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RESEARCH REPORT

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T4E 16 MAY 1975

CRITICAL MATERIALS NEEDS

(Midterm Technical Report)

to

DEFENSE ADVANCED RESEARCH PROJECTS AGENCY
Technology Assessments Office

May 1975

by

Curtis M. Jackson, James O. Frankosky
and Joseph G. Dunleavy

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Project Engineer:	Mr. J. O. Frankosky (202) 785-8400, ext. 238

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FOREWORD

The research and analysis reflected in this report were performed by Battelle's Columbus Laboratories. The project is supported by the Defense Advanced Research Projects Agency (ARPA) of the Department of Defense (DoD) and is monitored by the U. S. Army Missile Command, Redstone Arsenal, Alabama, under Contract No. DAAH01-75-C-0338. Mr. Rudolph A. Black, Director, ARPA Technology Assessments Office, is the Technical Monitor of this effort.

This midterm report is prepared as of April 15, 1975, embracing the research effort conducted up to that date.

DISCLAIMER

The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the Defense Advanced Research Projects Agency or the U. S. Government.

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on

CRITICAL MATERIAL NEEDS

by

Curtis M. Jackson, James O. Frankosky and Joseph G. Dunleavy

INTRODUCTION

During this century the rapid increase of technological advances and their incorporation into military systems and materiel have often created unforeseen demands for raw materials and consequent shortages, and economic rivalries among friendly as well as hostile nations. Such situations are often further aggravated and intensified by the onset of major military conflicts. The shortage of rubber and copper in World War II, the stockpiling of many metals during the Korean War, and the search for uranium ore during the 1950s are well-known historical examples. In such circumstances, the United States has many times found it necessary to categorize certain raw materials as essential or critical. To ensure adequate supplies of critical materials the DoD has then found it necessary, often belatedly, to initiate conservation measures (including design changes), material substitution programs, and/or raw materials stockpiling. It would be most helpful to the DoD if it could better anticipate the need for such measures through prior assessment and analysis of technological trends which impact on the needs for materials which could be classed as critical. This research project addresses those needs by making an assessment of emerging industrial technologies in the United States.

TECHNICAL OBJECTIVE

The objective of this research effort is to acquire data, information and explanatory analyses which identify certain emerging technologies, assess the materials involved in these emerging technologies and identify associated potential procurement and development problem areas for DoD which may result from these emerging technologies.

TECHNICAL APPROACH

On the basis of specific requirements stated in the contract, a technical approach has been devised to organize the effort and meet the research objective. The approach to the program is divided into four principal tasks:

- Identification and Selection of Emerging Industrial Technologies
- Description of Technologies and Assessment of Materials
- Assessment and Comparison of Material Requirements
- Identification of DoD Problems

Task I: Identification and Selection* of Emerging Industrial Technologies

In Task I, the emerging industrial technologies in 15 U.S. industries have been identified through interviews with Battelle staff members having knowledge and expertise in these industries. Emphasis was placed on emerging industrial technologies that (a) create demands for new materials, (b) increase or reduce demands for current materials, and (c) involve new extractive processes for ores that could expand available reserves. The industries that have been selected for scanning for emerging technologies are:

- Aerospace and Space Systems
- Chemical and Chemical Processes
- Communications
- Construction
- Electronics/Electrical
- Energy
- Food and Agriculture
- Forest Products
- Machinery
- Materials
- Medicine and Biomedicine

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* This task has been completed and the results are reported beginning on page 8.

- Mining and Minerals Processing
- Ocean Engineering
- Transportation
- Waste Treatment and Environmental Control

The technologies identified in the screening process as appearing to have the greatest impact on future requirements for critical materials are to be studied in greater depth under Task II. Three criteria have been applied in selecting these technologies:

(1) The quantity of critical materials required or supplied by the emerging technology.

(2) The degree of criticality of the particular critical materials required or supplied by that technology.

(3) The degree to which the emerging technology is expected to penetrate the market by the year 1990. [Among the factors to be considered in projecting the market penetration of the technology will be (a) any obvious energy intensivity of the basic processes involved in the technology and (b) any obvious negative effect of the technology on the environment.]

To apply these criteria, it has been necessary to identify critical materials and to rate the degree to which they are critical. The following factors were considered in the identification and rating of critical materials:

(1) Extent to which the United States relies on imported supplies of the material (a) at present and as currently projected and (b) in the future, on the basis of emerging technologies.

(2) Extent of needs for the material by the Department of Defense (a) at present and as currently projected and (b) in the future, on the basis of emerging technologies.

(3) Degree of competition between industry and the Department of Defense for the available supply of the material (a) at present and as currently projected and (b) in the future, on the basis of emerging technologies.

(4) Possible existence in the United States of a significant shortage of production capacity with which to process the material into the required form (a) at present and as currently projected and (b) in the future, on the basis of emerging technologies.

(5) Basic availability of the material (a) ore reserves and (b) amount produced per year.

(6) Availability of substitute materials.

Obviously, not all of these factors could be covered in detail for each emerging technology identified when the 15 U.S. industries were scanned. Rather, information that is readily available from Battelle specialists, selected government and industrial reports, and personnel of The Rand Corporation (RAND) and Stanford Research Institute (SRI) who are involved in related studies for ARPA was used to make value judgments on the basis of these factors.

Task II: Description of Technologies and Assessment of Materials

Task II involves obtaining information in the following areas for each of the emerging industrial technologies that were selected in Task I for deeper study:

- Technical description of the technology.
- Requirements of the technology for critical materials and for major material-processing equipment.
- Current projections of the supply/demand and cost situations through year 1990 for the critical materials involved in the technology.
- Current general projections for the future availability of the major material-production capacity required by the technology, to the extent that such information is readily available.

The technical description of the technology and its requirements for critical materials and for major materials-production capacity is being obtained both from Battelle specialists and through personal contacts with appropriate industry personnel. The projections of supply/demand and costs of the materials is based on data from Battelle and industry sources, from selected government and industrial reports, and from oral presentations at the DoD Material Shortages Workshop and National Conference on Materials Availability/Utilization. General projections of the future availability of major capacity for the production of materials is being obtained from industry sources, to the extent that such information is readily available.

Task III: Assessment and Comparison of Materials Requirements

In Task III, projections are being made of the anticipated penetration of the market by the selected technologies through the year 1990. Cognizant industry sources are being relied on for these projections, with additional input from Battelle specialists in these technologies.

Based on these projections of market penetration, and on the materials requirements (for supply) involved in the technology, the tonnage requirements for (or supply of) critical materials as a result of these emerging industrial technologies are being projected to the year 1990. These requirements (or supply) are then compared with the current supply/demand forecasts prepared in Task II.

Task IV: Identification of DoD Problems

Task IV, potential procurement and development problem areas for DoD which may result from the forecasted changes in supply and demand based on the emerging technology will be identified. Data on the projected DoD needs for the critical materials and major capacity for their production is expected to be available from the RAND and SRI personnel involved in related programs for ARPA. Additional data will be obtained from selected Government reports.

SUMMARY OF TECHNOLOGY EVALUATION TO DATE

Preparation for Research

The first steps in this project were the formulation of the work plan and the organization of the Battelle team. The core of the Battelle team consists of Mr. James O. Frankosky, Project Engineer (Battelle Project Manager), Dr. Curtis M. Jackson, Principal Investigator, and Mr. Joseph G. Dunleavy. In addition, Battelle specialists in the very many technical fields associated with the 15 industries were identified for specific expertise.

On January 13, 1975, Mr. Frankosky and Dr. Jackson met with Mr. Rudolph A. Black, the ARPA Technical Monitor, to review and discuss the work plan, including the technical approach described above and the schedule shown in Figure 1. Mr. Black approved the plan with the following additional guidelines.

- Inasmuch as federal agencies other than DoD are already looking at extractive processes for ores, Battelle should consider such processes as third-priority interest and perhaps provide an overview of that subject, if at all.
- The energy field is already being studied extensively by many federal agencies, including DoD. Accordingly, Battelle should exert only minimum effort in that area, particularly in fuel research, identifying only those emerging technologies that might have unusual significance or that might otherwise be overlooked.
- Another area deserving only minimum attention in this particular research effort is the food and agriculture industry. It may be appropriate just to highlight impacts on that industry. A possible example is platinum, which Battelle has identified as being a catalyst in the production of certain fertilizers, and which could become increasingly critical in its availability.
- Battelle should not spend a lot of time in search for substitute materials in the various technologies studied. Of course, any obvious substitutes that could impact on the availability of materials for a given technology should be included, as may be appropriate.
- In the conduct of the Task I effort, Battelle should quickly screen out those technologies which, on the basis of preliminary contact with Battelle specialists, do not initially satisfy the criteria for selection for study in greater depth. This is necessary in order that a major share of the research effort can be devoted to the technologies selected for Tasks II, III, and IV. (It was recognized in the discussion that some emerging technologies which are not so selected could possibly have been found qualified for the subsequent tasks if more extensive Task I effort could be undertaken.)

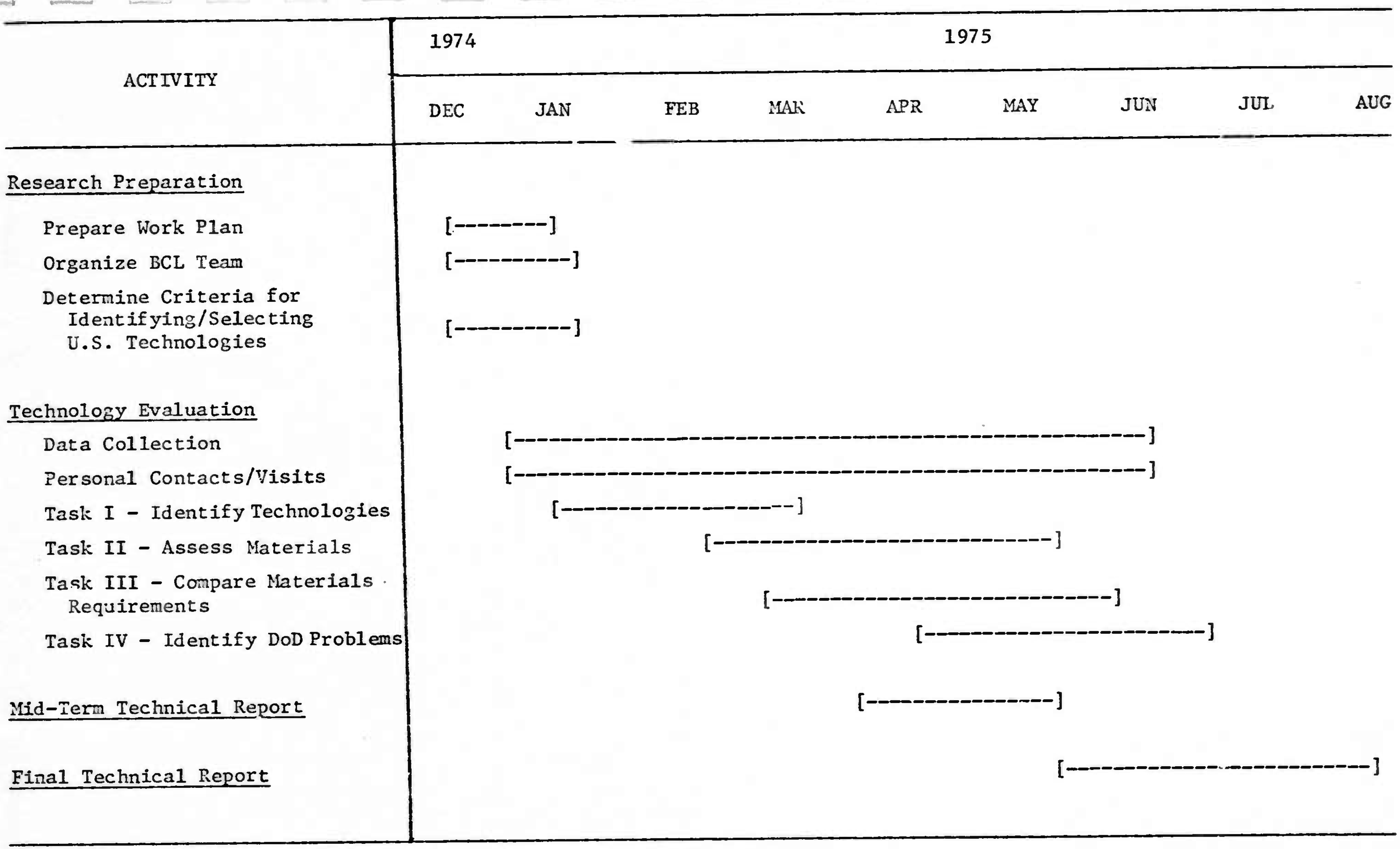

FIGURE 1. ESTIMATED SCHEDULE

Completion of Task I
(Identification and Selection of
Emerging Industrial Technologies)

Utilizing the agreed technical approach and methodology, technical discussions with Battelle specialists and the gathering of data were initiated in January, and these continued through March as an essential part of Task I. Altogether, 54 Battelle specialists were interviewed with regard to the 15 major U.S. industries so as to identify technologies for possible further study. Fifty-six emerging technologies were identified in this manner (see Appendix A).

As requested by the ARPA Technical Monitor, the Battelle core team met several times with RAND and SRI representatives who are researching other, related technological areas to exchange pertinent technical information.

The Battelle Project Manager attended the DoD Workshop on Materials Shortages in Washington, D. C. during January 14-16, 1975, and he made an informal report of the proceedings and highlights of the workshop to the ARPA Technical Monitor (see Appendix B). Background and technical information useful in Tasks I, II, and IV were obtained.

The Battelle Principal Investigator attended the First National Conference on Materials Availability/Utilization in Chicago during January 22-29, 1975, and he made a report of the conference proceedings and results to the ARPA Technical Monitor (see Appendix C). Background and technical information that are useful in Tasks I and II were obtained.

During March, 1975, Task I was completed, to include briefing ARPA on March 28 concerning the results of the research conducted under that task.

During the conduct of this task, there were 50 emerging technologies that, having been identified as potential candidates, were not selected for further research. Within the guidelines established for the research effort, they were judged not to meet the applicable criteria sufficiently to warrant continued application of remaining available contracted resources. Technical descriptions and the respective rationales for their being initially considered, but subsequently rejected, are briefly summarized in Appendix D.

Six emerging technologies were identified for further study in the subsequent Tasks II, III and IV, since they met the criteria for such selection best among the 56 studied. They were:

- Superconductors for Power Application
- Lasers for Materials Processing and Measurement

- Fiber-Reinforced Organic-Matrix Composites
- Fuel Cells for the Generation of Peaking Power
- Electroslag Remelting of Metals
- High-Temperature Gas-Turbine Engines for Automotive Applications.

Preliminary research results and data gathered as of the time of this report for the six selected technologies are summarized below.

Superconductors for Power Applications

Description of the Technology

Superconductivity was discovered in 1911 by Kamerlingh-Onnes,* who found that the electrical resistivity of mercury undergoes essentially a step-function decrease at 4.2° K to almost zero. Since then superconductivity, the essential absence of electrical resistivity below a temperature termed the superconducting transition temperature, has been found in many different metals and alloys (including compounds) and a few other materials. The superconductors that are of most interest for practical industrial applications are those with the highest transition temperatures. The higher the transition temperature, the less costly is the cooling required to maintain the material in its superconductive state during service.

Because of the essential absence of electrical resistance, an electric current in a superconductor will suffer very little loss. Hence, one of the commercial applications for superconductors is in the transmission of electric power. Most uses for superconductors are based on the use of large coils of these materials in the construction of very high field magnets.

Industrial Applications for the Technology

The primary potential applications of superconductivity appear to be the following:

- Generation of electric power
- Transmission of electric power

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* Kamerlingh-Onnes, H., Commun. Leiden, 120b, 122b, 124c (1911).

- Direct energy conversion (heat to electrical) by magnetohydrodynamics (MHD)
- Plasma-confining magnets for nuclear fusion reactors
- Energy storage
- Ship propulsion
- Levitated trains.

In all applications except power transmission, the superconductor is in the form of a high-magnetic-field magnet.

Between now and the year 1990, it appears that the major uses of superconductors will be in the first four areas listed. The use in that time frame in connection with the third and fourth applications, magnetohydrodynamics and nuclear fusion reactors, will probably be limited to experimental research. Nevertheless, the very large magnets required for this research will utilize large amounts of superconductive materials.

Critical Materials Utilized in the Technology

Types of Materials and Areas of Application. The critical materials involved in this technology are the superconducting alloys and the high-strength nonmagnetic steels required for the framework to support the very large electrical forces generated by superconducting magnets.

The primary superconducting alloys that are in commercial production at this time are Nb_3Sn and NbTi. For the purpose of this study, it is assumed that these materials will be used as the superconductors in the aforementioned applications between now and 1990.

The high-strength nonmagnetic steels of which the large magnet supports will be constructed will probably contain nickel and chromium, the former being largely imported and the latter being 100 percent imported and currently being stockpiled by the United States.

Projected Quantity Requirements. It has been estimated that 200,000 pounds of columbium (niobium) will be required in the year 1990 for use in the Nb_3Sn and NbTi superconducting alloys. This compares with 50,000 pounds of columbium projected for use in superconductors in 1975.

These quantities of columbium correspond to roughly 300,000 pounds of superconductors in 1990 and 75,000 pounds in 1975.

No projections are presently available of the quantity of nickel and chromium in the steels to be used to support the superconducting magnets.

Basis for Criticality Judgment. Since the United States is now 100 percent dependent on foreign sources for columbium and chromium and for nearly all of its nickel, these elements are deemed critical. All our columbium is imported, coming primarily from Brazil, Malaysia, and Zaire. All (except for domestic steel scrap as a source) of our chromium is imported; the principal suppliers are the U.S.S.R., Rhodesia, and the Republic of South Africa. Nearly all of our nickel is imported; the primary source of supply is Canada. Tin and titanium are also critical materials because of the dependence of the United States on foreign sources. However, the requirements of superconductors for these metals are expected to be considerably smaller fractions of the total yearly U.S. consumption than in the case of columbium.

The superconducting alloys Nb_3Sn and NbTi are judged to be critical for an added reason. At present, the several companies that manufacture these alloys and fabricate them into the desired form (e.g., wire or strip) have limited capacity. Whether or not the necessary capital will be available to expand operations (either by these companies or others) to meet the projected demand is now conjectural. Hence, it is possible, even if the required columbium were to be available, that the superconducting alloys themselves may become critical in the coming years because of insufficient production facilities.

Relationship of Technology to Needs of the Department of Defense

The Department of Defense also has interest in superconductors. Among the potential DoD applications are ship propulsion, power generation for airborne and shipboard use, and power generation in remote areas.

Lasers for Materials Processing and Measurement

Description of the Technology

The term laser is an acronym for light amplification by the stimulated emission of radiation. The radiation is in the visible or infrared portion of the spectrum. A laser consists of an active material situated between two parallel plates of an interferometer. In operation, the active material is excited by an external source of electromagnetic radiation; this excitation causes an increase in the population of higher energy levels in the material and a decrease in the population of the ground state. When an excited atom is struck by a photon of electromagnetic radiation from the external source, the atom will decay back to the ground state.* In so doing, it will emit a coherent light wave, i.e., a photon that travels in the same direction with the same frequency and in phase with the impingent photon.

The interferometer is adjusted to the frequency of the emitted radiation; hence, it acts as a resonant cavity and allows energy to build up. Controlled amounts of radiation, constituting a laser beam, are allowed to escape through a window.

Industrial Applications for the Technology

Lasers are being adopted in a wide variety of industrial applications, to include the following:

- Materials processing (welding, cutting, drilling, hardening and scribing)
- Measurement
- Medicine [laser scalpel with automatic cauterization ("bloodless surgery"); generation of X-rays]
- Communications
- Isotope separation
- Protection and detection (security systems, etc.)
- Holography.

Of these areas of application, it is estimated that materials processing and measurement will represent the largest market for lasers between now and the year 1990.

Not only have lasers proven their ability to accurately and rapidly weld, cut, drill, and scribe difficult-to-form materials, but also lasers are well suited for automated production-line operations. This is another important advantage of lasers. Measurement by means of a laser can be very accurate. This can, again, be automated. Moreover, there is an increasing tendency to use

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* Spontaneous emission of a photon, caused by spontaneous decay back to the ground state wihout being hit by a photon, also occurs. These photons are non-coherent.

lasers to align large, complex pieces of equipment during installation.

Critical Materials Utilized in the Technology

Types of Materials and Areas of Application. The two primary types of lasers that are used for materials processing are neodymium-doped yttrium aluminum garnet (Nd-YAG) lasers and CO_2 lasers. For measurement applications, where very much less power is required, a variety of lasers including helium-neon, argon, and semiconductor lasers are used. Nd-YAG may be a critical material in the future.

In addition, special optical glasses as well as natural crystals are utilized in the laser optics systems. These are critical materials, even at present.

Projected Quantity Requirements. A preliminary estimate is for the yearly requirements for lasers for materials processing and measurement to increase perhaps tenfold by the 1980-1985 time frame.

Basis for Criticality Judgment. Nd-YAG is viewed as a potentially critical material. This is a single-crystal, high-purity material. A very rough estimate of production in 1974 was only about 30 pounds. With rapidly growing demands versus such limited production capacity, the possibility of Nd-YAG becoming a critical material deserves further study.

Special optical glasses and natural crystals (e.g., calcite) are presently critical materials. Most of the U.S. consumption of these materials is imported. Much of the special optical glass is imported from Japan and West Germany, while Brazil is a large supplier of the natural crystals.

Relationship of Technology to Needs of the Department of Defense

The Department of Defense maintains a strong interest in lasers, mostly for fire control systems and other weapons applications.

Fiber-Reinforced Organic-Matrix Composites

Description of the Technology

As modern technology advances, it is becoming increasingly evident that there is no "ideal material." All materials have disadvantages as well as advantages. For instance, many high-strength metals and nonmetals have very little ductility and/or very little resistance to impact loading. Still other high-strength materials have inadequate resistance to attack by various environments.

The technology of composite materials has been developed in an effort to tailor materials that combine the advantages of two or more materials, while minimizing their disadvantages. The most common examples of the application of this concept are fiber-reinforced composites, where the very high tensile strength and modulus of elasticity of certain metals and nonmetals in filament form are used to increase the strength of a ductile matrix material. Other advantages of composite materials are reduction in the weight of components and systems, increased thermal stability, simplification of construction, increased stiffness and, often, reduced total life-cycle cost.

The matrix can be metallic or nonmetallic. The choice of fiber and matrix material depends on their properties, the properties required in the application, the environment while in service, the compatibility of the fiber and the matrix, the economics involved in a composite's manufacture and use, and other factors.

The fibers may be short and randomly dispersed on the matrix in an attempt to achieve isotropic properties, or they may be long filaments which are oriented in a single direction in order to achieve higher strength (although the strength is unidirectional).* Applications for both fiber types of composites are being pursued. However, it appears that between now and the year 1990 composites utilizing directionally oriented long fibers as the reinforcing medium will have greater impact on critical materials and DoD needs than will composites reinforced with random short fibers. In particular, in that time span it is judged that the most significant composites from these standpoints will be those consisting of graphite fibers and/or aramid organic fibers in thermoplastic and

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* Composites in which long fibers are oriented in two directions are also being investigated.

thermosetting organic matrices. These types of composites constitute the emerging technology that is to be examined.*

Industrial Applications for the Technology

Fiber-reinforced organic-matrix composites are currently being used as the materials for construction of a variety of leisure products, including golf shafts, bows, skis, tennis rackets, kayaks, fishing rods, bicycles, and snowmobiles. Leisure products are predicted to be a large growth area for fiber-reinforced organic-matrix composites. Another application area that is expected to have a high growth rate between now and 1990 is the selective reinforcement of automobiles.

Other, smaller, industrial applications of fiber-reinforced organic-matrix composites include flywheel energy storage devices, structural members of rapid transit vehicles, aircraft and ship parts, prosthetic devices, ducting in chemical treatment plants, and parts for textile-producing equipment.

Critical Materials Utilized in the Technology

Types of Materials and Areas of Application. The primary materials associated with fiber-reinforced organic-matrix composites that may become critical are high strength/modulus graphite and aramid fibers. The future availability of production capacity to manufacture these types of fibers is the matter of concern. The areas of application were delineated in the previous section.

While the availability of the organic matrices may be adversely affected by competing needs for other petroleum products, the investigation of petroleum-based critical materials is not within the scope of the study.

Projected Quantity Requirements. A preliminary estimate of the requirements for high strength/modulus graphite or aramid fibers for use in reinforcing organic matrices is as follows:

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* Glass-fiber-reinforced organic materials are well established and do not represent an emerging technology; accordingly, they will not be considered in this study. Boron-fiber-reinforced composites, and metal-matrix composites in general, are primarily of interest to DoD; and, thereby, are not emerging industrial technologies. Therefore, they are not specific subjects within the ground rules for this study.

Year	Preliminary Estimate, Pounds
1980	40 million
1985	120 million
1990	300-500 million

Basis for Criticality Judgment. The above requirements for high strength/modulus graphite or aramid fibers will require a very large increase in production capacity by 1990. The installation of this capacity will require a large commitment of capital, for which it is not yet clear that it will become available for this purpose.

Relationship of Technology to Needs of the Department of Defense

The Department of Defense is interested in fiber-reinforced organic-matrix composites for a number of applications. Among these are components of aircraft (including helicopters), hydrofoils, vehicles, and armor. Thus, a possible lack of graphite or aramid fiber production capacity would be detrimental to DoD.

Fuel Cells for the Generation of Peaking Power

Description of the Technology

The ever increasing demand for electric power has generated in-depth planning for the facilities required to meet these demands through the year 2000. One important factor in these considerations is the problem of uneven demand for power during a 24-hour period. To build additional primary facilities to meet these peak power time intervals is an unacceptable solution from the standpoint of expenditures and efficiency of the system. As a consequence, a number of methods have been investigated and used that utilize primary power-generating capacity in low demand intervals and the storing of this energy for release during periods of peak demand. For example, water pumped to elevated reservoirs during periods of low demand is used to generate power during peak load intervals.

Some of the more promising approaches to the important need for peaking power are the use of fuel cells to generate power or batteries to store energy for release during peak load intervals.

The seriousness of the power supply problem has in effect initiated a "revolution" in the area of fuel cells and batteries, with consequent rapid advances in technology. The present goal by the period of 1990-2000 is 20,000 megawatts of additional power for peak load intervals.

Fuel cells are essentially primary batteries where reactants can be fed continuously to the cells. The principle of the fuel cell was first demonstrated well over 100 years ago.

The preferred fuel for fuel cells is hydrogen; the oxidizer may be oxygen, or air with some slight decrease in output. Fuel cells can perform well on other fuels such as natural gas, methyl alcohol, propane, etc. However, in essentially all instances the fuel is converted to hydrogen during the process. The efficiency of fuel cells is excellent; the theoretical efficiency of a fuel cell operating on hydrogen at room temperature is 96 percent. Laboratory cells have easily reached efficiencies more than twice that of the most efficient steam power plants. Fuel cells are compact, with power densities in excess of 100 watts per square foot of electrode (making a kilowatt per cubic foot practical) with hydrogen as a fuel. The pertinent problems now being addressed are catalysts and fuels. In this regard the Electric Power Institute has committed $3,925,000 for research in 1975. The problems under study are:

- Identification of future fuel options
- Assessment of the technical-economic competitiveness of fuel cells with alternate methods
- Continued development of advanced fuel cell technology -- specifically the basic cell technology and fuel capability for the molten carbonate cell
- Exploration of the relative merits of alternate fuel cell technologies and the potential for advances in catalysts, efficiency, and economics.

Industrial Applications for the Technology

The industrial applications through the year 1990 for fuel cells will be confined to stationary installations for the generation of power to meet peak demands. However, some technological advances that will be made in achieving those goals might well be transferred to the transportation area, specifically automobiles.

Fuel cells of 10 megawatt capacity are envisaged for peak power demands. Cities would have the number of these units necessary to meet the demand requirements. Pratt & Whitney is now working on a one-megawatt unit using a proprietary catalyst and natural gas as the fuel. Demonstration of a one-megawatt unit is scheduled for 1978. If successful, a scale-up to 10 megawatts will be started immediately.

Critical Materials Involved

Types of Materials and Areas of Application. The critical materials involved in this technology will be platinum and palladium for catalysts. It is recognized that experimental fuel cells such as the Pratt & Whitney one-megawatt unit do not use platinum, but it is judged that the demands by the power industry for life times in the range of 20 years will necessitate the use of the platinum metals. Proprietary catalysts are usable for periods measured in only hours or, at best, months. Platinum metals can be substituted for these proprietary catalysts.

Projected Quantity Requirements. Fuel cells will require in the neighborhood of 385 ounces of platinum and 52 ounces of palladium per megawatt of output. Consequently 20,000 megawatts would require about 7.7 million ounces of platinum and about 1 million ounces of palladium, for a total of about 8.7 million ounces of platinum metals. The world production of platinum metals was about 6 million ounces in 1974. This single demand for platinum metals could well bring about a critical material problem by 1990.

Basis for Criticality Judgement. Platinum metals are almost totally imported by the U.S., and there is no presently identified potential for domestic production. The major sources of platinum are the U.S.S.R. and Africa.

Relationship of Technology to Needs of the Department of Defense

Potential Department of Defense applications for fuel cells include power generation in remote sites, peak power, and emergency power. The platinum metals are currently designated as critical materials by the Department of Defense.

Electroslag Remelting of Metals

Description of the Technology

The development of methods capable of producing metals and alloys with high levels of purity and in tonnage quantities has opened up new possibilities for structural designers. Specifically, the availability of such material in quantities great enough to be of interest for structural components offers the designer the opportunity of raising the usable strength level of these components without increasing the probability of catastrophic failure under load.

The inherently higher levels of ductility, greater toughness, and ease of deformation (rolling, forging, etc.) relative to conventionally melted materials stems from the reduced amount of inclusions and their improved morphology (size and shape), the reduction in other impurities and in microsegregation, and a favorable grain pattern.

The principal new process in this area is electroslag remelting (ESR). ESR involves the remelting of a metal electrode under an electrically conductive slag and solidification of the molten metal in a water-cooled (usually copper) mold. The source of heat is the resistance of the slag to the passage of current. The slag purifies the metal and provides a film on the surface of the water-cooled mold that promotes a good as-cast ingot surface. The high rate of cooling across the molten-metal/solid-metal interface yields low levels of microsegregation and consequently low levels of anisotropy in mechanical properties (anisotropy, a variation in properties with respect to direction, is a problem with many conventionally cast metals). The process can be utilized to produce ingots of various shapes; components can even be cast directly [Vacuum arc remelting (VAR), an older process for producing high purity metals, is not amenable to the production of shaped ingots, such as hollows or slabs, or the direct production of components. In addition, the level of microsegregation is usually higher and ingot yield is lower than obtained by ESR.]

To date essentially all steels, including specialty steels, all cobalt-base alloys, most nickel-base alloys, and other nonferrous alloys such as copper alloys have been successfully melted with the ESR process.

Industrial Applications for the Technology

ESR metals and alloys are rapidly finding application in components subjected to severe loading conditions (e.g., complex loading involving impact and torsion) such as in aircraft landing gears, tools and dies, and in components with requirements for high levels of endurance (fatigue) strength -- for instance torsion bars for vehicles and helicopter rotors and bearings. Typical higher tonnage uses include pressure vessels and structures such as "Texas Towers" (deepsea oil drilling rigs). As designers become aware of the advantages of these high-purity metals the amount of material produced and number of applications will rapidly increase. For example, the higher ingot yields and consistency of product has led to the changeover from VAR to the ESR process for the melting of cobalt-base alloys in the United States.

Critical Materials Involved

Types of Materials and Areas of Application. The availability of steels, specialty steels, and nickel- and cobalt-base alloys produced by the ESR process is expected to become critical well before the year 1990, unless significant additional ESR production facilities are installed. The critical area is ESR production capacity, not the specific metals involved. That is, the use of the ESR process is not expected to increase significantly the consumption of alloys containing critical materials such as nickel, cobalt, and chromium. These alloys will be made regardless of whether or not ESR capacity is available. However, the use of ESR (as a substitute for other melting processes) will significantly improve the properties and performance of the alloys to a degree which should logically lead to greatly increased usage of the ESR process.

The areas of application of the ESR-melted metals span the industrial applications noted in the previous section, as well as DoD requirements outlined in a later section. The greatest potential tonnage appears to be in pressure vessels, Texas Towers, and tools and dies.

Projected Quantity Requirements. Pressure vessels, Texas Towers, other structural applications, and products such as tool and die steels will require millions of tons of heavy plate bar and forgings by the year 1990. Since the performance of these engineering structures could be increased by the use of ESR steel, from a technical standpoint it appears that the ESR process would be used for most of this tonnage if ESR production capacity were available. Moreover, the economics of ESR material for these applications appears to be reasonable.

Basis for Criticality Judgement. With the U.S. production for ESR materials at 38,000 tons in 1973, an estimated capacity of 125,000 tons by the end of 1975, and the potential demand in the "millions of tons" range by 1990, the basis for the criticality judgement is the lack of ESR production capacity. Projected DoD demands for ESR materials increase the criticality.

Without signficantly increased U.S. industrial capacity for these materials, reliance on imports from foreign sources would be necessary. Foreign countries, including Japan and the U.S.S.R., are increasing their production capacity rapidly. For instance, the production goal in the U.S.S.R. for 1975 is 1,000,000 tons of ESR metal.

Relationship of Technology to Needs of the Department of Defense

The high purity metals are presently under intensive study for applications in the DoD such as armor plate, submarine hulls, aircraft structurals, gun tubes, torsion bars, and aircraft bearings and landing gears. At the present time development of DoD applications is being retarded because of a lack of material in the United States. A specific example is ESR plate for armor and ship hulls.

High-Temperature Gas-Turbine Engines for Automotive Applications

Description of the Technology

Gas-turbine engines have a number of significant advantages over internal combustion engines. Among these are significantly smaller specific weight and volume, high reliability, comparative mechanical simplicity, and low maintenance requirements. These and other advantages have enabled gas-turbine engines to penetrate a number of important industrial and military markets. Primary among these are aircraft propulsion and the stationary generation of power for peaking service at electric power plants, for the operation of pumping stations on gas pipelines, and for various applications in chemical plants.

The basic parts of a simple gas turbine engine are the compressor, the combustion chamber, and the gas turbine. Intake air, after compression, enters the combustion chamber where it is burned with fuel. The gaseous combustion products flow into another chamber, where they turn a gas turbine, which in turn generates power. Not all this power is available as output, however; some is used to drive the compressor.

A major potential new market for gas-turbine engines is in automobiles. The primary advantages of gas turbines is this application are the low specific weight of the engines, the almost complete lack of hydrocarbons and carbon monoxide in the exhaust, and the simplicity and low maintenance aspects of the engines. However, in order to improve the competitiveness of gas turbines with respect to internal combustion engines for automotive applications, it is necessary to increase the efficiency of gas-turbine engines. Increased efficiency results in decreased specific fuel consumption and decreased specific weight and volume.

The efficiency of a gas-turbine engine depends to a very large extent on the temperature of the combustion products as they enter the turbine; the higher the turbine inlet temperature, the more efficient the engine. Efficiency has always been important from the standpoint of economics; in this era of fuel shortages and increased fuel cost, efficiency is even more important.

Accordingly, significant effort is being directed toward increasing the turbine inlet temperatures of gas-turbine engines. The approaches to increasing turbine inlet temperature have involved constructing the gas turbine section from materials having higher temperature capability. The major materials considered are:

(1) Cooled nickel- and cobalt-base superalloys

(2) Coated refractory metal alloys

(3) Ceramics.

The need to minimize the capital cost of automotive gas turbines virtually eliminates the possibility of increasing the turbine inlet temperatures by the use of cooled nickel- and cobalt-base superalloys or coated refractory metal parts. Accordingly, the major developmental efforts toward improving the efficiency of automotive gas-turbine engines have been in the area of ceramics.

Industrial Applications of the Technology

Automotive gas-turbine engines, as the name implies, would be used in passenger automobiles, trucks, and buses. Moreover, technological developments which increase the efficiency of gas-turbine engines for these applications would most likely be adopted in other important industrial applications of gas turbines, such as in stationary power generation.

Critical Materials Utilized in the Technology

Types of Materials and Areas of Application. Silicon nitride and silicon carbide are the two critical materials of concern in automotive gas-turbine engines. They are the most promising materials for the construction of the hottest parts of high-turbine-inlet-temperature gas turbines for this application.

Projected Quantity Requirements. The current design of an automobile gas turbine that Ford has developed on its ARPA contract* requires about 10 pounds of silicon nitride per car. If one were to assume that 15 million automobiles are to be built in 1990 and that ten percent of them are powered by gas turbine engines, the requirement for silicon nitride for this application in 1990 would

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* "Brittle Materials Design, High-Temperature Gas Turbines," ARPA Contract No. DAAG 46-71-C-0162, monitored by the Army Materials and Mechanics Research Center.

be 15 million pounds (based on the present design).

Basis for Criticality Judgement. Certainly there is no intrinsic scarcity of silicon, nitrogen, or carbon -- the basic components of silicon nitride and silicon carbide. However, at present there is very little commercail manufacturing capacity for the economical production of these materials with the proper characteristics for this application. Accordingly, the basis for the criticality judgement in regard to silicon nitride and silicon carbide for automotive applications is the possible lack of manufacturing capacity in 1990 to meet a possibly projected 15 million pound demand for automobiles alone.

Relationship of Technology to Needs of the Department of Defense

The Department of Defense has a strong interest in these same critical materials, silicon nitride and silicon carbide, to achieve higher efficiency and greater thrust in gas-turbine engines for propulsion systems in aircraft, ships and ground vehicles to include tanks, in addition to stationary power plant applications at military installations.

Initiation of Task II and Task III

(Task II: Description of Technologies and Assessment of Materials, and
Task III: Assessment and Comparison of Materials Requirements)

Work was initiated on these two tasks in the degree necessary to provide data and information relative to the final selection of those to be studied further. The data and information so engendered are reflected in the above summaries of the six selected technologies and in Appendix D.

CONCLUSION

Based on the potential impact of the six selected emerging U.S. industrial technologies on critical materials of interest to DoD, it is concluded that those technologies should be studied in depth and reported in further detail in the final technical report.

FUTURE WORK

Future research effort will be devoted to detailed study and analysis of the six selected technologies. The end objective will be to identify potential procurement and development problem areas for DoD which are a result of the forecast changes in supply and demand.

APPENDIX A

EMERGING TECHNOLOGIES AND RELATED BATTELLE SPECIALISTS

APPENDIX A

EMERGING TECHNOLOGIES AND RELATED BATTELLE SPECIALISTS

U.S. Industry	Emerging Technologies	Battelle Specialists Involved
Aerospace and Space Systems	Dirigibles Superhuge cargo planes Air cushion vehicles - hovercraft	Elmer J. Bradbury Dr. Joe H. Brown, Jr. Dr. Stanley H. Gelles Walter S. Hyler Dr. Thomas E. Leontis Victor Levin Dr. Bryan R. Noton Richard G. Ollila
Chemicals and Chemical Processes	Fire retardant chemicals Use of titanium tubing in highly corrosive environments New methods for increasing the octane rating of gasoline Hydrodesulfurization of crude oil Recovery of metals from heavy crude oil Coal gasification Enzyme production Monomolecular films	Walter K. Boyd Dr. Elton H. Hall William M. Henry Dr. Douglas W. Hissong David M. Jenkins Edward S. Lipinsky
Communications	Optical communications Laser communications Large scale digital transmission of commercial data Use of picturephones for business conferences Use of microprocessors in the home Computer monitoring and control of processes Optical character readers	Joseph W. Benson George J. Falkenbach Emmett R. Reynolds William D. Stuart
Construction	Fiber-reinforced concrete Pre-engineered buildings for home units	Rolland B. Guy Dr. David R. Lankard
Electronics/ Electrical	Batteries for energy storage and automobiles Light-emitting diodes Large-scale integrated circuits Infrared detectors High-temperature electronics Traveling-wave tubes Microwave generators Liquid crystal displays	Dr. Eric W. Brooman John E. Clifford Winston H. Duckworth Dr. Harold M. Epstein Dr. Barry P. Fairand Gordon B. Gaines Donald J. Hamman Frank J. Jelinek Charles S. Peet

U.S. Industry	Emerging Technologies	Battelle Specialists Involved
Energy	High-voltage direct-current power transmission Gas centrifuge separation process Gas nozzle separation process Liquefied natural gas operations Use of zircalloy tubing to clad nuclear fuel elements Direct conversion of energy by magnetohydrodynamics	Lambert Bates Dr. Eric W. Brooman John E. Clifford Dr. Richard S. Denning Winston S. Duckworth Donald H. Frieling Dr. Elton H. Hall Frank J. Jelinek David M. Jenkins William M. Pardue Meyer Pobereskin John D. Waddell Dr. Thomas R. Wright
Food and Agriculture	Use of methyl parathion as an insecticide	Gerald W. Collings Dr. John H. Litchfield
Forest Products	Oxygen/alkali systems for the pulping and bleaching of wood Whole-tree pulping	Dr. W. James Frederick
Machinery	Automation	Francis W. Boulger Howard C. Davis John T. Herridge Thomas M. Trainer
Materials	Continuous casting	Elmer J. Bradbury Winston H. Duckworth Dr. Stanley H. Gelles Frank J. Jelinek Dr. David R. Lankard Dr. Thomas E. Leontis H. Dana Moran Dr. Bryan R. Noton
Medicine and Biomedicine	Use of stainless steel for blood catheters Ceramic bone replacements Use of vitallium and titanium alloys as orthopedic implants	Dr. Richard D. Falb

U.S. Industry	Emerging Technologies	Battelle Specialists Involved
Mining and Minerals Processing	Fused chloride electrolysis process	Dr. William Goldberger
Ocean Engineering	Ocean mining of manganese nodules Offshore mining	Arthur J. Coyle
Transportation	Microcomputers (microprocessors) for automobiles Levitated trains	Walter E. Chapin John B. Day John T. Herridge Victor Levin James P. Loomis Dr. Alfred C. Robinson Dr. Thomas R. Wright
Waste Treatment and Environmental Control	Waste-to-energy systems Recycling of materials from refuse Desulfurization of flue gases from electric power plants	Philip R. Beltz Dr. Robert H. Cherry, Jr. John B. Hallowell Dr. Douglas W. Hissong

APPENDIX B

REPORT ON DOD MATERIALS SHORTAGES WORKSHOP

APPENDIX B

Battelle
Columbus Laboratories

Date January 21, 1975

To Rudy Black

From Jim Frankosky *Jim*

Subject DOD Materials Shortages Workshop, 14-16 January 1975

As requested provided herewith is a report of the proceedings and highlights of subject workshop. The schedule is shown in Enclosure 1.* Attached are copies of individual papers presented in the workshop and also background papers of pertinent interest as covered during the two days of my attendance, 14 and 15 January. On the third day, 16 January, workshop was arranged in panels to address questions as shown in Enclosure 2. The panel results will be made available in a report now being compiled by Ralph Pringle, IDA, with Battelle assistance.

Greetings and Introduction, by J.S. Gansler, Deputy Assistant Secretary of Defense, Installations and Logistics. He stated this workshop is a problem solving session--not to review or suggest policy guidance. It is for an interchange of ideas on how the DOD can alleviate material shortages to include the prediction and prevention of future problems. A DOD Committee has been established to facilitate exchange of ideas between government and industry. This workshop is a first step to begin establishing a data base. The DOD committee is establishing liaison with other federal agencies.

Following is a listing of the presentations in order as they appeared on the agenda. In each case, summarizing comments are made to facilitate your review of the enclosed documentation.

Technological Factors Influencing Utilization of Domestic Resources, by A.M. Hall, Battelle Columbus Laboratories (Enclosure 3). Summarizes a recent examination for the National Science Foundation of 80 minerals and metals to identify critical problem areas where research and innovation appear needed. In the study 12 materials were identified for closer scrutiny because they were considered to have broad critical implications or specific impacts relative to our national needs. In this presentation, 6 of these 12 were discussed in a highlight sense to identify impacts and possible actions--manganese nodules, aluminum, copper, magnesium, nickel, and titanium. For example, it calls for improved recycling utilization of titanium scrap. A copy of the complete study can be made available if you wish. One of the audience comments made was that the rutile supply in Australia will probably be used up within 15 years.

Demand of New Technology on DOD Material Supply: Initial Findings, by E.D. Harris and C.C. Mow, RAND (Enclosure 4). In the course of this RAND presentation and subsequent discussion, the related ARPA TAO sponsored work by SRI and Battelle was also briefly illuminated. This RAND case study approach and initial results were described. The

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* Enclosures available at BCL-Columbus.

importance of germanium to FLIR technology for DOD was highlighted along with some tentative conclusions to examine expansion of domestic production and to consider it for the strategic stockpile. Similarly, the tentative conclusions in the propulsion area were covered to include a general conclusion that new propulsion technology will not create drastic new material problems for DOD. In answer to a question, Harris advised germanium would not be needed in the stockpile for pacing DOD problems, but only for a national emergency.

Production Problems in the Non-Ferrous Metals Industry Resulting from Environmental, Health and Safety Regulations, by Robert J. Muth, American Smelting and Refining Company (Enclosure 5). Highlights industrial concern for the high capital costs of the non-ferrous metals industry in meeting pollution control (25% of current combined capital budgets)(to require almost $8B total capital outlay by 1978). The principal concern is that the numerous impacts of environmental regulations are today the principal constraint upon the creation of a new capacity in the industry. He suggests that the DOD as a large consumer should help fight the problem.

Economic Elements Contribution to Materials Shortages, by J. Boyd, Materials Associates. (Handout not available.) His basic belief is that the needed materials are available somewhere in earth's crust. The problem is man's inability to provide the required production capacities to exploit nature's abundance. He highlighted Ed Dyckman's summary, Review of Government and Industry Studies on Materials Supply and Shortages as being an intelligent understanding and excellent summary of the current U.S. situation. He pointed out how technology can help in the copper example--10 lbs. of copper available per ton of rock vs 60 lbs. before, yet now copper price is lower.

The Effects of Energy Shortages on Materials Shortages, by E. Hayes, Materials Associates (Handout not available). U.S. needs a Manhattan-type project to solve problem of meeting U.S. energy/materials needs from U.S. reserves. Industries such as aluminum and titanium are highly energy intensive. In 1968 a SRI study showed that industrial energy needs were typically as follows:

Industry	% to US Energy Expenditure
Iron and Steel	5.4%
Petroleum Refining	4.4%
Paper	2.0%
Petrochemical Feedstock	2.0%
Aluminum	1.1%
Copper	.8%

Coal as a source as to fill the gap so that it rises from 17% of the U.S. energy base now to 40% by 1990. In answer to a question, he stated we should save natural gas as a fuel for homes and petrochemicals and require other industries to use alternate fuels.

The Effect of Materials Shortages on Materials and Processes Specifications and Standards Organizations, by E. Shobert, Stackpole Carbon Co., representing American National Standards Institute (Enclosure 6).

Highlights that materials shortages are resulting in increased substitutions. DOD should continue to monitor the procurement standards carefully through the established organizational structure. Recommends that changes of the order of 10% or more in costs or requirements for materials be phased in with a time delay on the order of the associated industrial capital equipment life rather than force such changes suddenly.

Impact of Materials Conservation and Recycling on Materials Shortages, BY R. Staehle, Ohio State University, (Enclosure 7). Highlights effects of such as high pressure/temperature operations, self-contained systems, recycling, and reliability on materials needs, particularly metal alloy performance. Stresses importance of Iron-Chromium-Nickel backbone for the industrial economy. Recommends chromium supply be protected and increased. In answer to a question, stated U.S. has only a 60 day supply of chromium at present.

DOD Usage of Strategic Resources, by M. Levine, SRI (Enclosure 8). Described study approach and results. Highlighted that DOD consumption of materials is concentrated in a relatively few sectors of the economy (refer figure 7, enclosure 8) and that the U.S. is highly dependent upon imports for many materials (refer figure 11, enclosure 8). One question was why titanium was not on the Figure 11 list, the answer was that SRI looked at materials in the elemental form, they would next look at certain substances or ores from which these elementals are derived. A Bu. of Mines representative stated we are getting close to a solution on alternate sources for aluminum (couple of years).

Aerospace Industries Association, by J. Kane, General Dynamics, (Enclosure 9). In the aerospace industry shortages in such as steel, aluminum, nickel, chemicals, castings, forgings, extrusions are real. Demand exceeding supply, increased energy costs, environmental control costs, increased labor costs are among the cited reasons. Has detailed statistics. Also recommends many possible government actions. (Refer last two pages, Enclosure 9).

Shipbuilders Council of America (SCA), by E. Hood, (Enclosure 10). His story was very similar to that of the Aerospace presentation. Shortages exist in such as steel plates and structural shapes, forgings and castings, pipe, electric motors. Lead times have increased nine weeks to nine months. Recommends Federal leadership in adopting recommendations which basically would treat shipbuilding as a fundamental resource base in support of defense, trade, and energy needs.

American Defense Preparedness Association, by R. Harmon, ADPA; J. Doyle, Westinghouse, and H. Frech, Olin Corporation. (No handout available.) Agrees with cited problems in Aerospace and Shipbuilding as being typical. Highlighted that U.S. problem is basically one of production capacity shortage rather than materials. In contracting there is an understandable reluctance of a supplier to crank up ahead of time and of contractor to call on him to do so. Also, for a potential DOD contractor today, the commerical market is easier because of willingness to make longer range commitments and less stringent specifications. In one area, forging/casting for tank turrets and hull sections, there is only one U.S. plant available. Recommends Defense do something to ease long lead times, special procurement requests, facility surveys, standardization needs, and pursuit of options. Also, recommends metal casting capabilities for such as tanks, railroad equipment, nuclear reactors, trucks, mining equipment be considered a national resource.

Aluminum Association (AA), by S. Goldsmith, AA (Enclosure 11). Stressed inherent flexibility and strength of aluminum industry to surge to meet requirements. No general aluminum shortage now, however, there are some short-term availability situations which could be improved. For example, he recommends that the lengthy stress corrosion test requirements to meet DOD particular needs be reexamined. Magnesium shortages affect aluminum production. Energy intensivity of aluminum has been reduced from 12 KWH per pound (WWII) to 8 KWH today. Recycling of aluminum and use of scrap plays a big role now and could be further improved. His detailed recommendations are in the last page of Enclosure 11.

American Iron and Steel Institute for Specialty Steels, by E. Andrews, Allegheny-Ludlum Industries. (Enclosure 12.) Has a provacative outlook that our shortages in critical materials are because of U.S. policies or lack thereof. He states, for example, that industrial forecasts on materials availabilities as made out are not reliable due to political rather than economic factors, for example, metallurgical grade chromite has fluctuated 300% up and down over the past 4 years. He also believes we should stockpile materials for economic reasons as well as national security reasons, per se.

Reactive Metals Incorporated (RMI) for Titanium, by J. Price. (Refer to Enclosure 13.) States that titanium is not short now. What must be done to avoid future shortage is to insure adequate supply of sponge. The industry in this country is currently considering a plant expansion for titanium sponge but has to deal with uncertainties such as dumping on the market by Soviets and Japanese and selling from the U.S. stockpile. Right now in cost comparison the RMI published price is 40¢/lb. under the Japanese price of $2.85/lb. and they believe under the Soviet price.

Society of the Plastics Industry (SPI) by J. Lawrence, SPI (Enclosure 14). Highlights vital role of plastics and other materials derived from petrochemicals integrated into structure of overall products procured by DOD--such as in electronics, life support systems, medical equipments. Also stated coal is a logical alternate source for feedstocks. He expects to see development to put it into cost competitive range.

Some Comments Noted in General Discussion

- Titanium--shortage is in production capacity. Perhaps DOD should help pay costs for increased plant capacity.
- Aluminum Plant Capacity--is of national policy concerns, not just DOD.
- Some ilmenite sources in Midwest and California have not been tapped.
- Glues are needed. EPA constraints are hurting industry.

- Magnesium--can rely on only one company now, 2 companies need help to get on stream.
- A Clearer Definition for Critical Materials is needed.
- ADPA is planning a fall meeting on materials.
- We need a Federal Reserve Board of Materials.

Overall Summary

- Consensus was this workshop was a useful forum for exchanging ideas and information.
- Consensus was that government plays a big role in materials availabilities. Solutions to current problems are something that Federal government as a whole has to act on, not just DOD. For example, the government has to share in the capital investment risks for new large scale endeavors such as shale oil and use of lesser grade aluminum ores.

Note

Other handouts not covered in the above which are of pertinent interest are also included for your possible use.

JOF:jp

APPENDIX C

REPORT ON FIRST NATIONAL CONFERENCE ON MATERIALS AVAILABILITY/UTILITATION

APPENDIX C

REPORT ON FIRST NATIONAL CONFERENCE ON MATERIALS AVAILABILITY/UTILIZATION

Chicago, Illinois, January 27-29, 1975

Presented by the American Society for Metals and Metal Progress magazine

This 3-day meeting was established with general talks each morning and at each noon luncheon, and simultaneous talks on many specific materials each afternoon. Battelle's Principal Investigator on this proejct, Dr. Curtis M. Jackson, attended all the general sessions (three mornings and luncheons) and the afternoon sessions on non-ferrous metals (two afternoons) and specialty and refractory metals (one afternoon).

This was an excellent meeting. The data obtained will be useful during Tasks II and III of this project. The papers presented at this conference will not be published, although copies of several papers were available at the meeting. Copies of these papers were obtained. In addition, Dr. Jackson took photographs of most of the slides in the sessions he attended, for project use.

The following paragraphs summarize the presentations given in the sessions attended by Dr. Jackson. It should be noted that, with very minor exceptions, none of the speakers was willing to project future selling prices of metals.

General Presentations (Morning and Luncheon Sessions)*

World Outlook for Critical Materials Shortages in the 70s, by Dr. John D. Morgan, Bureau of Mines. (A copy of this paper is available). Emphasized in this kickoff paper was the fact that the U.S. relies heavily on imports to meet much of its internal demand for metals and minerals. For instance, in 1974 imports accounted for more than 85 percent of the U.S. demand for such important metals as cobalt, manganese, titanium (as rutile), chromium, aluminum (ores and metal), tin, columbium, tantalum, and the platinum-group metals. Nevertheless, the position was taken that OPEC-type actions in non-fuel minerals and materials are much less likely than in the case of petroleum, despite the well-known action by bauxite producers. In addition, the need for industry and government to tackle and solve a variety of problems related to both fuel and non-fuel materials was noted.

Prospects for Materials Availability in 1975, by James M. Owens, U.S. Department of Commerce. (In the absence of Owens, this presentation was made by Dan R. Gill of the Department of Commerce). A surplus is predicted in essentially all basic commodities during 1975. This is not necessarily healthy, since it reflects a decrease in demand as well as the effect of recent additions to production capacity. Future expansions in production capacity to meet projected increases in demand will be hampered by the highly inflated cost of new capacity. A number of

* The introductory talks, which were presented on two of the mornings, were so very general that they are not summarized here.

possible approaches to relieving future materials shortages and decreasing the reliance of the U.S. on foreign sources were enumerated. Among these were the development of economic producers for utilizing low-grade resources, the use of substitute materials, the implementation of conservation techniques, eliminating the need for the materials by the use of different technologies, and encouraging recycling.

World Outlook for Steel Availability in the 70s, by Rev. William T. Hogan, S. J., Fordham University. Based on his many personal contacts with present and potential manufacturers of steel around the world, Hogan predicts that the availability of steel in the years ahead will be good in the U.S., inasmuch as companies are adding manufacturing capacity. However, in the remainder of the world he predicts a shortfall of 50 to 70 million tons of steel by 1980, although the situation will improve as additional foreign capacity comes on stream between 1980 and 1985.

Forecast of Manufacturing Materials Availability from the Viewpoint of a Major Corporation, by Dr. John C. Chambers and Ernest Goral, Xerox Corporation. Described study by Xerox is early 1974 to investigate the availability of materials they expect to require in the future for new products currently under development. In this connection, Xerox personnel visited 80 companies; they found wide divergence in the availability projections for the same materials, from company to company. To follow up this study and keep abreast of changes in the availability situation, Xerox has committed one man on a full-time basis.

A Multinational Corporation's Approach to Availability/Utilization, by Dr. William Leone and George Papas, Rheem Manufacturing Company. Stressed that the materials situation is "a new ball game". Whereas in the past the U.S. could buy anything it wanted, people around the world now have sufficient funds to compete strenuously with the U.S. for available supplies of materials. Companies now need a materials industry specialist to follow and project materials availability. This presentation agreed with others that the present excess materials supply is temporary; as the recession subsides, materials availability will be a problem once again.

Critical Materials/Components for Energy Systems, by Dr. Walter Hibbard, Federal Energy Agency and Virginia Polytechnic Institute. Briefly summarized in general terms were the environments that must be withstood by materials used in coal gasification/coal liquefaction plants, high-temperature gas-turbine engines, and solar energy and geothermal energy systems. Many improvements in materials and manufacturing procedures are required in order to apply these technologies.

How Washington Interprets the Shortage Situation, Senator Walter D. Huddleston (Democrat, Kentucky). Senator Huddleston described the activities of his subcommittee on materials shortages. His conclusions were that a better statistical data base is required in order to analyze materials availability, that additional stockpiling for economic (rather than military) reasons should be carried out, that production capacity should be increased, that recycling should be emphasized, and that research in the materials field should be increased. However, he recognizes that, although many studies on materials shortages have been carried out over the years, very little action has been taken to implement the results.

Forecasting Materials and Components Requirements, by John J. Piepgras, Booz, Allen and Hamilton. Three types of materials forecasts were described -- the inventory replenishment forecast, the operational planning forecast, and the business strategy forecast. In making these forecasts, it is important to avoid excessive precision. One should be selective, concentrating major attention on the important few materials and giving minimum attention to the trivial many. The importance of following through by establishing and implementing well-documented, realistic, and specific plans for dealing with potential supply problems was stressed.

A System for Managing Materials Information, by Dr. Jack H. Westbrook, General Electric Company. General Electric Company's EMPIS (Engineering, Materials and Process Information Service) information system was described. This system currently includes 21,000 pages of information in 49 volumes.

A Computerized Materials Data File, John R. Edwards, Deere and Company. Deere's computerized materials data file was described. Plans are to include in it the manufacturing cost for each manufacturing process, as well as materials properties.

Specification Strategy: Standards or Specials? Raw or Reprocessed?, BY G. Fred Bush, Ford Motor Company. Emphasis was placed on standardizing on a relatively small number of materials within a company (and between companies). Standardization enables the purchase of larger quantities at lower unit costs and minimizes inventory. Recycling and decreasing the amount of scrap generated in-plant were also discussed.

Overview of Partsmaking Methods for Improved Utilization, by H. J. Henning, Battelle Columbus Laboratories. Partsmaking methods that will enable greater utilization of materials (i.e., less scrap) were discussed. Among these are powder metallurgical methods, the use of preforms in forging operations, and precision hot forging.

R&D Approach to Solving Today's Materials Problems, by Dr. Robert E. Boni, Armco Steel Corporation. At Armco, the first step in R&D is the identification of needs; this is done through contacts with customers and at technical society meetings. The selection of subjects for research is next; this is done at Armco through risk analysis and sensitivity analysis involving projections of return on investment.

The Federal Government's Priorities and Allocations System, by Anthony A. Bertsch, Steel Service Center Institute. It was indicated that the present priorities and allocations system operates under the 1953 Defense Production Act. Normally, priorities and allocations have been established to ensure that defense, nuclear, and space projects are not hampered by materials shortages. Relatively recently, however, priorities and allocations have been established in connection with the construction of the Alaska pipeline and the work on the North Slope in Alasks.

The Materials Systems Approach to Utilization and Design, By Julius J. Harwood, Ford Motor Company. According to Harwood, the tendency in companies in the future should be to utilize a materials systems approach in which the choice of materials for specific applications is made on the basis not only of properties but also of total installed cost, and availability. Included in the economic considerations will be the possibility for recycling, and the economic value of weight saving.

Administration of Material Crises, by G. H. Hilbers, Chevrolet Division, General Motors Corporation. Defined three different types of material shortage crises: short-term, where temporary substitutions may be made; medium-term, where the design of the part should be modified or changed completely; and permanent, where there is a "change in life style". (There has never been a permanent material shortage crisis). He went on to say that the forecast of materials costs and availability is particularly important in connection with the introduction of new products.

National Materials Policy and the U.S. Congress, by Dr. Franklin P. Huddle, and Harold Bullis, Congressional Research Service, Library of Congress. (This was a composite presentation, based on two papers -- one by each of the authors. Copies of both papers are available). The 93rd Congress was the most materials-oriented Congress of any; over 400 materials-oriented bills (about half were identical) were introduced. These emphasized better management of domestic materials resources, increased recycling of materials, coping with existing shortages and presenting future ones, and avoiding possible dangers related to dependence on foreign sources of material. Very few bills passed, but the many hearings that were held simplified and laid the groundwork for the reintroduction and consideration of many of the bills by the 94th Congress. The 94th Congress is expected to approve some kind of an instrumentality to address shortage problems and to pass a major recycling bill as well as comprehensive stockpiling legislation. (In addition, it should be noted that the 93rd Congress approved the formation of a National Commission on Supplies and Shortages, which was being formed in early 1975 and is due to make recommendations later this year).

Cost-Effective Design, by Dean K. Hanink, Detroit Diesel Allison Division, General Motors Corporation. Hanink reviewed new technological developments related to aircraft gas-turbine engines, including directional solidification, Lamelloy material for transpiration cooling, and electron beam welding.

The Designer and Materials Conservation, by Ira G. Hendrick, Grumman Aerospace Corporation. Stressed were the facts that economics often does not encourage materials conservation and that Government support is sometimes required in order to advance the state-of-the-art in materials. In regard to the latter point, it was noted that $400 million was spent by the U.S. Government on composite materials during the last 15 years.

Design for Recycling, by Clifford E. Evanson, TAB Engineers, Inc. In addition to materials property and manufacturing cost considerations, Evanson recommends that materials be selected and parts be designed with thought given to recycling. For instance, parts made of different materials should have the different materials separable and coatings should be readily removable or should be of a non-detrimental type. (Composites may not be amenable to recycling). Moreover, when writing specifications one should allow the greatest amount of impurities in the alloy that the application can tolerate.

Prospects for a Better National Minerals Policy, J. Allen Overton, Jr., American Mining Congress. Overton feels that the National Mining and Minerals Policy of 1970 is satisfactory, but it needs to be implemented.

Presentations on Specific Metals (Afternoon Sessions)*

Specialty Metals, by R. R. Bissett, Huntington Alloy Products Division, The International Nickel Company, Inc. Subject was considered primarily from the standpoint of nickel-base alloys. The price of these materials increased 47 to 54 percent in 1974, to make up for the very small price increase in the 1971-1973 period. Availability and pricing of these materials stated to be "good" in the future.

Specialty Metals, by George Wile, Atek Specialty Metals Center. Iron-base and nickel-base superalloys were discussed. In order to minimize price increases in the future, recommended that suppliers decrease the number of alloys and section sizes. Also, users should consider alternate forms, e.g., castings and sheet metal fabrications. The rising cost of the raw materials involved is the primary cause of superalloy price increases.

Nickel-Base and Cobalt-Base Superalloys, by Ed P. Godschall, Stellite Division, Cabot Corporation. These alloys contain a number of critical and/or strategic materials including nickel, cobalt, chromium, molybdenum, tungsten, and columbium. Wile's comment that the cost of raw materials has the greatest effect on the prices of these alloys was supported. Notable is the fact that price adjustments are independent of demand.

Refractory Metals - Tantalum and Columbium, by Keith Garrity, Fansteel, Inc. No shortages of columbium is projected in the next five years, based on present applications for the metals and excluding possible effects of emerging technologies. Economic methods for obtaining tantalum from slags are required, in order to limit future price increases for this metal.

Tungsten and Tungsten Carbide, by Charles W. Hanna, Kennametal, Inc. The price of tungsten is very volatile, based primarily on very wide excursions in the price of ore. (For instance, ore prices increased from $44/ton in early 1974 to $104/ton in the Fall of the same year, and receded to $88/ton by early 1975). Naturally, this also affects the price of tungsten carbide.

Molybdenum, by Rudy Wood, M&R Refractory Metals, Inc. The U.S. is self-sufficient in molybdenum and supplies much of the world's demands. Nevertheless, the supply of molybdenum is currently short because of a lack of

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* Supply/demand curves and other statistical data from these talks are available in the project files, but for the sake of brevity are not presented here.

roaster capacity. By 1977, the supply position should be much improved, but until then molybdenum will be in short supply.

Aluminum, Long-Term Outlook, by Charles Parry, Aluminum Company of America. Three major factors affecting the supply and cost of aluminum are (1) capital requirements for expansion (new capacity will be reactive, not anticipatory, in the future), (2) energy requirements (this affects cost more than it affects supply) and (3) availability of foreign bauxite and/or non-bauxite domestic ores. Of interest is the fact that the price of bauxite has tripled since 1972.

Aluminum, Short-Term Outlook, by Sidney Blumenreich, Reynolds Metals Company. Demand for aluminum, presently very low, is expected to increase starting in the second or third quarter of 1975 as the aluminum inventories of users become depleted. To save energy, conserve material, and decrease reliance on (foreign) bauxite, recycling is being emphasized. However, there is a real need for processes for refining the returned scrap and ending up with higher purity aluminum than presently feasible economically.

Copper, by W. Stuart Lyman, Copper Development Association. The worldwide consumption of copper reached an all-time high, 7.38 billion pounds in 1973. In that year, the U.S. was 95.1 percent self-sufficient with respect to copper. Adequate supply of copper in the future is assured.

Zinc, by Edward R. Bergin, American Smelting and Refining Company. In the last few years, the Free World has used more zinc than it has produced; the balance came from the Iron Curtain and from stockpiles. This situation relates not to the non-availability of zinc ores or to lack of zinc production capacity, but to considerations of value added. For instance, if Canada were to refine the concentrate that they normally sell, their balance of payments would go up substantially.

Lead, by Keith C. Hendrick, Noranda Sales Corporation. Tetraethyl lead, used for increasing the octane rating of gasoline, represents considerable percentages of the U.S. and world usages of lead (20% and 12%, respectively). Accordingly, banning lead from gasoline could have a significant impact on lead usage. The U.S. domestic supply of lead is strong, although some lead is imported from Canada, Australia, and Mexico.

Nickel, by Rover V. Mellon, The International Nickel Company. Nickel is not presently on allocation. Added capacity is expected to keep pace with demand for "the next few years". There are no large new uses for nickel that would tax capacity. Realizing that there are substitutes for nickel in many applications, International Nickel will try to keep the price of nickel from increasing too rapidly.

Titanium, by Ward W. Minkler, Titanium Metals Corporation of America. 1974 was a record year for titanium. Ingot production was 73 million pounds, which represents the true domestic ingot production capability. Approximately 14 million pounds of titanium sponge were imported during 1974. Most of this was from the USSR, whereas in previous years the majority of the sponge imported came from Japan. Five reasons were given for the lack of large announced domestic capcity increases in sponge production or ingot melting, as follows: (1) 75 to 80 percent of the yearly production of titanium is for the aerospace market sector, where there is uncertainty regarding short-term requirements for commercial aircraft, (2) th existence of the Federal stockpile, which currently contains 60 million pounds of titanium sponge, (3) inventory accumulation by customers, amounting to perhaps 10 million pounds at present, (4) the large capital requirements for expansion, particularly in the case of sponge plants, and (5) uncertainty regarding the supply and prices of titanium from foreign sources (politically-based prices are feared).

Precious Metals, by David E. Lundy, Matthey Bishop, Inc. The U.S. depends very largely on imports for platinum; these come primarily from South Africa, the USSR, and Canada. Some people feel that new applications for platinum catalysts will cause a supply problem in the early 1980s. No supply problem is foreseen for palladium, silver or gold, for several years or more.

Magnesium, by Robert L. Featherly, Dow Chemical Company. No continuing shortage is envisioned for magnesium, although demand will exceed supply in 1975. The selling price of magnesium is very sensitive to the cost of energy. (For instance, the oil tax proposal by President Ford early this year would add 6 cents to 8 cents per pounds to the cost of magnesium).

Tin, By R. D. Coursen, Malayan Tin Bureau. The U.S. produces no tin; two-thirds of the U.S. tin consumption comes from Malaysia. International tin politics often have a greater effect on prices than does any action by tin producers or users. Coursen believes that world tin reserves are adequate for even more than the 10 years stated in a recent U.S. Government report. Tin prices will rise from time to time as the floor price is changed by the International Tin Council. (To represent all interests, producers and users each have the same number of votes on the Council).

APPENDIX D

ADDITIONAL EMERGING TECHNOLOGIES IDENTIFIED IN FIFTEEN U.S. INDUSTRIES

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ADDITIONAL EMERGING TECHNOLOGIES IDENTIFIED IN FIFTEEN U.S. INDUSTRIES

(These technologies either overlap with the six selected for further research or were not so selected because they did not sufficiently meet the applicable selection criteria)

Industry	Emerging Technology	Brief Description of Technology	Criticality Consideration(s)	Basis for No In-depth Analysis
Aerospace and Space Systems	Dirigibles	For the transport of heavy large-volume cargo, such as nuclear reactor components and space shuttles. Dirigibles with volumes of about 30 million cubic feet are under consideration.	None apparent at this time.	It is not presently envisaged that there would be any types/amounts of materials or processes involved which significantly affect the critical materials situation and would therefore impact adversely on the DoD.
	Super Huge Cargo Planes	The use of super huge cargo planes on the order of one million pounds or more gross weight to carry freight at reduced costs. Aircraft of these sizes will require the use of lightweight structural materials such as composites, magnesium and possibly beryllium.	Graphite or organic-fiber composite materials will be critical materials. The aircraft have obvious potential as military transports.	(Composite materials were selected for further study)
	Air-Cushion Vehicles-Hovercraft	A family of vehicles which ride close to the surface on a cushion of trapped air. They are being utilized for limited passenger and/or freight transportation with a potential for greatly expanded use.	The materials most commonly used in the construction of hovercraft are aluminum and composites. At the present time, these composites are largely glass-fiber-reinforced composites. Later hovercraft will probably utilize improved composite materials such as graphite fiber composites. Hovercraft also have a potential for military utilization.	(This technology is similar to super huge cargo planes in that it utilizes composites which were selected for further study).

Industry	Emerging Technology	Brief Description of Technology	Criticality Consideration(s)	Basis for No In-depth Analysis
Chemicals and Chemical Processes	Fire-Retardant Chemicals	Clothing and cloth are treated with three types of chemicals to give fire-retardant protection: Phosphorous compounds for cotton, bromine compounds for synthetics, and antimony oxide for all types of cloth.	Legislation will probably be passed that will require that all clothing and cloth for wear be treated with fire-retardant chemicals. Large amounts are needed, e.g., 20% of the weight of cotton cloth in chemicals is required - corresponds to 500 million pounds of phosphorous compounds per year. These compounds need elemental phosphorous, for which there is very limited production capacity. Bromine is not in short supply. Antimony oxide imported from Peoples Republic of China and South Africa.	This is a critical area that was not selected for in-depth study on the basis of ranking, i.e., other emerging technologies were judged to have a greater impact on the critical materials situation.
	Use of Titanium Tubing in Highly Corrosive Environments	Titanium tubing is replacing copper-nickel tubing in heat exchanger installations utilizing sea water and in desulfurization systems used in the chemical and petroleum industries. Titanium tubing is also being introduced into the chlorine production process.	Chlorine production now uses 1.5 million pounds of titanium tubing, with an expected growth to 8 million pounds by 1980-1985. Power plants are expected to use 2 million pounds by 1980, and petroleum refineries 1 to 2 million pounds by 1980. The critical problem is production capacity.	Potential problem area, but considered to be less critical than six technologies chosen for in-depth analysis.

Industry	Emerging Technology	Brief Description of Technology	Criticality Consideration(s)	Basis for No In-depth Analysis
Chemicals and Chemical Processes (con't)	New Methods for Increasing the Octane Rating of Gasoline	Because of restrictions on the use of lead in gasoline, other methods are to be used to increase octane rating. Catalytic reforming and alkylation are the major methods. Another candidate is isomerization.	Platinum catalysts are required for catalytic reforming and isomerization. Research is being carried out on new materials for use as catalysts in isomerization.	Market penetration depends on continuation of Environmental Protection Agency regulations. Effect of technology on critical materials judged not as great as that of technologies chosen for further study.
	Hydrodesulfurization of Crude Oil	As the sulfur content of crude oils increase and government limits on sulfur decrease, an increasing amount of hydrodesulfurization is carried out.	Cobalt-molybdenum catalyst impregnated in alumina. A rough estimate is that about two million pounds of cobalt-molybdenum alloy is used in this application per year. Also, possibly titanium tubing.	The rate of growth of this technology is not sufficiently rapid to suggest that a shortage of cobalt-molybdenum catalyst will occur by 1990.
	Recovery of Metals From Heavy Crude Oil	Metals, especially vanadium and nickel, in certain heavy crude oils poison the cobalt-molybdenum catalyst used in hydrodesulfurization. Therefore, attempts may be made to remove these metals prior to hydrodesulfurization, but a viable demetallization process has yet to be developed. Also U.S. companies exert strong efforts to minimize the amount of high metal heavy crude oils that they import. (Venezuelan crudes and some Iranian crudes, for instance, have relatively high metal contents).	Vanadium and nickel recovered from heavy crude oils may serve as an additional source of supply of these important materials.	Possible source of vanadium and nickel, but the market penetration of the technology by 1990 will probably be low.

Industry	Emerging Technology	Brief Description of Technology	Criticality Consideration(c)	Basis for No In-depth Analysis
Chemicals and Chemical Processes (con't)	Coal Gasification	A variety of processes for producing gas from coal are under investigation. Either high-BTU gas or low-BTU gas is produced, depending on the process.	Alloys and ceramics that are resistant to erosion, wear, and corrosion in complex high-temperature environments and to corrosion in specific liquid environments at lower temperatures. Very thick steel plate, for which U.S. production capacity is relatively small.	Relatively small market penetration projected by 1990.
	Enzyme Production	Enzyme technology is emerging as a replacement for fermentation in the production of agricultural products. Petroleum products, required in fermentation, will not be needed. For example, glucose is being produced from starch.	The production of enzymes is the critical issue and in particular, the substrate upon which the enzymes are grown. Only one company has the technical know-how required to produce the substrate material.	This technology is not directly critical to DoD, but will lower cost of required agricultural products and lower our dependence on foreign supply, e.g., sugar. Important, but criticality not high enough to investigate further.
	Monomolecular Films	Monomolecular films are critical to many processes such as seawater desalinization where a water-impervious layer is required that does not significantly degrade heat transfer. Films now made by a gas plasma process which is difficult to control. Two new processes, photopolymerization and vapor deposition from plasma, are being developed into production processes.	The materials used in these films are not critical.	An important area but one that does not impact on DoD's critical material needs.

Industry	Emerging Technology	Brief Description of Technology	Criticality Consideration(s)	Basis for No In-depth Analysis
Communications	Optical Communications	Optical radiation is coupled into optically perfect waveguides and transmitted over a distance, after which the signal is detected with a high-fidelity sensor.	High-purity low-imperfection glass for use as wave guides not currently available in large quantities.	Availability of high-purity low-imperfection glass may become a problem if the use of optical communications is expanded significantly. However, this materials problem is not as great as in the technologies selected for in-depth study.
	Laser Communications	Laser radiation is transmitted over a distance, either with or without the use of waveguides, after which the signal is detected using a high-fidelity sensor.	High-purity low-imperfection glass for waveguides, if used. Laser materials.	The availability of special glasses for waveguides and of laser materials may be a problem if laser communications grows significantly. (Laser materials and special glasses are being considered further under the emerging technology "Lasers for Materials Processing and Measurement").
	Large-Scale Digital Transmission of Commercial Data	Transmission of commercial data in digital form throughout computer networks.	Materials used are not considered critical.	Negligible usage of critical materials.
	Use of Picturephones for Business Conferences	The use of picturephones for business conferences will eliminate transportation expenses and inconvenience, and save time.	No large quantities of critical materials required in this technology.	No significant effect on critical materials.
	Use of Microprocessors in the Home	Microprocessors (essentially very small computers) can be used, for instance, to translate into digital format periodic changes in the recorded usage of utilities. The microprocessors would yield the desired information when interrogated from a central station.	Critical materials are not involved in this technology.	Small usage of critical materials.

Industry	Emerging Technology	Brief Description of Technology	Criticality Consideration(s)	Basis for No In-depth Analysis
Communications (cont'd)	Computer Monitoring and Control of Processes	The utilization of properly programmed computers to monitor the operating parameters of production processes and to make changes as required.	Materials criticality has not been demonstrated.	Insignificant usage of critical materials.
	Optical Character Readers	This technology involves illuminating planes or volume patterns, such as on a flat surface (e.g., printing) or in a volume such as in a hologram, and processing the detected modulated signal.	No critical materials involved.	No impact on critical materials.
Construction	Fiber-Reinforced Concrete	The use of fibers in concrete is revolutionizing the construction industry. The engineering properties of fiber reinforced concrete are superior to plain or conventionally reinforced concrete and at a lower cost. At the present time, these new materials are being evaluated worldwide. For example, the State of Ohio has recently specified that all bridges be built with Wirand concrete (a type of fiber-reinforced concrete). Gains in flexual and impact strength are two important advantages.	It is anticipated that, if fiber reinforced concrete is widely accepted, literally millions of tons of fibers will be required. Economic methods for producing fibers is a likely point in this situation.	The fibers used in fiber-reinforced concrete are not critical materials and should not have a significant effect on the DoD materials outlook.

Industry	Emerging Technology	Brief Description of Technology	Criticality Consideration(s)	Basis for No In-depth Analysis
Construction (cont'd)	Pre-engineered Buildings for Home Units	Pre-engineered buildings which were originally represented by "Butler" type commercial buildings will experience a significant jump in the 1975-1990 time period as they enter the home market.	The critical material, if any, is coated metal. Plastic coated steel will probably account for the majority of the materials usage.	The materials involved should not be critical with respect to DoD's needs.
Electronics/ Electrical	Batteries for Energy Storage and Automobiles	The anticipated demand for peak power through 1990 will have to be supplied by means other than primary power generation. Battery units of 10 megawatt capacity are now planned to meet this need. Several battery types are in development: sodium-sulfur, lithium-sulfur, sodium-chlorine, zinc-chlorine, and of course, lead. Similar battery types are also under study for automobiles.	Battery types other than lead will not use materials that are in danger of short supply. Our supply of lead has been adequate to date. However, if lead is used, the amount of lead required would be one million tons for peak power by 1990, and six million tons for automobiles by 1985. However, the latter figure is based on a very optimistic projection of 20 million electric cars by 1985.	The amount of lead required for these potential applications could well exceed domestic supply. However, no real problems are envisaged if suppliers have sufficient notice.
	Light-emitting Diodes (LEDs)	Increasing use of LEDs for radiation detection and displays.	Increased demand for current materials (GaAsP, GaP, or GaAs).	Supply expected to keep pace with projected demand through 1990.
	Large-scale Integrated Circuits (LSIs)	The trend is toward finer line widths in integrated circuits. This allows more functions to be performed within a given surface area.	Silicon chips. Organic materials such as polyamides are beginning to replace silicon oxide and silicon nitride as the insulating layers.	No lack of materials or manufacturing capacity is envisioned.
	Infrared Detectors	Increasing use of narrow-band-gap materials for the detection of infrared radiation.	Growing demand for current narrow-band-gap materials (e.g., PbSnTe and HgCdTe).	No serious materials supply problems anticipated through 1990.

Industry	Emerging Technology	Brief Description of Technology	Criticality Consideration(s)	Basis for No In-depth Analysis
Electronics/ Electrical (cont'd)	High-temperature Electronics	Specialty applications may require electronic systems that operate at elevated temperatures in the vicinity of heat sources. These systems would detect, filter, and/or generate radiation. Wide-band-gap materials would be required.	Wide-band-gap materials (e.g., SiC) in the proper purity would be required. Preparation procedures would probably have to be developed for these materials.	Very small market penetration of this technology is projected by 1990.
	Travelling-wave Tubes	Travelling-wave tubes amplify microwaves.	Samarium-cobalt magnets. Possibly mischmetal-cobalt magnets in the future, if compositions are developed with improved properties; these should be cheaper than samarium-cobalt magnets.	Supply and demand expected to remain in-balance through 1990.
	Microwave Generators	As the name implies, this technology involves electronic devices that generate microwaves.	Zone-refined-and-doped single-crystal silicon, or 3-5 compounds (e.g., GaAs and InSb).	No shortage of materials or processing capacity expected by 1990.
	Liquid Crystal Displays	Liquid-crystal-type organic materials can be used as displays, for instance in electronic watches.	None apparent at this time.	No critical materials involved in this technology.
Energy	High-voltage Direct-current Power Transmission	Direct current power transmission at high voltage is advantageous both for long overhead lines and for underground cables. Also, it is beneficial in inter-regional power transfer and can be used to tie systems together asynchronously.	High purity silicon for rectifiers. Additional production capacity may be required.	Projected market penetration by 1990 probably not sufficient to cause serious materials shortage problems.

Industry	Emerging Technology	Brief Description of Technology	Criticality Consideration(s)	Basis for No In-depth Analysis
Energy (cont'd)	Gas Centrifuge Separation Process	Possible replacement for the gaseous diffusion process for uranium enrichment.	Possible use of stainless steel in centrifuges, with a resulting requirement for chromium and nickel.	Large market penetration by 1990 not anticipated.
	Gas Nozzle Separation Process	Replacement candidate for the gaseous diffusion process for enriching uranium.	Minimum requirements for critical materials.	No significant impact on critical materials. Only minor market penetration anticipated by 1990.
	Liquefied Natural Gas (LNG) Operations	Liquefaction of natural gas for long-distance transportation by ships.	9%-nickel steels and aluminum candidates for construction of cryogenic sections of liquefaction plants, LNG tankers, and storage facilities.	Requirements for critical materials judged to be low, and much of the construction could take place in foreign countries (presumably using foreign materials).
	Use of Zircalloy Tubing to Clad Nuclear Fuel Elements	Zircalloy (a zirconium alloy) tubing is used as a cladding for fuel elements in nuclear reactors.	Ten million pounds of zircalloy tubing required for new light-water reactor power plants projected to 1990. Possible problem with production capacity for high-purity alloy preparation and tube forming if these plants are actually built. U.S. zircon ore reserves are large, so zirconium itself will probably not be a problem.	Likely that the necessary production capacity will become available as plans for nuclear power plants solidify.
	Direct Conversion of Energy by Magnetohydrodynamics	By moving a column of extremely hot ionized gas (a plasma) through a strong magnetic field at high velocities, magnetohydrodynamics enables direct conversion of heat into electricity. The strong magnetic field is provided by a superconducting magnet.	Columbium (niobium) in superconducting alloys; nickel and chromium in high-strength steels for large magnet supports. Also, production capacity for superconducting alloys. These requirements are for large superconducting magnets for magnetohydrodynamic research; full-scale plants are not expected by 1990.	(The requirements of magnetohydrodynamics for critical materials are considered in Tasks II through IV, under the emerging technology "Superconductors for Power Applications").

Industry	Emerging Technology	Brief Description of Technology	Criticality Consideration(s)	Basis for No In-depth Analysis
Food and Agriculture	Use of Methyl Parathion as an Insecticide	Replacement of DDT, because of its toxic effects, by methyl parathion.	Availability of methyl parathion.	Production capacity readily expandable to meet anticipated needs.
Forest Products	Oxygen/alkali Systems for the Pulping and Bleaching of Wood	Because of environmental problems caused by sulfur-containing emissions in the kraft pulping process, oxygen/alkali pulping and bleaching systems are under development.	No additional requirements for critical materials when switching from a kraft to an oxygen/alkali system.	No added requirements for critical materials.
	Whole-tree Pulping	As the name implies, this technology involves pulping the entire tree -- including limbs, bark and leaves.	Increased consumption of chemicals per ton of product, but these are not critical materials.	No impact on critical materials.
Machinery	Automation	We are on the verge of accelerated expansion in the automation of rapidly moving machinery and mechanisms for production and assembly. The inherent problem of inertia in rapidly moving machinery is forcing designers to utilize lasers in place of mechanical systems for operations such as cutting, drilling sizing and for various measurements. Simple computers will also be used to control the many operations in an automated line.	By 1980 the use of lasers and simple computers will be widespread in the manufacturing area.	Simple computers for these applications will not utilize significant amounts of critical materials. (Materials used in lasers are being considered further in Tasks II through IV, under the emerging technology "Lasers for Materials Processing and Measurement").

Industry	Emerging Technology	Brief Description of Technology	Criticality Consideration(s)	Basis for No In-depth Analysis
Materials	Continuous Casting	The continuous casting of metals is a rapidly expanding technology. Steels and many non-ferrous alloys are now being cast by this method. In the direct casting of copper and aluminum alloys into rod for the electrical industry, the U.S. is now selling considerable equipment abroad.	Sufficient capacity is the potential problem area.	DoD utilizes metals that are continuously cast. However, analysis of the situation indicates that sufficient capacity in continuous casting machines could be built with lead times of only six to eight months.
Medicine and Biomedicine	The Use of Stainless Steel for Blood Catheters	The use of PVC in contact with human blood has been stymied because of toxicity. Accordingly, PVC catheter tubes are to be replaced with stainless steel.	The critical materials are nickel and chromium in the stainless steel. Some one million catheter tubes of PVC will be replaced with stainless steel. This is an increased demand for stainless steel (chromium and nickel). Total amount of stainless would be in the neighborhood of only 30 to 40 tons.	The anticipated demand for additional stainless steel in this application will not significantly affect the supply situation.
	Ceramic Bone Replacements	The use of bioabsorbable ceramics as bone replacements and as tooth roots is a new technology that is just becoming of interest in the U.S. The bone cells invade the porous ceramic and eventually replace it.	The ceramic materials involved are not in short supply and are not considered to be critical.	This new technology does not utilize materials that are critical to the DoD or in short supply in the commercial area.
	The Use of Vitallium and Titanium Alloys as Orthopedic Implants	Stainless steel orthopedic implants are being replaced by vitallium (a cobalt-base alloy) and titanium. These metals are proving to be more resistant to the chemical actions of human tissue and body fluids.	The present demand for orthopedic implants is about 200,000 per year. These have a total weight of about 200,000 pounds.	The materials involved are critical to the DoD; however, the amounts involved are not sufficient to affect the DoD's critical materials situation.

Industry	Emerging Technology	Brief Description of Technology	Criticality Consideration(s)	Basis for No In-depth Analysis
Mining and Minerals Processing	Fused Chloride Electrolysis Process	Electrolysis of fused aluminum chloride which is obtained from alumina by chlorination. This process is a possible replacement for the Hall process, and is said to consume 30% less energy. A 25,000 ton capacity plant is being built in Palestine, Texas, to scale up the process.	Possibility for energy conservation in the production of aluminum.	Critical materials not involved significantly.
Ocean Engineering	Ocean Mining of Manganese Nodules	The recovery of nodules from the ocean floor as a source of nickel, copper, cobalt and manganese is on the borderline of being an economically viable process.	Manganese, nickel, cobalt and copper are all metals imported by the U.S. Manganese and cobalt are almost completely imported, and about 75% of the nickel consumed by the U.S. is imported. The estimated reserve of manganese nodules on the Pacific ocean floor is 1.5 trillion tons, and nodules are forming at the rate of 10 million tons per year.	Although these nodules could supply metals that are important and critical to the DoD, and the potential supply could materially decrease our dependence on foreign sources, it is anticipated that the production of these metals from nodules will not have a significant effect on our supply situation before 1990.
	Offshore Mining	Possible expansion of offshore mining to include other materials in addition to gravel, sand, and phosphate.	Chromium and nickel in high-strength steels.	Market penetration by 1990 probably will be insufficient to impact on critical materials needs.

Industry	Emerging Technology	Brief Description of Technology	Criticality Consideration(s)	Basis for No In-depth Analysis
Transportation	Microcomputers (Microprocessors) for Automobiles	The use of microcomputers in automobiles is rapidly approaching reality. Microcomputers will control functions such as fuel injection, spark plug adjustment and braking to prevent skidding.	When microcomputers come into such use, annual requirements in automobiles and trucks could approach 10 million production units.	An emerging technology, but not utilizing significant amounts of materials critical to DoD.
	Levitated Trains	Trains suspended by magnetic forces can attain much higher speeds than can conventional trains. Magnetic forces for the suspension system are supplied by superconducting magnets.	Columbium (niobium) in superconducting alloys. Production capacity for Nb_3Sn and NbTi superconducting alloys.	U.S. market penetration by 1990 judged insufficient to impact on critical materials. (Also, the requirements for superconducting alloys are being considered in the further study of the emerging technology "Superconductors for Power Applications").
Waste Treatment and Environmental Control	Waste-to-Energy Systems	Systems used to convert waste materials into energy, thereby performing the two valuable functions of waste disposal and energy production.	Chromium and nickel in specialty alloys.	Market penetration anticipated by 1990. Should not have significant demand impact vis-a-vis other needs for specialty alloys.
	Recycling of Materials from Refuse	Efforts have been made to recycle ferrous and nonferrous metals, and other materials such as rubber and glass, from refuse.	Possible source of materials, some critical.	Recycling of most materials from refuse is uneconomical at present, except in a few special cases (e.g., when customers bring aluminum beer cans to a central collection point, thus obviating the need for special separation equipment). Probably will not serve as an important source of supply of critical materials by 1990, unless the scarcity of related critical materials increases greatly or materials costs rise significantly.

Industry	Emerging Technology	Brief Description of Technology	Criticality Consideration(s)	Basis for No In-depth Analysis
Waste Treatment and Environmental Control (cont'd)	Desulfurization of flue gases from electric power plants	A number of processes for removing the sulfur from flue gases from electric power plants, and thereby decrease air pollution, have been developed	Chromium and nickel in alloy steels. Titanium tubing	Requirements for critical materials by 1990 judged insufficient for further study

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The report presents, at mid-term in the research period, a report of a brief assessment of the materials involved in certain U.S. emerging industrial technologies with the end objective of identifying potential procurement and development problem areas in critical materials for the Department of Defense.

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