agencies."

COMAT has elected to continue to meet on an ad hoc basis and Dr. Press has expressed the hope that its Chairman (Henrie, Bureau of Mines) will keep FCCSET informed of its activities and provide copies of reports, actions, and recommendations. It meets approximately every 45 days to exchange information on agency materials R&D programs, upcoming Congressional legislation, events and activities both foreign and domestic of common interest, and discuss issues. It is dominated by natural resource interests (Bureau of Mines), a significant change from ICM and CCMRD, which were more interested in materials R&D.

COMAT is sponsoring an inventory of materials R&D in the private sector - Battelle Memorial Institute being the contractor - with funds (approximately \$250K) contributed by member agencies - \$50K from BES Materials. Task 1 of a separate three-task effort was assigned to the Bureau of Mines and led to a report entitled "Life Cycle Research and Development in the Federal Government - Fiscal Year 1976". The other two tasks of this second effort are as follows:

Task 2 - "Determine materials requirements and Government-sponsored materials R&D for the near- and long-term energy program - assigned to ERDA (referred to in Section IV). The publication situation as of December 1978 was:

Vol. 1 - Near-Term Energy Program is available as ERDA-76-28 VI (Preliminary Version)

Vol. 2 - Long-Term - never released.

Task 3 - Develop a governmental perspective between need for production of industrial materials, the maintenance of a safe environment and preservation of physical well being - assigned to EPA. The report was never completed (?) or released.

D. K. Stevens of BES is the present DOE representative to COMAT. The agenda of the September 29, 1978, meeting lists the following subjects for discussion:

FCCSET Contacts	Henrie
Non-Fuel Mineral Policy Study	Henrie
DOD Materials Availability Committee	Persh
Materials Policy Legislation Hearings	Stevens
Corrosion Workshop	Huddle
Henniker Conference	Henrie
COMAT Inventory Study	Schwartz
International Cooperation in Materials R&D	Kovach
DOE Materials Coordination Committee	Stevens

The various program offices seem to have widely varying practices in this area. An excellent example is set by the Naval Reactors Division (NR) with a prominent policy of thorough, documented and reviewed development step. The Reactor Materials Branch of NR is intimately involved in this process. In Naval Reactors, a program implementation is accomplished through dedicated contractors, but technical direction resides in Headquarters. Project managers and functional branch chiefs (e.g., the Reactor Materials Branch) work closely together. Their coordination is enforced by Admiral Rickover's requirement that each concur on every relevant piece of correspondence in the organization. The Reactor Materials Branch carries responsibility for materials in all phases of projects: development, definition of end-item requirements, fabrication, operations and post-operational inspection.

In Defense Programs (DP), Reactor Research and Technology (RRT) and Naval Reactor Programs and Projects (NR), materials people are made part of the effort at all stages including requirements definition, system design teams, and test and operations. In DP the nuclear weapons laboratories have developed their own organizational philosophies and management systems. Appendix D-1 describes the DP philosophy and the laboratory management systems. It is worth noting that NR and DP offer, respectively, examples of centralized and decentralized management systems, both of which have enjoyed considerable measures of success.

Reactor Research and Technology (RRT) has had a procedures system in place for five years which assures that project materials needs are identified and that R&D to satisfy these needs is initiated and properly managed either by the base technology program or the project organization to meet these requirements. This system has as its first step the formulation of Development Requirement Specification (DRS) documents in which development needs and programs to satisfy these needs are described (See Appendix D-2). A significant number of these DRS's address materials development requirements. In addition, RRT also has an effective system of formal design reviews (required by RDT Standard F 2-2, Quality Assurance Program Requirements), which specifically include materials considerations.

Interagency coordination of basic materials science research occurs through monthly meetings at the NSF of working level staff of the sponsoring agencies - AFOSR, ARO/D, ONR, NSF, NASA, DOE, and Bureau of Mines. The estimated level of Federal support for fundamental materials research is \$200M (FY 1979) of which DOE is one third (\$70M, BES Materials Sciences) and over one-half is expended in the university sector. Emphasis at these monthly meetings is placed on the administration of the university portion. Information is exchanged on staffing changes, program directions, budgets, actions on proposals under consideration, support of conferences and workshops, new thrusts, and pertinent policy matters such as support of foreign travel (general and to specific important foreign conferences), multiagency support, implementation of the Freedom of Information Act (e.g., release of peer review documents) and the Privacy Act (e.g., disclosure to other agencies of support levels or reasons for proposal declination), and uniform approach to requirement of total disclosure of research support prior to contract or grant award, as examples.

These monthly meetings are supplemented almost daily by telephone contacts concerning commonly held proposals, generation of statistics concerning the entire field or specific sub-areas, cooperative efforts, etc.

This same type of interagency coordination takes place in other basic research fields such as chemistry, physics, high energy physics, and geosciences, as examples.

Other, less direct, interagency coordination takes place through liaison participation in activities of the NAS/NRC such as the National Materials Advisory Board, the Solid State Sciences Committee, and the Committee on Chemistry.

Defense programs have special mechanisms for exchange of information in the classified area. Several formal information exchange groups exist between the DOE, DOD, the individual military services, and the Defense Nuclear Agency. These groups discuss any pertinent materials problems. Joint working groups (JOWOGS) were established many years ago to provide for information exchange between the U.S. and the United Kingdom, with the weapons laboratories participating. The various JOWOG groups, some of which deal specifically with materials, have also served as channels for exchanging information between the U.S. weapons laboratories.

Further information exchange of a particularly useful nature takes place through the exchange of scientists between DOE labs and foreign labs.

There is a Materials Advisory Group, made up of representatives from Government laboratories. This group has been asked to provide an overview of the materials needs of the gas centrifuge program under RA. There, a key materials development problem is rotor materials, which are a classified subject in an otherwise unclassified program. Without this assistance, the project manager had to guess who was most qualified to support him on these problems and to solicit help.

The Naval Reactors Office finds the most profitable information exchange occurs with counterpart groups of the Navy.

Existing and proposed "technology centers" in DOE and other agencies (e.g., NBS) could be natural vehicles for technical information exchange in selected areas. An example is ORNL's proposed Structural Materials Engineering Technology Center.

B. Data on Whether the Coordination is Adequate and in Most Effective Form

Question. What data bear on whether the coordination is adequate and in the most effective form?

Objective data regarding adequacy of coordination have not been found. No problem areas in interagency coordination have been brought to the Working Group's attention. However, there is a general impression that the effectiveness of the COMAT is sure to deteriorate without official sponsorship and formal agency participation.

Aside from other agencies, areas that would apparently benefit from some attention are coordination with industry and greater use of professional standards groups.

C. Conclusions

1. The disestablishment of COMAT, the FCCSET Committee on Materials causes concern in that it is very likely to reduce the effectiveness of interagency coordination and interaction.

2. The Group found that much informal contact between agencies nevertheless exists (meetings, working groups, etc.). Varying opinions as to the effectiveness of these activities were again received, attesting to the general lack of formal coordinating mechanisms for energy and energy-related materials R&D.

6. Balance of Effort - Budget Categorization amongst Universities, Industry, DOE Laboratories and Centers and Other Government Research Centers

Issue #6. Balance of Effort Among Universities, Industry, DOE Laboratories and Centers, and Other Government Research Centers.

Clearly, this issue in its broadest terms involves considerations that far transcend the sphere of this study and even of the DOE. This report will be limited to a few observations on the current budget categorization, present policies and their effects on the efficacy of materials RD&C.

The subject is complicated by difficulties of definition, which make statistical data and categorical arguments inherently imprecise and often misleading. For instance, functionally and organizationally Lawrence Berkeley Laboratory is somewhere in the continuum between a National Laboratory and part of a university. Dedicated contractors are similarly somewhere between National Laboratories and industry. National Laboratory work that is carried out primarily by industrial subcontractors is difficult to categorize and segregate by budget examination. There is even some limited overlap of functions between Operations Offices and National Laboratories (where subcontracting merges into program management). The most meaningful question, thus, seems to be as to whether given arrangements best serve the needs of the Department and do not violate Federal policy. The most meaningful statistics might be those based on the performance of assigned manpower, and even those are of bounded meaning.

A. Criteria for Determining Appropriate Locations for R&D Elements

Question. What are some criteria for determining appropriate locations for elements of materials R&D?

The Working Group has not discovered policy statements on this subject. Several DOE offices and projects give rationales for existing assignments that probably reflect criteria applied in the past.

A common observation cited earlier is that at each stage of an RD&C activity different kinds of materials responsibilities come into play (see Part 2, Section III, Figure 1), but it is crucial at each stage that materials specialists interact intimately with analytical, design, test and manufacturing engineering (and no less with project management) to be genuinely effective. The implication is that materials support for each program or project should reside physically and organizationally with the managing and implementing elements of the program or project.

It is reasonable to expect that the level of materials R&D at a DOE laboratory is linked to the advanced materials needs of the projects assigned to that laboratory. An analysis has not been attempted. The Naval Reactors Program, technically directed from DOE Headquarters and implemented through dedicated contractors, epitomizes the approach of closely coupled materials support.

Defense Programs have been required to develop most of their technology base within their own complex of government-owned, contractor-operated facilities because of weapons secrecy and other limitations imposed by statute, uniqueness of weapon and fusion technology, and the fact that most outside sources do not provide the wide base of technology required. They place high priority on maintaining a broad technological base within the weapons laboratories to insure that their future program goals can be met. That technology base is directed toward those physical and engineering sciences and technologies which can be specifically identified as being uniquely relevant and applicable to near- and intermediate-term problems.

The CS and RA programs, directed at advancing technological performance within existing industries or at near-term commercialization of maturing technologies, generally implement materials (and most other) R&D through industry. However, industries with a need for specialized fundamental knowledge sometimes turn to universities.

The Magnetic Fusion Reactor Materials Program is not only being conducted at a number of university, Government and industrial laboratories, but the program management itself is being guided by task groups of equally broad membership.

Fossil Energy emphasizes many of the same considerations as CS and RA regarding existing and pending commercialization. A practical consideration of FE missions clearly shows the importance of enlisting a favorable mix of industrial participation at the earliest possible stage and in the maximum depth. This includes materials R&D. The kind of high technology industry involved in some FE projects has often, by necessity, built up strong materials R&D capabilities - including the basic sciences. This is particularly so in power equipment manufacturing. FE programs generally reflect the policy that, whenever possible, for the sake of the overall development efficiency, such highly qualified industries should carry the bulk of the relevant materials R&D work. FE does use DOE laboratories in some lead center capacities as noted in Appendix D-3.

B. Criteria Bearing on Balance

Question. What are criteria bearing on balance per se?

The Working Group has found no criteria bearing on balance. The present distribution (FY 1978), as presented in Part 2, Section V, Table IV and bearing in mind the cautions given above about the imperfect definitions of assignments is, for all DOE-sponsored materials R&D:

University	11%
DOE Laboratories	59%
Industry	30%

For the strictly nonmilitary efforts, the distribution is:

University	17%
DOE Laboratories	36%
Industry	47%

This distribution does not seem inconsistent with the DOE mission related to technology development. In a more precise calculation, the DOE Laboratories figure should be reduced by some part of the funds applied to large specialized research facilities and service activities which serve the broad R&D community (e.g., research reactors, NSLS).

C. Mechanisms that Determine Existing Assignments

Question. What are the mechanisms that determine the existing set of assignments of materials R&D?

The Working Group has collected no objective information on this subject. Some of the rationales (as distinct from mechanisms) have been cited above for major assignments. Once made, such assignments tend to persist and become inextricable parts of institutional infrastructure. Assignment of laboratory roles and missions is apt to change this--as a similar process occurred in NASA laboratories.

Decentralization of project/program activities will place greater responsibilities on DOE laboratories and cause a growth of the proportion of R&D effort placed there (especially as amplified by pass-through funds) unless offset by other reassignments. It is worth noting that this move will make an incremental change in the intra-laboratory balance of effort between management and technical work with fundamental institutional implications.

D. How Well the Existing Balance of Effort Serves DOE

Question. How well does the existing balance of effort serve DOE?

This has not been systematically examined. The question can probably only be approached in the context of an examination of the total R&D balance - with that examination guided by a long-term

projection of the level of DOE R&D and by some statement of national policy regarding appropriate roles and sizes of Federal laboratories. Short of that, investigation could be limited to a search for efforts that are obviously out of place - e.g., unrelated to the mission of a given institution.

Some observations of present practices and attitudes will be given. Defense Programs and Naval Reactors make a special point that their institutional arrangements are key strengths of their programs. Several ET offices with near- and intermediate-term materials goals find the basic science activity of limited support and feel that a greater infusion of industrial participation would result in the basic work being better guided by practical needs. Presumably, the basic research programs to be built up with ET will reflect this orientation.

While some Fossil Energy Centers appear to have little or no materials research (Part 2, Section V, Table V), this field is one in which industry must by necessity carry the bulk of responsibility in materials R&D. This is because materials and processes are inextricably tied to specific design requirements. Materials R&D, to meet these requirements, must be closely tied in with design, analytical, and test engineering. The adequacy of the R&D effort in the Centers can only be assessed by a technical evaluation, but the Working Group questions whether effective, high technology project management by these Centers can be done without in-house materials experts. The latter, as active researchers, would require a visible R&D investment.

E. Conclusions

1. The Group limited its treatment of the matter of balance between national laboratories, universities and industry to the gathering and analysis of budget data.

2. A budget breakdown based on the data received suggests that the funding distribution to the three sectors is, a priori reasonable in the light of the policies and management attitudes of predecessor agencies. A considered judgment on this point would require a detailed definition by DOE of the roles of these classes of institutions, including the socio-technical relationships and in-depth reviews of the outcome and character of the materials R&D being currently undertaken and planned for the future in each of the three classes.

APPENDICES

Department of Energy
Washington, D.C. 20585

AUG 1 1978

TO: John Deutch
Director of Energy Research

FROM: Dale D. Myers
Under Secretary

SUBJECT: MATERIALS SCIENCE TASK FORCE

I am requesting that the R&D Coordinating Council establish a Task Force to review the status of Materials Science in the Department. The product of this effort will, in part, enable the formulation of an effective materials science R&D policy.

- 51 -

Department of Energy
Washington, D.C. 20545

MEMORANDUM FOR: Assistant Secretary for Energy Technology
Acting Assistant Secretary for Defense Programs
Assistant Secretary for Environment
Assistant Secretary for Conservation and Solar
Applications
Assistant Secretary for Resource Applications

FROM: Director of Energy Research

SUBJECT: R&D COORDINATION COUNCIL MATERIALS COMMITTEE

The Under Secretary has asked the R&D Coordination Council to establish a Materials Committee to review the materials science, engineering and development needs of the Department. The addressees of this memorandum should constitute the membership of this standing committee.

Please designate a senior member of your staff (Division Director level or above) so that we may form a working group to take on the task force assignment requested by the Under Secretary in Enclosure 1. The initial report on the status of the Department's materials efforts should be ready by October 15, 1978, and a final report by December 1, 1978. The Chairman of the Working Group will be a senior staff member from ER.

The RDCC Materials Committee will absorb the functions of the DOE Energy Materials Coordination Committee which, in turn, was originally constituted as the ERDA Materials Coordinating Committee (EMACC). A copy of the last (February 1978) EMACC report is enclosed for your information. It is notable that the materials activities of the Solar program were omitted from consideration. This further emphasizes the need for a comprehensive and continuing assessment of Materials activities in the Department. Some of the key issues to which the Task Force could address itself are:

1. Is there adequate coverage of all identified materials problems expected to be encountered in the energy R&D programs?
2. Is enough early attention being given to materials problems which may be critical to future energy system performance and economic competitiveness?

3. Is there an adequate exchange of materials information among R&D programs in the Department?
4. Is there an adequate linkage between the more basic materials science work in BES and the more applied work in the technology programs?
5. Is there an appropriate balance of effort among universities, industry and DOE laboratories?
6. Is there adequate coordination of DOE materials science, engineering and development efforts with that being pursued in other federal agencies, e.g., NSF, DOD, NASA?

Analysis of these issues should facilitate the formulation of an effective materials R&D policy for DOE.

Please provide the name of your principal point of contact (Working Group member) to Dr. Robert A. Summers, Executive Director, RDCC, by August 15, 1978.

Enclosures

Department of Energy
Washington, D.C. 20545

OCT 11 1978

TO: Director, Office of Energy Research
FROM: Assistant Secretary for Energy Technology *Sub*
SUBJECT: BASIC RESEARCH IN DOE

During this last year, we have had several discussions on an expanded role of fundamental research in the Department's energy technology programs, especially the fossil program. In fact, I conveyed our viewpoints to the university research community during your meeting with them on April 27; ET Program Directors followed my remarks with their supporting statements.

I am pleased that your and my view is consistent with the view expressed by the Office of Science and Technology Policy (OSTP) Committee on Basic Research in DOE, chaired by Sol Buchsbaum. The essential feature of this consistent view is that research -- work undertaken under the budget categories "basic research" (6.1), "applied research" (6.2), and "exploratory development" (6.3) -- must be an integral part of the ET technology programs. This has three important advantages:

1. The combined ER and ET research efforts will build a broad technology base for the future and new ideas will be permitted to influence the course of our technology development efforts.
2. Research which is part of a technology program can be expected to contribute to the identification of technical opportunities and the solution of technical problems that arise in our ongoing generic development programs, e.g., materials sciences, component and instrumentation development.
3. There should be improved effectiveness, and coordination in joint ER and ET research efforts; welcome examples already underway include (a) solar university grants, (b) combustion research, (c) nuclear cross section data, and (d) heavy ion accelerator technology.

However, it is apparent that some misunderstanding has arisen in the directions, as outlined above, which we wish to achieve. In my view, neither the preparation of the FY 80 budget, nor the report of the R&D Council on the FY 80 Technology Base Program, have placed adequate emphasis on research efforts supporting ET programs. Consequently, I trust that this memorandum will help clarify your and my policy on this matter, and I shall be taking steps to assure it is implemented. In particular:

1. I am circulating this memorandum to my Program Directors for their information and ask that you circulate the memorandum to ER program managers.
2. I intend to seek a modification to ET's FY 80 budget submission to OMB for \$15-20M for fossil research consistent with the importance of this technology and the recommendations of the Buchsbaum Committee. I hope your office will support this request and assist us in structuring both the content and management mechanisms for this initiative.
3. I request that you strengthen the standing Research Committee of the R&D Coordinating Council. This group should be our source of information on how well our technology base efforts are faring.
4. I request that you keep me informed of research areas that deserve strengthening in ET. It would be useful to share a list of projects and problem areas for us to examine soon.
5. I want to continue to help support your new R&D initiatives and hope that during this next year we can add several more to the portfolio.

Finally, I note that there has been some confusion about the role of university research performers in the ET programs. While universities are mostly concerned with basic research, many of the larger schools also have impressive applied research capabilities. I want to assure you that it is our intention in ET to continue to support university performers whenever their basic or applied research work makes the most effective contribution to our technology programs.

cc: Frank Press
Hugh Loweth
Dale Myers
Mary Tuszka
George Fumich
Robert Ferguson
Bennett Miller
Edwin Kintner
Sheldon Myers

Selected References on Energy Related Materials R&D Problems

During the course of its review of materials R&D, the Working Group was exposed to a extensive relevant literature. The following references have been selected to illustrate the range of overviews, studies of specific problem areas, activities in related fields and management concerns:

1. "Materials Technology in the Near-Term Energy Program, Report of the Ad Hoc Committee on Critical Materials Technology in the Energy Program to the Science Advisor to the President," National Academy of Sciences, September 1974.
2. "A Federal Look at the Needs for Energy-Related Materials Research and Development, Volume 1: Near Term Energy Program" (ERDA-76-28V1 preliminary version) prepared by the Energy Task Group, Committee on Materials (COMAT), Federal Council for Science and Technology, August 1976.
3. "Materials Sciences Overview, Report of a Series of Workshops Recommending Future Directions in Energy-Related Basic Materials Research," ERDA-77-76/1,-/2, August 1977.
4. "Materials Needs and the Environment Today and Tomorrow." Final Report of the National Commission on Materials Policy, Stock No. 5203-00005, U.S. Printing Office, June 1973.
5. "Materials and Man's Needs." Summary Report of the Committee on the Survey of Materials Science and Engineering, National Academy of Sciences, 1974.
6. "Erosion Control in Energy Systems." National Materials Advisory Board, National Academy of Sciences, November 1977.
7. EPRI Ductile Fracture Research Review Document. Electric Power Research Institute Special Report NP-701-SR, February 1978.
8. "Stress Corrosion Cracking - Problems and Research in Energy Systems." Summary of a Workshop held at ERDA-Germantown, ERDA-76-98, May 1976.
9. "Ceramic and Glass Automotive Waste Forms." Summary of a Workshop held at ERDA-Germantown CONF 770102, Energy Research and Development Administration, January 1977.
10. "Proceeding of the Meeting on CTR Electrical Insulators." Los Alamos Scientific Laboratory, CONF 760558, ERDA, February 1978.
11. "Some Potential Materials Supply Constraints in Solar Systems for Heating and Cooling of Buildings and Process Heat." A preliminary screening to identify critical materials. Pacific Northwest Laboratory, September 1978.

12. "Operating Manual and Data Base for the Critical Materials Assessment Program (CMAP)." Pacific Northwest Laboratory, September 1978.

13. "Optimizing the Use of Materials and Energy in Transportation Construction." Proceedings of a conference jointly sponsored by the Federal Highway Administration, The Federal Energy Administration and the Energy Research and Development Administration. Special Report 166, Transportation Research Board, National Academy of Sciences, 1976.

14. "Management of Federal Materials Research Should be Improved." Report EMD-78-41 prepared by the Comptroller General, July 1978.

Critical Materials Problems in Energy Systems

(Summarized from Various EMACC Briefings)

I. Energy Technology

A. Nuclear Energy

1. Advanced Systems and Materials Production (see Space Nuclear Systems Division)

- . containment of plutonium during reentry
- . thermal pulse resistance, ablation, thermal stress
- . thermoelectric conversion - better and longer lived materials

2. Reactor Research and Technology (LMFBR)

- . temperature limitation and gamma ray embrittlement of elastomeric sealant materials
- . NDE of weldments
- . fuel cladding - compatibility with fuel and sodium, / resistance to radiation damage, strength for resisting fission gas pressure, low neutron absorption cross-section, thin sections for heat transfer

3. Nuclear Power Development

No presentation to EMACC but programmatic emphasis is on

- . creep and corrosion of structural metals
- . radiation effects in graphite

4. Naval Reactors

Programmatic emphasis is on

- . corrosion, mechanical properties, and wear of reactor structural materials
- . irradiation effects in fuel elements

B. Fusion Energy

- . swelling and embrittlement due to 14 Mev neutrons
- . surface blistering, sputtering, and erosion
- . effects of large concentrations of gases (H, D, T, He)
- . lack of materials engineering capability in this new field

C. Fossil Energy

1. Coal Conversion

- . metals - hot corrosion, hot erosion, sliding wear, lack of hot strength, strength degradation, aqueous corrosion
- . refractories - gaseous corrosion, degradation by gases and alkali vapors, liquid slag erosion and corrosion, particulate erosion, thermomechanical failure, degradation by acid condensate

2. Magnetohydrodynamics

- . combustor - insulators, slag/seed compatibility, high temperature stability, erosion
- . generator - high electrical conductance in electrodes and highly resistive insulators, thermal diffusivity, erosion, slag/seed corrosion
- . regenerator - slag/seed corrosion, thermal fatigue
- . boiler tubes - hot corrosion/erosion

3. Fuel Utilization (turbines)

- . ceramics - brittle material design, ceramic fabrication (esp. SiC and Si_3N_4)
- . metals - erosion/corrosion of blades, creep strength of superalloys

D. Solar, Geothermal, Electric and Storage Systems

1. Electric Energy Systems

- . materials needed for new concepts in electric transmission and conversion
- . materials for superconducting generators
- . underground and overhead high voltage transmission - superconductivity and cryogenic transmission materials, insulator materials, new materials such as Nb_3Ge , commercialization of Nb_3Sn conductor

2. Energy Storage

- . superconducting magnet energy storage - higher temperature superconducting materials, lower manufacturing costs for superconducting ware
- . hydrogen storage - minimize hydrogen embrittlement, NDE for hydrogen effects

3. Solar Technology

- . Photovoltaics - improved materials, encapsulating cells without introducing electrical contact problems
- . ocean thermal - biofouling and corrosion of heat exchanges
- . wind - low cost rotor blade materials
- . heating and cooling - heat transfer fluid/absorber plate compatibility
- . thermal conversion - piping, heat exchanges and receptor materials compatibility with coolants and other fluids

4. Geothermal

- . corrosion and erosion of casing and heat exchanges in geothermal fluids
- . high temperature degradation of downhole cement
- . erosion and wear of drill bits, drill pipe, and mud pumps

E. Nuclear Waste Management

- . Glass suitable for waste containment
- . possible canister corrosion

II. Defense Programs

A. Military Application

No specific major materials problems cited to EMACC

B. Laser Fusion

No specific major materials problems cited to EMACC but programmatic emphasis is on

- . advanced optical materials for high power lasers
- . high quality glass microspheres for laser fusion pellets
- . irradiation effects in structural materials
- . fabrication and quality control methods for optical and electronic components

III. Environment

A. Biomedical and Environmental Research

No specific major materials problems cited but programmatic emphasis is on

- . radiation detector materials
- . dosimeter materials

B. Environmental Control Technology

- . constitutive equations of materials for shipping container systems

IV. Conservation and Solar Applications

A. Industrial Energy Conservation

- . thermal insulation materials
- . accurate testing methods for insulating materials
- . improved or new fabrication methods
- . materials for energy recovery processes (e.g.,
incineration and biochemical processing)

B. Solar Applications

This is the heating and cooling portion of the earlier Solar Program which is now under the Assistant Secretary for Conservation and Solar Applications (see item I.D.3. on heating and cooling under Solar Technology)

THE FUSION REACTOR MATERIALS PROGRAM

The Reactor Materials Program Office of the Office of Fusion Energy has completed an extensive program planning effort which has culminated in an exemplary fusion reactor materials program plan (DOE/ET-0032/1, -/2, -/3, -/4, "dated July 1978"). This plan required the concerted efforts of some 112 individuals from 18 laboratories.

The plan is consistent with the goals and schedules of the Magnetic Fusion Program which currently envisions a fusion system producing net energy gain in the early 1990's and a demonstration of practical fusion power at the turn of the century. It is supportive of near and long term goals of the fusion program and is developed to the detail of tasks and subtasks, with level 1 and level 2 milestones.

The challenge of the fusion materials development program is probably significantly more severe than that of any other DOE program. At the inception of the Magnetic Fusion Materials Program in FY 1974, the fusion materials community consisted of individual investigators from the fission reactor community. A large scale assessment of fusion materials problems had not been conducted, and relevant data included only fragmentary evidence and speculation that high energy neutron damage is different from damage produced by fission neutrons, and that radiation emanating from the plasma attacks first wall materials.

The initial effort was to organize the scientists engaged in fusion materials research into a coherent community which could impact not only materials development but program planning. Essential to this effort was the formation of four Task Groups staffed by appropriate individuals from R&D laboratories. These Task Groups were established along program element lines and include Alloy Development for Irradiation Performance (ADIP), Damage Analysis and Fundamental Studies (DAFS), Plasma-Materials Interaction (PMI), and Special Purpose Materials (SPM). Each group is composed of 6-10 principal investigators and consultants, and works under the guidance of a Chairman drawn from a National laboratory and his counterpart, a member of the Materials and Radiation Effects Branch. A broad representation of laboratories and technical specialties represents the widest possible range of viewpoints, and Task Group membership includes individuals from the reactor design, engineering, and research communities. Each group operates through a number of Subtask Groups which are charged with problem definition and program planning in specific technical areas and are distributed from among National laboratories, universities, industrial laboratories and other Government organizations. The functions assigned to the Task Groups are the following:

- . Convening of ad hoc groups for special reports.
- . Problem analyses and technical approach.
- . Preparation of program plans including milestones and estimates of manpower and facility requirements.

- . Convening of ad hoc groups for special reports.
- . Selection of materials for modeling and development.
- . Coordination of ongoing work.
- . Periodic reporting by task group.

The processes of program planning and implementation rely on individuals from the R&D laboratories and the functions carried out by the laboratories are the following:

- . Staffing of Task Groups.
- . Proposals for technical work.
- . Research and development on authorized tasks.
- . Contributions to Task Group reports.

It is important to note that although the Program Plans furnish an outline of major avenues to be explored and a task structure for implementation, the detailed approaches to problem solutions must come from individual investigators and it is they who implement the research and development tasks in the program.

The Fusion Materials Coordination Committee was convened for independent assessment and advice to overview the above activities and to provide independent review and recommendations. The functions of the Committee are the following:

- . Review of program objectives.
- . Review and coordination of Task Group activities.
- / . Recommendation for establishment or disestablishment of Task Groups.
- . Independent input to Materials and Radiation Effects Branch.

The Committee includes the four Task Group Chairmen, members of the Materials and Radiation Effects Branch, representatives of other parts of the Office of Fusion Energy, representatives of several other DOE programs and consultants from industry and universities.

Finally, a number of functions are carried out by the Materials and Radiation Effects Branch and these are given below:

- . Policy and overall guidance.
- . Formulation of major program objectives.
- . Tracking and reporting of major milestones.
- . Resource allocation.
- . Work authorization to laboratories.

It is important to reiterate that the traditional functions of proposals by the laboratories and work authorizations by DOE have not changed. The principal functions of the Task Groups in the planning phases were to identify and analyze problems and to suggest a task structure for their solution; in the implementation phase their functions will be to coordinate and assess the ongoing work.

PLANNING DOCUMENTS

Prior to the preparation of Program Plans, two technical assessments, Alloys for the Fusion Reactor Environment and Special Purpose Materials for the Fusion Reactor Environment were prepared by the Task Groups. In addition, the Materials and Radiation Effects Branch published a series of Fusion Materials Program Bulletins in order to outline the goals and objectives of the program and to serve as input to the Program Plans.

A common format was adopted by the Task Groups for the Program Plans. An Executive Summary is followed by an Introduction which contains a listing of Task Group and Subtask Group members and consultants. This is followed by a chapter on Problem Definition and Analysis and a chapter on Program Strategy and Major Milestones. The latter is the most important part in each of the Plans. It is a description of the strategy to be followed in solving the problems and includes on the order of 15 to 20 major milestones between now and the initial operation of a commercial fusion reactor. The final chapter in each Program Plan is entitled Task Definition and is a detailed description of work for the next five years including milestones within a given task.

Following the completion of Program Plans, the Task Groups have shifted their activities to coordination of the ongoing research and development activities. As part of this effort, each Task Group will assemble a quarterly progress report of ongoing work in its specific technical area.

The Fusion Materials Program Plan is elaborate and detailed than would be needed for most other areas. However, its structure and approach to implementation management make it an excellent paradigm for guiding the development of plans for less ambitious programs.

The Plan is in four volumes, corresponding to four subprograms.

I. Alloy Development for Irradiation Performance. Its ultimate goal is the production of a material that will survive an exposure of 40MW-y/m² at a temperature of at least 600°C.

II. Damage Analysis and Fundamental Studies. Its objective is to enable the application of irradiation data obtained in test environments to fusion reactor design environments.

III. Plasma/Materials Interaction. Its goals are to minimize impurity introduction, to provide a quantitative data base for plasma recycling, to minimize detrimental near-surface alteration of first wall materials and to provide designers...with innovative materials concepts.

IV. Special Purpose Materials. It addresses most of the nonstructural materials problems not addressed by the other subprograms. These cover some seven development areas.

As two examples of program strategy, Alloy Development and plasma/materials interaction problem are particularly challenging; to alloy development because of the many materials failure modes foreseeable in a reactor environment (nine are identified) and the plasma/materials interaction problem because it affects not only long-term considerations for the economic production of fusion power, but has immediate impact of near-term confinement devices which are designed to prove the scientific principles upon which fusion power is based.

Design or operating conditions can be envisioned for which any failure mode could limit performance, so the program must encompass all of them simultaneously. Performance goals are three to five times those of the breeder reactor alloy development program for displacements-per-atom and over 50 times them for the helium content.

Because there is today no single class of candidate materials that clearly will be able to meet the requirements of a commercial reactor, the program must initially be very broad. The Plan, thus, follows four parallel paths involving different classes of materials (austenitic alloys, higher strength Fe-Ni-Cr alloys, etc.). Plans are developed for all four paths, although it is expected that one or another may atrophy as new information is developed with time.

Fearing the likely non-convergence of a trial-and-error, or "Edisonian," approach to materials development, the task groups have arrived at a philosophy of alloy development structured to lead to measured progress toward the quantitative program goals. It proceeds from the development of fundamental principles governing materials behavior, involves successive screenings that narrow the range of alloys considered, and culminates with a complete characterization of a set optimum alloys. The level 2 subtasks are each given a priority and an assessment of the required man-years for FY 78-82. The required test facilities are also stipulated. These are clearly a key to progress in the program.

An important statement that appears in the plan is, "It is the judgment of the Task Group that an alloy for commercial fusion power can be developed by the early 21st century if the schedule given in the plan is followed." However, a development path entitled, "Innovative Concepts," is included because "the conventional concepts of metallurgical development that are implicit in paths A, B, and C may not be adequate for fusion reactor applications."

It is a strength of the total plan that the basic approach is geared toward developing and understanding of the fundamental principles governing materials behavior in the fusion environment. This will both provide an analytical guide to further materials development work and enable a more quantitative statement than is at present possible concerning fundamental factors limiting the exposure survival of any class of material.

The Plan contains a number of examples of managerial acumen. For instance, it is the intent to begin the program with the greatest possible breadth and to reduce it as rapidly as profitable paths can be identified. Therefore, a deliberate effort will be made to avoid identifying an individual laboratory with a single material or path. This will avoid massive dislocations caused by decisions to eliminate materials, and will allow more objective debate of the merits of the materials.

Appendix D-1

Coverage of Materials Problems in
Defense Programs

1. In Defense Programs, we place high priority on maintaining a broad technological base within the weapons laboratories to insure that future weapon and inertial confinement fusion program goals can be met. We have been required to develop most of our technology base within our own complex due to weapon secrecy, uniqueness of weapon and fusion technology, and the simple fact that most outside sources cannot provide the wide base of technology required. Our technology base, however, is directed toward those physical and engineering sciences and technologies which can be specifically identified as being uniquely relevant and applicable to near and intermediate term problems.

A basic building block in the nuclear weapons program is the ability to synthesize and work with new materials. Just as the nuclear design capability depends on the ability to handle physics of phenomena far outside the region of usual interest and experience, the realization of those designs often requires materials not conceived of by any other technology. A striking example of this development of a material is the use of plutonium in the weapons program. Plutonium is a man-made element, first produced about thirty-five years ago. Today it is the material that makes possible the whole field of small diameter, lightweight nuclear warheads that are the backbone of our nation's nuclear deterrent capability.

In an organization responsible for state-of-the art technology advancements, beginning with basic research and carried through the development cycle to production hardware, a fabrication capability serves several vital functions. These functions include fabrication of experimental apparatus not available from commercial sources for research investigations, fabrication of prototype hardware that is not economically feasible to obtain from production sources, and most importantly, to provide state-of-the-art fabrication capabilities to the designer for use in advancing nuclear technology. A direct corollary to advancing fabrication capabilities is the need to pass this technology on to the production complex so that advances realized in development programs are also realized in production programs.

The purchase and development of research instruments and the design and construction of new facilities, both of which are necessary to support state-of-the-art technology advancements, are a vital portion of the problems in managing R&D programs. The optimum balance between operating and capital expenses is never easy to determine. Obsolescence is thus a continuing concern.

Management of activities within the weapons program is highly decentralized. Responsibility for detailed direction is consistently placed at the lowest level possible. Headquarters activity is primarily one of monitoring field progress and of adjusting field activity based on programmatic requirements.

The laboratories are responsible for technical leadership, and the field offices are responsible for production scheduling and coordination, testing coordination and safety, and contract administration. The current decentralization is a continuation of the policy of the past. This approach minimizes staffing requirements at upper levels and puts technical direction in the hands of those responsible for the work.

Generally, as part of the decentralized management concept, field offices, laboratories, and GOCOs are permitted, and use, direct access to other members of the program's community. Anyone in the system can surface problems. The system operates with a minimum of intervening levels of review, following a concept of "management by exception." At the same time, a process of coordination and monitoring keeps all levels of management abreast of these interactions.

Requirements for weapon development and production come to DOE from DOD. Formulation of requirements is an iterative process involving continuous interaction between DOD and DOE, the one to present force needs and the other to propose warheads and bomb candidates and estimate the time and cost for their development and production.

The Office of Military Application (MA) translates development requests from DOD and the stockpile quantities approved by the President into an integrated development, testing, and production program. MA issues development guidance directly to the weapons laboratories, guidance on testing to the Nevada Operations Office and the laboratories, and production directives to the Albuquerque Operations Office.

The directors of the weapons laboratories are given wide discretion to formulate and carry out research and development which will provide nuclear weapons responsive to specific DOD requirements and which will maintain the general superiority of United States nuclear weapons technology. The focus of MA direction is on meeting DOD requirements within time and resource constraints, with technical decisions largely delegated to the laboratories.

The nuclear weapon laboratories have been free to develop their own organizational philosophy and management systems. To accomplish their jobs they have had to develop a structure and a management philosophy that permit both efficient and timely response. Through independent evaluation of different approaches and recognition of a system best suited to good research and development programs, the three laboratories have developed similar systems. A brief look at the systems at the individual laboratories follows.

LLL has chosen the "task force" approach as that management method which best supplies the required flexibility and blends with the philosophy of examining a problem in its entirety rather than as a group of independent parts. A basic administrative organizational structure exists in which there are departments and divisions composed of people of similar disciplines. Cutting across administrative lines is a programmatic organization put together to solve a particular need. Program and project leaders are drawn from the administrative organizations on the basis of the need and character of the program. This programmatic structure allows very wide freedom in putting together and disbanding a team as the needs and resources of a project vary. Yet, solidarity of the overall organization is maintained as personnel are always tied to their administrative group and have a "home" and other projects needing their services when a team breaks up.

To give management at various levels the means to guide the programmatic effort, there are a great number of formal and informal meetings in addition to periodic progress reports and written reports of significant milestones reached. There is also continuous informal review by Division Leaders. It is through such reports, reviews, and the LLL programmatic structure that rapid and flexible communication channels are open from all corners of the laboratory. Project leaders have frequent (usually weekly) reviews of project status. Technical progress is discussed and problems reviewed.

The nature of the LLL programmatic structure is such that the number of management layers from top to bottom are very few. Problems can quickly move up the structure to a level where action can be taken.

At LASL, laboratory divisions are based on disciplines or functions. No large programs are concentrated within single divisions, although a single division may sometimes have a large fraction of a program because of the particular disciplines involved. Programs are managed or coordinated in a variety of ways--by committees, by individuals, or by the Director's office--depending on the nature of the particular program.

For administrative convenience and ease in reporting, laboratory work at LASL is divided into programs or reporting categories. These program codes, as they are called, are determined by the type of effort and the amount of resources required. Although work in most programs is well-defined, work in some programs, such as advanced materials development, is more loosely defined and varies from year to year.

Program management at the technical level varies, depending on the program which is to say that the management approach is tailored to the specific needs of individual programs. For large programs with well-defined schedules, program managers are assigned. For small programs, particularly in advanced technology, program management is assigned to a small group or committee

representing participating laboratory divisions. Sometimes members of a division office will watch over a specific program. Members of the Director's office keep track of technical and financial progress through trip reports, program managers' reports, committee reports, and periodic financial reports. The Director's office is immediately available whenever a program needs top-management participation.

A committee form of management is used to determine the allocation of money, nuclear tests, and time which are the three limited resources that the laboratory must handle. The Director makes the final decisions, but seldom without advice from one or more of the three committees--Planning, Program Review, and Budget.

Sandia Laboratories uses a project group approach for control of the technical, financial, and programmatic aspects of weapon ordnance developments. Support for the project group is drawn from functional groups which are organized by technical or scientific specialties. In the main, the technical capabilities reside in corresponding functional organizations. An objective of the basic project/functional group approach is to provide continuity of control. Under this approach, one technical organization maintains responsibility for a project from conception to prototype evaluation, to full development, to "care and feeding" during deployment, and to eventual disposal--a birth-to-death responsibility. The experience gained during one project is readily applied to other projects.

At Sandia the dual approach of technical specialty management and project management is called the Case System in which the basic project unit is termed the Case. The application of the Case System allows for focusing the work of many organizations toward a single technical objective. Each Case covers a defined project or task for which costs are authorized and on which costs are accumulated and reported. Each Case is controlled by a Case Manager who is responsible for establishing the technical objectives, setting time scales, obtaining and justifying Case budget estimates, and controlling Case costs. Although primary responsibility for the control of the Case is assigned to the Case Manager, it is the responsibility of the supervisor of the technical organization charging the Case to assure that authority to charge a Case has been granted and that such charges are both reasonable and appropriate.

The following guidelines can be applied in differentiating between Case Manager responsibilities and organization management responsibilities. The Case Manager is responsible for designating what should be done and when it should be done while the organization manager is responsible for designating who should do it and how it should be done. The success of this system is obviously predicated on the necessity for a continuing dialogue between the Case Manager and organization manager.

Each case covers a defined task and is usually characterized by a single technical objective or discipline. Certain levels of laboratory tasks, however, do not lend themselves to management by means of case members. For those unique areas, a system subordinate to, but compatible with, the Case System has been established. This subsystem covers such functional areas as the Process and Fabrication laboratories and the Design Information Center.

2. Nuclear weapons development depends, in a most intimate way, on a fundamental knowledge of the properties of material and of basic physical processes. The research required covers a broad range, such as measurement of microscopic nuclear reaction cross sections needed for criticality calculations, macroscopic thermodynamic properties of bulk material involved in high pressure hydrodynamics, mechanical properties of materials for assessing structural strengths, and chemical kinetics and rate processes necessary for assessing chemical compatibility problems for the stockpile. As an example of the range of applicability of even one kind of this basic research, consider measurement of fission cross sections. A new type of device design may be made possible by knowledge of cross sections for a fissile isotope not previously employed in nuclear weapons. On the other hand, in the late stages of the weaponization project, it may be necessary to more accurately determine nuclear properties of a common isotope in order to have a very accurate normalization of performance of a weapon about to enter stockpile. The history of science and the history of weapons development as well show that new concepts often arise from measuring physical properties in ever more precise ways. This is particularly true as devices become more complicated and more dependent on previously unimportant physical processes for their functioning.

The materials used in nuclear explosives are chosen not only on the usual engineering criteria such as strength, fabricability and cost, but also because of their atomic, nuclear, and bulk hydrodynamic properties. Materials with what are often thought of as mutually exclusive properties are sometimes needed, such as "high strength voids," low density materials with high atomic number, and insensitive high explosives. The materials are often explosive, toxic, or radioactive. Rare and exotic elements are often needed.

Often the required materials do not exist, and must be made for the first time, which often requires invention of a new process for synthesis and forming. The whole range of materials is spanned, from metals and alloys, through ceramics, salts, plastics, fiber composites, and explosives. Developing, handling, and analyzing these materials has required the building of one of the broadest and most versatile chemistry and materials science capabilities in the world.

The materials scientist is an integral part of the nuclear design team. His contributions span the whole range of device design. For example, creation of a new material may allow development of a device design which operates in a qualitatively different way with improved characteristics. At every stage in evolution of a design, joining dissimilar materials is important. In the weaponization of a device for stockpile, how the materials in the weapon will react chemically with each other over the stockpile life must be known. In fact, it is the slow and obscure reactions that limit the lifetime of the weapon. The obvious incompatibilities are taken into account from the beginning.

All these factors must be considered in the nuclear design process. Continual interaction of the design physicist and engineer with the materials scientist is necessary.

Almost as intimately involved, and certainly as important, is the capability to fabricate parts and assemble them. Modern nuclear explosives often require very close tolerances, and always involve the fabrication of hazardous materials. The materials are often intractable, and special forming or machining methods must be specially developed. Special inspection and measurement methods must also be developed to verify that the part is built as specified. The fabrication capability provides state-of-the-art effort for the designer, fabrication of prototype hardware for development programs that are not economically feasible to obtain from production sources, and allows for fabrication of experimental apparatus for research investigation that is not commercially available.

Process development involves the development of the materials processes necessary to produce nuclear and nonnuclear parts. This area also includes manufacturing research and development work to improve existing processes for efficiency and safety. Weapons laboratory personnel work closely with production plant personnel in process development and in following a weapon design through to the completion of the finished product. This feedback loop which includes materials related information significantly aids in the timely identification and solving of materials problems.

Materials and process development activities emphasize the balance between research and development necessary to provide materials compatible with the extreme environments and performance requirements associated with nuclear ordnance. Detailed knowledge of materials and their behavior often provides the only way to eliminate problems associated with their use and achieve the objectives of functionability, reliability, and longevity. The ability to investigate, characterize, recognize, and develop materials has enabled the weapons program to meet development scheduled for warheads that have remained in the Nation's stockpile with minimum maintenance, maximum safety, and high reliability. Accurate data describing behavior of materials during and after long-term exposure to special environments

necessitates observing their performance over these long periods. Thus, the limited time-span of a weapons development program restricts the use of materials to those that have already been studied. Continuing efforts to characterize new materials beforehand are vital to nuclear device design; without these efforts, one is limited to the materials already used.

The history of nuclear weapon development reveals examples of the establishment of whole new fields of research dealing with the development, production and processing of radioactive materials. From the beginning, special nuclear materials have posed unique problems. The radioactivity of special nuclear materials is potentially hazardous to personnel who conduct research with these materials, operate the manufacturing facilities, or handle nuclear weapons. Materials scientists have played a major role in developing processes and facilities for producing and handling special nuclear materials.

Many examples also exist of new materials which have been developed to resolve structural, corrosion, stability, and compatibility problems. Material scientists have developed a number of plutonium and uranium alloys that have been important engineering materials and without which most of the Nation's modern nuclear stockpile could not have been realized. Several stocks that meet stringent requirements for strength, weldability, and compatibility with other weapon components have also been produced.

The materials program consists of research projects selected for their scientific merit and anticipated future benefit to the nuclear designs and nuclear test elements of the weapons program. Materials technology provides new materials, improved processes, and more precise characterization methods to raise material design limits.

3. Nuclear weapon and, to a smaller extent, inertial confinement fusion development depends on our ability to develop a fundamental understanding of material properties and physical processes under conditions of extreme pressures and temperatures and in severe operating environments. Weapons research covers a broad range of basic and applied science and technologies including such areas as the measurement of microscopic nuclear reaction cross sections for criticality calculations, microscopic thermodynamic properties of bulk material involved in high pressure hydrodynamics, mechanical properties of materials for assessing structural strengths, and chemical kinetics and rate processes necessary for assessing chemical compatibility problems. The Laser Fusion program has interest in phase transitions and phenomena associated with the three hydrogen isotopes and mixtures thereof at cryogenic temperatures. This type of research is receiving the major support in our program, and laboratory capabilities and facilities have been developed to address them. We devote a rather small percentage of our effort to the broader range of fundamental sciences with potential payoffs in the longer term. This is not because we place

lower importance on these basic science programs. New discoveries and basic data from many of these fields of science, especially those related to national security, provide the foundation from which most of our new concepts will inevitably evolve. The primary reasons for lower emphasis can be attributed to the following:

- We have always expected that a major part of our basic science needs would be funded by other organizations whose charters are to support such research. BES has always been a major contributor to basic research of interest to Defense Programs.
- Near-term programmatic priorities and resource restrictions have minimized the amount of basic and exploratory research we can support.

4. The organized and productive exchange of materials data, information, and experience between materials R&D programs conducted under the ASDP and other programs within the department is limited to mechanisms which handle only unclassified data. Such mechanisms are personal contacts, reports, integrated contractor meetings, and publications in the open literature. Department wide committees such as the Energy Materials Coordinating Committee (EMACC), which is the primary formally organized method of exchange, and the Hydrogen Energy Coordinating Committee (HECC), which is a spinoff of EMACC, are the only organized mechanisms of regular or periodic exchange. Due to the limitations imposed by classification, DP is constrained in its ability to exchange information through whatever mechanisms exist although DP is able to benefit from knowledge of the activities of other programs and technologies. Within Defense Program activities, the exchange of information takes two forms--the interchange between different laboratories and the interchange between programs within an individual laboratory.

The nuclear weapon development laboratories exchange information continually through regularly scheduled meetings, established working committees, or frequent informal meetings between members of the respective laboratory staffs. These interchanges promote rapid dissemination of new technical developments among the laboratories. We work hard to avoid reinventing the wheel and to make maximum use of developments among the laboratories within our program.

LASL and LLL have established a number of working groups that meet regularly to exchange information on topics related to nuclear weapon design. These groups are called Interlaboratory Working Groups (ILWOGs) and include materials information within the topics covered. LASL and Sandia have established several committees to coordinate their efforts and to exchange information relating to the full-scale development of warheads.

Within DP activities, an information exchange called the Interagency Mechanical Operations Group (IMOG) meets regularly. All DP contractors concerned with nuclear weapon development and production participate as well as the Albuquerque Operations Office. Active IMOG subgroups are concerned with machine tools, joining, gaging, engineering data, environmental tests, numeric systems, and metrication.

The Albuquerque Operations Office has established a Weapons Advisory Committee (WAC) to identify goals for the integrated contractors. This committee meets periodically to consider appropriate topics.

The design laboratories and the integrated contractors continually exchange information on priorities for process development efforts. Through these changes, both the laboratories and the contractors receive information on new technological developments. In addition, LASL and LLL have established a formal exchange for nuclear test information whereby the laboratories exchange drawings and technical information on the design of nuclear devices they have tested. Through informal meetings with each other, designers and engineers from the respective laboratories obtain more detailed information than they could obtain from each other's documents.

The information exchange between the laboratories is extensive and detailed. Whenever one laboratory hears of developments at another, a telephone call is all it takes to arrange for a desired exchange of information.

The organization of the laboratories by functions or disciplines facilitates the information exchange between programs. Many of the divisions have sizeable efforts in other than the weapons program. Since most programs share the same basic resources and expertise, transfer of information from one program to another is quite simple. Where there is a program effort concentrated largely within a single division, the group and division offices are encouraged to exchange information on their new developments with the rest of the laboratory and to obtain relevant information from the rest of the laboratory. The goal is to ensure that efforts within the laboratory are not being duplicated.

5. Coordination of materials R&D activities with other Federal and State agencies, non-government organizations, and nondomestic activities falls into one of the following categories when only unclassified information is concerned: personal contacts, reports, open literature, and professional society meetings. When classified information is exchanged, some of the above mechanisms can still be used. In addition, several formal information exchange groups exist between the DOE, the DOD, the individual military services, and the Defense Nuclear Agency (DNA) which discuss materials problems if they are pertinent to the group.

Joint Work Groups (JOWOGs) were established many years ago to provide for information exchange between the U.S. and the United Kingdom, with the weapon laboratories participating. The various JOWOG groups, some of which deal specifically with materials, have also served as channels for exchanging information between the U.S. weapon laboratories.

6. The question of balance of effort among universities, industry, DOE laboratories and centers, and other government research centers is not one which is germane to Defense Programs activities. We have been required to develop most of our technology base within our own complex of government-owned, contractor-operated facilities due to weapon secrecy and other limitations imposed by statute, uniqueness of weapon and fusion technology, and the simple fact that most outside sources cannot provide the wide base of technology required.

Existing Reactor Research Technology Division Management Policies and Procedures Related to Materials and Evidence Concerning Their Effectiveness

a. Project Level Mechanisms

During the past five years the Reactor Research and Technology (RRT) Division of Energy Technology has had a procedures system in place directed at (a) the identification of the development needs of reactor projects, (b) the incorporation of the required studies into the contributing base technology programs and c) monitoring of these related development programs to assure that they are responsive to the identified project needs.^{1/} These procedures result in the formulation of Development Requirements Specification (DRS) documents which contain detailed descriptions of the technical, scheduler and cost estimate aspects of the development need, including the rationale for the activity, and the technical consequences of not performing this activity. A significant number of the DRSs currently in place are materials activities.

A complete flow chart for the development and implementation of the DRS is given in Figure 1. The major steps in the process of establishing and implementing DRSs in support of the project are summarized below:

- 1) Reactor Manufacturer (RM) identifies development need and prepares brief scoping document, the Development Activity Description (DA), following exploratory discussions with the Project Office, potential performer(s) and the headquarters sponsor.

- 2) Following approval of the DAD by the Project Office, the Reactor Manufacturer (RM) prepares the detailed document, the Development Requirement Specification (DRS). This document is prepared in consultation with the Project Office, the recommended performer and the appropriate headquarters sponsor.

- 3) The DRS is then submitted to the Project Office by the RM for approval and if approved is submitted to Headquarters by the Project Office with the request to implement the work.

- 4) RRT Headquarters reviews the DRS and if approved the DRS is transmitted to the performer through the appropriate Field Office for implementation. Headquarters provides the funding and technical direction of the specified studies.

- 5) Periodic audits of the activity by the project organization are performed to assure that the contributing base program is meeting the specified project needs.

^{1/} Attachment 1 is a recent revision of the Contributing Base Program Procedures currently under review by RRT management.

The procedures described above cover the Contributing Base Development Program of the reactor project. Development requirements which are directly related to the plant design and operating requirements are covered by the Applied Base Program Activities under DRSs which are funded and directed by the project.

As indicated earlier, the system described above has been in place for five years and although a number of problems have been encountered, involving principally funding mismatches between project requirements and limited Headquarters resources, on balance the system is judged to be an effective way of meeting project needs. The procedures described "force" early communication between the project personnel and base technology specialists and the resulting documentation, DADs and DRSs, minimize the possibility of oversight of significant and possibly systems limiting materials problems. This "support work" by the base technology program also builds and strengthens the established generic technology base and the expertise of technology specialists.

The materials needs associated with the development of specific advanced components such as steam generators, pumps, etc. for future reactor systems are addressed early in the proposal cycle. Potential contractors are required to address all the development needs, including materials, of the proposed component program. Following award of contract, the component development and materials technology specialists at Headquarters work together closely with the component contractor and materials program performers to assure that the materials needs are satisfied in a timely and cost effective manner.

b. Base Program Mechanisms

Within the Reactor Research and Technology Division there are procedures and practices in place to assure that adequate attention is directed at materials needs of the base program. In most of materials technology areas, such as mechanical properties, reactor fuel and cladding alloy development, structural alloy development, friction and wear, nondestructive testing, etc., lead roles have been assigned to highly qualified laboratories to coordinate or manage the national programs in support of breeder reactor development. An important and necessary function of these lead laboratories is to prepare the needs and planning documents required to assure proper focus of resources on the highest priority materials technology needs. These planning documents are utilized in the preparation of the RRT Schedule 189a,^{2/} the program and budget proposal document, prepared by the performing contractor for a specific

^{2/} Work Package Authorization System (WPAS) to be utilized in future to replace current 189a management system.

work area within the RRT program. The materials 189a is designed so that the milestone and cost structure can be effectively utilized to monitor the progress and effectiveness of the program. In recent years, an effort has been made to reference specific 189a milestones to the material planning document for the various base program technologies. Monthly reports prepared by the performer are utilized by the Operations Offices and the Headquarters component to monitor the contractor performance.

RRT Quality Assurance Standard

In order to assure that materials selection receives adequate attention early in the component or system design process, there is a requirement for design reviews. The specific requirements of the design review, including materials consideration, are spelled out in detail in Section 3.5 of RDT Standard F2-2, Quality Assurance Program Requirements, dated August, 1973 (see Attachment 2).

FIGURE 1

Attachment 1
to Appendix D-2

Clinch River Breeder Reactor Plant Project Management Requirement Guide
for Identifying and Satisfying Development Needs (Portions Only)

3.2 Development

The Lead Reactor Manufacturer (LRM) with the guidance of the Project Office shall exercise the necessary management to assure coordination of the development programs required to support the CRBRP Nuclear Island activities of the Reactor Manufacturers (RM's) and Architect-Engineer (A-E). This includes coordination of:

- a) Identification of development needs
- b) Recommending performer selection
- c) Establishing priorities
- d) Obtaining technical approvals
- e) Obtaining funding approvals
- f) Detailed planning
- g) Monitoring performance

The CRBRP contractor (RM, LRM or A-E) having a technical responsibility is responsible for the identification of development requirements for that area and for monitoring the related development programs to assure that they are responsive to CRBRP identified needs. The development programs which are funded as a part of the CRBRP Project Office (PO). Other development programs required by CRBRP are funded directly by Reactor Research and Technology Division (RRT), Headquarters Department of Energy (DOE) as a part of the Base Technology Program. Those portions of the Base Technology Program which are responsive to CRBRP needs are identified as Contributing Base Development. Although these latter programs are under the technical and programmatic direction of RRT, the CRBRP technical and programmatic requirements are provided by the CRBRP Project Office to RRT for agreement and implementation.

For all development work required by the CRBRP Project Office, i.e., Applied Base Development or Contributing Base Development, the LRM Development Coordination Office shall serve as the central point of control on programmatic matters regarding obtaining Project Office approval, program priorities, budget or budget recommendations as appropriate and the selection or recommendation for selection of performers as appropriate.

3.2.1 Identification of Needs

Development requirements shall be identified by the LRM, RM or A-E engineer responsible for the design or analysis of the impacted CRBRP system or component (the Requester). A brief scoping document

shall be prepared by the Requester in standard Development Activity Description (DAD) format (Appendix A to this section). During preparation of the DAD, the Requester should hold exploratory discussions with the potential performer, the LRM, the CRBRP/PO and RRT (with Project Office representation) as appropriate to assure that the DAD reflects such items as the proper scope, schedule, preliminary budget requirements, and recommended performer. The LRM shall assign an appropriate identification number of the DAD at this stage.

Requester prepares the Development Requirements Specification (DRS) directly as described in Section 3.2.2.3 and the Performer prepares the Test Plan as described in Section 3.2.2.6. The LRM shall inform the CRBRP/PO of all tasks being performed which do not require AIP.

3.2.2.2 Approval-In-Principle

The LRM reviews, approves and submits the DAD to CRBRP/PO with appropriate recommendations relative to AIP and budget. Copies of this transmittal should be sent to the potential Performer at this point, if appropriate.

CRBRP/PO reviews and provides AIP to the LRM along with approval of the budget as recommended by the LRM or provides direction as appropriate.

3.2.2.3 Detail Development Requirements Specification (DRS)

After AIP, the Requester shall prepare a DRS fully consistent with the DAD for use as detailed guidance to the Performer. The DRS shall include appropriate criteria to be used to determine the success or failure of the development results and where appropriate, the analytical results or calculational basis to be used to predict the results prior to initiation of the development activities. The preferred content and format are outlined in Appendix B to this section. In any case, the DRS number (same as DAD number) and its revision status shall be displayed at the top of each page. Close communication between the Requester and Performer during preparation of the DRS is encouraged in order to assure most effective use of the Performer's capabilities and to assure that the scope and schedule can be accomplished by the Performer within the approved budget. The DRS shall be approved by the Requester responsible engineer, the Requester QA, and Requester engineer line management as specified by the Requester internal procedures.

Following approval, the DRS shall be forwarded directly by the Requester to the Performer organization with copies to standard Project distribution.

Appendix B to Section 3.2

DEVELOPMENT REQUIREMENTS SPECIFICATION (DRS) CONTENT

1. Development Task Number

Same number as that assigned to Development Activity Description.

2. Development Title

Same title as that assigned to Development Activity Description.

3. Objectives

State what is to be investigated, determined, verified or obtained by conducting the development program. If there are multiple objectives, list them in order of importance.

4. Justification

State why the activity should be performed, why this problem is significant, and the technical consequences of not performing this activity. The impact on the Project should be stated with specific reference to affected Project Level 2 activities and/or milestones.

5. Description of Development Program (Scope)

Include a description of the development program. State what is expected of the performer organization. If an analysis tool such as an analytical model is to be developed, state the special.

Appendix E to Section 3.2

**CONTRIBUTING BASE DEVELOPMENT
CLINCH RIVER BREEDER REACTOR PLANT**

WORK AGREEMENT

SUPPORTED WA

PRINCIPAL INVESTIGATOR

WA NO.

REV.

RMVAE

SUPPORTING PROGRAM (ICR Number _____ ERDA Contract No. _____)
DESCRIPTION:

WA TITLE

ENGINEERING/DEVELOPMENT

[illegible]

COST ESTIMATE DISTRIBUTION (\$ IN 1980'S)
(COST ESCALATED TO BE YEAR OF EXPENDITURE DOLLARS)

[illegible]

COST-SCHEDULE

[illegible]

FINANCIAL STATUS:
LEVEL 2 SCHEDULE NO.
MILESTONE LEGEND

MONTH

APPROVALS DOLLARS IN

SUPPORTED RM COG.
MGR/ENGR.

DATE _____

CABRP/PO

DATE _____

LRM DEV. COORDINATION

DATE _____

DEPUTY DIRECTOR FOR
DEVELOPMENT & TECHN

RESP. ARO
ASST. DIRECTOR

DATE

Excerpt From Standard RDT F2-2, Quality Assurance Program Requirements
August, 1973

3.5 Design Reviews

The contractor shall conduct planned and documented design reviews in accordance with procedures to verify that the design meets requirements. Design reviews are intended to provide assurance that studies, calculations, and analyses involving nuclear effects, electrical, mechanical, thermal, hydraulic, safety, reliability, maintainability, and other pertinent considerations are complete and correct; that research and development programs and tests associated with the design provide optimal benefits to the design; that materials and design interface are compatible; that maximum use is made of qualified, standardized, or approved parts, materials, components, and processes; that accessibility for in-service inspection, maintenance, or repair is adequate; and that acceptance criteria for inspections and tests are delineated. Design reviews shall be held to discuss and resolve technical problems concerning design adequacy among the design contractor, the purchaser, and other project participants.

The contractor shall identify those components and systems for which independent formal design reviews are to be scheduled and conducted by the responsible design organization. Design reviews shall be independent in the sense that the reviewers have no direct responsibility for the design, but are technically competent and may be from the same organization that prepared the design. Participation in design reviews should be interdisciplinary, involving key technical personnel in the areas of design, manufacturing, testing, quality assurance, operation, and maintenance, as well as project management and consultants, as appropriate. Joint design reviews with other participating contractors shall be held by the responsible design organization when design interfaces are under consideration.

Hold points shall be established in the project beyond which further design work or initiation of fabrication shall not proceed pending an independent design review. Each design review shall be documented by the contractor in a report that shall include a synopsis of significant problems, decisions, and assigned action items. Design review reports shall be reviewed, approved, and issued by the responsible design organization and submitted to the purchaser as required by the contract.

Coverage of Materials Problems in Fossil Energy

Fossil Energy projects, by and large, derive from existing mature industries and can be classified in the "Technology" or "Engineering Systems Development" stage (see Thorne memo to Deutch, subject R&D Planning). There are, of course, material "problems" (i.e., barriers to improved performance, longer life, or lower costs). These are readily identifiable. For example, in gas turbines, both efficiency and life are limited by materials. With higher temperature materials, air cooling could be eliminated or inlet temperatures raised. Either would improve efficiency. Improved hot corrosion resistance of airfoils could extend life with "clean" fuel or liberalize "dirty" fuel tolerances without penalizing durability. These objectives have been at the core of all advanced propulsion and industrial gas turbine development over the past 20 years. Billions have been spent by DOE and private industry in reaching the advanced stage represented by contemporary commercial transport and military propulsion and industrial engines. Fossil energy programs to exploit these major accomplishments in the utilization of coal focus precisely in these well-defined material constraints. Their solution, or mitigation, is being sought through carefully planned applied research projects combining all essential analytical, design, fabrication, material, and process considerations. Project status or technical reviews are almost completely devoted to these "material" issues (recognizing, again, that the true sense of "materials R&D" lies in the total integrated design issue).

Similarly, Fossil Energy's efforts to develop commercially viable coal or oil shale conversion processes take into account durability, cost, and reliability constraints imposed by materials. Potential corrosion/erosion problems have been, and continue to be, identified and attacked through systematic materials/design evaluation testing under simulated plant - duty operating conditions. Process schematics are reviewed in detail to identify specific components or flow regions where combined thermal, chemical, and fluidynamic stresses pose a potential threat to life, cost or reliability goals. Plant lay-outs are likewise reviewed to identify potential fabrication and NDI problems.

Potential material problems in Magnetohydrodynamics were systematically identified and addressed experimentally at the outset of the Government's initiation of the National Program. This practice is being continued and modified as appropriate to the program's advance from the exploratory phase into technology and engineering systems development.

As noted, Project Managers in Fossil Energy are directly charged with the responsibility to identify, define, and address material and fabrication problems which impair the substitution of coal and oil shale for imported oil and high cost natural gas. Status and program reviews concentrate on these issues. Both individual DOE Headquarters' engineers and outside organizations are assigned specific responsibilities in carrying out the

purposes of the project. For example, the Illinois Institute of Technology has been assigned the job of systematically evaluating candidate low cost materials for coal liquefaction and gasification duty; NASA-Lewis Research Center is coordinating a DOE-Industry effort to improve the hot corrosion resistance of turbine materials in coal-driven fuel combustion gases; ORNL regularly investigates the material aspects of equipment failures or malfunctions in coal conversion pilot plant operation; Idaho Operations has been assigned the job of evaluating corrosion characteristics of material candidates for oil shale recovery equipment; ANL material engineers are determining the relative resistance of commercially available and improved industrial ceramics to slag erosion-corrosion; NBS is compiling materials properties data relating to coal conversion system design applications; the Francis Bitter Magnet Laboratory (MIT) and ANL have been given the job of developing improved fabrication technologies as necessary to ensure the integrity of superconducting magnet designs; ANL is conducting bench rig experiments to determine the performance of candidate materials in MHD heat and seed recovery equipment. This is only a partial list of responsibility assignments Fossil Energy has made to overcome material barriers in the exploitation of coal by U.S. industry. In each case, projects are either managed directly or suitably staffed by metallurgists, chemists, ceramists, and analytical specialists as appropriate to the specific requirements of the job.

Through regular briefings, topical reports, progress reports, and specific "white paper" situation summaries, Project Managers and staff keep upper DOE management levels advised of the progress of the work. As noted before, in many cases, the "job" is "materials."

Material issues or "problems" are, by definition, of principal concern in competitive procurement RFP's and resulting contract Work Statements. Since project and, often, program planning depends significantly on material performance projections, Procurement Requests, planning documents, briefing notes, and other managerial communications across organizational lines clearly highlight the material "issue."

Managers of Fossil Energy projects are expected to, and in fact do, assure themselves before a project contract is awarded that all necessary resources are available to handle the job, i.e., materials research and analytical laboratories; engineering design, fabrication, and test capability; analytical capability to interpret data and show the way towards design improvements; and finally experienced development and research engineers with a demonstrated record of accomplishments in the solution of design and cost disciplined material "problems." Indeed, the main responsibility of a Project Manager to the Government is to see to it that the industrial Contractor possesses all these basic resources before a contract is awarded.

How well this system works can be measured to some degree by the effectiveness of Fossil Energy - Contractor communication and responsiveness and, further, by the promptness of DOE/Fossil Energy - Industry-wide communication of important data. The former has been, on the whole, very successful; the latter could be improved. The most noteworthy examples of good FE/Industry communication are (a) the publication of a quarterly news bulletin on the performance of materials in experimental coal conversion and combustion pilot operations, and (b) work shops which are held regularly to acquaint relevant industrial and government representatives of materials progress in such important program as advanced gas turbines, fluid bed combustors, coal conversion plants, and MHD power systems.

As noted before, Fossil Energy projects represent advanced derivatives of existing mature industrial technologies. None are "future" in the sense of magnetic fusion, photo voltaics, or even thermionic power systems. As emphasized at several points before, "basic scientists" and "basic scientific methods" are being regularly employed in the pursuit of well-defined FE design/materials development goals.

Planning of FE work, at both project and program levels, recognizes and clearly identifies material issues.

There is no direct linkage between FE applied materials project R&D and the BES materials science programs. The practical cost, performance, reliability, and durability concerns of the applied FE materials work (described previously) are not comparable to the specialized requirements of the magnetic fusion, advanced weapons systems, or advanced LMFBR fuel and material projects being pursued by the BES office. These latter center, generally, on metals and ceramics intended for a single purpose, highly selective application, involve controlled materials, impose classification restraints, require equipment and sometimes highly specialized experience no longer available (or sought) by industry, or involve a final product which has dubious future market interest to a high grade technically-qualified industrial organization. The substance of FE applied work, on the other hand, is of important commercial significance to large and important segments of the U.S. power equipment, chemical, and metal and ceramic industries.

Information exchange has been discussed previously, i.e., reports, bulletins, workshops, conferences, etc. In the other direction, FE contractors and Project Managers are constantly searching related R&D activity world-wide in efforts to find a quicker, cheaper answer to the question. This is a singular advantage of having an industrial contractor conscious of future market opportunities. The other main advantage to the Government is that, if successful, production readiness is practically assured.

FE Project Management attempts to identify promptly promising sources of improved materials or fabrication techniques. A review of project documents will reveal a number of examples to illustrate this.

Materials Management in ET, Advanced Systems

ETS includes the following technical divisions:

- 1) Geothermal
- 2) Solar Technology
- 3) Electric Energy Systems
- 4) Energy Storage

Materials Management Policy varies among the four divisions.

Geothermal Division

Materials work is performed in an identifiable materials program and additionally as integral parts of major developmental projects.

Materials projects are identified from:

- 1) Unsolicited proposals
- 2) Problems occurring during developmental work
- 3) Cost/benefit analysis of geothermal utilization systems
- 4) The establishment of national materials performance standards

Existing information on geothermal materials from prior and ongoing projects has been collected in a Materials Selection Guidelines Handbook. The handbook contractor staff also serve a review function for larger national laboratory programs. Task groups composed of members of the American Society for Testing Materials and the American Petroleum Institute review parts of the program and provide a mechanism for technology transfer to industry. In addition to the handbook activity, the applied materials R&D manager has on one occasion mandated generation of a materials test plan for a larger project in the developmental area. A consultant materials expert from Ohio State University supports the materials manager with proposal, contractor and technical area reviews. The program is in the process of being more completely decentralized. In the proposed new management structure Brookhaven National Laboratory will carry out small projects in applied R&D and manage university applied R&D projects. Larger materials development projects will be let through and managed by a materials engineering person in the Chicago Operations Office.

The role of the headquarters materials manager is to coordinate the applied research effort with larger development efforts managed by Chicago and interface this with related materials work going on in other government agencies, national technical societies and international activities.

Energy Storage

This division has no materials program as an entity. Materials activities are integrated into developmental activities. The two most heavily oriented materials programs are run by materials specialists, and the two senior level managers in the division are materials experts by education. The materials specialists and the other eight program managers on the staff function as component and subsystem program managers. No formal review procedure occurs of materials work in the various programs, but informal coordination does occur. Materials information is kept available in an Energy Storage Data Base. Contractors for subsystems or component development may have individual subcontractors carrying out 100% materials applied or developmental R&D.

Electric Energy Systems

The division has no materials experts. Materials activities are fully integrated into developmental activities. Large portions of the program are run through the national laboratories (i.e., BNL and LASL are developing superconducting cable). The BNL program is \$2.5 million and the LASL program is \$1.5 million. Approximately 10% of the BNL program is devoted to NBSN material for the cable.

Solar Technology

This division is subdivided into two parts. One of these, Central Solar Technology and Ocean Systems, is further subdivided.

The Solar termal section includes materials work under hardware development. The program is divided into large power systems, small power systems, and advanced technology. Funding levels are 25 to 30 million, 13 million and 2 to 3 million respectively. The three managers for this section do not have materials training. No formal materials reviews are carried out in DOE, Washington.

At present, SERI and JPL are preparing plans and actively handling materials R&D work. Materials are considered to be a possible limiting factor in technology development due to short lifetimes.

Specific materials areas for development have been identified. These and the due dates for corresponding development plans include:

	<u>Plan Due</u>
1) Absorber materials	November 15, 1979
2) Reflector materials	November 15, 1979
3) Transmitting materials	April 15, 1979
4) Glass development	
5) Measurements and standards	August, 1979

SERI is presently working out developmental plans for these activities on the schedule indicated above.

SERI has no direct materials program but manages approximately \$2.1 million in FY 79 of subprograms in basic and applied research that are heavily materials-oriented. They have formal oversight councils that review materials aspects of programs. The materials branch is composed of 16 people and includes an interdisciplinary group of materials experts. They are actively working with the National Association of Corrosion Engineers and have a TllF technical committee for solar energy materials. They have a review board and standards group that works with the American Society of Mechanical Engineers and Materials Properties Council.

The Ocean Thermal Program has a materials expert in charge of the DOE effort. He has a management support contractor at Argonne National Laboratory. Materials play a predominant role in program development. Planning is done by the DOE program manager in conjunction with an advisory panel.

The program is establishing new standards and reviewing existing materials standards through ASTM Committee E44.

Decentralization and the impact of it on the program are not clear at this time.

The photovoltaics section in DOE headquarters has two managers. Both are oriented toward solid state but are not materials experts. The program is managed through the Jet Propulsion Laboratory and SERI. JPL handles technical development through commercialization and SERI handles applied and basic R&D. The photovoltaics and thermal storage programs have been transferred to SERI with a materials manager formerly with DOE/Solar.

Approach for Improved Coordination In the Research and Development
of Materials for Energy Conservation and Solar Applications

1.0 MATERIALS RESEARCH

Research and development on materials amounts to a relatively small portion of the Office of Conservation and Solar Applications' budget. Of the \$1 billion funded, only \$15 to \$20 million may be used for materials R&D. But this does not mean that CS is unconcerned with material research. Expanding use of solar energy to power America's homes, farms, and factories will require new and better materials. Likewise, conserving energy will require new methods of producing many goods that are basic to our economy.

The types of materials and shape of the technology that will be required in the future are impossible to describe in precise detail. Nevertheless, it is necessary to set goals which are subject to change. But it is not sufficient just to set goals; there must be a plan and an organizational structure by which the goals can be achieved quickly and efficiently.

1.1 MATERIAL NEEDS

The material needs in conservation and solar energy are fairly well known. Some requirements (and organizations that would work on them) are:

- Better insulating material (CS/BES)
- Improved ceramic material for engines (CS)
- Improved industrial processes, such as in aluminum (CS/ET)
- Improved low cost solar collector material (CS/ET)
- Improved materials for wind generator blades (CS/ET)
- Corrosion resistant materials for OTEC systems (CS/ET)
- Methods of improving the energy released from biomass (CS/ET)
- Improved batteries for electric vehicles (CS/ET)

The Office of Conservation and Solar Applications does relatively little research and development of materials compared to ET or ER, but is responsible for developing solar energy systems that are marketable. The materials research that CS carries out is related directly to the solar or conservation market. Such projects have included:

- Developing improved ceramics for turbine engines;
- Improving the insulating efficiency of cellulosic material;

- Improving the energy yield from urban waste, especially in the production of methane gas;
- Improving the methane yield from landfills;
- Discovering more energy efficient methods of producing materials

As shown below, the proportion of CS funds going to materials research is very small. CS is involved mainly in the commercialization of new products. As such, its materials research is a minor part of its effort. It is mainly a user of new materials rather than a producer of them.

FRACTION OF FY 80 CS FUNDING PERTAINING TO MATERIALS SCIENCES BY SECTOR (SHADED)

The matrix on the following page shows the types of materials research and development being done that will affect projects in Conservation and Solar Applications. The materials affecting the most CS projects are not under the direction of CS. The projects in coatings, glasses, polymers, steel, batteries, alloys and composites are directed by others. That makes coordination of efforts very important to CS.

2. PROBLEM OF DEFINING MATERIALS RESEARCH

The budget figures on CS materials research and development should be considered only rough estimates. They are intended to give an order of magnitude rather than make a definitive statement about funds available for this purpose.

There are two major problems in deriving a budget figure for material research and development. The first is that materials research is not broken out as a separate item. Determining the amount spent in this area would require fairly extensive research. The budget for each project would have to be examined carefully to determine what part of it might be considered research on materials. Obviously, this would be a difficult and lengthy project. There is insufficient time to perform that task now, although it could be done later if needed.

The second problem is the definition of materials research and development. The definition is so broad that it can encompass almost any activity dealing with any material. The Committee on Materials defined a material as "any substance segregated, introduced or used by man in performance of functions." Research and development "includes all basic research, applied research and development.... It includes R&D directed toward any portion of the total materials life cycle, from exploration and mining through manufacture, to final disposal and recycling/reuse."

Under these definitions, materials research and development is virtually unlimited in scope. Since the Office of Conservation and Solar Applications is seeking ways to produce goods in a more energy efficient manner and to find alternative sources of energy, its entire budget could be considered as devoted to materials research and development. Indeed, the entire Budget of the Department of Energy could meet the definition since it seeks to reduce energy consumption without a serious disruption of the economy.

Determining how much is being spent for materials research will first require a more restrictive definition of the term.

3.0 MATERIALS RESEARCH IN CS

The Office of Conservation and Solar Applications is allocating \$15 million to \$20 million in materials research and development in the new fiscal year. Spending is unlikely to change greatly in the foreseeable future. The funding of materials R&D is shown in the table on the next page.

MATRIX OF CS PROGRAMS AND CURRENT MATERIALS R&D

CS SECTION/ACTIVITY	CS MATERIALS/MATERIALS RESEARCH AND DEVELOPMENT													
	ALUMINUM	MINERALS	STEEL	COMPOSITES	COATINGS	CERAMICS	ALLOYS	SUPERCONDUCTORS	FUEL CELLS	DIELECTRICS	GLASSES	POLYMERS	CEMENT	WOOD, ETC.
<u>STATE AND LOCAL</u>														
WEATHERIZATION ASSISTANCE				△						△	△			
SCHOOLS AND HOSPITALS				△						△				
EPCA/ECOA														
SEMD														
LOCAL GOVERNMENT/PUBLIC HEALTH CARE BUILDINGS														
<u>SOLAR APPLICATIONS</u>														
DEMONSTRATIONS														
SYSTEM DEVELOPMENT				△		△				△	△	⊙		
FEDERAL PROGRAMS														
MARKET DEVELOPMENT AND TRAINING														
COMMERCIALIZATION PLANNING AND ASSESSMENT														
<u>BUILDING AND COMMUNITY SYSTEMS</u>														
URBAN WASTE														
BUILDING SYSTEMS				△						△	△			
TECHNOLOGY AND CONSUMER PRODUCTS														
COMMUNITY SYSTEMS														
APPLIANCES														
ANALYSIS AND TECHNOLOGY TRANSFER														
RESIDENTIAL CONSERVATION SERVICE														
SMALL BUSINESS														
FEMP														
<u>TRANSPORTATION</u>														
VEHICLE PROPULSION R&D		△	△		⊙									
ELECTRIC & HYBRID VEHICLES						△								
TRANSPORTATION SYSTEMS AND COMMERCIALIZATION UTIL.														
ALTERNATE FUELS UTILIZATION														
NEW CONCEPT AND IMPACT ANALYSIS														
NON HIGHWAY TRANSPORT														
<u>INDUSTRIAL</u>														
INDUSTRIAL PROCESS EFFICIENCY	⊙											⊙		
WASTE ENERGY REDUCTION														
INDUSTRIAL COGENERATION														
IMPLEMENTATION AND COMMERCIALIZATION														
<u>APPROPRIATE TECHNOLOGY</u>														
APPROPRIATE TECHNOLOGY														
<u>TECH TRANSFER SUPPORT</u>														
TECH TRANSFER SUPPORT														

⊙ DIRECT CS EFFORT
 △ OTHER DOE EFFORTS

FUNDING FOR MATERIALS RESEARCH IN
THE OFFICE OF CONSERVATION AND SOLAR APPLICATIONS

<u>FISCAL YEAR 1978</u>	<u>FUNDING</u> <u>(millions of \$)</u>	<u>FUNDING FOR</u> <u>MATERIALS R&D</u> <u>(millions of \$)</u>	<u>MATERIALS R&D</u> <u>AS % OF FUNDING</u>
INDUSTRIAL ENERGY CONSERVATION	\$ 30	\$ 1	3.3%
TRANSPORTATION ENERGY CONSERVATION	65	5	7.7%
BUILDINGS & COMMUNITY SYSTEMS	61	5	8.2%
SOLAR APPLICATIONS	130	6	4.6%
STATE & LOCAL	361	0	0
OTHER	2	0	0
TOTAL	\$ 649	\$17.0	2.6%
<u>FISCAL YEAR 1979</u>			
INDUSTRIAL ENERGY CONSERVATION	\$ 49	\$ 1	2.0%
TRANSPORTATION ENERGY CONSERVATION	97	5	5.2%
BUILDINGS & COMMUNITY SYSTEMS	69	5	7.2%
SOLAR APPLICATIONS	153	5	3.3%
STATE & LOCAL	590	0	0
OTHER	9	0	0
TOTAL	\$ 967	\$16.0	1.7%
<u>FISCAL YEAR 1980</u>			
INDUSTRIAL ENERGY CONSERVATION	\$ 103	\$ 1	1.0%
TRANSPORTATION ENERGY CONSERVATION	122	5	4.1%
BUILDINGS & COMMUNITY SYSTEMS	124	5	4.0%
SOLAR APPLICATIONS	209	5	2.4%
STATE & LOCAL	398	0	0
OTHER	11	0	0
TOTAL	\$ 967	\$16.0	1.7%

In developing new materials or processes, CS relies heavily on the Office of Energy Technology and the Office of Energy Research. This points out the need for good coordination of efforts between the different organizations working on different facets of the same project. We do not have good information on work being done by business, universities or other independent agencies.

3.1 INDUSTRY

Designs are being analyzed for efficient, high-temperature waste heat recuperators. These will operate in the 1,200 degree to 3,000 degree range and can be used in the manufacture of steel, aluminum, glass and cement. In addition, oxygen enriched combustion is being studied as a means of reducing fuel consumption.

Efforts are also being made to reduce the energy consumed in the most energy intensive segments of the manufacturing economy. These include steel, aluminum, paper, chemicals, petroleum, textiles, agriculture and food.

One materials project under the auspices of CS is research into the direct reduction of aluminum. Current aluminum processing uses an enormous amount of electricity. The objective of the research program is to develop a direct carbothermic reduction process to produce commercial grade aluminum. The process reduces bauxite and aluminum silicate with coke, producing an aluminum silicon alloy which is then refined.

In addition, a vertical shaft heat exchanger is being designed to preheat glass pellets in glass melting operations.

Paper making may be made more energy efficient if studies are successful on increasing the paper pulp fiber density of the headbox. Improvements are also being made in concentrating black liquor and chemical recovery in this industry.

Paint curing shows great potential for energy saving. Use of paint fumes instead of natural gas for combustion in curing coil coating lines has saved enough energy in just the demonstration unit to heat about 8,000 homes.

Textile operations are also being studied. Waste heat is being used to dry dyed cloth. This is a joint effort with the Environmental Protection Agency which is testing hyperfiltration of diestuffs to enable the manufacturer to recycle the hot water, dyed and other chemicals used in the operation.

Another project seeks to conserve energy by using slag and fly ash in cement and concrete. The slag and fly ash, waste products, are partially substituted for cement, thereby, saving the energy required to produce cement. Its goal was to modify cement specifications to provide a cement substitute, develop more performance oriented standards for blended cement, develop a more meaningful sulfate resistance test and develop reactivity tests for slag and fly ash. About \$130,000 was devoted to this project in FY 1978.

Tests are being taken to determine the possibility of substituting glass polymer for clay in pipe.

The CS budget is about \$1 million in these areas.

3.2 BUILDINGS AND COMMUNITY SYSTEMS

Buildings and community systems devotes about \$5 million to materials research and development.

Considerable testing has been done on home insulation materials. Materials on the market have been tested for their thermal characteristics, toxicity, flammability, and code requirements. Research has also been conducted to determine the effectiveness of different types of insulation under actual use conditions rather than just in the laboratory. Application techniques are also investigated to determine their effectiveness. About \$600,000 was spent in this area during the past fiscal year and \$750,000 will be spent in FY 1979.

On a community wide scale, a heat pump oriented Integrated Community Energy System, if successful, would make it possible to use unusual sources of heat in providing energy to the public. Heat from the air, water and ground as well as liquid wastes and low grade heat discharges can be converted to usable energy.

Research into urban waste is providing new uses for material that it often considered more of a nuisance than a resource. Efforts are under way to derive methane from recent waste as well as from old landfills. In addition, waste is being tested as a source of fuel for generating electricity as well as being burned to provide a heat source for drying sludge. Even more importantly, waste is source or recyclable material. This resource has the potential both to reduce the need for depleting resource stocks and to save great amounts of energy in foregone processing of virgin material. Funding is between \$4 million and \$5 million.

3.3 SOLAR APPLICATIONS

In the area of solar applications, research is directed mainly toward heating water and space heating and cooling. The requirements of such systems have been placed in five major categories: collectors, storage and heat exchangers, air conditioning and heat pumps, systems and controls and non-engineering aspects.

These categories imply the development of materials to improve economic and engineering efficiency. Research is being conducted on concrete materials, cover plates, coatings, sealants, fluids for solar absorption, insulation materials, protection of glazing materials, polymer coatings, corrosion evaluation and other areas. Funding was about \$6 million for these projects in FY 1978 and is about \$5 million in FY 1979.

3.4 TRANSPORTATION

CS is spending about \$5 million on basic materials resources in transportation. Work is being conducted on ceramic components for engines. The type of research being done includes determining its reaction to different environmental exposures and determining its life expectancy in an engine. Ceramics are being tested for their use in the heat engine, the hybrid engine, the Stirling engine, and the gas turbine engine. They are being used in generators, nozzles, shrouds and turbine blades. The gas turbine engine is being developed as a ceramic/metal engine, and as an all ceramic engine.

Work is also underway to develop improved batteries for the electric car.

4.0 NEED FOR COORDINATION

When such research is carried on by CS, coordination is very simple. The research is carried on for a specific purpose and is geared toward the ultimate marketing goal.

The situation can be considerably different when the materials research is carried out under the aegis of a different organization. When this happens, it is not necessarily geared to the requirements of marketing the product. Without close cooperation between the researcher and the individual who will try to make the product acceptable in the market, the cause of energy conservation and development of a strong solar energy market could be harmed. A material might be too expensive to find ready acceptance or it may not be durable enough or light enough to find widespread use. Timing differences can also be harmful. An improved material might be developed after the product for which it was intended is already on the market. The result would be a waste of resources.

The possibility of something like this happening is altogether too real. There appears to be no formal means of coordinating the materials research done by the Office of Energy Technology and the Office of Energy Research, for instance, with the materials requirements of the Office of Conservation and Solar Energy.

The development of the electric and hybrid vehicle might serve as an example. The vehicles are being developed by CS, but the improved battery is being developed by ET. Lack of formal procedures for coordination between the two organizations will cause the vehicles to be ready far before the battery. In fact, the vehicles may not be able to reach their program goals because of the lack of a battery.

Whatever coordination exists between the development of improved materials and the effort to market energy saving devices or alternative energy systems is very informal. Individuals trying to develop a marketable energy product may show enough initiative to learn what new materials are being developed. People trying to develop new or improved materials may occasionally try to learn the specific requirements of the products on which it may be used.

5.0 MATERIALS COORDINATION SYSTEM

Formal coordination of materials research and the uses which the research will be put could improve the efficiency of DOE programs. The DOE Under Secretary, in a memorandum dated May 31, 1978, defined in a general fashion a management scheme for DOE programs.¹ Detailed directives to formally implement the management system are being prepared, so the operation of the system is unclear at this time. However, a DOE R&D materials "strawman" management scheme, based upon the Under Secretary's interim policy and guidance, is presented as an initial attempt to address the R&D Coordination Council Materials Working Group's main problem. This is, as Dr. Stevens asked in the September 20 meeting "How is DOE to manage its materials R&D?" The new system should allow numerous opportunities for input from the materials community from program initiation through completion.

The Energy Systems Acquisition Cycle is divided into 7 Phases which have 4 Milestone Decision Points. The first three phases are Basic Research, Applied Research, and Exploratory Development. These comprise the Technology Base of the DOE Research, Development and Commercialization (RD&C) effort. The function of the Technology Base is to conceive, scope and explore technology options. Through these activities, a broad R&D base evolves which provides the underpinning for the development of specific projects.

¹DOE Under Secretary Memorandum of 31 May 1978. Subject: Program and Project Management System for DOE Outlay Programs.

The second general category of RD&C consists of Energy Systems Acquisition Project options which are selected for further development. For projects in this category, there is a commitment to large scale systems leading to commercialization strategies. Effort in this category encompasses four phases: Technology Development; Engineering Development; Demonstration; and Commercialization, Production and Operation. Each project reaches a Milestone Decision Point before entering into each of the four phases.

The seven Phases of the RD&C effort have been defined as follows:

- Basic Research

- Systematic, fundamental study directed towards fuller scientific knowledge or understanding of subjects bearing on National energy needs. This includes efforts to increase scientific knowledge of natural phenomena and the environment.

- Applied Research

- Systematic study directed toward scientific knowledge for specific energy requirements. These efforts are directed toward the solution of problems in the physical, biological, behavioral, social and engineering sciences which have no clear-cut applicability to specific projects. This includes the technical means of obtaining the knowledge or understanding and a solution.

- Exploratory Development

- Efforts guided by the principle that the work should lead ultimately to a particular application or product. Exploratory development can cut across several scientific disciplines and is intended to explore possible innovation in particular areas of energy technologies.

- Technology Development

- Systematic use of the knowledge and understanding gained from research to achieve technical feasibility. It is used to gauge the economic and environmental potential of energy concepts, processes, materials, devices, methods and subsystems. It comprises development of engineering technologies and subsystems, planning and analysis studies, energy system concept formulation, comparison of alternative concepts, and development and tests of laboratory-scale engineering models. This includes demonstration of alternative systems, as well as preliminary studies encompassing system analysis, trade-offs, preliminary cost-benefit studies, planning, and programming environmental studies.

- Engineering Development

- Systematic use of the knowledge and understanding gained from research and technology development for detailed design and construction. It includes tests for performance, production and reliability of energy system prototypes and pilot plants. Engineering development may be concerned with processes, pre-production components, equipment, subsystems or systems. This phase also includes major system test facilities directed toward specific project development and the preparation of environmental impact statements.

- Demonstration

- Verification of economic and environmental viability for commercial application through design, construction, testing and evaluation of large-scale energy systems in actual operation. Demonstration projects are intended to: a) overcome "scale-up" problems; b) show the economics of construction and operation; and c) resolve other questions such as public assistance and institutional and environmental issues. Preparation of environmental impact statements is included in this category.

- Commercialization, Production, Operation

- Commercialization - When the predominant problem is bringing the system or project to commercial reality rather than demonstrating technical feasibility.

- Production - When the predominant problem is producing the item in a quantity which meets specifically stated requirements.

- Operations - When the predominant problem is bringing the system or project from prototype or pilot plant to full-scale operation.

A DOE R&D materials "strawman" management scheme is presented in Figure 1. It is a top-down approach in which the RD&C selection starts from the national energy strategy and long-range planning defined by the Secretary of Energy. As indicated, there are numerous opportunities for the materials R&D community to contribute in a number of formalized planning documents. This could provide high visibility to materials research and allow considerable contact with all phases of the DOE RD&C effort. The following is a sample flow of the management scheme:

- 1) The source of a National energy strategy and long-range planning effort would include NEA, NEP, and related energy legislation as well as ongoing analyses and studies by various elements within DOE.

Figure 1. DOE R&D Materials "Strawman" Management Scheme

2) The Secretary of Energy will determine national energy needs and provide broad policy and implementation guidance.

3) Using the guidance provided by the Secretary, the principal outlay line managers of the Department develop plans for programs under their aegis. These plans will emphasize program strategies and the translation of general policy guidance into a specific program covering a multi-year period. The program plan is a goal-oriented description of specific technical, environmental, economic, and other efforts which result in a significant contribution to national energy needs. The program plans provide an opportunity to address materials needs.

4) The R&D Coordination Council (RDCC) is chaired by the Director of the Office of Energy Research and composed of the program Assistant Secretaries. It assures that the R&D activities of all program Assistant Secretaries are coordinated. In addition, a DOE Research Council has been formed as a standing committee under the RDCC. The Research Council, chaired by the Director of the Office of Energy Research, assists the Under Secretary in establishing and sustaining an effective research and technology base. It also assures an efficient linkage between Technology Base activities and Energy System Acquisition projects. Materials R&D considerations should play an important role here.

5) Upon receiving program guidance from the RDCC and the Research Council, the Director of the Office of Energy Research and the Assistant Secretary for Energy Technology oversee the bulk of the Technology Base activities in the Basic Research, Applied Research, and Exploratory Development Phases of the Energy Systems Acquisition Cycle.

6) The Technology Base, comprised of Basic and Applied Research and Exploratory Development, provides the basis for further development of specific projects.

7) Movement of a specific project from the technology base to further development requires the preparation of an Energy Systems Acquisition Project Plan (ESAPP). The initial ESAPP, ESAPP 1, covers the following points:

- Identification of the energy system need in terms of projected market penetration, i.e., time of entry, quad requirements, relationship to energy supplies displaced or substituted, regional characteristics and general applications.
- Assessment of the current state of technology and the potential for existing or known energy systems to meet the need, including the results of "State-of-the-Art" assessments. The objective of these assessments is to insure that DOE officials have a clear understanding of where a specific energy related technology stands before initiating any new activity aimed at bringing the particular technology to commercialization.

Updates to ESAPPs 3 and 4 follow the same procedure. The plan is revised as each phase is completed.

The principal advantage of the management scheme presented is that it presents the opportunity to have materials needs addressed and materials community input into the five key documents:

- Program Plan
- ESAPP 1
- ESAPP 2
- ESAPP 3
- ESAPP 4

In addition, materials R&D can be stressed in the RDCC and the Research Council. The solution proposed here is to make full use of the program and project management system introduced by the Under Secretary.

Secretary for Resource Applications or the Assistant Secretary for Conservation and Solar Applications will act as Assistant Chairman. The Office of the Controller provides staff support to the Chairman (ESAAB).

Materials Aspects of Resource Applications Programs

RA Mission

To commercialize new energy technologies.

Materials Concerns

To assure that materials R&D needs are identified early and addressed so that they don't represent critical path to commercialization.

Program Status

With exception of uranium enrichment (see below), the RA commercialization responsibility is new. Programs are now being formulated and management procedures are being developed.

Agenda Formulation

A number of technologies for consideration as commercialization candidates were identified in May, 1978. For each, a task force was established. Each task force had members from ET, RA, CS, EV, PE. The task force investigated the technical, economic and environmental readiness of the technology for commercialization. Included in the status report was a set of concerns or uncertainties; this included materials problems and uncertainties.

For those technologies judged to be ready, a commercialization strategy was formulated. The Task Force report was released to the public on October 1, 1978. Based on the outcome of the task force activities, a number of technologies have been assigned to RA. A resource manager has been designated for each technology. It will be the responsibility of the program manager, charged with specific demonstration to develop an appropriate management system to identify materials problems and to assure that complementary materials studies (for example, long term aging studies) are undertaken to provide information required by decision makers who would provide the market for the technology. The potential problems and necessary complementary studies have been identified in the commercialization task force report.

Uranium Enrichment

A major on-going activity in RA is the development of the gas centrifuges. Centrifuge rotor materials were identified early as a key program requirement to be investigated. A number of parallel development efforts were initiated. The selected centrifuge materials have been qualified. The materials development program is continuing to qualify materials which are of greater strength, cheaper, or less hazardous in processing operations.

- Evaluation of the impact of not meeting the need in terms of energy shortfalls, economic consequences, environmental concerns and institutional or regional effects.
- Proposed organization to explore alternative design concepts including summary estimates of resource needs, milestone dates, use of government or other institutions, management issues and other questions bearing upon the execution of the Technology Development.

The State-of-the-Art assessment in ESAPP 1 would provide an excellent vehicle for addressing the materials needs of the proposed system.

8) Once ESAPP 1 is prepared, it must be reviewed and approved before the project can move to the Technology Development Phase. This is Milestone Decision Point 1. System acquisition projects can only be approved by designated management officials (DMO). The Under Secretary must approve all major projects. The decision is made on a case-by-case basis whether a system acquisition project should be designated as major. The criteria for the decision include: significant resource level; deliverable major hardware; critical schedule need; and high visibility or sensitivity. An Energy Systems Acquisition Advisory Board (ESAAB) serves as an advisory board to the Under Secretary, provides supporting information and makes recommendations when decisions are necessary.²

9) Approval by the Under Secretary or the DMO allows the project to proceed to the Technology Development Phase.

10) Upon completion of the Technology Development Phase, ESAPP 1 is updated to ESAPP 2.

11) Milestone Decision Point 2: Review by US/ESAAB/DMO as appropriate.

•
•
•
•

12) Commercialization, Production, Operation

²The principal members of the ESAAB are: the Under Secretary, as chairman; the Deputy Under Secretary for Commercialization; the Assistant Secretary for Energy Technology; the Assistant Secretary for Conservation and Solar Applications; the Assistant Secretary for Resource Applications; the Assistant Secretary for Environment; the Assistant Secretary for Defense Programs; the Director, Office of Energy Research; the General Counsel; the Assistant Secretary for Policy and Evaluation; the Controller; and the Director, Procurement and Contracts Management. Other Assistant Secretaries and program officials may be invited to attend as advisors when appropriate. The Assistant Secretary or Director whose major energy system is presented for decision will act as Assistant Chairman. For decisions about proceeding to commercialization (Milestone Decision Point 4), the Assistant

Because operating speed of the centrifuge, a prominent indicator of centrifuge technology, is limited by the strength of the centrifuge rotor materials, identification of rotor materials has not been released. Materials scientists under government contract and in industry have been sought into this classified program as required to assure the quality and availability of required rotor materials. A materials advisory group, comprised of representatives from DOE laboratories, provides an overview of the materials needs of the centrifuge program. Representatives from industry are continuing efforts to develop improved materials for future program use.

EV PROGRAM POLICIES AND CONCERNS RELATED TO MATERIALS

The DOE Organization Act of 1977 gives to the Assistant Secretary for Environment (EV) the responsibility of advising the Secretary on matters relating to the conformance of DOE programs and activities to environmental protection laws and principles. EV also has responsibility for "conducting a comprehensive program of research and development on the environmental effects of energy technologies and programs."

These EV responsibilities quite naturally include concerns related to the environmental, health and safety (EH&S) impacts of materials used in energy development programs.

Potentially adverse EH&S effects, such as toxic or carcinogenic inhalation or ingestion hazards from materials and their degradation products, must be identified and addressed at every stage in the technology development cycle in order to assess risks and take necessary corrective actions. In this regard, EV is responsible for seeing that adequate attention is given to environmental control development and assessment activities. EV is also responsible for independent overview and assessment of all DOE programs and operations to assure that DOE-controlled efforts are conducted in a manner which minimizes undue risks to health and safety of the public and employees and provides adequate protection to property and the environment. This includes consideration for the safe transportation of hazardous materials.

A more detailed description of the mission, functions, and management relationships of EV is presented in the enclosed "Office of the Assistant Secretary for Environment Mission and Functions Statement" (Attachment 1). A few responsibilities having importance to materials programs are those associated with the coordination of DOE activities under the National Environmental Policy Act (NEPA), and with the development and preparation of Environmental Development Plans (EDP) and Environmental Readiness Documents (ERD). These documents are developed and prepared in close cooperation with other DOE offices and provide a mechanism for identifying and incorporating EH&S concerns in major DOE technology programs and decision-making processes. The policy, responsibilities and procedures concerning the EDP system are set forth in DOE Order No. 5420.1, Subject: "Environmental Development Plans," (Attachment 2).

A copy of "EV Environmental Planning and Review Requirements" is enclosed (Attachment 3), which presents a brief description of the formal documents supporting EV's EH&S functions. This writeup was prepared for inclusion as an annex to the new DOE "Energy Systems Acquisition Projects Plans."

Compliance with NEPA and the preparation and use of Environmental Assessments, Environmental Impact Statements, Environmental Development Plans, Environmental Readiness Documents, and Safety Analysis Reports all provide ways for identifying and addressing EH&S issues associated with materials in DOE programs and activities. The most useful of these is the Environmental Development Plan.

Environmental Development Plans were conceived and prepared as basic documents for planning and managing environmental requirements of energy technology development including aspects of development related to materials. Approximately 33 EDP's covering the major developing energy technologies have been prepared in close cooperation with the affected DOE technology programs. These EDP's are updated annually to assure that all potential EH&S problem areas are considered so that appropriate steps can be taken to remove or control environmental barriers to eventual commercialization.

In summary, it is EV's position that in addition to concerns that some energy development and commercialization projects may fall short of their goals due to unforeseen materials problems, it is also important that special attention be given to concerns which relate to the health and environmental acceptability of the materials being considered for use.

OFFICE OF THE
ASSISTANT SECRETARY FOR ENVIRONMENT
MISSION AND FUNCTIONS STATEMENT

A. Background

The Office of the Assistant Secretary for Environment was established on October 1, 1977, as part of the organization plan for the Department of Energy. The Organization Act stipulated that environmental functions should be the responsibility of one of the eight assistant secretaries authorized in the Act. The specified functions included advising the Secretary with respect to the conformance of the DOE's activities to environmental protection laws and principles, and conducting a comprehensive program of research and development on the environmental effects of energy technologies and programs.

Most of the environmental research and development functions came from the former ERDA, although some environmental policy and NEPA functions came from the former FEA.

B. MISSION

The Assistant Secretary for Environment is responsible for developing policy and issuing guidance to assure Department-wide compliance with environmental, health and safety plans, regulations and procedures. The ASEV prepares certain environmental impact statements (EIS), exercises independent reviews, approves other EIS's prepared within the Department and provides the link between the Department and other agencies and the public on environmental issues. In these responsibilities, the Assistant Secretary is principally responsible to the Secretary.

The Assistant Secretary also conducts a comprehensive program of research and development on the health, safety and environmental effects of energy technologies and programs. Additionally, the ASEV is responsible for ensuring that adequate emphasis is given to environmental control development activities. In carrying out this management function, the Assistant Secretary is under the primary cognizance of the Under Secretary. The Assistant Secretary also is responsible for independent overview and assessment of DOE-controlled activities to assure that they are conducted in such a manner that there are no undue risks to the safety and health of the public and employees and that adequate protection is provided to property and the environment. The ASEV will be the point of contact on safety and health matters for other Federal agencies, e.g., EPA, DOL, DOT, DOD.

In carrying out these responsibilities, the Assistant Secretary exercises executive direction over his immediate staff, the Office of Technology Impacts and other headquarters elements, and the Environmental Measurements Laboratory.

C. FUNCTIONS

The Assistant Secretary for Environment:

- o Assures that all Departmental programs are consistent with environmental, health and safety laws, regulations, and policies.
- o Provides policy guidance and technical assistance to DOE program offices with respect to the implementation of the National Environmental Policy Act (NEPA), including the review, quality control, and approval of NEPA documents prepared by other DOE organizations.
- o Conducts a comprehensive program of research and development on the environmental and health effects of energy technologies and programs.
- o Provides policy guidance and overviews DOE/Contractor employee safety and health programs.

D. DELEGATIONS OF AUTHORITY

The Assistant Secretary for Environment is delegated authority to perform the functions described above. This delegation includes the following authority:

- o Plan, advocate, execute, evaluate, assess, assign priorities, and defend programs in assigned areas including altering or terminating programs as necessary.
- o Commit resources.
- o Determine the requirements for and have performed contracts, leases, or similar transactions with public agencies, private organizations and persons.
- o Exercise authority to transfer funds within an agency decision unit under the control of the ASEV where not otherwise restricted.
- o Critically review all elements of DOE/Contractor ES&H programs.
- o Take such other action as the Secretary or his authorized delegate(s) may, from time to time, direct or authorize.

E. RELATIONSHIPS

The Assistant Secretary for Environment is responsible for determining the need for and achieving appropriate coordination with other Offices and Administrations within the Department directly concerned with the activities or the effects of the activities undertaken by this Office:

- o Serves as a member of the R&D Coordination Council and the Field and Laboratory Coordination Council.
- o Participates when requested in DOE management affairs by serving as a member of the Program Review Board, and the Management Review Board.
- o Coordinates DOE activities required or specified under the National Environmental Policy Act (NEPA) and provides technical assistance and policy guidance to program and regulatory officers in their preparation and defense of NEPA documents.
- o Develops mechanisms with other offices and administrations within DOE to insure joint preparation of EDP's and incorporation of environmental concerns in all decisionmaking processes.
- o Serves as point of contact for development of DOE ES&H standards and criteria.

U.S. Department of Energy
Washington, D.C.

ORDER

DOE 5420.1

8-10-78

SUBJECT: ENVIRONMENTAL DEVELOPMENT PLANS

-
1. PURPOSE. This order establishes the policy, responsibilities, and general procedures for the Department of Energy (DOE) Environmental Development Plan (EDP) system. The system is a means by which the DOE's commitment to environmental aspects of energy programs is established.
 2. CANCELLATION. Interim Management Directive Number 5102, "DEPARTMENT OF ENERGY (DOE) ENVIRONMENTAL DEVELOPMENT PLANS," of January 19, 1978, as previously canceled by DOE 1321.1.
 3. SCOPE. The provisions of this order apply to organizational elements which manage energy programs. Paragraph 6 describes responsibility for selection of specific EDP topics.
 4. DEFINITIONS.
 - a. Environmental means occupational and public health and safety, socioeconomic, legal, and ecological factors and mitigating measures.
 - b. Energy programs means the programs for conservation and solar commercialization, commercialization and demonstration, research, development, and technology demonstration; nuclear weapons; basic sciences; and energy extension service.
 5. POLICY AND OBJECTIVES.
 - a. It is DOE policy to identify, characterize, assess, and mitigate real and potential adverse environmental impacts from any of its programs.
 - b. Through the EDP system, environmental issues will be identified for use in management decisionmaking from the earliest stages of energy program development onward. The system will also assist in making environmental issues competitive with technological, economic, and institutional issues and in coordinating a timely resolution of conflicting issues.

**DISTRIBUTION: All Departmental Elements
Federal Energy Regulatory Commission (Info)**

INITIATED BY: Office of Environment

DOE 5420.1

8-10-78

- c. An Environmental Development Plan will contribute to National Environmental Policy Act (NEPA) compliance, provide a common basis for high-level management planning and reviewing of environmental aspects of the selected programs, and allow interested and responsible parties outside DOE to become aware of its environmental efforts.

6. RESPONSIBILITIES AND AUTHORITIES.

- a. The Assistant Secretary for Environment (EV-1) is responsible for:

- (1) Administration of the EDP system.
- (2) Determination of general planning guidelines; special planning considerations; specific EDP topics; and the schedules and priorities for EDP preparation.
- (3) Description of environmental issues and identification of the requirements necessary to satisfy those issues.
- (4) Preparation and approval of each EDP.
- (5) Implementation of the environmental efforts required, throughout the EV organization.

- b. Each Energy Program Assistant Secretary/Director of Energy Research is responsible for:

- (1) Actions specified in subparagraphs 6a(2), (3), and (4) above, jointly with EV-1.
- (2) Provision of technical energy data, description of the energy program, and establishment of relative priorities among energy options.
- (3) Implementation of the program and environmental efforts required.

- c. EV-1 and the Responsible Assistant Secretary(ies)/Director of Energy Research may jointly devise and activate a mechanism(s) for assessment of the adequacy and progress of the energy program and the associated environmental development.

- d. The Assistant Secretary for Policy and Evaluation (PE-1) is responsible for:

DOE 5420.1
8-10-78

- (1) Review of each EDP to advise the energy program assistant secretary/Director of Energy Research, and EV-1 on planning and policy issues.
- (2) Integration of EDP's into the DOE's Policy and Program Planning System (formerly IMD No. 0203).

7. PROCEDURES.

- a. Each EDP should contain the following information:
 - (1) Brief description of the energy program and its status.
 - (2) Descriptions of environmental issues.
 - (3) Strategies required to address these issues.
 - (4) A coordinated schedule for program development and requisite environmental activities.
 - (5) Designation of milestones for NEPA actions and documents.
 - (6) A plan for management review.
- b. EV-1 will organize an Environmental Coordination Committee (ECC) for each EDP (or group of EDP's). Members of each ECC will be appointed by EV-1 and the responsible energy program assistant secretary(ies)/Director of Energy Research to assist in:
 - (1) Preparation of EDP's and their external and internal review.
 - (2) Overview of current and planned environmental activities relevant to the EDP.
- c. EDP's should be unclassified and contain nonproprietary information whenever possible. If classified or proprietary information is unavoidable, a separate supplement containing the classified or proprietary information should be developed.
- d. EDP's are prepared at a level compatible with Management Review and Control Documents. They are updated continually and reissued annually. EDP's are also prepared for energy programs, which although not the statutory responsibility of DOE, affect significantly DOE environmental missions.

- e. EDP's length will vary, depending upon the scope of the energy program addressed.

FOR THE SECRETARY OF ENERGY:

William S. Heffelfinger
Director of Administration

ENVIRONMENTAL PLANNING AND REVIEW REQUIREMENTS

Environmental planning and review requirements are an integral part of the Program and Project Management System for DOE Outlay Programs. These requirements pertain primarily to the preparation, review, and decisions on Program Plans, and Energy Systems Acquisition Project Plans.

The principal environmental requirements and their intersection with the Program and Project Management System are illustrated in Figure 1. The figure provides a representation of how environmental activities and their documentation work to support the removal of barriers and identification of uncertainties that must be considered within the technology movement to commercialization, production or operation. The Assistant Secretary for Environment (ASEV) will provide to the Program and Secretaria offices assistance and judgements concerning significant environmental factors that should be considered in program planning and in the acquisition of major projects. Each of these is supported by a set of formal documents that are discussed below.

ASEV has developed two major documents to support the program plans. The first of these is the Environmental Development Plan (EDP) which takes cognizance of environmental, health and safety uncertainties that can be resolved through research. An overview of these research needs and probable scheduling prior to each key decision point is delineated in the EDP to assure the environmental research and decisionmaking are not out of phase with the technology development plans. The second document, the Environmental Readiness Document (ERD), derives from the Environmental Development Plans and assessments of environmental impacts and summarizes the status of environmental barriers and uncertainties for a given energy technology to directly support the decisionmakers at the four Key Decision Points.

Within the major energy systems acquisition area, the scope of environmental concerns turns from research and status reports to environmental safety, and health assessments of specific projects and operations which are proposed. Three documents are utilized in these phases: Environmental Assessment, Environmental Impact Statement, and Safety Analysis Report.

The Environmental Assessment and Environmental Impact Statement, if required, are prepared first for a program, and then on a site or process specific basis with timing developed to allow major procurements and construction activities to begin with reduced uncertainties and minimum time delay. In a similar fashion, the Safety Analysis Report examines the health and occupational hazards of proposed major operations under the cognizance of DOE to assure that barriers and impacts are resolved without undue time delays.

The ERD provides the basis for the ASEV position on the environmental acceptability of a DOE technology at the Key Decision Point.

Environmental Assessment (EA)/Environmental Impact Statement (EIS)

The National Environmental Policy Act of 1969 requires that agencies prepare Environmental Impact Statements "on proposals for legislation and other major Federal actions significantly affecting the quality of the human environment." For all proposals which may require EIS's and Environmental Assessment may be prepared. An Environmental Assessment is a statement which provides the information upon which to base a determination of the necessity for an Environmental Impact Statement or a finding of no significant impact. Environmental Assessments may be prepared for any action and at any time in order to assist Departmental planning and decisionmaking. EA's and EIS's are prepared by program offices according to DOE procedures and reviewed by the Office of Environment. They can be prepared at any phase of the Management System as required, but will normally be required beginning at the Technology Development Phase.

Safety Analysis Report (SAR)

The Safety Analysis Report (SAR) is prepared by program managers according to DOE procedures and reviewed by the Office of Environment (EV) early in the design phase of a proposed facility that DOE intends to procure and operate. The SAR will identify hazards, their elimination and control, assess residual risk and document management authorization of a DOE operation. The purpose is to limit risks to health and safety of the public and employees and adequately protect property and the environment. The Safety Analysis preparation and review process assures that:

- potential hazards are systematically identified.
- potential impacts are accurately analyzed.
- all reasonable measures to eliminate, control or mitigate the hazards have been taken.
- there is documented management authorization of the DOE operation based upon an objective assessment of the residual risk identified in the Safety Analysis.

**United States
Department of Energy
Washington, DC 20585**

**Official Business
Penalty for Private Use, \$300**

**PENALTY FOR PRIVATE
USE TO AVOID PAYMENT
OF POSTAGE, \$300**

DOE 350

FIRST CLASS MAIL