CONFERENCE
PROCEEDINGS

A NATIONAL PROSPECTUS ON THE FUTURE OF THE U.S. ADVANCED CERAMICS INDUSTRY

July 10-11, 1985
National Bureau of Standards
Gaithersburg, Maryland

NBS IR 85-3240

DEPARTMENT OF COMMERCE ★ NATIONAL BUREAU OF STANDARDS ★

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- Office of Productivity, Technology & innovation
- Institute for Materials Science and Engineering
National Bureau of Standards

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Edited by
Samuel J. Schneider
Institute for Materials Science and Engineering
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PREFACE

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Recently issued Department of Commerce reports and a number of other studies carried out in the past year have shown that the U.S. competitive position in advanced ceramics is being seriously challenged. Our lead in ceramic electronic components has been largely lost and unless action is taken now, it is unlikely that the U.S. will regain a significant competitive position. Similarly, in engineered (structural) ceramic products, other nations are aggressively targeting this area for development and the U.S. will gradually fall behind if current trends continue. The implications of these findings could be far-reaching for both the overall strength of the U.S. economy and for national security.

To address this problem, the Commerce Department held a conference on July 10 and 11, 1985, jointly sponsored by the Office of Productivity, Technology and Innovation and the National Bureau of Standards. Leaders from ceramics producing and user firms as well as from the universities and government were invited to meet to assess the status of U.S. structural and electronics advanced ceramics research, where we are going, and, hopefully reach a consensus on further steps that are needed.

This report constitutes the Proceedings of the Conference and represents the factual information and documentation available at the conclusion of the meeting. What may not be evident from the printed word is the spirit and enthusiasm shown by the conferees in carrying out their charge. It was obvious that the advanced ceramics industry and those from government and academia were concerned about competition and the American system and intend to work cooperatively in the best interests of all.

As with all conferences, it takes many dedicated people to plan and carry off a successful meeting and special thanks are due to the staffs of our organizations, the speakers, and participants for their many contributions.

Lyle H. Schwartz
Director, Institute for Materials Science and Engineering
National Bureau of Standards

D. Bruce Merrifield
Assistant Secretary for Productivity, Technology and Innovation
Department of Commerce

EXECUTIVE SUMMARY

EXECUTIVE SUMMARY

Advanced ceramics are a new generation of high-performance materials, widely believed to hold promise of markets in the tens of billions of dollars by the end of the century. Collectively, they represent an enabling technology, development of which is critical to advances in a host of high-technology applications ranging from modern microelectronic components to futuristic auto engines. Because of their potential, worldwide interest and activity is growing. Numerous studies and assessments have indicated that foreign competition is intense, with current markets in major electronic applications areas largely lost, even though the U.S. once held a technological lead. The prognosis for U.S. dominance of future advanced ceramics markets would appear to be equally dim, if these current trends continue.

In recognition of the competitive issues confronting the U.S. advanced ceramics industry, the Department of Commerce, through two sister agencies--The Office of Productivity, Technology, and Innovation and the Institute for Materials Science and Engineering, National Bureau of Standards, served as conveners of an industrially oriented conference, held July 10-11, 1985. Leaders from ceramic producing and user firms as well as from the universities and government were invited to meet for the express purpose of:

> Identifying and assessing the critical issues affecting the competitive position of U.S. industry in the current and future electronic and structural advanced ceramics world market, and developing approaches for improved market posture through cooperative industrial R&D and associated efforts.

The structure of the meeting was designed, first, to provide information on the status of advanced ceramics technology in the U.S. and second, through workshop and panel sessions, define what might be done to enhance the U.S. competitive position, from both a technological and business viewpoint.

In **Session I-Overview**, Representative Don Ritter stated that "Nowhere is the competition in international trade more evident than in ceramic technology. There is still today in the United States only a weak U.S. industry in high technology ceramics while the Japanese have made a strong commitment to become the major world source of these materials. U.S. industry must accept responsibility for the bulk of the work. The government can help but massive government intervention cannot achieve competitiveness in any industry." Albert Westwood, Corporate Director, R&D, Martin Marietta Corp., noted that recent cooperative efforts in ceramics, including the formation of several research consortia at universities, is a step in the right direction, but warned that this is not enough to ensure that U.S. companies win their fair-share. For this to happen, U.S. industrial management must develop a long-term commitment to exploit advanced ceramics in new and existing markets, spur materials scientists in their ceramics work, and do a better job of collecting and utilizing technical knowledge about ceramics generated here and abroad.

Session II--Information Base, provided summary reviews of previously conducted studies and assessments of the technological and economic aspects of advanced ceramics. Lyle Schwartz, Director, Institute for Materials Science and Engineering, NBS, stated that the technical issues were clear but what remains to be answered is how they can be resolved in expeditious manner while still maintaining the traditional roles for industry, universities and government. Basically the competitive challenge equates to one of cooperation and coordination. Deputy Assistant Secretary Kelley, Basic Industries, ITA-DOC, discussed the U.S. competitive position, emphasizing that Japan has benefited from government targeting policies in the high-tech areas like ceramics. By contrast, the advanced ceramics industry in the U.S. is fragmented with little cooperation between companies. S. L. Blum, Vice President, Charles River Associates, presented statistical information on current and future markets and on the changing structure of the U.S. advanced ceramics industry. He projected that the future is bright, but depends upon the solution of a number of significant technical problems. The level of ceramic R&D and strategies devoted vary among nations but no clear winner in the worldwide ceramics race has emerged. J. J. Harwood, President, Ovonics Synthetic Materials Co., talked about market opportunities and about the barriers which limit commercialization and market penetration. He categorized the major barriers as related to (a) production costs, (b) manufacturing reliability and uniformity of properties, and (c) reliability in performance. Harwood further identified three areas which might have an impact on the U.S. competitive position through RDLP opportunities: (1) improved powder characteristics, (2) wear components, and (3) sensors.

Session III--Cooperative Mechanisms and Response, dealt with the forms and benefits of cooperative industrial R&D. D. Bruce Merrifield, Assistant Secretary, OPTI, DOC, emphasized that the U.S. has remarkable attributes and resources including, an industrial advanced technology base, an incomparable industrial infrastructure, a most effective capital formation capability and an unique entrepreneurial culture. Cooperative R&D arrangements initiated by the private sector can mobilize these resources for enhanced competitiveness with the federal role focused only on removing barriers, providing incentives and catalyzing the cooperative process. Lansing Felker, Director, Industrial Technology Program, DOC, pointed out that the cost of keeping pace with technology development is increasing beyond the capability of individual firms, but that under the Cooperative Research Act of 1984, enhanced industrial cooperation is now possible. Notable examples of cooperative ventures registered under the Act include the Microelectronics and Computer Technology Corporation (MCC) and the Semiconductor Research Corporation (SRC). Malcolm McLaren, Chairman, Ceramic Department, The Rutgers State University, described forms of university/industry interactions and their benefits to the state, the university and to the participating industrial organizations. He cited various modes of interactions, including consulting, grants, single sponsor research and particularly multiclient consortia such as those now established at Rutgers, Penn State, MIT and UC (Berkeley). The consortia mechanism is especially useful in not only producing generic research to complement industrial R&D but also, in assuring the training of talent specifically needed by industry. Ora Smith, Senior Policy Analyst, OSTP, elaborated on the role Federal laboratories could have in assisting industry. He emphasized that while these labs have great technical resources (1/6th of the Nation's scientists and engineers), their utilization by industry requires in-depth joint program planning and structuring and mutual interest. Coordination and communication is the key to successful government/interactions and if properly pursued, the rather tenuous past relationships could be improved.

Sessions IV and V--Workshops and Consensus Views were the central feature of the conference, providing a forum for industrial views on where the advanced ceramic industry is and where it should go to meet the competitive challenge. The conferees were asked to address the following questions for the business areas of electronic and structural ceramics:

1. What is the status of R&D? Are current activities sufficient? In what areas are there deficiencies?

2. What are the market growth areas and what is industry doing to meet the challenge?

3. Does industry need and want cooperative research and if so, in what areas and in what form?

Joseph Panzarino, Director of Research, High Performance Division, Norton Company, led the structural workshop and Robert Stokes, Principal Staff Scientist, Honeywell Physical Science Center, a separate one on electronic ceramics. Richard Spriggs, Senior Staff Officer, National Materials Advisory Board, NRC, organized the summary panel to synthesize the findings of the two workshops and obtain consensus views on future actions and define the next steps to achieve conference recommendations.

The individual workshops, although varying in detail, arrived at basically the same set of conclusions and recommendations:

Technical Status

R&D activities exist throughout the complete spectrum from basic idea generation to prototype manufacture to commercial products. Additional R&D investment could be beneficial for several product classes, with emphasis on the translation phase (development-prototype-interim manufacture).

Market Potential

Current and future advanced ceramic markets are substantial with certain product classes more attractive than others; all deserve attention by U.S. industry as potentially fruitful business areas. With respect to competitive position, U.S. industry was judged to have the advantage in only few areas and average or below for the others.

Cooperative Research

A major need exists for cooperative industrial R&D. Such activities are needed to maintain at a minimum, the present competitive status and essential to establish a better position.

In summary, workshop participants agreed on the most critical areas for R&D and on the necessity for inter- and intra-industrial cooperation to encourage the growth, productivity and competitiveness of the U.S. advanced ceramics industry. Based on a consensus of the conferees it was recommended that the assistance of the Department of Commerce be sought to form an industrial steering committee to build upon the work of conference and pursue such actions leading to one or more cooperative research ventures. (Editor's Note: A letter dated August 12, 1985 was sent to the Department of Commerce requesting assistance; a reply, dated October 11, 1985 indicated that appropriate assistance would be provided.)

INTRODUCTION

CONFERENCE RATIONALE, PURPOSE, AND ORGANIZATION

Samuel J. Schneider
Institute for Materials Science and Engineering
National Bureau of Standards

Advanced ceramics are a new generation of high-performance materials which have begun to be used for sophisticated high-technology applications. They have unique properties (electrical, mechanical, optical, magnetic, heat/corrosion resistance) that make them the preferred material for diverse applications including electronics, heat engines, cutting tools and wear parts, biomedical devices and sensors. Their superior properties allow use in extremely demanding environments far beyond the capabilities of advanced metals and plastics and even conventional ceramics. The potential impact of advanced ceramics on U.S. industry and the national economy is becoming clear: their development and exploitation is critical to advances in transportation, communications, energy conversion, computers, defense systems, and a host of modern consumer products.

Worldwide production capability for advanced ceramics is growing rapidly creating significant competition for the U.S., initially from Japan but with Western Europe also beginning to make in-roads. The implications of ceramics markets are far reaching. At stake is not just the ceramics producing industry but also the industries which, in order to stay competitive, will use ceramics materials to manufacture their own products. For example, according to a study by Argonne National Laboratory, if the U.S. could develop and capture a significant portion of the advanced ceramics market for auto engines, the result would be an increase in GNP of as much as $279 billion over the next 20 years, along with 250,000 jobs.

Currently, the U.S. appears to have lost significant segments of existing advanced ceramics markets, particularly in electronics areas. The capture of future markets (e.g. heat engines, cutting tools, advanced electronics, etc.) depend upon significant technical R&D successes and, at present, there is no clear indication that either the U.S. or its foreign competition holds a broad technical lead. Technical excellence and advancement alone, however, do not assure market entry and dominance; there are many interrelated and competing factors that mitigate and often control commercial success. Industry structure and capabilities, marketing and investment strategies, and commitment are as important as R&D thrusts.

At present there is growing interest and activity in advanced ceramics in the U.S. However, those efforts are disaggregated and may not be sufficient to achieve and maintain a competitive position. Conversely, Japan has mounted a national program using cooperative mechanisms and techniques many of which are not viable in the U.S. economic system. However, alternative approaches are possible which would allow a new level of cooperation among U.S. firms. Specifically, joint research ventures--mechanisms by which industry cooperatively can fund basic or generic research--may be especially appropriate for the emerging Advanced Ceramics technology. The National Cooperative Research Act of 1984 now has removed the antitrust uncertainty from such ventures, thus providing one effective avenue for U.S. industry to better compete with the targeted industry consortia of our main trading partners.

The competitive challenge confronting the U.S. Advanced Ceramics industry clearly equates to one of better cooperation and coordination. In recognition of this, the objective of the conference was to identify and assess critical issues affecting the competitive position of U.S. industry in the current and future advanced ceramics world market, and to develop approaches for improved market posture through cooperative industrial R&D and associated efforts.

The structure of the meeting was designed, first, to provide information on the status of Advanced Ceramics technology in the U.S. and second, through workshop sessions and summary panels define and obtain consensus views on what might be done to enhance the U.S. competitive position, from both a technological and business viewpoint. The following questions were assessed for the business areas of electronic and structural ceramics:

1. What is the status of R&D? Are current activities sufficient? In what areas are there deficiencies?

2. What are the market growth areas and what is industry doing to meet the challenge?

3. Does industry need and want cooperative research and if so, in what areas and in what form?

The Proceedings of the conference, given in the following sections, detail the views of the speakers and participants and reflect their efforts to develop approaches for future actions that will optimize the growth, productivity, and competitiveness of the U.S. Advanced Ceramics industry.

SESSION I: OVERVIEW

WELCOMING REMARKS

Ernest Ambler
Director
National Bureau of Standards

Thank you Dr. Merrifield. Good morning Ladies and Gentlemen, Congressman Ritter, distinguished guests. It is my pleasure to welcome you to the National Bureau of Standards for this conference on advanced ceramics. As you will note from the program, the co-sponsors of the meeting are the Office of Productivity, Technology and Innovation and the NBS Institute for Materials Science and Engineering. It is especially fitting, I believe, for these two Department of Commerce sister organizations to join together to host an industry oriented conference having an inter-related theme focusing on R&D and competitive issues. This is an important area of concern to the whole of the Department of Commerce and your deliberations--the industrial viewpoint and consensus actions--are vitally important to the future of the advanced ceramic industry.

It is also appropriate for the site of the conference to be NBS for we have long been engaged in ceramic research. Our first recorded ceramic activity dates back to 1910, only nine years after the Bureau was formed. The intensity with which we have worked on ceramics has varied since then but right now is undergoing a resurgence. We have now a substantial effort in advanced ceramics and expect to do more. I encourage you to visit our facilities to see first hand some of the interesting research we have underway on powder synthesis, mechanical proprieties, phase diagrams, neutron scattering, and the like.

I take great pride in the fact that since its founding, our activities at NBS have been directed to support industrial needs. We interact daily with industry through our Industrial Research Associate Program and in a host of other ways. This conference today is but one example illustrating how NBS and the Department of Commerce attempt to serve industry. I note that the objective of the organizers of this meeting is to catalyze and stimulate discussion and interaction between prominent industrialists, representing different interest, so that industry can chart its own course in the important and growing area of advanced ceramics. This is an appropriate role for government to play, and I am looking forward to the results of the conference.

I certainly welcome you to NBS and wish you great success in your deliberations.

ADVANCED MATERIALS IN THE NATIONAL ECONOMY

Honorable Don Ritter (R-PA15)
U.S. House of Representatives

My objective today is to share with you some of my own thoughts about how important advanced materials are to our national economy and to relate some of the actions now underway in the Congress to help the United States maintain (or in some cases, perhaps to reclaim) a leadership role.

Over the past three or four years, members of your Congress have become increasingly aware of the importance of advanced materials to our national economy. We have seen, for example, tremendous increases in the efficiency of our telecommunications systems which have been made possible by advances in optical fiber transmission systems. Advancements continue to be made in the telecommunications field by further refinements in fiber optics and other electronic components.

Expert witnesses appearing before members of the House Committee on Science and Technology have described the potential value of many other "advanced materials." In every case, while the market value of a new material may itself be quite substantial, the timely, practical application of these new materials can have an ultimate impact on the national economy that extends far beyond the specific dollar value of the new material. This cascading effect is often quite remarkable.

A joint effort of the Department of Energy and the American Iron and Steel Institute may be successful in combining modern electronics and modern materials to develop a special purpose sensing device to directly measure the chemical composition of molten steel. Use of this device could save the industry somewhere in the range of 200 million dollars annually in operating costs and energy costs.

The potential development of a strip casting process combined with in-line rolling to produce steel sheet for automotive and other applications is another example of new technology in the traditional field of metallurgy. It has been estimated that such a development would save the country 10^{15} BTU's of energy per year. This development also has the potential for lowering costs, and perhaps most importantly to produce steel of higher quality and improved properties that would be more competitive at home and abroad.

Another example of an important advanced material is the specialty steels used in the core of electric transformers. Our current annual loss of energy in power transformers is 50 billion kilowatt hours--this is equivalent to the loss of about 2 and 3/4 billion dollars each year. By making improvements in existing crystalline silicon sheet steels, it may be possible to reduce this loss by 30 percent--and new amorphous metal sheet materials have the potential to cut that loss in half.

Lightweight materials--including composites, newer steels, and magnesium--have also begun to have their impact on the automobile industry. The potential impact of these materials on fuel economy has been well documented and could result in savings in excess of 20 percent of today's U.S. oil consumption. But there are other advantages to the uses of these new materials. They provide the opportunity to produce longer lasting, more reliable, lower cost, peppier automobiles, with greater design flexibility. This could be a powerful factor in helping us gain a competitive advantage. Toyota was the first to develop and put into production a commercial application of metal matrix technology. It is vital that we catch up and pass our competitors in this and in other new materials technologies for automotive applications.

There are many other examples, but advanced ceramics surely is one of the most exciting topics in the advanced materials field. The market forecast for advanced ceramics assures for them a prominent place in the economy of any nation. Recent studies by Charles River Associates estimated the value of advanced ceramics produced by the free world nations at 12 billion dollars in 1990. This estimate is increased to 17 billion dollars in 1995. The consumption of ceramic products in heat-engine components and integrated optic devices, neither of which are at present produced commercially in the United States, is projected to grow at more than 40 percent per year during the 1990s. The skillful application of advanced ceramics can achieve fantastic collateral benefits. Advanced ceramic materials offer the chance to increase the operating temperatures of truck and automobile engines very substantially, and thus could increase fuel efficiency at least 30 or 40 percent. I am told that between the years 1985 and 2005, a successful United States ceramic engine program could add 280 billion dollars to our gross national product. Now that is an objective that is certainly worth working for!

Nowhere is the competition in international trade more evident than in modern ceramic technology. There is still today in the United States only a weak U.S. industry in high technology ceramics while the Japanese have made a strong commitment to become the major world source of these materials. A study on high-technology ceramics in Japan was recently completed by the National Materials Advisory

Board of the National Research Council. A study team visited Japan and met with members of the Japanese Government and leaders in their ceramic industry. The team concluded that in Japan, advanced ceramics is recognized as an extremely significant emerging technology with the potential for important economic, industrial, and social impacts. Because of this, the Japanese are committed to develop the field of high-technology ceramics vigorously, and perhaps even to dominate this field.

I think it is important that the United States meet the challenge of this competition. In this regard, the study team made several recommendations, which include such actions as:

⊙ The development of mechanisms for gathering and disseminating timely information on Japanese ceramics publications, reports, and patents, and the creation of better communications with Japanese counterparts in the ceramics industry.

⊙ The advancement of U.S. industry's timetable for the emergence of high-technology ceramics markets.

⊙ Capitalization on research and development funded by DOD and other government agencies by applying the results to civilian markets.

⊙ Acceleration of research and development of production technology for high-technology ceramics.

⊙ Establishment of a U.S. "Ceramics Industry Association" to facilitate gathering and dissemination of information and to develop a sense of purpose for the industry.

The Congress is very concerned about the many challenges that our industries face from foreign suppliers. In the House of Representatives, I am involved in activities which are searching for ways to help our industry improve its competitiveness and its ability to successfully meet these challenges. The House Science and Technology Committee has formed a task force to study our Nation's science policy with the objective of improving the knowledge of Congressmen in this important area of policy and identifying policy modifications which will promote both advancements in science and the international competitiveness of American industry. The task force is holding a series of hearings in which pre-eminent scientists, engineers, and policymakers representing many disciplines and viewpoints will provide the task force with a broad picture of U.S. science policy and form a strong foundation for future policy recommendations.

I also serve as vice chairman of the House Republican Research Committee's Task Force on High Technology. The objective of this special group is to identify and work for a legislative agenda which will promote the advancement of technology in the United States. We believe that strengthening the prerequisites for innovation is the real solution to meeting the challenges of the international marketplace. These prerequisites are:

- A strong commitment to basic research;
- Incentives for risk taking and capital formation;
- An ample quantity of trained workers; and
- Expanding market opportunities.

A few examples of the ways these prerequisites may be strengthened include:

- An extension and refinement of the incremental research and development tax credit to make it more useful to more industries and companies;
- Liberalization of IRA rules to allow individuals to withdraw from their savings without penalty or taxation to pay for employment retraining; and
- Amendment of the Freedom of Information Act by requiring that owners of proprietary information filed with the Federal Government be given the opportunity to challenge requests made under the FOIA for that information before it is released.

I strongly believe that the Government cannot achieve competitiveness in your industry, or any other, by massive intervention. You have to accept responsibility for the bulk of the work needed to make yourselves successful in the world marketplace. The Government can help--but the Government's help can only be efficient and effective if it is properly focused on your true needs. We want to hear your ideas on the ways in which obstacles to your progress can be most effectively removed.

There must be closer relationships between research conducted in the Federal laboratories and the high risk research needs of industry.

There must be better coordination and interchange of ideas between industry, the universities, and government so that scientific advancement can be achieved in the most effective and efficient manner.

We must all pool our knowledge so that market and technological forecasts can be as good as we can make them.

I think the bottom line is simply this--we have got to play team ball! And the "we" is all of us--government, industry, and the universities. Good team action requires clear, open channels of communications between all of the players. This conference is clearly a step toward establishing the information exchange which can lead to success.

ADVANCED CERAMICS--OPPORTUNITY AND CHALLENGE

A.R.C. Westwood and Jan Skalny[1]
Martin Marietta Laboratories

Introduction

The Ages of Man are sometimes referred to in terms of the predominant materials of construction of the period... hence the Stone Age, Bronze Age, Iron Age, etc. However, the accelerating pace of technological development has reduced such ages to mere overlapping decades, the aluminum decades merging into the plastics decade, and most recently the silicon decade. Soon, it seems, progress will occur so swiftly that we will have time only to refer to the "year" of some new wonder material or other!

But this is not likely to be the case for the latest cause of excitement on the materials scene, Advanced Ceramics. These are made from extremely pure, ultra-fine, inorganic particles, the composition of which is very carefully controlled. The particles are formed, agglomerated, and heat-treated under tightly monitored conditions. Indeed, the care used in the preparation of Advanced Ceramics is more akin to that used in the production of semiconductor materials for electronic applications than that for traditional ceramic whiteware and, predictably, it results in superior and more reproducible performance characteristics.

Of particular interest are the approaches now being developed to overcome the intrinsic brittleness of ceramics, for example, by incorporating fine fibers and/or phase-transforming particles. Such techniques are providing values of fracture toughness approaching those of metals, e.g. 10-20 $MPam^{1/2}$.

Impressive though the physical and mechanical properties of Advanced Ceramics of the near future will be, there are other reasons why this class of materials are likely to be of enduring economic importance. They include (a) the fact that they can be made from readily available raw materials, an important factor for nations of limited natural resources, e.g. Japan; (b) the diversity of areas of application, ranging from automobiles to electronics, photonics, energy systems, and medicine; and (3) the growing realization that the fine particle chemistry approaches being developed to produce Advanced Ceramics are likely to be equally applicable to other structural materials. Thus, before long, it may be possible to produce

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[1] Now at the Research Division of W. R. Grace and Company, Columbia, MD 21044.

near-net green shapes in steels, aluminum alloys, and other basic structural materials by similar colloid chemistry routes, circumventing the traditional and capital intensive heat-and-beat approach.

In short, Advanced Ceramics represent much more than merely the latest opportunity for materials scientists to ply their craft. This is why they are causing excitement and anticipation in both the technical and economic communities.

In this contribution, we discuss some of the challenges and opportunities presented by Advanced Ceramics to U.S. industry. We shall not address the substantial technical problems that lie ahead, confidently assuming that our scientific and engineering ingenuity will successfully overcome or circumvent most of them.

The Prospects for Advanced Ceramics

What might be the situation in the year 2000, given the vigorous application of imagination, technical effort, and capital in the intervening years? We foresee:

A U.S. market of order $15B per year[2] (about equal to that estimated by Japan's Fine Ceramics Association for their home market [1]).

A significant export market, the result of efficient, automated production processes in and dedicated marketing by U.S. industry.

More than 50 U.S. corporations committed to the long-term development and exploitation of Advanced Ceramics. Multicompany consortia and multinational operations common.

An auto industry producing cars containing 50 kg of ceramic components, some millions of which cars are exported. They will operate without traditional cooling or lubricating systems, be essentially non-polluting, and travel well over fifty miles on each gallon of fuel consumed.

Post VSLI-chips based on more temperature-resistant materials than silicon, e.g. doped silicon carbide.

Communications mostly via photonics, utilizing advanced ceramic fiber transmission lines possibly made from doped-fluorides. Holographic applications will be common, based on multiwave mixing in ceramic crystals.

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[2]Figure includes value of ceramic materials and of ceramic-dependent components.

New types of optoelectronic, acousto-optic, and other types of sensors, modulators, and switches based on complex ceramic compositions widely used in automated and robotic systems in industry and the home.

Dental and orthopedic surgeons using ceramic prostheses with properties closely comparable to nature's own, and a lively supporting bioceramic industry.

Nuclear energy recognized as the best mid-term option with Advanced Ceramics utilized in fuel and structural elements, and for waste containment.

The Present Situation

Recognizing the prospects outlined above, and others, interest in Advanced Ceramics is extremely high in Japan. Indeed, the term "Ceramic Fever" has been used to reflect Japan's enthusiasm for this emerging area of materials technology, and especially for its near-term objective of producing more efficient auto engines based on the extensive use of Advanced Ceramics.

Enthusiasm has also been growing recent in the U.S.... especially during the past two years. And though it does not yet rival Japan's "fever," the situation fortunately is a far cry from that of just a few years ago...when our ability to put together an effective equivalent to the cooperative and focused efforts of Japan's MITI-catalyzed government and industry consortia was in real doubt [2,3].

At that time, U.S. industry and government seemed to see themselves as adversaries rather than allies, and university engineering departments were wasting away...underfunded, poorly equipped, and out of touch.

The atmosphere has now changed significantly, with recognition of the vitality of this latest technological challenge from Japan playing a large part in our belated recognition of the need to regain control of our technological fate.

In the past, American companies were effectively prevented from cooperative action by strong antitrust laws intended to prevent the formation of monopolies that might not operate in the best interests of the citizen. But, as Simon Ramo has commented [4], such legislation was created for an isolated, stand-alone America. Today, however, products, markets, and competition are increasingly international. Thus, to compete with foreign government-industry teams, U.S. companies must form their own teams, and integrate more effectively the brain power of our universities. This is beginning to happen.

Industry support of academic researchers has increased markedly in the past three years. And though most of industry's grants are for "undirected" research, the coming together of university and industry researchers to discuss the results and implications of their efforts will inevitably influence the direction of work in both sectors, and especially the professors' perception of industry's needs. Especially significant is the formation of the Ceramic Processing Consortium at MIT, the Center for Ceramic Research at Rutgers University, and the Center for Dielectric Studies at Pennsylvania State University. Each have support from more than 20 corporations.

Federal support of engineering research in the universities has also begun to increase substantially with the establishment by NSF of several new multi-disciplinary Engineering Centers. Eventually, each will be funded at a level of several million dollars per year, be focused on some important area of technology, and be guided by an Advisory Board containing industrial managers. Interest in this new initiative has been great; the National Science Foundation received well over a hundred proposals from which to select its first six Centers. One of the new Centers, that on Composites Manufacturing, contains a Rutger's component concerned with Advanced Ceramics.

Ceramics-related activity in American industry also has increased substantially in the past two years, and the acquisition of small entrepreneurial companies by industrial giants seeking to establish or expand their foothold in this field has begun. Among such acquires are W.R. Grace, Air Products and Chemicals, Dow Corning, and Koppers. Other major players in Advanced Ceramics include Alcoa, Carborundum, Corning, Cummins, DuPont, Ford, Garrett, General Electric, GM, GTE, IBM, Norton, and TRW.

A new spirit of cooperation between Federal agencies and industry also is arising. Federal laboratories such as the Oak Ridge National Laboratory now have technology transfer functions in place and active. Cooperative programs are increasing in number, especially projects involving the shared use of expensive apparatus, such as ion-implantation machine. Industrial support of promising work by scientists working in government labs is beginning to occur.

Cooperation between government agencies also is improving, as exemplified by that between DOE, DOD, and NASA in the funding of research on ceramics for advanced heat engines at DOE's Oak Ridge National laboratory and NASA's Lewis Research Center. Funding related to this particular effort increased to about $16M in 1985, DOE's overall automotive technology budget for FY 85 being about $50M.

The recent upsurge in ceramics activity in the U.S.A. is further evidenced by statistics on the attendance and number of papers presented at annual meetings of the American Ceramics Society [5], as follows:

Year	1981	1982	1983	1984	1985
Attendance	3850	3670	3690	5170	5700
No. of papers	750	760	890	1100	1035

We see that, in the past two years, attendance is up about 45 percent and papers presented about 30 percent. In short, the U.S. has now woken up to the potential of Advanced Ceramics, and is beginning to respond to the prospects of stiff foreign competition. But is our response yet sufficient?

The Challenge...and Some Responses

The answer to the question above is..."No." It would be nice to be able to report that the U.S. Advanced Ceramics industry is beginning to develop and vigorously market competitive products...but, as yet, it is not so.

It may be that, in part, this is because there are still many U.S. industrial managers who believe that their Japanese counterparts are overly optimistic about the early impact of Advanced Ceramics in auto and other applications, and that there is still plenty of time left before the competition will heat up. In our view, these managers are misreading the nature of the fierce competition between Nissan and Toyota to be first with the auto application, and between other giants, such as Toshiba, Showa Denka, and Kyocera, to capture other market segments. The winner of the auto race will be in a position to gain prestige and market share by virtue of (a) superior engine performance and economy, albeit only modest at first, and (b) public perception, molded by astute advertising, of the advantages of going with the company with the best available technology. Now it is true that the latter advantage is at present more important when marketing in Japan than in the U.S. But the reputation in the U.S. of Japanese auto manufacturers for quality and reliability is excellent, and this would be further enhanced by evidence of technological superiority. Conversely, the prospects for the sale of U.S. autos abroad will be further reduced.

Comparable concerns can be expressed regarding the development of Advanced Ceramics for electronic applications, tools, prostheses, etc. Again, U.S. companies appear to be working against a more relaxed time frame than their competitors. We believe this to be a losing strategy.

What then should U.S. industry be doing? The answer is that it needs to get its act together and overcome what Albert Bowers has termed the "commitment gap"...this being defined as a "lack of national resolve to gain and maintain (international) leadership [6]. Specifically, it must identify the specific technical and marketing challenges to be addressed, develop bold and focused R&D programs and accelerated marketing schedules and strategies to meet them...and then commit itself to beating both technical and marketing goals!

Time is of the essence...and so is attitude. Slogans such as, "If it ain't broke, don't fix it," heard ad nauseam around American industry over the past decade, are passé for the internationally competitive situation in which we now find ourselves. More appropriate might be slogans such as "Good enough ain't good enough," or "perfect today...and better tomorrow."

In short, the U.S. government and industry needs a new working philosophy that recognizes that technology is global and respects no borders, and that if we are to maintain technological competitiveness, a fair share of both domestic and international markets, and a stable and growing economy, then we must meet and beat the world's best in their markets as well as our own. We must be economically assertive, not protectionist. This will require concerted action by industry, government, and academe. And each of us associated with Advanced Ceramics has a responsibility to see that the U.S. does not miss out on the exciting opportunities offered by these new materials. Here are some specific suggestions:

Industrial managers must accelerate their timetable for the expected emergence of markets for Advanced Ceramics, and set in motion efforts to produce imaginative products against these advanced schedules. This, in turn, will require R&D to be more strongly focused, and to be concerned as much with production processes and product design and performance as with improved materials properties. The development of much closer relationships between scientists and design engineers will be required, with much stronger feedback and response than usually is the case today. Managers should consider also the strategy and conducting research and product development programs in parallel...in contrast to the customary sequential conduct of basic research, applied research, process development, product development, etc. Japanese companies move more swiftly to the marketplace by running some of these steps in parallel, and with strong feedback loops. This approach is riskier, but the payoff can be early market access, improved product identity, and enhanced market share.

The efficiency with which foreign competitors target and address U.S. markets has been commented on by many observers. For example, Aoki noted recently [7] that Japanese firms now have 1600 branches or offices in the Los Angeles area alone, and are adding to this number (almost) daily. But there is nothing in their strategy that could not be adopted equally well by U.S. corporations...given a willingness to study the foreign market, learn the language and culture, and commit to a long term relationship. Companies such as Honeywell have used this approach in Japan over the years, and thus are not now amongst those calling for our government to develop tougher trading policies.

A national marketing strategy for Advanced Ceramics should involve the formation of an Advanced Ceramics Association, comparable to the Japanese Fine Ceramics Association [8]. The functions of this organization should include the development of a sense of identity, purpose and momentum for the industry through the convening of action-producing meetings of its leaders, the collection and dissemination of technical and economic information, and the establishment of international standards of performance. The association should also work closely with the Department of Commerce and other Federal agencies to establish coherent and effective strategies for accessing foreign markets. Attention to export control issues is especially needed.[3]

The formation of U.S. based international trading companies by large banking organizations to facilitate marketing abroad also should be considered as an element of national export strategy.

Industrial managers should also take the time to educate legislators to the needs and potentials of Advanced Ceramics, and other technologies, without personal axe-grinding, so that sound forward-looking legislation can be enacted.

They should also bring their perspectives and knowledge to the workings of government committees and not, as at present, leave these chores largely to the academics. Valuable though professorial input is, it does not bring the acumen of hands-on experience to the issues.

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[3]Since this contribution was prepared, such an organization, the U.S. Advanced Ceramics Association (USACA) has been formed, thanks to the initiative of Professor J. I. Mueller [9].

Science teachers should be brought into industrial R&D organizations for summer assignments, revitalizing their skills and providing the enthusiasm and perspective needed to ensure a flow of outstanding students into the materials profession.

Industrial researchers must identify and capitalize more swiftly on technical developments...regardless of origin. Much excellent science is done in DOD and other national laboratories, and abroad. In particular, the results of R&D conducted in Japan and the Soviet Union should not be overlooked.

Our perception of the present situation, however, is that foreign literature, even when translated, is not routinely studied. And travel to other laboratories, both in the U.S. and abroad, is regarded by management as a pre-requisite (or even a boondoggle!) instead of as one of the fastest ways of acquiring new knowledge and perspective... and of preventing the costly and time consuming "reinvention of the wheel."

In this regard it is instructive to note that in 1980 Japan sent about 8800 scientists abroad, of which about 3500 came to North America. In the same year, only 730 foreign scientists visited Japan. Yet, in our experience, Japanese scientists are every bit as open in discussing their work with visitors as are their U.S. counter parts, given time to overcome cultural differences. So this opportunity for reversing the customary flow of information is being missed.

In short, the time has come for U.S. researchers to become more global in outlook, and to recognize that the whole world (almost) is a source for ideas, as well as a sink for products.

National laboratories, and their funding organizations, must step-up to their responsibility for identifying, prioritizing, and committing critical masses of effort to the rapid solution of problems pivotal to the development of technologies underlying national competitiveness. Presently, though R&D in the national laboratories is often first class, it also tends to be diffuse, and does not add up in such a manner as to provide the bases for any quantum jump advantages for U.S. industry. Some hard-nosed management will be required to change this situation.

In our view, the function of national laboratories is both straightforward and critical...it is to move important developments through the stage where they are too large to be conducted in universities but too risky to be pursued by industry. They should accept this responsibility with a self-imposed sense of urgency based on recognition of the fact that there is a real national need for their efforts.

Industry, for its part, must work more closely with the national laboratories, acting through Advisory Boards to provide the laboratories' staffs with knowledge of its generic needs and specific timetables, so permitting intelligent prioritization and long range planning by the laboratories. Until recently, however, most Advisory Boards of national laboratories (and of their sponsoring agencies) were composed primarily of academics, and thus did not properly represent the views of the customers for the laboratories' product...industry. Consequently, the labs were out of touch with their market, always a senario for disaster! This situation now appears to be changing as both parties recognize their mutual dependence.

Beyond doing its best to reduce the cost of money and the national debt, the <u>federal government</u> can help develop an enabling environment for innovation by positive acts (legislation of <u>Trust</u>-Regulations as opposed to Anti-Trust, tax incentives, etc.) to encourage (a) the cooperation of companies in joint R&D ventures and consortia, (b) the import of knowledge and skilled immigrants, and (c) the export of value-added products. We believe that the <u>best</u> way for the U.S. to maintain international leadership and a sound fiscal condition is to run faster and smarter than the best of the opposition...not simply to run well in closed races against the local talent. The government can help towards this objective in many ways, for example (a) by facilitating the translation and dissemination of foreign technical and marketing literature, whenever this is not an economically viable business, (b) by reducing the multilayer bureaucracy that saps the vitality of the national laboratories, (c) by enunciating clear policies with regard to such fields as energy, transportation, space exploitation, etc., (d) by accelerating the transfer to green card and subsequently citizen status of low-security risk immigrants possessing high-level technical skills; such persons constitute an underutilized national resource, and (e) by developing programs to instill a greater awareness in high school students of the enduring need for engineers and applied scientists, and of their fundamental role in generating the wealth of the nation.

<u>In summary</u>, the most important non-technical prerequisites to ensure for U.S. industry a health domestic and international market for Advanced Ceramics include the development of (a) an enduring and vigorous sense of commitment to well-defined long-term product/market goals by the CEO's and boards of participating U.S. corporations, with the full understanding and encouragement of the financial community, (b) improved trust, understanding and mutual respect between government and industry, brought about by

the joint development of strategies to enhance our international competitiveness (a role for DOC), and (c) an increased sense of urgency and responsibility in the total scientific and engineering community for the future well-being of the nation [10], leading to a more discriminating and economically responsible approach to the selection of R&D projects, an increased willingness to undertake high-risk, high-payoff projects...rather than to merely add in incremental knowledge, and an enthusiastic involvement in transferring results to profitable practice.

Acknowledgments

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SESSION II: INFORMATION BASE

SESSION CHAIRMAN REMARKS

Lyle H. Schwartz
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As Director of the Institute for Materials Science and Engineering--the NBS organization co-sponsoring this conference, I wish to extend my personal welcome and express my appreciation for the time each of you are devoting to this conference. I sincerely believe that the time will be well spent as we are taking a major step in confronting the complex problem of U.S. industrial competitiveness in the emerging business of advanced ceramics.

Our interest at NBS in the advancement of high technology materials, including ceramics is of course more that peripheral or proforma. As you know NBS, as well as other Federal organizations have sizeable advanced ceramics R&D programs underway so that we in government are vitally concerned with industrial needs for basic long term research and the directions industry is taking. Universities have similar concerns, but with the added mandate of assuring the provision of trained talent. Currently, the U.S. University system turns out less than 500 ceramic science and engineering graduates each year, including less than 40 Ph.D.'s. No comprehensive plan for expansion of the advanced ceramics industry will be complete without addressing the issue of increasing these numbers. This dilemma is but one factor to consider in assessing where the advanced ceramic industry is, and where it is going.

In my view, and I am sure you agree, the technical issues for advanced ceramics are clear. What remains to be answered is how they can be resolved in an expeditious manner sufficient to meet the competitive challenge while still maintaining the traditional, but appropriate, roles for industry, universities, and government. Basically, the competitive challenge equates to one of cooperation and coordination At present there is good ceramic research going on, and more is planned, both in the private sector and at the federal laboratories. These collectively add up to a formidable research base with the universities and the government focusing on "technology push" basic research, and industry on "market pull" R&D. To make most effective use of the limited manpower available it will become increasingly important that communication be optimized between those doing basic research and those doing product development. Currently the advanced ceramic industry is disaggregated and there is no central organizational group or key spokesperson to represent the industrial views and provide interchange with allied university and government activities. Better coupling is required for the industry-university-government triad to be effective and this conference is intended to explore this precise question.

The first session set the stage for the meeting. The second session deals with the information base available for assessing the status of the technology; and include presentations on our competitive position and market opportunities as well as R&D status and needs. These areas have been the subject of several recent studies that could provide substantial guidance to the advanced ceramics industry.

U.S. COMPETITIVE POSITION IN ADVANCED CERAMICS

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At no other time in our history has ceramics drawn such worldwide attention. Advanced ceramics will be to the 1980's what plastics were to the 1960's. It will be the decade of the ceramics and basic industries revolution. In recent years, efforts in technical research have intensified because of basic industry's concern over rising energy costs and scarcity and high cost of super alloy metals. Basic and capital goods industries are undergoing radical restructuring. They will either leave the noncompetitive business they are in, or shift to a high-tech type of product line to stay competitive. What competing basic industries are doing domestically and internationally in chemicals, metals, and other smokestack industries will have an impact on the marketplace 10 years from now. The importance of high-tech in basic industries and ceramic materials has been equally recognized throughout the world. Several U.S. competitors, notably, Japan, West Germany, the United Kingdom, France, and Australia, are ambitiously working to develop world-class commercial programs in basic industries and advanced ceramics.

While the production of advanced ceramics--powders and products, involves sophisticated chemical processing and is closely dependent upon the quality and purity of the compounds used, the basic raw material--the silicate compounds--are among the most abundant material in the earth's crust. We believe that the defense and economic security of the nation depends upon our assured supply of advanced ceramics.

Advanced ceramic products have many inherently useful and unique properties, besides some negative attributes as well. Advanced ceramics exhibit resistance to high temperature, wear, and corrosion. They also have superior electrical insulation properties and high magnetic permeability along with special optical and conductive properties. In order to capitalize on these superior attributes, however, substantial research and development must be done before the negative properties of ceramics, primarily their extreme brittleness and difficulty in joining can be overcome.

Many ceramic products are still in the development stage. The most important being adiabatic diesel engines and auto parts. While they draw great promise, however, their commercial introduction is still in the future. The commercial applications of advanced ceramics have begun on a small scale in some industrial components such as cutting tools, engine nozzles, biomedicals, and as replacement for several important parts. The requirements for advanced ceramics in turbines, tubocharges and high-efficiency diesel engines require ceramic materials with quite different properties, which have not yet been full achieved.

Advanced ceramics are also used in products such as tiles for space vehicles, microwave and solar heating devices, cylinders to store atomic and chemical waste, electrodes for corrosive liquid electrolytes, microprocessors, solar energy photovoltaic cells, gas and oil drilling valves, armored tanks, motor plates and shields, and a myriad of other products.

A vast new market for ceramics is expected to open up in automobiles and temperature-sensing and temperature-control devices. The success of the advanced ceramics industry depends upon how quickly R&D can successfully develop ceramic components in different end uses.

The electrical properties of ceramics are already heavily exploited in electronics, particularly in capacitors and integrated circuit substrates, and the applications are still expanding. Advanced electronic/photonic/magnetic ceramics used in the defense area are vital to super computers in supporting signal sensing and processing. In the civilian area, they are becoming equally vital in electronics, communications, space technology, automated production systems, and in robotics.

Today, the electronic components/electrical segment of the advanced ceramics business is by far the largest and most developed sector. The U.S. market for electronic and electrical products was estimated at more than $4 billion in 1984 and is expected to increase about 20 percent in 1985.

Although the United States had enjoyed a prominent position and enviable reputation in advanced ceramics technologically, much of our advanced ceramics industry is behind its Japanese counterparts. This has occurred because the Japanese have been able to take a development project to a commercial stage considerably faster than most U.S. companies. The Japanese rationale in international marketing is that a firm with an early internal successful entry will have a better chance of international competitive edge. The cooperation between Japanese producers and end users helps them to resolve design or defective raw material problems. Their internal cooperative system has been instrumental in helping them to capture the international markets. Similar cooperation is required in the United States between the advanced ceramic producers and the consumers to go from research stage to commercialization.

Motivated by its lack of indigenous supplies of energy and scarce metals, Japan has mounted a determined, well-coordinated research and development effort to establish itself in--and, perhaps to dominate--advanced ceramics. Unlike the United States, the Japanese advanced ceramics makers are a heterogeneous group. They include traditional ceramics manufacturers, motor vehicle manufacturers, and electronic systems manufacturers, as well as chemical and metals companies. Japanese producers of advanced ceramics for electronics are thought to be more horizontally integrated across a number of electronic ceramics applications than their U.S. counterparts. Most firms in Japan that are involved in a number of ceramics products are typically large systems producers such as Toyota and Toshiba, with only one exception, Kyoto Ceramics (Kyocera in the United States). It manufacturers advanced ceramics heat engines and parts, some of which are currently commercialized. Both their spark plugs and precombustion chambers are used by Isuzu in auto diesel engines. Other applications for Kyoto's advanced ceramics products include cutting tools, capacitors, and most notably, packaging for integrated circuits, where the company accounts for nearly two-thirds of world open market sales.

Japan is said to hold a 10-to-1 lead over the United States in the number of patents issued in advanced ceramics. In multilayer capacitors, gas sensors and cutting tool R&D, the Japanese industry is believed to focus heavily on characterizing and optimizing new material components. Their R&D led to more and more patentable inventions into ceramic powders. High-tech advanced ceramics industries in Japan have benefited from government targeting and support. The Japanese Ministry of International Trade and Industry (MITI) coordinates the research activities between the universities and the companies to avoid duplication and to minimize research dollars. It also provides research results to all companies concerned with rapid dissemination of basic technical information and engineering design. Their forecast calls for a $25 billion market in advanced ceramics by the year 2000. MITI's targeting techniques include home market protection, favorable tax policies, suspension of antitrust laws for emerging high-tech industries and research and financial assistance. Additional R&D is encouraged in the new fields that have promise of large pay-offs.

The United Kingdom was considered the world leader in advanced ceramics until about 15 years ago. Major budget reductions in British Government programs have slowed down British activities in advanced ceramics. Lucas, the first automotive components firm in the United Kingdom, invented the hot-pressed silicon nitride (sialon) during the 1960's for gas turbine applications. Sialons applications included car engine components, extrusion dies and metal cutting. Lucas produced diesel engine tappets, which showed virtually no wear after extended operations. Small energy savings were also obtained. The United Kingdom also produced slip-cast crucibles for the metal casting industry. Long-term medical applications included long-life artificial hip and knee joints.

Recently, a Japanese company, Shim-etsun announced a new plant for the manufacture of silicon in Scotland, with British collaboration. West Germany is fairly active among the European countries in advanced ceramics research. Their industrial engineering research and development budget over the past 10 years was at a total level of nearly 100 million marks ($40 to $50 million). Currently, the German government and the industry are jointly attempting to form an R&D program in energy and automobile engines. The Ministry of Research and Technology (BMFT) is supporting a program dealing with advanced ceramics components for vehicular gas turbines. Almost half of the R&D funding is provided by the industry. Germany is known for its rapid growth and they have the potential to catch up with the United States and Japan in advanced ceramics R&D.

The French Ministry of Industry and Research recently announced the start of top-priority research program for new advanced ceramics materials and powders. The proposed funding for this program is over 1 billion francs, spread over 3 years. The areas to be covered include advanced ceramics, composites, technical polymers, and amorphous materials. France has successfully penetrated the advanced ceramics market in Europe and has several products for civilian and defense uses; notable among them are: small-diameter tubing for electrical insulation; fiber-et-mica for lamination and uni-directional-sheets. In a similar fashion to some U.S. international chemical companies, the Rhone-Poulen of France has ventured in the production of silicon and silicon compounds for use in photo-electric cells and for electronics applications.

A sense of urgency over Europe's loss of competitiveness in high technology trade led to the opening of the Belgium Technology International Fair in March 1985. The fair, promoted as the largest of its kind in Europe, served as a showpiece for the hundreds of high technology industries, especially advanced ceramics, within Europe. Some 730 companies and research groups set up high exhibits in the fair. Europe's continuing need to close the technology gap with the United States and Japan has been the main concern behind the exposition. Between 1970 and 1982, the European Economic Community (EEC) lost 17 percentage points of world market share in high technology products, while the United States and Japan gained 36 and 38 points, respectively. A European strategic 5-year program for R&D in high-technology was approved with a budget of about $1 billion, half of which is to come from the EEC Government budget and the other half from industry.

Canada, Sweden, and Australia do not intend to be left behind in the advanced ceramics race. They too have a number of R&D projects in advanced ceramics for auto and other uses. Australian manufacturers are presently exporting ceramic powders to the United States for the manufacture of electronic components. The Australian Ceramics Society and a number of companies have approached us for information on the advanced ceramics industry in the United States. Recently, the representatives of two leading Australian companies visited DOC for assistance in setting up a manufacturing facility in the United States. They are interested in either an outright purchase of a U.S. facility or in starting a joint venture with a U.S. firm, which has knowledge of advanced ceramic product manufacturing.

The advanced ceramics industry in the United States is highly fragmented and there is little cooperation among companies. The U.S. companies engaged in the advanced ceramics do not want to be bound by national research efforts or by national boundaries. They are looking for international markets, competitive advantages in manufacturing within or outside the United States, and are even ready to acquire technology from abroad. Recently, GM announced its plan to manufacture components and vehicles worldwide in efficient models, using its own or Japanese technology. With its recent affiliation with Isuzu, which has started using advanced ceramic parts in the automobiles, GM intends to assemble trucks in the Peoples' Republic of China and eight other countries: Australia, New Zealand, Singapore, the Philippines, South Korea, Hong Kong, and Taiwan. GM-Isuzu Diesel engines will soon be manufactured in Indonesia. In addition they have established a number of component manufacturing joint ventures in South Korea.

Dupont's chairman recently announced that his company is strengthening and building worldwide business in high growth areas such as electronics, high performance fibers, and other materials. Unlike Japan, Dupont does not want to be tied to the national R&D efforts or national production alone.

U.S. defense agencies, are heavily involved in advanced ceramics research. Heat engines for defense use represent the only major applications where government R&D funding is playing a major role. At present, the government defense agencies alone contribute about one-half of the estimated $100 to $140 million per year devoted to ceramic heat engine research in the country. Contribution from the auto industry in R&D does not appear to be significant. A major effort on the part of industry is required to maintain our leadership in the field of advanced ceramics for defense and to catch up in development in commercialization for civilian purposes.

Even the determination of the size and growth in advanced ceramics industry in the United States is made imprecise because of: (1) lack of Standard Industrial Classifications for advanced ceramics powders and products; (2) the unwillingness of large corporations to identify figures for their smaller advanced ceramics products separately; and (3) the disclosure act, which prohibits publication of data from three or less companies, or when one company is the major producer in the group.

The notion that American basic industries are dying is probably wrong. What you will most likely see is the basic and capital goods industries undergoing radical restructuring. Most of the high-technology applications and the majority of the materials substitutions are taking place in basic industries. The primary mission of the Basic Industries Division at the Commerce Department is to implement and monitor the changes through trade and industry analysis, trade promotions, and by developing government policies and legislation.

The DOC is closely watching growth and development in advanced ceramics. We are cooperating with our Science and Electronics group, whose industries are the largest users of advanced ceramics components, to study the U.S. competitive situation. We have met with the U.S. auto manufacturers in Detroit to discuss their plans for new ceramic applications, and we have been attending technical sessions and seminars to keep ourselves aware of the latest developments and growth potentials in this industry.

Our technical experts have prepared a number of internal documents and have recently published a Commerce competitive assessment which outlines the issues facing the U.S. advanced ceramics industry. A chapter on advanced ceramics in our 1985 Annual Industrial Outlook publication also was prepared. Our objective is to inform U.S. advanced ceramic companies of the latest developments and market potentials in order to encourage greater interest in a U.S. based industry.

TECHNOLOGICAL AND ECONOMIC ASSESSMENTS OF ADVANCED CERAMICS

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Background and Introduction

Great interest has been shown in advanced or high-technology ceramic materials in recent years, both in the United States and abroad. The timing of the recent surge of interest in advanced ceramics represents something of a marriage between need and opportunity. The need, or demand, for materials with the properties exhibited by advanced ceramics is greater than ever due to changes in the technologies of potential using sectors, as well as in the supply of key raw materials to those sectors. For example, the availability of cheap microprocessors and industrial robots increases the need or demand for many kinds of sensors, and thus increases industrial interest in ceramic materials with specialized sensing properties. On the opportunity, or supply side, advances in ceramics process technology offer hope that critical reliability, cost, and reproducibility barriers that impede the commercial introduction and/or adaption of many advanced ceramic products may be overcome in the relatively near future.

This paper summarizes the findings and conclusions of a study by Charles River Associates Incorporated (CRA) for the National Bureau of Standards that assesses the expected economic impacts of technological advances in advanced ceramics and the remaining technological barriers. The study examined five specific existing and potential applications of advanced ceramic materials: heat engine components (e.g., turbocharger rotors); multilayer ceramic capacitors; integrated optic devices (e.g., guided-light switches and modulators); gas sensors; and cutting tools. These five cases are not intended to encompass the only promising application areas of advanced ceramic materials and products; rather, they are meant to exemplify five leading representative application areas from which implications can be drawn concerning major technological barriers generic to classes of advanced ceramics.

Technological Barriers that Need to be Overcome

A number of important technological barriers were identified in the CRA study. At a general level, the key barriers to be overcome before the full potential of advanced ceramics can be achieved lie in the areas of production cost, reliability in service, and reproducibility in manufacture. In some cases these barriers are severe enough to retard commercialization (e.g., ceramic heat engines). In other cases commercialization has occurred, but the barriers serve to limit market penetration (e.g., cutting tools). The severity of the technological barriers and hence the likely timing of their removal varies considerably across ceramic application areas. Moreover, the relative importance of cost, reliability, and reproducibility also varies across the applications examined.

For example, multilayer capacitors is an application of advanced ceramics that has already achieved wide commercial diffusion. The most important barriers remaining in the capacitor area are cost-related. Overcoming these barriers will have relatively little impact on the diffusion of capacitors, which is already significant. However, because of the magnitude of sales of multilayer ceramic capacitors, substantial economy wide savings may result from incremental innovation in production processes in the near term.

Unlike the case of capacitors, ceramic gas sensors and cutting tools have achieved only limited diffusion to date. Here the key barriers impeding rapid diffusion of ceramic technology are performance-related rather than cost-related, although the nature of the barriers differs across these two cases. Barriers limiting the reliability of ceramic cutting tools in service and barriers limiting the selectivity (ability to distinguish among different gases) are the key barriers that inhibit diffusion of these products. Because of the relatively limited magnitude of current sales, the economic impacts of overcoming these diffusion-impeding barriers are expected to be relatively modest for the remainder of this decade. However, significant productivity benefits may result in the 1990s from the timely removal of these barriers.

In the two other cases examined, heat engines and integrated optics, the technological barriers are more severe and need to be overcome before commercialization can be achieved. This is particularly true for heat engines, where commercialization cannot be achieved until the reliability of ceramic parts is improved to commercially acceptable levels. Because of these barriers it is expected to be the end of the 1980s, at the earliest, before ceramic heat engine parts and integrated optic devices are seriously produced on a commercial basis and begin to diffuse. Thus, although both types of ceramic products offer significant productivity benefits, substantial aggregate cost savings resulting from the development of these technologies are not expected to accrue until the late 1990s at the earliest.

The Potential for Industry Growth

The advanced ceramics industry is expected to grow very rapidly through the end of this century, both in the United States and abroad. Estimates of 1982 U.S. consumption of advanced ceramic components, along with projections to 1990 and 2000, are given in Table 1 for the five application areas analyzed. In the United States, consumption of advanced ceramic products in these five application areas was estimated to be $365 million in 1982. The bulk of this ($350 million) was accounted for by multilayer ceramic capacitors, the only relatively large existing advanced ceramic market segment analyzed. By the year 2000, U.S. consumption of advanced ceramics for these five application areas combined is projected to grow to approximately $4 billion, a 14 percent average annual compound growth rate.

No consistent, reliable source exists for market data for advanced ceramic products. Sales data must be developed through a variety of sources, including review of trade press and industry interviews. Accordingly, there is considerable variation among sources in estimates of historic and current levels of sales of advanced ceramic products. Table 2 presents two sets of estimates of 1980 advanced ceramic sales with projections into the 1990s drawn from the open literature. The two estimates were developed by Kent Bowen of MIT and by the U.S. Department of Commerce.

Bowen estimates that U.S. shipments of advanced ceramic materials and components were $1.5 billion in 1980. given the rate of growth in the industry, this estimate is consistent with unpublished estimates of U.S. advanced ceramic sales of about $2 billion in 1983. Bowen projects that U.S. shipments will reach over $7 billion by 1995. This represents an average annual growth rate of nearly 11 percent. If this average rate of growth were to continue beyond 1995, U.S. shipments would reach approximately $10 billion by 2000. The Bowen data indicate that the United States is the second leading advanced ceramic producing nation in the world (with a 35 percent share of world sales), behind Japan (with a 45 percent market share).

The DOC figures represent an attempt to estimate and project only the value added by ceramic processing. This difference is reflected in their considerably smaller estimates and projections of U.S. advanced ceramic shipments. What is striking in comparing the Bowen and DOC projection is the close agreement between the two in the projected growth rates in U.S. shipments. The Department of Commerce projects U.S. shipments of advanced ceramic materials and products to grow at an average annual rate of 12 percent from 1980 to 2000. This compares to the 11 percent average annual growth rate projected by Bowen for 1980 to 1995. Charles River Associates projected slightly more rapid growth, 14 percent per year on average, for the aggregate of the five applications studied. This more rapid projected growth reflects the fact that relatively high-growth application areas were selected for study.

Potential Savings of Critical Materials

Potential savings of critical materials such as tantalum, cobalt, chromium, and nickel through the substitution of advanced ceramics were found to be a secondary benefit, much less important than the productivity gains expected to result from advanced ceramic products. This is particularly true in the case of structural ceramics, where it is projected that the amount of those critical materials that can be expected to be displaced by advanced ceramic materials by the end of the century is at best quite modest (e.g., less than 10 percent of annual U.S. consumption). However, the aggregate dollar total for all critical materials saved could be quite large.

International Differences in Competitive Strategy

How U.S. industry fares in world markets for advanced ceramic products will depend in large measure on the relative success of the competitive strategies employed by U.S. ceramic firms. Ceramic producers differentiate themselves along a number of strategic dimensions which include, but are not limited to: level of resources devoted to R&D and the focus of that R&D; the degree of integration of the firm; and the willingness to risk early introduction of a product in order to gain experience in product performance and processing.

Table 3 presents proxy data for the level of R&D effort in advanced ceramics in the United States, Japan, and Western Europe. The table indicates that Japan is investing more heavily than the United States in all application areas examined except integrated optics. The Japanese are thought to be increasing their R&D effort rapidly in that area, however, and may soon catch up to or pass the United States, at least in annual R&D input if not in R&D success.

Researchers in the field believe that the United States holds the lead in basic research and generic technology in most of these application areas. This is particularly true of heat engines, integrated optics, and multilayer capacitors. It is, however, unclear how much of a strategic advantage this lead offers to U.S. firms. Japanese firms may be as capable as U.S. firms of applying basic research results and generic technology developed in the United States. Based on interviews with U.S. researchers, it appears that Japanese industrial R&D is aimed relatively more heavily at incremental improvements in process technology and materials composition than is U.S. R&D. If true, such a strategy appears aimed at optimizing existing generic technology in order to shorten the time frame in which commercialization of new products take place, with early commercialization used as a device to gain production experience and thereby reduce market prices.

There is a wide range of variation in the degree of horizontal integration (i.e., the degree to which firms produce ceramic products in multiple application areas) among companies in the United States, Japan, and Western Europe. Some companies remain relatively specialized, whereas other companies pursue more aggressive integration strategies. However, Japanese ceramic firms appear to be more aggressive than their U.S. counterparts in integrating horizontally.

This is particularly true of Kyoto Ceramics. The world's largest producer of ceramic packaging for integrated circuits, and a leading producer of ceramic capacitors, Kyoto appears to be following a strategy of attempting to attain a leadership position in structural ceramics through borrowing technology from the electronic applications in which it is involved. Other leading Japanese manufacturers of electronic ceramics that have become involved in structural ceramics include Sumitomo Electric Industries, Toshiba, Mitsubishi, and NGK Spark Plug. Although some U.S. companies involved in structural ceramics are also involved in electronic ceramics, these firms typically do not have nearly the production experience of a company like Kyoto in electronic ceramics.

Since completing this study, we have observed a trend towards greater diversification or horizontal integration on the part of U.S. advanced ceramics producers. For example, traditional structural ceramic producers such as Norton and Carborundum are exploring entry into production of electronic ceramic products. Similarly, IBM recently hired its first structural ceramic engineer. This trend is being reinforced by the entry into the advanced ceramic industry of large, diversified chemical and materials companies such as Alcoa, Cabot, DuPont, and W. R. Grace. These companies have both the broad technical base and the financial capabilities required to pursue an aggressive horizontal integration strategy if real possibilities of technological spillovers truly exist. However, while we envision a number of large, diversified players in the future, the U.S. advanced ceramics industry will continue for some time to be characterized by many niche producers.

Another important strategic distinction between the Japanese and U.S. advanced ceramics industries is that some Japanese firms are highly aggressive in seeking early commercialization of advanced ceramic products. This strategy is based on the theory that there will be a steep learning curve in the manufacture of advanced ceramic components and powders. If true, this would endow significant manufacturing cost and possibly reliability advantages to firms with greater cumulative production volumes (e.g., early, successful entrants). Such a strategy is not without its risks. In particular, the early entrant bears the risk that the performance of the new product will not meet users' expectations. Considerable goodwill, not to mention investment of time and money, may be lost as a result of premature entry.

This strategy of early commercialization is especially evident in the heat engine and integrated optics examples. Kyoto currently produces two ceramic engine parts on a limited commercial basis. These parts--glow plugs and precombustion chambers--are used by Isuzu in some of its diesel engines and represent the first two structural ceramic parts to be used in heat engines on a commercial basis. Toshiba recently introduced the first commercially available integrated optic device, a spectrum analyzer. Although U.S. firms are also working in this area, none have been willing to risk commercial introduction until their products are refined further.

Summary

Advanced ceramics represents a relatively new technology with potential for rapid technological advance and resulting market growth. The achievement of this technological advance would provide substantial leverage on productivity. Depending on how rapidly the technology develops in the United States versus the rest of the world and on how well U.S. manufacturers strategically position themselves, advances in advanced ceramics may also have important leveraging effects on U.S. competitiveness in world markets. The dependence of the United States on foreign sources of supply for critical materials will also be reduced, although to a limited degree, by substitution of ceramics for these other materials. However, a number of difficult technological problems must be overcome in a timely fashion in order to achieve these benefits.

Table 1

U.S. CONSUMPTION OF ADVANCED CERAMICS BY APPLICATION AREA: 1982, 1990, and 2000
(Millions of Dollars)

Application	Year 1982	1990	2000
Multilayer Capacitor (Shipments)	350	970	1580
Cutting Tools	10	35	160
Gas Sensors	5	30-40	185-250
Heat Engine Parts	--	25-45	920-1,300
Integrated Optic Devices	--	5-10	910
Total for Five Selected Application Areas	365	1065-1110	3755-4200

NOTE: Prices for these advanced ceramic products are expected to decline over part or all of this time period. Therefore, these projections, which are expressed in current dollars, may understate real growth to some degree.

SOURCE: Charles River Associates, 1984.

Table 2

U.S. AND WORLD SHIPMENTS OF ADVANCED CERAMICS:
1980, 1990, 1995 and 2000
(Millions of Dollars)

Source	Country or Region	Year 1980	1990	1995	2000
Bowen*	United States	1,500	5,000	7,500	---
	Japan	1,900	6,500	9,000	---
	Free World	4,100	12,000	17,000	---
U.S. Department of Commerce	United States	601	2,531	---	5,895

*The Bowen and Department of Commerce estimates represent somewhat different measures of ceramic shipments. The Bowen estimates are intended to measure the full value of shipments of advanced ceramic materials and components. The Department of Commerce estimates represent a value added by ceramic processing measure. That is, the nonceramic portions of advanced ceramic products have been subtracted.

SOURCES: Bowen estimates and projections are from J. B. Wachtman. December 1984. "Ceramic Fever--Advanced Ceramics in Japan." <u>Ceramic Industry</u> 121, 6.

U.S. Department of Commerce. March 1984. <u>A Competitive Assessment of the U.S. Advanced Ceramic Industry</u>. Washington, D.C.

Table 3

INTERNATIONAL COMPARISON OF R&D EFFORTS IN ADVANCED CERAMICS BY APPLICATION AREA

Application	United States	Japan	Western Europe
Electronic Applications:			
Multilayer Capacitors	$10 to 15 million per year	R&D spending unknown said to hold 10:1 lead over United States in number of patents and engineers	Not estimated
Gas Sensors	No more than $1 to 2 million per year	R&D spending unknown; said to hold 3:1 lead over United States in number of technical papers and 10:1 lead in patenting	Probably similar to U.S. level
Structural Applications:			
Heat Engines	$35 to 40 million per year	Greater than $50 million per year	Less than United States; Germany and Sweden are the European leaders
Cutting Tools	Probably no more than $1 million per year	R&D spending unknown; 20:1 lead over United States in patents for period 1973 to 1982	Probably more than United States; Germany alone nearly even with the United States in patents for period 1973 to 1982
Optical Applications:			
Integrated Optics	Approximately $10 million per year	Slightly less than U.S. expenditures	About half of U.S. expenditures

SOURCE: Charles River Associates, 1984

MARKET OPPORTUNITIES

J. J. Harwood
Energy Conversion Devices, Inc.

and

D. W. Lee
A. D. Little Inc.

Introduction

In late 1983 the Industrial Research Institute (IRI) entered into a Cooperative Research Agreement[1] with the Economic Development Administration of the Department of Commerce to undertake a series of business assessments of selected industrial sectors.

The primary purpose of each assessment was to provide a statistical and qualitative framework to enable identification of technical opportunities that might make each of the above sectors more competitive in worldwide markets and speed up commercialization of advanced technologies. The technologies sought were to be amenable to development through the use of Research and Development Limited Partnerships.

The assessment of each of the industries listed (or particular selected segments) have been issued and are available through the National Technical Information Service.

This paper summarized a report prepared by A.D. Little, under contract to IRI, on the "Assessment of the Advanced Ceramics Industry--Competition and the Role of Technology." The A.D. Little Study was conducted under the leadership of Dr. W. Lee. J.J. Harwood acted as the study project manager for the IRI.

This study focused on:

(a) the nature of advanced ceramic industrial segments and the competitive and market dynamics at play;

(b) past and emerging trends in industry performance and competitiveness and the influence of emerging technological developments;

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[1] Project No. RED-80-3-G-83-5(99-7-13611).

(c) key factors influencing the size and growth potential of advanced ceramic markets and the identification of key and pacing technologies associated with each market segment, and finally;

(d) the preliminary identification of areas which represented RDLP opportunities.

Nature of Advanced Ceramic Industry

Electronic and electrical products predominate in the marketplace and will continue to do so in the foreseeable future. The technologies are relatively mature and new developments are expected to be evolutionary. But the driving force for much of the "ceramic fever" and national programs is the long range future potential for ceramic heat engines, yet it is unlikely that any significant markets for gas turbine engines or diesel components will develop within the next decade. Wear markets (seals, valves, cutting tools, etc.) represent the most likely near term business opportunities for the growth of the structural ceramics industry into a viable status. It was concluded that the areas where accelerated technology development could have the most impact on international competition in advanced ceramics include the mechanical/structural segment and selected products and technologies in the electronic segment.

Past and Emerging Trends

A product-technology matrix (abbreviated in Exhibit 1) was prepared to examine the relationship between technologies and specific industry and product segments.

Key factors affecting the future position of the electronic/electrical segment will be cost reduction and improved materials and processing, in particular automated processing. Improved powder processes, involving such techniques as sol-gel, gas phase reactions and chemical precipitations as routes to nonagglomerated (< 1 μm), nearly monodispersed particles are seen as pacing technologies in a range of structural and mechanical products.

Heat engine components are still in an embryonic stage. They do not as yet comprise a market sector. Technical developments more than manufacturing or marketing factors appear to provide the competitive edge. Key factors affecting the future competitive situation will be improved materials, processing, and manufacturing reliability in high volume operations.

Prevailing barriers in growth potential in worldwide markets of advanced ceramic market segments involve:

(a) Production costs--both ceramic powders and finished components;

(b) Development of low cost, high purity methods of powder synthesis, which can be scaled up for high volume production;

(c) Improvements in fracture toughness and reliability of ceramic products;

(d) Near net shape fabrication methods--capable of making parts at reasonable cost, with high reliability, consistency, and quality control, requiring minimum finishing and the capability for automated processing;

(e) Joining methods for bonding of ceramic shapes;

(f) Nondestructive evaluation methods capable of detecting critical flaw sizes and capable of being installed into on-line fabricating systems;

(g) Characterization of ceramic materials and understanding of process dependent, time dependent, and surface dependent properties. Development of standardized testing techniques; and

(h) Industrial experience in manufacturing advanced ceramic hardware and reliable knowledge of performance behavior of ceramic components in industrial service.

The findings of the market segment assessments indicated that accelerated technological development in at least two industry segments and in one pacing technology could significantly enhance the U.S. industrial performance and competitive position.

Wear Components--to overcome market fragmentation which currently impedes commercialization and industrial growth.

Sensors--their generic end use applications and importance to robotics, automation, fuel management, and control systems support this as a significant growth area.

Powder Processes--improved powder characteristics are key to growth and success in almost all advanced ceramic market areas. This is a pacing technology which requires coherent programs and the best of industrial expertise.

One key area in which the emerging American advanced ceramic industry is lagging behind Japan is in the application of known ceramics technology and materials into hardware and simulated/real production and performance proveout. More mature learning curve experience underlies

Japanese industrial program with rapidly increasing knowledge about manufacturing and performance issues and problems and realistic solutions.

Concluding Remarks

The advanced ceramic industry is a highly fragmented one in terms of the products, participants and end use markets and applications. The utilization of advanced ceramics depends, by and large, on the unique combination of electronic and mechanical properties and to a lesser extent on their high temperature stability. Electronic end uses resulting from the insulating, magnetic, ferroelectric, and conductivity properties constitute the major markets, many of which are mature. Applications of advanced ceramics based on their structural or mechanical properties, per se, are smaller in number but represent significantly greater potential for future growth.

A key factor in the industry is the emergence of foreign competition in the development of structural and mechanical ceramic materials for heat engines and industrial applications. Japan is seen as a major threat in this segment and it is of concern that Japanese technology and products will become as dominant in this segment as they are presently in several major electronic segments of the advanced ceramics industry.

The fragmented nature of the wear component market (excluding heat engine wear applications) and the structure of the component supplier, equipment manufacturer and the end user has, in many ways, inhibits the integrated technological development that is necessary to address this market. Few industry participants have the requisite understanding of material properties, component fabrication, design and end user conditions to address the problems. Basic understanding of wear mechanisms, micro and macro structural effects and design criteria are required. Japanese competitors have integrated capabilities either internally or through joint ventures.

In all these key and pacing technologies, the Japanese competition appears to be moving ahead rapidly. They have aggressively pursued "thin markets," i.e. small specialized market segments where customers are willing to acquire products embodying new technology even though the cost may be somewhat greater than existing products. The Japanese ceramic suppliers thus gain valuable technical and production experience which can be translated to product opportunities in larger future markets. This strategy is expected to result in the transfer of wear component technology to heat engines if that potentially larger but longer term market develops. The result of a lagging technology development in the key and pacing technologies for industrial wear components in the U.S. could eventually impact the domestic industry's position in the future market for heat engine components. The accelerated development of selected pacing technologies in the U.S. could potentially increase the U.S. shares of the estimated $14 billion U.S. market (1995) for industrial wear components as the result of significantly improved materials, manufacturing process and hardware at a competitive cost.

ADVANCED CERAMIC PRODUCT/ TECHNOLOGY MATRIX

Technology / Mechanical/ Structural Segment	Low Cost Material Preparation	Improved Powder Characteristics	Forming Technology	Sintering Technology	Finishing Technology	Forming Technology	Automated Processing	Evaluation and Testing	Design and Reliability	Property Improvements
Heat Engine Components	Growth Pacing	Growth Pacing	Growth Key	Growth Key	Growth Key	Growth Pacing	Growth Pacing	Growth Pacing	Growth Key	Growth Key
Cutting Tools	Growth Pacing	Growth Key	Mature Key	Mature Key	Mature Key	Growth Pacing	Growth Pacing	Growth Pacing	Growth Pacing	Growth Key
Valves, Seals, Pump Components Industrial Equipment	Growth Key	Growth Key	Mature Key	Mature Key	Mature Key	Growth Pacing	Embryonic Pacing	Growth Pacing	Growth Pacing	Growth Pacing
I.C. Packages	Mature Base	Mature Key	Mature Key	Mature Base	Mature Base	—	Growth Key	Mature Key	Mature Key	Embryonic/ Growth Pacing
Substrates	Mature Base	Mature Key	Mature Key	Mature Base	Mature Base/Key	—	Growth Key	Mature Key	Mature Key	Growth Pacing
Capacitors	Mature Base	Mature Key	Mature Key	Growth Pacing	Mature Base	Mature Base	Growth Key	Mature Key	Mature Key	Mature Base
Sensors	Growth Key	Growth Pacing	Mature Key	Mature Key	Mature Basc	—	Embryonic Pacing	Growth Key	Growth Pacing	Growth Pacing

Advanced Ceramic Market Segments

Mechanical/Structural Segments

- Heat Engine Components
- Ceramic Cutting Tools
- Pump/Valve Components
- Wear Components

Electronic/Electrical Segments

- IC Packages
- Substrates
- Capacitors
- Hard Ferrites
- Soft Ferrites
- Varistors
- Thermistors
- Piezoelectrics
- Sensors

EXHIBIT 2

SESSION III: COOPERATIVE MECHANISMS & RESPONSE

FORCES OF CHANGE IN THE INDUSTRIAL SECTOR

D. Bruce Merrifield
Office of Productivity, Technology and Innovation
U.S. Department of Commerce

The United States has created in recent years a historically unique climate for investment and entrepreneurial growth. Failure to fully understand and appreciate the factors that have made this possible could easily lead to their dilution with very unfortunate consequences. This climate now needs to be further strengthened, in order to take full advantage of our basic knowledge in materials, in electronics, in biosystems and many other areas of advanced technology.

The basic understanding is that technology now drives all the world economies, and literally, for the first time in history, offers unparalleled opportunities for the continuous creation of new wealth and a rapid rise in quality of life for all nations.

- About 90 percent of all scientific knowledge has been generated in the last 30 years, a major proportion of it in the United States.
- The knowledge pool will double again by the end of the century rapidly compressing life cycles of products and processes to less than 5 to 10 years.
- Technology development will increasingly become a worldwide phenomenon, with all nations participating in very competitive global markets.
- Developing nations will capture major shares of those industrial markets where their inexpensive labor and natural resources provide them with an overwhelming advantage.
- The "targeting strategy" first modeled by the Japanese and now being copied by many other nations will continue to affect many industries (semiconductors, machine tools, consumer electronics, motorcycles, steel, etc.).

As a result, segments of the U.S. industrial base are in a period of rapid and pervasive restructuring. Some industries that have failed to adapt advancing technology will continue to decline. Others will automate and grow, or fragment into many niche markets served more effectively by totally new systems replacing the old. This is illustrated in Exhibit I by the Kondratieff Longwave. The Longwave is not precisely accurate, since many developments have occurred that do not follow this pattern. Nevertheless, it is a reasonable representation for many "smokestack" industries. Professor Jay Forrester at the Massachusetts Institute of Technology has further refined and elucidated the "Longwave" through his "System Dynamics" model. He identifies four phases to the Longwave: (1) a 15-year period of collapse in which obsolescent operations are shut down and written off, (2) a 20-year period of reinvestment in state of the art technology, (3) a 10-year period in which overcapacity is built, and (4) a 10-year period in which recession cycles deepen and then the next collapse occurs. We are now at the end of such a cycle.

However, this will be the last of the 50-year Longwaves simply because few products or processes are likely ever again to have more than a 5 to 10-year life before they are obsoleted by new developments. Also, a collapse such as occurred in the 1929 to 1945 period will not happen in the United States, because the current writeoff of obsolescent facilities, on balance, is being more than offset by the generation of new businesses. However, the process of restructuring is not uniform and pockets where the older industries are concentrated will continue to be in difficulty.

The Dynamic U.S. Economy

Nevertheless, net GNP growth is positive and as the process of restructuring proceeds, the U.S. should be moving into an exceedingly positive period. The dynamic nature of the U.S. economy has been little understood. More than 21 million new jobs have been generated over the last 10 years, 90 percent of them in small businesses with fewer than 500 people. Eight million of these jobs have been generated just since 1982 when the Economic Recovery Tax Act incentives were put in place (Exhibit II). This "American miracle," as the Europeans call it, has absorbed the baby boom and millions of women into the work force, at a time when the European economy has lost jobs.

The reason for the job growth is that over 600,000 new companies are incorporating each year in the U.S. economy. Many of these are technology driven, but only about 10 percent actually are "high-tech" jobs. However, each high-tech job, on average, creates a spectrum of 5 to 15 support jobs. For example, these are in maintenance, construction, distribution, marketing, financial, legal, communications, and clerical services. These support functions now make up about 70 percent of the GNP, and are a stabilizing flywheel for the economy because they remain in constant demand by a growing number of enterprises, which themselves may come and go from time to time.

Global Competition

The urgent need is to maintain and enhance this remarkable climate for innovation that has been created in order to cope with massive global changes that are occurring. For example, foreign nations are targeting selected businesses through government-industry collaborative efforts that involve various forms of subsidy. These involve a "learning curve" concept of "forward pricing" below true costs to capture new growth and drive competitors out of the market (Exhibit III). The government, in effect, carries the negative cash flow involved. The Japanese have captured virtually 100 percent of the consumer electronics business (VCRs, etc.), 95 percent of the motorcycle business, 90 percent of the 256,000 bit memory chip business, and made major inroads into many others. The European Airbus Industrie has copied this strategy capturing 15 percent to 20 percent of the wide body jet market and now are targeting a next-generation 150-passenger jet market, running enormous debts to do so. Ariane, the French space agency has captured about 50 percent of the space-shot business, pricing below true costs.

These targeting strategies will continue to affect U.S. industrial operations in any business where U.S. companies do not have a technology edge. The need, therefore, is to continually develop next-generation technology to maintain such an edge, building on the tremendous pool of advanced technology that the U.S. alone is capable of maintaining.

Global competition is further exacerbated by the emergence now of developing nations that are taking advantage of cheap labor and natural resources to capture market share in businesses that are sensitive to these factors. Much of the $80 billion U.S. commodity petrochemicals industry will go off-shore to hydrocarbon rich developing nations. The world glut of oil and gas allows these countries to charge in natural gas and naptha feedstocks at close to zero cost, when they represent 50 percent to 80 percent of U.S. costs.

Much of the primary production of metals also will go off-shore as will labor intensive operations that can produce at lower costs, for example, in Korea, Taiwan, Singapore, and China.

Flexible Automated Manufacturing

The steady loss of some manufacturing, however, does not mean that the U.S. is moving to an all-service economy. In fact, manufacturing in the U.S. has been constant for decades averaging between 20 percent to 25 percent of GNP.

If anything it will increase, but in a multitude of new forms. Software development, for example, is an explosively growing "manufacturing" business.

And contrary to some speculations, the cumulative effect of thousands of new products and processes will more than offset the obsolescence of older businesses or the loss of others to foreign countries. However, manufacturing <u>jobs</u> will continue to decrease as flexible automated systems continually restructure process technology. Automation, however, will be essential for survival in world markets, and incentives for developing these systems are exceedingly important.

- o Within a decade, very few manufacturing operations may be viable that are not automated flexible systems--that can be continually reprogrammed to make a large variety of products, but still run 75 percent or more of the time for economies of scale.

- o The U.S. has the advanced technology in sensors, computers, software, and construction materials necessary to recapture leadership in most industrial areas.

- o Flexible automated systems even have the potential for recapturing labor intensive businesses that have gone offshore (textiles, shoes, semiconductors, consumer electronics, etc.).

The importance of the investment tax credit and rapid depreciation allowances enacted into tax law in 1981 have been much more important than has been generally realized. About $70 billion in capital investments made in 1984 were in automation equipment, with profound consequences (Exhibit IV). One hundred to one thousand percent improvements in productivity have been demonstrated through automation. For example, General Electric has realized over a 1000 percent improvement in their Erie, Pennsylvania locomotive plant and in their Louisville, Kentucky washer-dryer operations.

Automation lowers unit costs and increases profits that then can be invested in expanded operations that create new jobs.

The alternatives to automation are to go out of business or move off shore. The ITC and ACRS incentives have been an important factor in the "climate" for industrial resurgence in the U.S.

The U.S. Potential

The U.S. has unparalleled advantages over all other nations. If effectively mobilized, these advantages can reestablish technical and industrial leadership for U.S. industries in most world markets:

- o In our universities and government laboratories we currently are spending about $13 billion each year to expand the pool of basic scientific knowledge. No other nation can make this sort of investment...a permanent enduring advantage for U.S. industries.

- o No other nation has a comparable depth, breadth, or scope of technical-industrial infrastructure that can translate basic discoveries into useful products and processes.

- o No other nation has a comparable enterpreneurial culture that takes great risks without fear of failure or loss of face if unsuccessful.

- o No other nation has the flexibility of capital development that we have.

- o We have the world's largest market with a common language in a democratic culture.

The imperative is to remove barriers to the mobilization of these resources and to provide incentives to accelerate the latent creativity that exists. Increased efforts need to be made to remove antitrust and counterproductive regulatory barriers. The high cost of capital (12 percent to 15 percent in this country) is a severe deterrent both to necessary investment in fixed assets and to the innovation process itself. Also, the strength of the dollar which largely reflects the relative strength of the U.S. economy has seriously affected exports and reemphasizes the urgent need for low-cost automated manufacturing.

But with all these problems, the U.S. still has managed to create an historically unprecedented climate for growth and prosperity. It is important that we recognize the nature of the "American miracle" that is the envy of our European friends, and strengthen it. A robust U.S. economy is essential for world peace.

EXHIBIT I
KONDRATIEFF/FORRESTER LONGWAVE

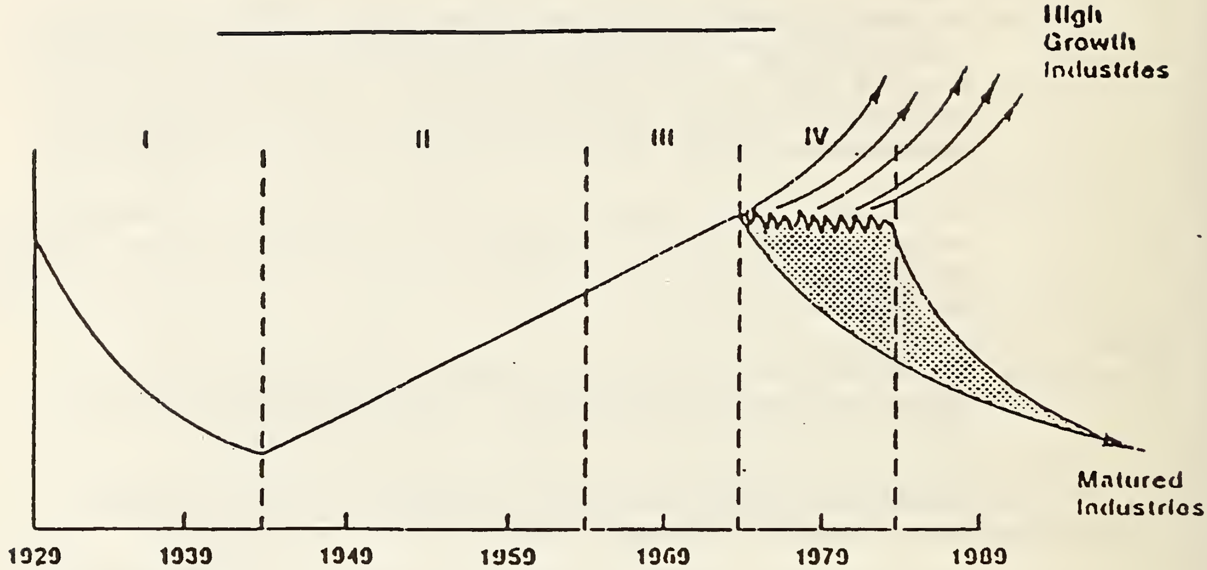


EXHIBIT II
ERTA Stimulated Growth

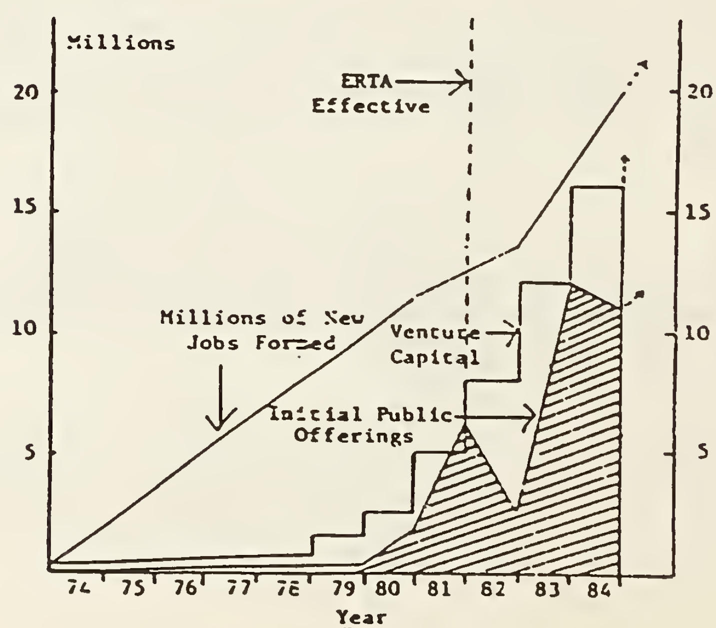
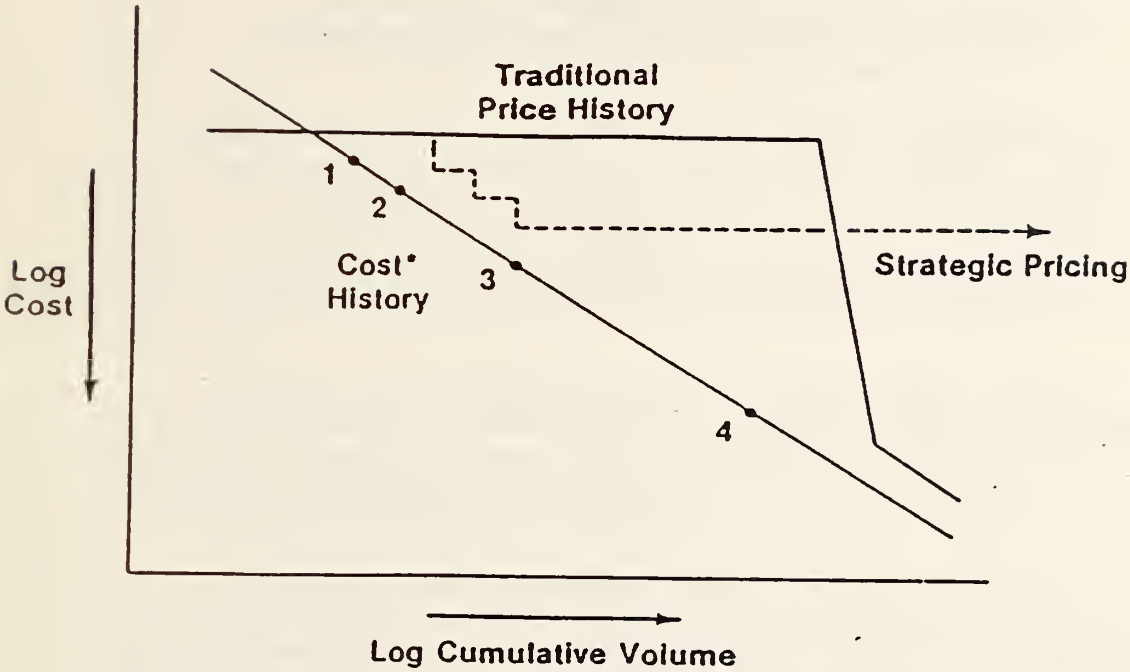
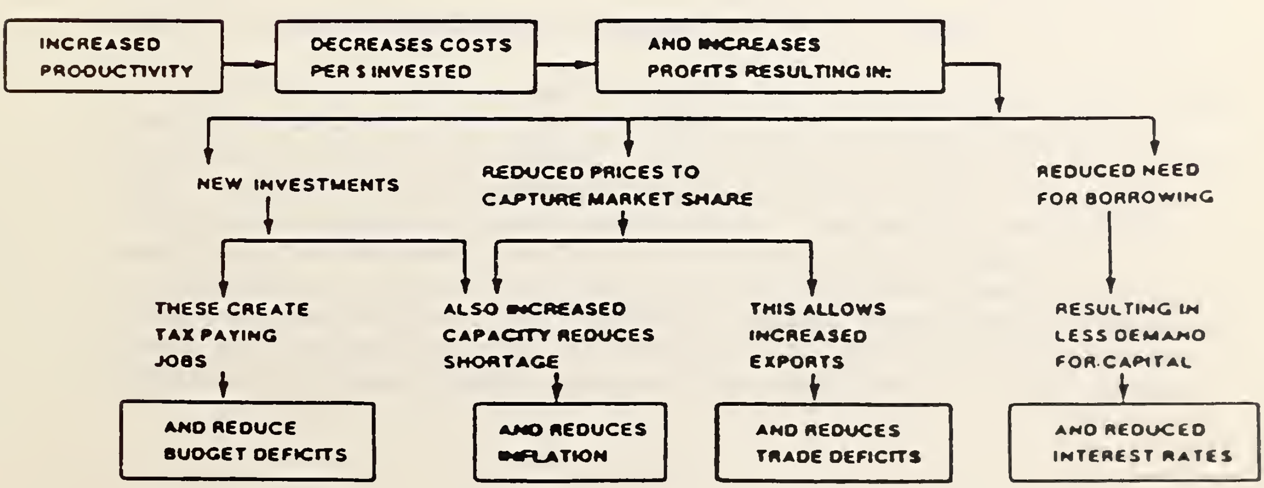


EXHIBIT III
The Learning Curve



*Costs Decrease About 20% for Every Doubling of Total Industry Volume

EXHIBIT IV
Productivity
The Effects of Automation



THE NEED FOR COOPERATIVE R&D--CASE STUDIES

Lansing R. Felker and Susan L. Miller
Industrial Technology Partnerships Program
U.S. Department of Commerce

Cooperative industrial research and development (R&D) has never been more important than it is today. Ventures that pool the resources of private firms are critical to America's competitiveness because they can strengthen the weakest link in the U.S. innovation system--translation of basic research into commercially successful products or processes.

Principal U.S. trading partners have made use of cooperative R&D for some time. Partly because of these ventures, foreign firms have developed a competitive edge in several industries in which the United States traditionally has been a leader.

Even though the government spent over $7 billion on basic research this year, the United States is not transforming this strong base of fundamental knowledge efficiently into commercial products and processes. It is this translation phase that our competitors are more effective in exploiting. Other nations license U.S. technology in its early stages, make the necessary investment for its development, and commercialize the results ahead of U.S. firms.

Foreign competition, such as that posed by Japan in a number of technological areas, is just one of the three types of "threats" that normally lead to formation of an industrial R&D consortium. The second is a leading domestic competitor (such as IBM represents in the computer industry), which also can stimulate collaborative efforts by other firms in an industry. "Threat" number three is that of a new technology menacing the market share of traditional technology (e.g. new materials to metals; plastics to glass).

The National Cooperative Research Act of 1984

In view of its accepted importance to productivity and competitiveness, why hasn't more cooperative R&D been performed in this country? Part of the answer lies in the view consistently expressed by firms that U.S. antitrust laws have inhibited such activity. Companies have been hesitant to become involved in collaborative R&D arrangements because of the risk of treble damages and criminal sanctions. And treble damage remedies virtually provided an incentive for third party suits. A Commerce and Justice Department initiative resulted in the recent enactment of the National Cooperative Research Act of 1984. Passed unanimously by both house of Congress, the new laws revises the antitrust laws to:

- Analyze cooperative R&D ventures under a "rule of reason" assessing their overall effect on domestic and international competition, rather than deeming them *per se* illegal;

- Protect R&D ventures from treble damage liability and;

- Award attorney fees to the prevailing party when the plaintiff has brought spurious litigation.

Since the Act authorizes cooperative R&D through the stage of prototype testing, it does not change application of the antitrust laws to production, marketing, or the sale of products, so that their effectiveness in insuring competition during those stages will not be diminished. Thus, the government has cleared away what U.S. businesses perceived to be the main barrier to cooperation--risk of antitrust liability.

Since the Justice Department and Federal Trade Commission published procedures for filing for the protections of the Act in December 1984, 25 groups have already registered, and many others are in the process of forming. These ventures range from high tech industries--microelectronics, telecommunications, biotechnology--to the more traditional industries, e.g. steel, glass, autos. The Commerce Department is currently working with a number of industries to help set up cooperative R&D ventures.

Cooperative R&D in the Innovation Process

Government laboratories and universities perform the majority of basic research, most of which is funded by the federal government. The private sector invests primarily in the high-cost, but lower-risk, later phases of innovation. What remains is a gap in funding for the applied research and early development phases.

Acting alone, even the largest company cannot undertake this phase of the innovation process in some research areas because of the prohibitive costs and risks associated with early development of major technological breakthroughs. In addition, firms must innovate faster because of the dramatically increasing pace of technological change.

In many cases, especially the development of new manufacturing processes, investment in this stage does not result in products or processes that can be protected through patents or copyrights. The benefits of the investment cannot be captured by the investing firm. Thus, there is little incentive for a business to invest in research whose results are not proprietary. The risks for a firm to invest in this stage often outweigh the incentives.

Cooperative R&D usually is performed to develop base technology that is an input to the member firms' own proprietary work; companies group together to fund research, then each tailors the results to its own products. True cooperative R&D usually involves collaboration among competitors. Therefore, once it has developed base technology, a cooperative effort must end or risk potential antitrust problems. By contrast with joint ventures between two firms, cooperative R&D has a less clear agenda; the end product of base research is usually more uncertain.

Current Cooperative R&D Activity

It is difficult to determine the actual amount of cooperative R&D activity in the United States, since the government does not require reporting of such ventures. The Department of Justice has records of R&D joint ventures that sought rulings on antitrust implications between 1968 and 1980. Most projects reviewed were directed at later-stage R&D involving existing technologies. A large number of R&D ventures among manufacturers and suppliers were also formed, often involving joint production.

In the past, in part due to fear of antitrust suits, cooperative R&D has been carried out primarily by industry trade associations, rather than by direct cooperation among firms. However, their research agendas were designed to improve technologies generic to an entire industry. Associations normally do not attempt major breakthroughs in technology.

The most positive sign that industry has perceived the utility of R&D cooperation is in the computer and semiconductor industries. In the Microelectronics and Computer Technology Corporation (MCC), 21 leading U.S. computer and high-technology firms pooled research funds and personnel with the objectives of competing with Japan and radically advancing the state of computer technology in five to ten years. Participants agree to share costs of the programs for at least three years, guaranteeing continued funding and entitling them to share research results. Three years after project completion, the technology can be licensed to nonparticipants, but members have received several years head-start. The consortium enables individual companies to take advantage of scarce technical personnel and to benefit together from levels of funding they could not afford individually.

The Semiconductor Research Cooperative (SRC), a subsidiary of the Semiconductor Industry Association, is another model of a cooperative project whose goal is to achieve longer-term advances in microelectronics R&D. Semiconductor manufacturers, merchants, and users are eligible to participate. Industry members provide funding, equipment, and technical personnel to universities for collaborative research projects in generic fields related to the semiconductor industry, such as electron beam technology, materials science, and computer-aided design. Nearly 200 SRC projects are scheduled at more than 40 universities. As in the MCC, sponsors have a time advantage and receive rights to any patents or copyrights.

A model of the state-sponsored cooperative industrial R&D venture is the Microelectronics Center of North Carolina (MCNC). Approximately $50 million dollars--state and industry funds--will be devoted to manufacturing research at North Carolina universities with the goal of producing a one million megabit chip. Ventures such as MCNC can fund R&D through the entire innovation process: the universities will perform the basic research; MCNC will carry out applied R&D; and industry affiliates will commercialize the new technology.

Organizational Issues

Thus, several basic models of cooperative research have been formed just in the past few years: industry/industry; industry/university; industry/university/state government. Variations on these models have already begun to appear as cooperative ventures evolve. For firms considering forming R&D consortia, there are certain standard issues that must be considered in the early stages of setting up a cooperative:

Choosing the Technology Agenda

Any R&D consortium is built on the existence of an unfunded R&D agenda, common to a number of firms, which cannot be funded conveniently by any one of them. The identification of that agenda, at least in general terms, is essential to the successful formation of a consortium.

Also, commercialization of R&D has been found to be more successful when the potential users of the technology participate in setting the technology agenda, thereby introducing a "market pull." By contrast, "technology push" by the R&D performers, often develops answers in search of a question, and is less successful. Industry needs to set the agenda, even when the research will be performed by university members.

A Champion

Every group successful in forming an R&D consortium has been able to identify one or more people who originated the idea and followed it through to actualization. A champion can be a business leader who recognizes the need for collaborative activity in the industry, or state or university leaders who want to promote local economic growth. For example, William Norris, Chairman and CEO of Control Data, was the originator and prime mover of MCC. Champions represent the support and commitment of high level management, essential to successful completion of any R&D project.

Time

Commitment to the project, by the champion, leaders, and participants is essential because formation of the venture alone usually takes one year; in the case of MCNC, five years were needed to complete a major facility and coordinate with universities and industry affiliates.

Funding

Certain decisions fundamental to any joint venture must be made, such as number of participants, budget, and whether the organization will be for- or non-profit. Many groups require multi-year commitments of funds, to ensure continued participation through completion of projects.

In MCNC, funds are pooled by sponsoring companies for all projects. By contrast, MCC members pay separately to participate in each individual project. Several consortia allow sliding-scale membership fees for small companies. Donations of equipment or other in-kind payments are also permitted.

Internationalization

This issue needs to be considered when deciding number and types of participants. Because foreign competition is frequently the reason behind formation of a joint venture, many consortia do not accept non-U.S. members. For example, MCC shareholders have to be 50 percent owned and controlled by U.S. citizens, and must conduct a "substantial portion of their R&D in the U.S." SRC by-laws exclude non-U.S. firms, as does MCNC.

Management

The for-profit cooperative organizations emphasize the importance of a strong CEO or President to coordinate the members' interests. A common arrangement is to have one executive per sponsor on the Board of Directors; and one representative per member, usually at the Vice President for R&D level, on a Technical Advisory Board. It has been recommended that legal and business staff work closely together in the formation stage, because of antitrust, intellectual property or other issues that could cause potential problems.

Personnel

Procurement of research personnel can occur in a number of different ways:

(1) They can be loaned by the member companies, MCNC, for example, requires a commitment of personnel as well as funding from its members;

(2) Direct hire;

(3) Contracts to universities. SRC contracts fund 200 faculty and 400 graduate students per year;

(4) MCNC has temporary industry residents at its facility, and also hosts international visiting scientists;

(5) MCC members send "science liaison representatives."

Intellectual Property

The last two issues, patents and licensing and technology transfer, are considered by consortia leaders to be the most important in setting up cooperative ventures. For example, MCC found intellectual property to be the "key issue for participants," requiring lengthy contractual arrangements. MCC will license findings to non-members after three years, giving its sponsoring companies three year lead-time--substantial in the electronics industry. Participants will receive 70 percent of any income from royalties; the remainder will return to MCC's research fund.

When cooperative membership includes universities, intellectual property arrangements can vary depending on individual university's demands. Some universities may retain title to patents, while others may not. SRC encourages participating universities to file for patents resulting from research funded by the cooperative; if not, SRC files. Members receive non-exclusive, royalty-free access up the amount of their payment to SRC.

At MCNC, an Intellectual Property Rights Review Committee was set up for decision making regarding patents resulting from pooled research. MCNC retains ownership of joint (university/industry) developments; and industry affiliates receive royalty-free, non-exclusive rights to pooled industrial research.

Technology Transfer

Dr. Palle Smidt, Chief Operating Officer of MCC, points out that if you don't promote transfer, there's no point in doing the research. Long-standing methods used by research groups have been: reports, seminars and conferences, and exchange of scientific personnel. MCC "science representatives" promote transfer on their return to member companies. Graduate students trained under SRC contracts often are hired by sponsoring firms. SRC's Ralph Cavin, Director of the Design Sciences Program, states that "people transfer" is much more effective than "paper transfer."

Conclusion

Cooperative research and development programs promote competition. They reduce duplication, make efficient use of scarce scientific and technical personnel, and help achieve desirable economies of scale. Small firms are able to collaborate on projects that, because of prohibitive costs, they could not perform on their own. Large firms are able to tackle jointly today's large and complex technological problems, which often are beyond the technical or financial capability of individual companies. For these reasons, cooperative research efforts will play a key role in the ability of US. industries to remain competitive in the international marketplace.

ADVANCED CERAMICS--INDUSTRY/UNIVERSITY INTERACTIONS

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Surging industrial interest in advanced ceramics in the last several years has caused greatly increased Industry/University interaction in this field. Some of this interaction takes the form of increased activity in traditional modes including consulting, unrestricted grants, and single-sponsor research projects. In addition new centers for ceramics research with multiple sponsors sharing in a pool of basic research have come into existence. Industrial sponsorship is supplemented by federal and state sponsorship in most cases but considerable variations in the roles of the sponsors and their involvement in the direction of research is evident.

Advanced or high-performance ceramics, now entering commercial use, are inorganic, nonmetallic materials having combinations of fine-scale microstructures, purity, complex compositions and crystal structures, and accurately controlled additives. Such materials require a level of processing science and engineering far beyond that used in making conventional ceramics.

Ceramics are an enabling technology. The competitive performance of many devices and large systems depends on ceramic components that currently make up a small but vital part of the total package. The competitive economic leverage of superior ceramic components is large. These superior components depend, however, on carrying the scientifically demonstrated performance of new ceramics into engineering realization as well as on pursuing the science of still better ceramics. The challenge of realization is a continuum of problems in advancing the science and engineering of ceramic processing to levels of purity, perfection, and scale not previously achieved.

Advanced ceramics is a critical arena of intense international competition. The United States at present is strong in the basic science of ceramics but appears to be increasingly threatened in the extension of this knowledge into the engineering and commercialization of advanced ceramics. Japan, in particular, has a 10-year program in high-performance ceramics with extensive industrial participation and commitment. Japanese firms already control 70 percent of the free-world market for electronic substrates and appear likely to dominate much of the rest of the market for advanced ceramics in the near future unless the United States responds immediately in a more effective manner. Recent events in Europe indicate that similar strong competition founded on excellent technical capabilities is also developing there.

The size of such overseas efforts, their coordinated approach by industry, university, and government, and the close coupling of research and development to applications all underscore the seriousness of the competitive race faced by the United States. Many U.S. firms not previously active in ceramics have identified this as a promising area and have started new programs in ceramics; many firms with existing ceramics programs have strengthened these and expanded their scope. Over 50 firms have joined university-industry programs in ceramics in the last three years. There is a strong commitment to succeed, but also an urgent need to expand the ceramics manpower base if these new initiatives are to prosper and bear fruit. Thus, the time is opportune for government, university, and industrial cooperation in high-technology ceramics.

Promising high-priority research opportunities can be grouped into four broad areas, each of which would support development in both electronic and structural ceramics:

1. New thin films and layer structures with improved properties.

2. Exploration of completely new, multicomponent ceramic crystal structures and composites.

3. The mechanical behavior of ceramics and tough composites.

4. Ceramic processing of large parts and assemblies.

There are 12 institutions certified by the Accreditation Board for Engineering and Technology that grant B.S. degrees in ceramics or ceramic engineering. There are 15 schools that offer formal advanced degrees in the field; many more schools granting degrees in "materials science" or "materials engineering" have faculty performing research on ceramics. Approximately 300 B.S., 90 M.S., and 35 Ph.D. degrees are awarded annually in ceramics or ceramic engineering.

At present, a large fraction of the B.S. graduates enter the more traditional areas of the ceramics industry such as glass and refractories. An increasingly larger fraction of the B.S. graduates, perhaps 40 percent, currently enter the electronics field. On the other hand, virtually all the M.S. and Ph.D. graduates are filling positions related to high-technology electronic and structural ceramics. The demand for advanced-degree graduates, particularly Ph.D.s, is far greater than the supply. As a result, many positions that could and should be filled by ceramics graduates are being filled by graduates from related fields, such as metallurgy, geology, and chemistry, who are being retrained during their first few years of industrial experience.

As high-technology ceramic production expands, the demand for B.S. graduates will increase. By 1990, most B.S. graduates will be entering the high-technology industries. At present, probably more than half of those entering graduate ceramics education have an undergraduate degree in the field. Thus, the number of B.S. graduates must grow to meet the needs of both expanding industry and expanding graduate research.

In the last few years research centers focused on ceramics with multiple industrial sponsorship have been established at several universities including Rutgers University, the Massachusetts Institute of Technology, and the Pennsylvania State University. In addition, university research centers with strong industrial involvement, such as the Center for Advanced Materials at the University of California at Berkeley, have recently been formed with a broader theme, but including a substantial program in ceramics.

The development of an improved science base and its ultimate conversion to technology can be facilitated by a "partnership" approach in the university research centers [1]. Typical partners are the National Science Foundation, the university, industrial firms, and a state government. Other government agencies may join with the National Science Foundation, or take the lead themselves as appropriate to their mission requirements, but we focus on the NSF discussion because of the traditional NSF concern with research in universities.

Each of the partners makes inputs to a research center and each expects to get certain outputs. Typical inputs by the NSF are: (1) seed money, (2) organizational guidance, (3) evaluation, and (4) providing an impartial monitor at meetings. Typical inputs by the university are: (1) faculty direction of research, (2) students, (3) review, and (4) use of special facilities. Typical inputs by a state are: (1) high technology equipment, (2) a critical mass of operating funds to hire additional faculty and professional or technical supporting personnel, (3) peer review of the state's needs and capabilities, and (4) buildings.

For the NSF the desired outcomes include: (1) achievement of scientific progress, (2) high leverage for federal money, and (3) documentation of success of centers and the impact of the science and technology developed.

For the university the desired outcomes include: (1) fundamental research for faculty and students, (2) financial support for research, (3) high technology equipment with capabilities for additional research beyond the immediate center, (4) facilities including buildings and supporting personnel, and (5) increased reputation.

For industry the desired outcomes include: (1) fundamental scientific concepts which can be applied to individual companies technology, (2) better knowledge of students and faculty, (3) use of patents developed in a center, (4) high leveraging for their money in "pooled" research, (5) use of the center as a broad information source on the field of ceramics, and (6) opportunity to meet with other firms (suppliers, competitors, and customers) in an atmosphere oriented toward technical discussion.

For the state the desired outcomes include: (1) a better educational system in the center's area of research, (2) reputation as an innovative state interested in industry, and (3) potential new companies, and potential new jobs.

Such university research centers are only one portion of an overall strategy to build academic and industrial strength. For example, the New Jersey Governor's Commission on Science and Technology [2] identified four mechanisms for action: (1) academic-industrial centers, (2) research grants for innovation partnerships of commercial importance, (3) space for new business on a business incubation facility basis, and (4) a technology extension service program. The University/Industry Center can be a very valuable component, but it requires patience and tact by the various partners, a recognition of the needs and limitations of each, and a willingness to work together to succeed.

The Research Briefings Panel on Ceramics and Ceramic Composites made the following recommendations [3]:

To maintain leadership in ceramics technology the United States needs to strengthen engineering research on ceramics and to increase the number of properly trained scientific and engineering personnel for current and future work. Critical-mass efforts focused on ceramics but drawing upon advances in other disciplines, in advanced instrumentation, and upon computer-assisted modeling are needed.

Such efforts should be centered on ceramics, not dispersed in a variety of scientific and engineering disciplines. Still, other disciplines including chemistry, physics, chemical engineering, and electrical engineering need to be involved. Research should be done in teams of sufficient size and should have a common focus on major themes. This should augment, not displace, existing single-investigator programs in ceramics. The groups should have as a major goal the production of trained personnel. Industrial involvement is essential. However, these group efforts should not be an attempt to perform industrial development or to substitute for necessary, ongoing research and development activity in the industrial sector.

To achieve critical-mass efforts on ceramic research three mechanisms are recommended:

1. A modest number--a minimum of five--ceramic science and engineering programs should be established at universities over the next few years. Each such program should have a focus on aspects of ceramics in keeping with the base of faculty capability on which it is built, but the focus should not be too narrow, and there might be overlap between programs.

2. A summer institute program should be established to bring together leading ceramics researchers.

3. The feasibility of establishing at least one large interdisciplinary ceramics center be studied. Such a center could be equipped to carry out research on the basic science and engineering of ceramic processing and the application of ceramics on a practical scale. It could be viewed as a national facility for interdisciplinary experimental and theoretical work on high-performance ceramics.

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ADVANCED CERAMICS--INDUSTRY/GOVERNMENT INTERACTIONS

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Today I am limiting my remarks on ceramics and addressing a more general topic, one which is equally applicable to ceramics, composites, steel, polymers, or even Martian exobiology, and that is the subject of government/industry interactions, especially interactions between industry and federal laboratories, such as NBS.

Previous speakers have shown clearly that the U.S. has an industrial competitiveness problem that extends far beyond the field of ceramics.

Many people have suggested using the resources of the federal laboratories as a tool to enhance America's industrial competitiveness. The President's Commission on Industrial Competitiveness concluded that technology and talent were the only two areas in which the U.S. stood a good chance of maintaining major long-term advantages over its international competition. Technology and talent are certainly two things that the federal labs have in abundance. The government spends about $18 billion each year in the federal labs, and employs about one-sixth of all the nation's scientists and engineers.

The federal labs fulfill at least two functions: one of these is performing research directed at accomplishing the missions of the agencies to which they are attached. The second is performing basic research and thereby adding to the nation's storehouse of fundamental knowledge. Both these functions benefit our nation's industrial capability, but in my experience the link between industry and the federal labs is tenuous.

There is a common perception that some really excellent capabilities--facilities, people, ideas, and things--are just sitting around federal labs waiting to be picked up and used in important industrial applications. This perception, however, is false, because the people and facilities within federal labs are not just sitting around waiting to be tapped. They are already actively at work on projects that probably bear little direct relationship to most industrial research problems. Consequently, industrial/government joint programs are highly unlikely to occur spontaneously. They must be carefully structured and planned, even forced.

I would like to suggest four elements to improve the probability of having a successful industry/government research interaction:

1. Have realistic expectations,

2. Make sure the project meets the "site specific industry receptor" test,

3. Create joint ownership of the project,

4. Keep management flexible.

The first element is to have realistic expectations. It is all too easy for a potential industrial partner to think he may find a "silver bullet" in a federal lab. After all, these are the people who invented the atomic bomb, right? Well, yes, but that was a very expensive and lengthy project, not to mention a national goal and priority. A few million dollars spread out over several years will have the same result in a federal lab that it will have in an industrial lab: it's a good start on a major problem. It might (and I emphasize might) produce a usable solution to a well-specified smaller problem.

There are two basic reasons why industry would want to have a cooperative project with a federal lab:

1. The lab has technology available that a company would like to have transferred to it.

2. A group of companies would like to fund research work of common interest which none of them can afford to undertake alone.

In the case of number one, the transfer of technology, there should not be an expectation problem. Companies ought to be able to recognize whether a technology they can make use of exists within a federal lab. As former Supreme Court Justice, Potter Stewart, said about obscenity, "I know it when I see it." It is mainly a matter of clear communication and honest evaluation.

With regard to reason number two, a situation in which a group of companies want to get together to fund long-term research work at a federal lab, I urge some cautions:

The federal labs have good people, but they're not magicians. I would propose the following thought experiment for a corporate R&D manager trying to decide whether to try to accomplish a research goal through a cooperative arrangement with a federal lab: imagine what it would take for <u>your</u> industrial lab to do the job. Imagine the facilities and the kinds of people. Ignore the cost. Assume your general manager is infinitely benevolent. Then, if you can imagine circumstances under which you, the industrial R&D department, would be equipped to do the job, it's okay to look for a federal partner. If you can't imagine these circumstances, then what you really need is magic, and you won't find it in the federal labs, at least not in unclassified form. Plus, keep in mind that if you're dealing as part of an industrial consortium, all of your fellow members, who are probably competitors, will know about the research results as soon as you do.

The second element of success is making sure the project meets the "site specific industry receptor test." This is a test I dreamed up after reading about how narcotics work. Apparently the way opiates and some other kinds of narcotics suppress pain is that the brain comes equipped with certain little receptor sites of a particular shape and chemical configuration. When an opiate molecule comes along it fits into one of these sites just like a key into a lock. Presto! Dr. Feel-Good at work! I think the same phenomenon could describe the successful industry/government cooperative research program. First, there must be identified a very specific need in industry--a "receptor site" if you will--and the work the federal labs will be doing in cooperation with the company must fit it ever so precisely.

The "specific" receptor requirement places a terrific burden on both industry and government. Industry has to be able to describe what the receptor site looks like in excruciating detail, in far greater detail than they have ever thought about it before. Government, on the other hand, is faced with the problem of designing a research approach, tailored to that industry requirement, that probably doesn't fit very well into what is already going on in the laboratory. This tension can lead to much mutual agony; however, if industry can't define its needs very specifically, and if government can't tailor a program exactly, then, just like the molecule that's almost but not quite an opiate, the research results will go floating right on by the receptor site, and the industrial partner will never see any benefit.

Additional complications arise in cooperative programs involving several companies. The research results will not be proprietary to just one company. The "specific site receptor" must be one that is shared by other industrial participants in the program. Finding such common ground may be difficult.

The third element of successful interaction is creating joint ownership of the project. It is vitally important to the success of any kind of undertaking, especially when it cuts across organizational boundaries, that all parties involved feel they have an ownership stake in its outcome. This is key to all entrepreneurialism and most other kinds of human motivation. It is also a goal that is especially hard to accomplish when the organizational boundaries being crossed are between the private and public sectors.

Creating a sense of ownership within industry is more straightforward than creating it in government. By providing money and people an industrial partner will create within itself significant feelings of ownership, especially at the general manager level. In these days of tight supply of high quality technical personnel, the commitment of people is more difficult for a company to make than the commitment of money. Consequently, the people commitment is primarily what will lead to a sense of ownership of the undertaking on the industrial side.

Creating a sense of ownership on the part of government is more difficult. Resource investment does not create the same sense of ownership in the government that it does in industry. Strong ownership feelings in government do arise when an undertaking is in the mainstream of the lab's or agency's business; that is, when it becomes more of a line item and less a carve-out from discretionary programs. When undertakings in federal labs become line items, they get intensive management scrutiny, both in the lab and in the parent agency, much congressional attention, and also attention from OMB and other parts of the Executive Office of the President, such as OSTP for example. In addition to creating commitment all this scrutiny brings risk with it and a dilemma results: to get really strong government commitment to a program, the program must be highly visible; yet high visibility leads to substantial risks regarding performance versus expectations, and creates political sensitivity. I know of no escape from this dilemma. It is the kind of messy situation in which there is no substitute for skilled and dedicated lab management who are championing the same cause.

I need to add another dimension to the previous dilemma. As we look to the future we need to think in realistic economic terms. In my opinion the very best way to assure a cooperative program <u>will never</u> be funded is to make it contingent on getting all new federal money. There are just too many other forces at work--deficit reduction, tax reform, defense recovery--to make 100 percent new money funding a sure thing. Furthermore, since industry is presumably benefiting from the cooperative undertaking, industry should be paying a big part of the cost. To the extent that federal money will be used, federal laboratory management will be faced with a priority setting job: if you want something new, room must be made for it.

The fourth and final element is to keep management flexible. Government/industry programs are novel. They do not represent the bulk of what most companies or most agencies are involved in. Consequently, management on both sides needs to forget about all the rules of "how things are done." Rules are the organizational equivalent of habits. Some of them are bad habits. Like habits, rules provide automatic coverage for routine situations, such as brushing your teeth in the morning. They also represent a guide to organizational policy. But rules about how to do routine business are not always good at coping with anomalous situations, such as being chased down the street by someone who's shooting at you, or conducting a cooperative research program.

I hope these observations have been useful. In summary, here are my four candidate characteristics for successful joint government/industry interactions:

1. Have realistic expectations.

2. Make sure the project meets the "site-specific industry receptor test," more conveniently known as the "opium test."

3. Create joint ownership of the project.

4. Keep management flexible.

SESSION IV: WORKSHOPS ON INDUSTRIAL COOPERATION

STRUCTURAL CERAMICS

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Introduction

The field of structural high performance ceramics for purposes of this workshop report included heat engine components, cutting tools/dies, bearings, seals/wear parts, armor/military applications, substrates (electronic/chemical), powders/fibers, biomaterials and thick/thin film coatings. Some of the above were discussed and considered in combined form generally based on the knowledge base of the workshop participants. All agreed that the above set of products/application areas generally would apply to a reasonable definition of the structural ceramic area with some potential for constructive overlap into the other major category of this workshop, namely, electronic ceramics.

A number of studies in the recent past as well as some current endeavors of various governmental, university, and industrial agencies have indicated a significant market potential for structural high performance ceramics, growing stronger in the late 1980s and 1990s. However, serious potential technology gaps primarily in U.S. industry have also been projected by these studies. This assessment is multifaceted (as is the high performance ceramics industry) and difficult to definitively assess but the overall message remains quite clear and pressing. Unless new initiatives and implemented action plans are undertaken without delay, the next major materials revolution and the economic gains associated with it will be basically a foreign event. The U.S. is still in a position to dominate academically as well as commercially in this area and at the same time protect the independence of military applications, but we must respond broadly and perhaps in a new way. The DOC workshop convened on 10 July 1985 was designed to explore the potential for industry-government liaison as well as serve as a sounding board and catalyst for future actions designed to address the perceived threat already discussed.

In the structural workshops, three basic issues were discussed: (1) technological assessment, (2) market potential, and (3) cooperative possibilities. The results of these discussions are presented as follows and conclude with the recommendations from the structural portion of the workshop.

Technological Assessment

Using as an analytical tool the phases of technology movement from ideas through commercialization (Figure 1, [1]), the workshop concluded that adequate resources were currently being applied to the early part of the cycle (concepts, feasibility), while some concerns were expressed about the commercialization phase. This seemed to be tied to end user commitment, and/or market uncertainties perhaps associated with, reliability and market inertia. The net result seems to be having a "delaying" effect on the motivation of market penetration for high performance structural ceramics.

However, even more serious, needs and deficiencies were identified in the translation phase of Figure 1 (development, prototype, interim manufacture) with respect to heat engine components and powders/fibers in the opinion of workshop participants. Other deficiencies pointed out and discussed, but of somewhat lower priority in face of the major need in the translation area, included the need for materials/ceramic curricula with more emphasis on subjects necessary to high performance ceramics, i.e. physics, polymers, metallurgy, colloidal science, etc. Also, cited were a lack of quality assurance development, cross fertilization of engineering/science disciplines, test standardization and adequate technological focus coupled to end user commitment and needs.

Market Potential

The workshop assessed the potential of various areas of structural ceramics using the format in Figure 2 as a guide. There are many ways of doing this, and while the methods can be addressed in subsequent specific assessments, the general trends are felt to be significant and seem reasonably consistent with studies undertaken in much greater detail. The highest potential areas with the most significant technological (competitive) gaps appear to be heat engine components, fibers (whiskers) for reinforcement and non-alumina substrates. One area of high potential and high competitive position was seen in the use of these materials in military/space applications. To minimize overlap with the electronics workshop, the structural group emphasized non-alumina types of substrates. These items are important with respect to thermal conductivity, dielectric constant, expansion, strength, and radiation hardness.

Items with moderate market potential and reasonable current competitive position included bearings, wear parts, powders, and cutting tools. Part of the assumptions built into Figure 2 are assumed dollar values in the year 2000 as the ordinate measure. Both axes use a qualitative scale from low to high (1-5). The numbers indicate <u>trends</u> and areas of emphasis. Many studies have been already undertaken in significant detail which attempt to quantify dollar values. All have associated assumptions and potential for error. This assessment, therefore, did not attempt to address the quantitative aspects of market potential. It was further agreed that ceramic coatings and biomaterial applications would not be considered as separate items, but would be best covered as part of the other categories as appropriate.

Cooperative Possibilities

The third topic of workshop discusson was really the major focus of discussion since, as already mentioned, other efforts have covered in detail the first two topics. The structural group had strong consensus that a major need exists in the areas of collaborative industrial R&D. This should be targeted toward the major needs identified in technology translation and related to those items with highest and moderately high potential, eg. heat engine components, etc. While much information on collaborative R&D concepts, government interactions, etc. was presented to the attendees during the workshop plenary sessions, a somewhat different and specially focused initiative is proposed. This is directed at the "Translation-Transfer" deficiency and could have real potential if implemented at the appropriate government/industry levels without delay.

The concept would be called an Advanced Manufacturing Development and Engineering Center (AMDEC) and would operate both core programs and member/user programs using in the latter an advanced automated and highly flexible pilot manufacturing capability (line). The center would act much like a hotel with a small, critically sized permanent nucleus (minimum of 10 exempt) to carry out core programs, maintain facilities and assist member-users in their programs undertaken on site. The member-users would have proprietary protection in the use of center facilities due to the nature of logistics and by design. Core programs could be more generic or where cross informational risks are acceptable to the industrial user. This center should have the potential of <u>early</u> useful outputs and facilitate on-site training of member personnel while pursuing its major function of accelerating technology transfer to the commercialization stage.

Since regionality and its advantages of logistics, knowledge base, geography, etc. may suggest <u>more</u> than one such center, implementation could be envisaged as follows:

- Cooperative industrial funding with the potential for state participation.

- Potential locations could include in order of preference, national labs, research park, university, stand alone. The national lab location addresses some key potential negatives in establishing such centers, i.e. heavy construction costs, long time to first results, inadequate local support.

- The center must be independently managed by industry but university affiliation and government advisory assistance are considered of utmost importance.

Recommendations/Action Plan

From the structural ceramic workshop the action plan recommended, therefore, is targeted at the major needs identified, i.e. significant collaborative R&D concentrated in the technology transfer area and directed at major targets of opportunity in high performance ceramics.

1. Building on the beneficial aspects of the DOC workshop herein reported, the DOC with other government agencies as appropriate should act as forum and catalyst by fostering the formation of an Industrial Steering Committee to evaluate the overall workshop's recommendations and synthesize as necessary. The committee/DOC should then report conclusion/recommendations to key CEO's and federal agency officials. Comments and support would then be solicited leading to recommendations to the presidential science advisor.

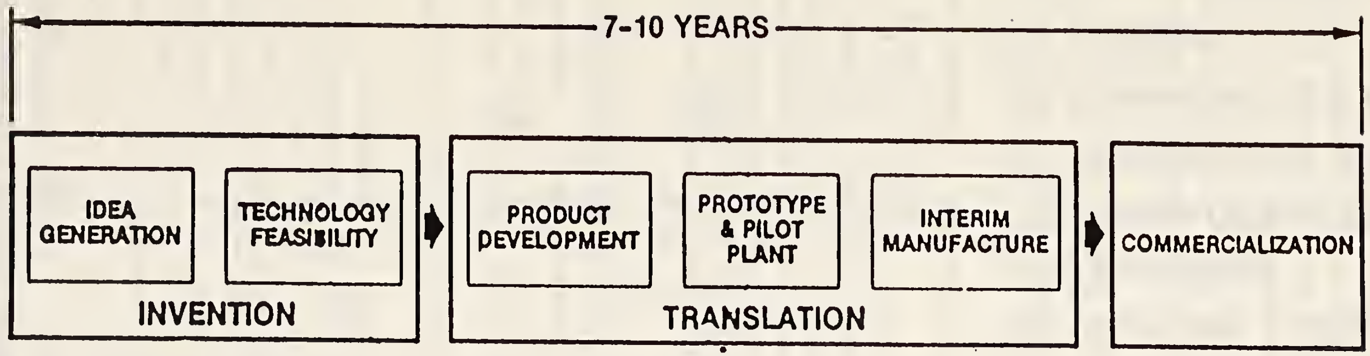
2. Assuming Item 1 leads to a recommendation to proceed, the interested/key CEO's would then meet under DOC auspices for final consensus building and implementation of the appropriate technique(s) for collaboration.

Acknowledgment

The significant help of Dr. V. J. Tennery (Oak Ridge National Laboratory), Dr. Robert Eagan (Sandia National Laboratory), Dr. Robert Gottschall (DOE), and Dr. Dale Niesz (Battelle/Columbus) in the facilitation and analysis of these workshop proceedings is acknowledged with pleasure and gratitude.

Reference

[1] D. Bruce Merrifield, "Forces of Change: Need for Innovative Action," Conference Proceedings, The New Climate for Joint Research, May 13, 1983, U.S. Department of Commerce--Office of the Assistant Secretary for Productivity, Technology and Innovation Publ. P12.

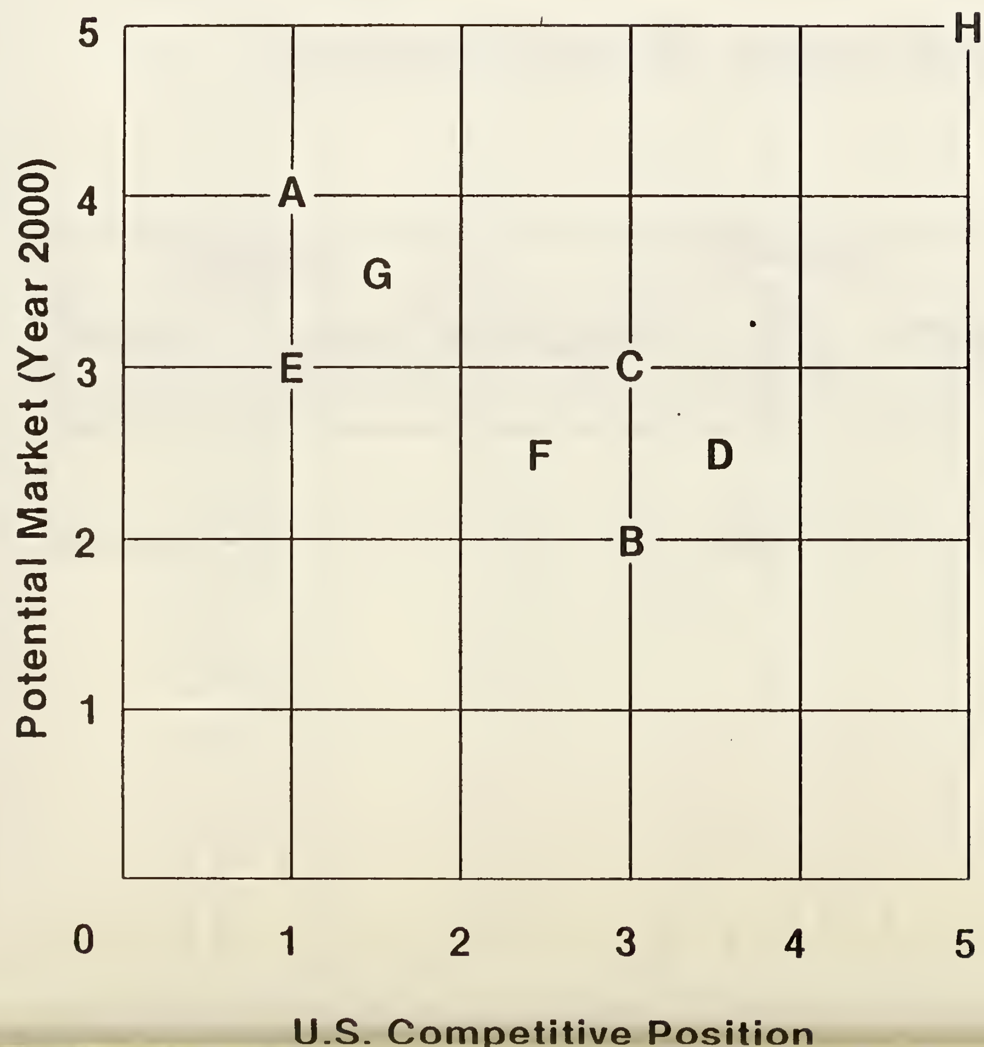


TECHNOLOGICAL INNOVATION

Figure 1

Figure 2

BUSINESS STATUS STRUCTURAL CERAMICS



Key:

A. Heat Engine Components
B. Cutting Tools/Dies
C. Bearings
D. Seals/Wear Parts
E. Substrates (Ex $Al_2 O_3$)
F. Powders (Ex $Al_2 O_3$)
G. Fibers
H. Armor/Military Applications

ELECTRONIC CERAMICS

Robert J. Stokes
Honeywell Physical Sciences Center

The largest single market for Advanced Ceramics is the electronics market which by various assessments is now as large as $8B worldwide with the potential to grow to $20B by the mid 1990's [1]. This market is taken to include the business associated with the processing, fabrication, and application of ceramics for the specific electrical, magnetic, and optical properties.

The subject is very diverse and the products associated with it range from the innovative to the mature. To put a boundary on the topics for consideration by this workshop, we discussed the following applications:

Insulators--Substrates, I.C. Packages, Microwave Dielectrics
Capacitors--Single layer, Multilayer
Ferroelectrics--Piezoelectrics, Pyroelectrics
Resistors--Resistors, Varistors, Thermistors
Electrolytes--Batteries
Sensors--Semiconductor Sensors, Electrochemical Sensors
Ferrites--Soft Recording Media, Hard Permanent Magnets
Optical Components--Optical Fibers, Electro-optic Devices

For each of these categories, the workshop attendees were asked to assess: the status of the technology; the business projection and U.S. competitive position, the advantages and best approach to cooperative industrial R&D.

Technical Status

Figure 1 is an attempt to place the various developments in Electronic Ceramics on a single plane. It recognizes the fact that in all cases (with two exceptions) electronic ceramics have reached the commercialization stage, but in each case there are new materials in earlier stages of development to meet evolving needs and new applications. Thus there is R&D activity throughout the spectrum from basic idea generation to prototype manufacture.

The technical deficiencies identified with these developments range from a lack of basic knowledge to reproducibility in the manufacturing process. They are presented in Table 1 with the scientific needs listed at the top and the manufacturing needs at the bottom. There is a common emphasis on research into new materials (based largely on the perovskite and spinel crystal structures);

processing of reliable high purity, well characterized materials; reproducible manufacturing; and the ability to market and evaluate prototypes.

Business Projection

Two parameters were used for this assessment, first the magnitude of the world wide market, and second the U.S. competitive ability to penetrate this market. Figure 2 is an attempt to present both of these parameters on a single plane. The scale for potential market is approximately logarithmic, the value 1 corresponds to about $10M per year and 5 to about $1B per year. Optical components were rated very high because of the substantial projections for optical fibers in the communication industry.

With respect to competitive position, the U.S. was judged to have an advantage in only two areas, the other eight were only average or below due chiefly to the Japanese dominance in the electronic ceramics industry. The Japanese advantage stems from substantial Government investment in R&D, particularly the synthesis, processing, and characterization of ceramic materials; long range industrial support for project development; and a sympathetic marketplace willing to accept and evaluate prototype materials and devices.

Cooperative Research and Development

The general consensus of the workshop was that an industrial cooperative enterprise is essential to maintain the present status and to establish a better competitive position. Each of the technical deficiencies summarized in Table 1 requires a different allocation of resources as indicated in Figure 3.

(1) The fundamental ceramic sciences need continued support through the Federal Government, particularly agencies such as the National Science Foundation where the emphasis is on a basic understanding of the principles involved in materials selection and processing. An important product of a strong university scientific research program is the flow of suitably trained graduates to staff the technology development programs aimed at commercial development.

(2) Generic research in ceramic processing is best conducted in a program requiring university-industrial cooperation. Penn State, Rutgers, and MIT are outstanding examples of multi-industrial sponsorship of university research. Although the style and emphasis of each affiliate program is

different, the financial commitment and participation by the industrial members in the selection of research topics is a key feature.

(3) It was the opinion of the attendees at the workshop that the most important need in electronic ceramics is a cooperative research and development effort on topics critical to product development and the manufacture of product prototypes. The objectives are very specific and timing is shorter than can be expected of university research. Such an effort is conducted best by an industrial consortium, of which MCC is an excellent example, wherein industrial participants work cooperatively to achieve common technology goals essential for prototype manufacture.

Points made in connection with a consortium for electronic ceramics research were

(a) An electronic ceramics consortium must not be isolated from a similar consortium envisaged for structural ceramics.

(b) Laboratory facilities for an electronic ceramics consortium should be located close to a national laboratory or major university strong in ceramic materials research.

(c) Electronic ceramic materials research at the stage of prototype development cannot be conducted in an isolated environment. It must be closely coordinated with and responsive to the needs of electronic engineering and manufacturing.

(4) The workshop also identified the need to achieve a fully competitive position to develop receptive markets in which prototypes could be evaluated. It was felt that such an activity was appropriate to the objectives of a consortium but needed coordination with the commercialization objectives of the newly formed United States Advanced Ceramics Association.

(5) Finally, it was recognized that in some instances highly specialized developments in advanced electronic ceramics require access to special facilities and expertise. To the extent that they exist, the industry is encouraged to draw on the resources in the National Laboratories.

TABLE 1

TECHNICAL DEFICIENCIES IN ELECTRONIC CERAMICS

Substrates/I.C. Packages	Capacitors/Ferroelectrics	Others	
o Fundamental Physical Property Measurements for Computer Aided Design	o Physics and Crystal Physics of High Permettivity Materials	o New Physical Phenomena	Basic Science
o New Materials - Low Dielectric Constant - High Thermal Conductivity	o Fine Powder Processing - Dopant Control - Thin Film Processing	o New Materials	Basic Science
o Effects of Processing Parameters	o Effects of Process Variables - Binder Removal - Microstructure Control	o Crystal Growth o Thin Films o Process Effects	Basic Science / Processing Science and Technology
o Characterization of Fired Surface - Chemistry - Roughness - Adhesion			Processing Science and Technology
o Interface Stability - Ceramic/Metal - Ceramic/Polymer	o Metal/Ceramic Interface - Delamination - Electrical Breakdown	o Sensor Specificity	Product Development
o Low Sintering Temp. Co-Fired Multilayer Ceramic - Cu metal compatible	o Base Metal Electroding - Firing Characteristics		Product Development
o Manufacturing Process Reproducibility - Quality Control Instrumentation			Prototype Manufacture
o Market Development - Prototype Evaluation - Security of Custom Packages	o Fragmented Market - Military Specifications - Low Cost Commercial	o Relatively Small Markets	Marketing

TABLE 2

COOPERATIVE R&D IN ELECTRONIC CERAMICS

Technology need	R&D mechanism
Basic science	Federally sponsored university research (e.g. NSF)
Generic research in ceramic processing	University/industry affiliates (e.g. Penn State, Rutgers, MIT)
Product development and prototype manufacture	Cooperative industrial consortium (e.g. MCC)
Market development	Trade association (e.g. USACA)
Special facilities	National laboratories (e.g. DOE Labs)

Acknowledgment

It is a pleasure to acknowledge the input of all the attendees at the Workshop. Special help was provided by Dr. James Heasley, Ferro Corporation, Dr. David Johnson, Jr., AT&T Bell Laboratories, Mr. James Wade, Coors Porcelain Co., in organizing the workshop.

Reference

[1] "A Competitive Assessment of the U.S. Advanced Ceramics Industry"--U.S. Department of Commerce, March 1984. NTIS Accession Number PB84-162288.

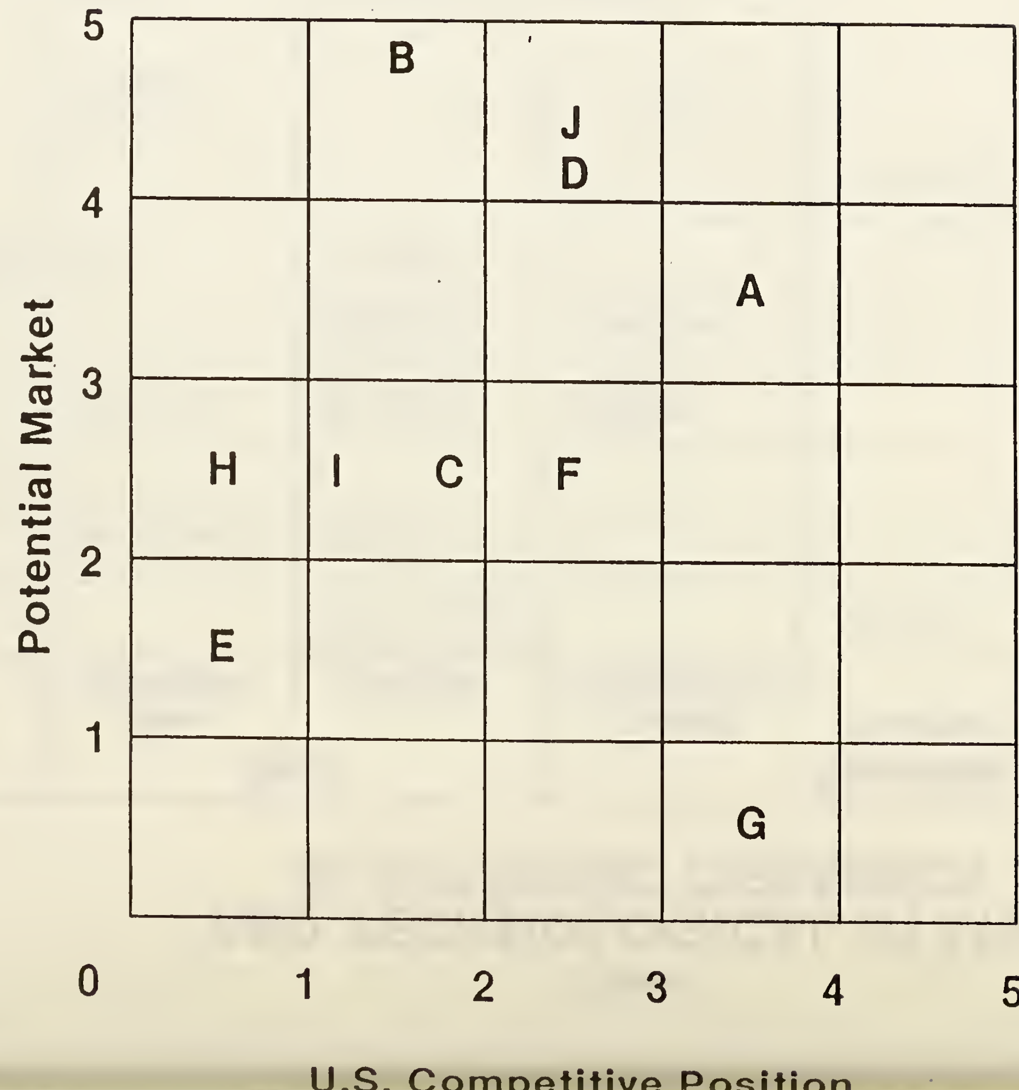
Figure 1

R&D TECHNOLOGICAL STATUS ELECTRONIC CERAMICS

	Basic		Translation			Commercialization
	Idea Generation	Feasibility	Product Development	Prototype	Interim Manufacture	
A. Substrates		·SiC:BeO ·AlN ·Cord., Mullite		·Mullite		·Al_2O_3 ·BeO ·Porcelain/Steel
B. I.C. Packages	·Low K, High f	·Composites			·Multi Layer Cofired	·Cerdip ·Custom IC's
C. Microwave Dielectrics						·$ZrTiO_4$ ·$BaTiO_3$
D. Capacitors	·Multi Layer	·New Relaxor Materials	·Boundary Layer		·High K, Low Fire Relaxors ·Base Metal (Ni)	·$BaTiO_3$
E. Piezoelectrics		·Multi Layer Composites	·Composites			·PZT ·$PbZrO_3$ ·$BaTiO_3$
F. Resistors, Varistors, Thermistors	·SiC	·TiO_2:Nb_2O_5				·ZnO ·$BaTiO_3$ ·Ruthenates ·Ink
G. Electrolytes			←——	β-Al_2O_3	——→	
H. Sensors	·Ceramics/ Polymers	←——	Fibers ——→			·ZrO_2 ·SnO
I. Ferrites						·NiZn Ferrites ·Ba Ferrites
J. Optical Components	·Storage Materials	·Flouride Fibers ·KTP	·$LiNbO_3$:Ti ·PLZT Fibers			·Optical Fibers ·PLZT

Figure 2

BUSINESS STATUS
ELECTRONIC CERAMICS



Key:

A. Substrates
B. I.C. Packages
C. Microwave Dielectrics
D. Capacitors
E. Piezoelectrics
F. Resistors, Varistors, Thermistors
G. Electrolytes
H. Sensors
I. Ferrites
J. Optical Components

Figure 3

COOPERATIVE R&D FOR ELECTRONIC CERAMICS

	Cooperation Needed?		Cooperative R&D Mechanism				
	Yes	No	Industry Assoc.	Multiclient: Univ.&Non-Profit	Industry-Univ.-State	Industry-Industry	Industry-Federal
			★ EPRI	★ MIT, Battelle	★ Rutgers	★ MCC, SRC	★ U.S. Steel-DOE
A. Substrates		X					
B. I.C. Packages	X					X	
C. Microwave Dielectrics	?					X	
D. Capacitors	X			X		X	
E. Piezoelectrics	?					X	
F. Resistors, Varistors, Thermistors	?					X	
G. Electrolytes	?					X	
H. Sensors	?					X	
I. Ferrites	?					X	
J. Optical Components	X				X	X	
			★ Examples				

SESSION V: A NATIONAL AGENDA-- CONSENSUS VIEWS

A NATIONAL AGENDA FOR ADVANCED CERAMICS: CONSENSUS VIEWS

Richard M. Spriggs
National Materials Advisory Board
National Academy of Sciences

The task of the final session of the Conference is to synthesize the findings of the two workshops on Structural Ceramics and Electronic Ceramics and to develop approaches for future actions that will lead to an optimization of the growth, productivity, and competitiveness of the U.S. Advanced Ceramics Industry--in essence, to attempt to provide a National Agenda for Advanced Ceramics--A Call to Action.

While some may view such an objective as overly ambitious, others are convinced that great strides can be made toward the basis for such an Agenda. The importance of this endeavor cannot be underestimated because if this group does not, there is no assurance that anyone else will do so. Partial success may already be claimed on at least two counts: (1) the participants to this Conference have been usefully exposed to the challenge, and attendant changes in attitude have already occurred, and (2) the newly conceived U.S. Advanced Ceramics Association has used the occasion of this Conference to finalize its charter organization.

Thus, in this session, time will be allowed for individual review of the two workshop summaries, for summarizing remarks by the two workshop chairmen, and for general discussion that will lead to any consensus views and conclusions as to the next steps toward implementation, i.e. to fashion a National Agenda for Advanced Ceramics.

By way of a preface, it could be reiterated that concerns for the threat to the U.S. advanced ceramics industry posed by foreign competition, especially from Japan, have been increasingly voiced by spokesmen of the field, initially, for example, by H.K. Bowen of MIT, and convincingly by A.R.C. Westwood of Martin Marietta in yesterday morning's industrial overview/keynote talk. Both spokesmen served on a recent National Materials Advisory Board Committee, chaired by Dr. Westwood, whose report, High Technology Ceramics in Japan, reported on the nature and extent of Japan's commitment to high-technology ceramics.

A similar commitment by the United States, it is felt, has heretofore been lacking. However, promising signs have recently been noted, e.g. conferences such as this one, workshops, a host of technical and economic articles, new and enlarged individual corporate commitments by U.S. industrial firms, the establishment of academic centers of excellence fostering industry-university-government relations and cooperative research in ceramics, and the very recent formation of the U.S. Advanced Ceramics Association.

Describing the period we are entering as the New Era of Ceramics, this author has called for the establishment of new cooperative research organizations, ones of which might be known, for example, as the American Corporation for Engineering Research on Advanced Materials, Including Ceramic Structures, i.e. American CERAMICS, Inc. The recent enactment of the National Cooperative Research Act of 1984 would facilitate the establishment of cooperative R&D ventures in advanced ceramics among domestic firms. Such ventures would appear to be a principal vehicle by which American industry can close those technology gaps that exist and can improve U.S. competitiveness.

Ezra Vogel, author of a previous book, "Japan as Number One," in his 1985 book, "Comeback," identifies the common elements for an "American-style competitive strategy" and asserts that "... to deal with complex issues that require national coordination, there is no alternative to developing a selective industry strategy." Advanced ceramics would appear to be such a selective industry deserving of its own strategy.

In a related vein; a recent editorial (Research and Development, July 1985) called for a new national pastime for the United States, competition--competition in world markets in ways that this nation never has competed in the past. Again, advanced ceramics represents such a world market.

One could easily develop a rationale for a national commitment in advanced ceramics,

- The markets are large and growing at significant rates
- Foreign competition and market share presently predominate
- U.S. efforts have heretofore been disaggregated
- There are deficiencies in the current approach
- An industrial focus is needed.

What are the major pathways to such a commitment? These can be identified:

- Industrial promotion and support
- Optimized technical directions (focused R&D, enhanced manpower training, effective information systems and technology transfer), and
- Cooperative research (industry/industry, industry/university, industry/government)

Ideally, the next steps of this Conference would be to reach a consensus on organization and to develop an action plan.

A summarization and general Conference discussion of the workshop summaries on structural and electronic ceramics has led to a general consensus for a strong need for cooperative industrial R&D in identified high-market potential areas, e.g. heat engine ceramics, capacitors, optical components, integrated circuit packages, etc.

The concept was put forth in Session V of this conference for an Advanced Manufacturing Development and Engineering Center (AMDEC), which would operate both core programs and member/user programs employing an automated and highly flexible pilot manufacturing line. One or more such centers, regionally located--perhaps at national laboratories, operated by an industrial cooperative, and with university affiliation, and federal and state government advisory assistance, were envisioned.

In similar fashion, some form or forms of cooperative R&D were also envisioned in several areas of electronic ceramics, especially capacitors, optical components, and I.C. packages. Industry/industry cooperation is needed for technology/product development; university/industry affiliations are required for basic research in processing, and industry/federal laboratories interactions were stressed for special facilities and expertise.

Based on the above consensus, it was recommended that the assistance of the Department of Commerce be sought to convene a meeting of an Advanced Ceramics Industrial Steering Committee. This Committee would be requested to evaluate the recommendations of this Conference, with the committee's conclusions and recommended actions being reported back to industrial chief executives and corporate decision makers, and shared with high-level executive offices, e.g. the Office of Science and Technology of the President, and ultimately result in consensus building and action to create one or more cooperative generic Research and Development Centers for Advanced Ceramics. (Attached is (1) a copy of the letter drafted by the Session V panelists and sent to the Department of Commerce on August 12, 1985 and (2) the reply letter from DOC.)

Attachment: August 12, 1985 letter to D. Bruce Merrifield, DOC; October 31, 1985 letter to Richard Spriggs, Robert Stokes and Joseph Panzarino

August 12, 1985

The Honorable D. Bruce Merrifield
Assistant Secretary for Productivity,
Technology and Innovation
U.S. Department of Commerce
Room 4824, H. C. Hoover Building
Washington, D.C. 20230

Dear Dr. Merrifield:

We are writing to request your concurrence and good offices in convening a meeting of an Advanced Ceramics Industrial Steering Committee.

The purpose of this Committee would be to build on the work of the Conference and Workshop sponsored by your office and the National Bureau of Standards on "A National Prospectus on the Future of the U.S. Advanced Ceramics Industry," and held at NBS on July 10-11th.

This Conference, attended by well over 100 representatives of the U.S. advanced ceramics industry, as well as representatives from universities and government agencies, revealed considerable interest in such an action as the next step in a series that could ultimately lead to one or more industry-industry cooperative research ventures under the rubric of the National Cooperative Research Act of 1984.

As you are aware, representatives from ceramic-producing and user firms met to assess the competitiveness of U.S. structural and electronics advanced ceramics industries and to discuss the types of cooperative research programs that would be needed to improve U.S. competitiveness. A high degree of interest was expressed in undertaking cooperative research. The Conference also provided an excellent opportunity to exchange views on how government and academia might be supportive of industrial efforts in this vitally important and essential area. Copies of the Workshop summaries are enclosed for your information.

It is envisioned that this Steering Committee would review the Conference findings and discuss and recommend the next steps that might be taken by high-level corporate planners and decision makers to bring about one or more cooperative research ventures under the 1984 Act, embracing generic research in both structural and electronic ceramics.

We would greatly appreciate the active involvement of your office in facilitating the convocation of such a Steering Committee. The membership of this Committee is now being established, and this information will be sent to you and your staff. As representatives of the Conference, we stand ready to share the findings of the Conference with the Steering Committee, but we recognize that we, personally, may or may not participate in the Steering Committee, depending upon the wishes of industry.

Thank you for your interest and anticipated assistance.

Sincerely,

Joseph N. Panzarino
Director of Research
High Performance Ceramics Division
Norton Company

Robert J. Stokes
Principal Staff Scientist
Physical Sciences Center
Honeywell, Inc.

Richard M. Spriggs
Senior Staff Officer
National Materials Advisory Board
National Research Council

Enclosures

UNITED STATES DEPARTMENT OF COMMERCE
The Assistant Secretary for Productivity,
Technology and Innovation
Washington, D.C. 20230

(202) 377-1984

OCT 11 1985

Dr. Richard M. Spriggs
Senior Staff Officer
National Materials Advisory Board
2101 Constitution Avenue, N.W.
Washington, D.C. 20418

Dear Dr. Spriggs:

I've very pleased that you are taking the initiative to follow up the excellent work accomplished at the July Conference at the National Bureau of Standards. Your participation contributed a great deal to the success of the conference and I believe your idea of forming an Industrial Steering Committee as a next step is an excellent one.

We will be glad to work with you to foster a continuing dialogue within the ceramics industry, including hosting a meeting of the Industrial Steering Committee. Let me or Lanse Felker know when you are ready and don't hesitate to ask if there is anything else we can do to assist you.

Sincerely,

D. Bruce Merrifield

Original letters sent to:

Dr. Joseph N. Panzarino
Dr. Robert J. Stokes

APPENDIX

CONFERENCE PROGRAM

Tuesday, July 9

7:00 p.m. Early Registration and Mixer
Gaithersburg Marriott Hotel

Wednesday, July 10

8:00 a.m. Registration
Green Auditorium
National Bureau of Standards

I OVERVIEW

Session Chairman:
D. Bruce Merrifield
Assistant Secretary for Productivity, Technology and Innovation
Department of Commerce

8:45 **Welcome**
Ernest Ambler
Director, National Bureau of Standards

8:50 **Conference Goals**
D. Bruce Merrifield
Assistant Secretary for Productivity, Technology and Innovation

9:00 **Advanced Materials in the National Economy**
Honorable Don Ritter (R-PA)
U.S. House of Representatives

9:40 **Advanced Ceramics: Challenges and Opportunities for U.S. Industry**
Albert R.C. Westwood
Corporate Director - Research and Development
Martin Marietta Corporation

10:20 Break

II INFORMATION BASE

Session Chairman:
Lyle H. Schwartz
Director, Center for Materials Science
National Bureau of Standards

10:45 **U.S. Competitive Position**
Michael T. Kelley
Deputy Assistant Secretary for Basic Industries
International Trade Administration
Department of Commerce

11:15 **Technological and Economic Assessments**
S.L. Blum
Vice President
Charles River Associates, Inc.

11:45 **Market Opportunities**
Julius Harwood
President
Ovonic Synthetic Materials Co.

III COOPERATIVE MECHANISMS AND RESPONSE

Session Chairman:
Egils Milbergs
Deputy Assistant Secretary for Productivity, Technology and Innovation
Department of Commerce

1:15 Forces of Change in the Industrial Sector
D. Bruce Merrifield
Assistant Secretary for Productivity, Technology and Innovation
Department of Commerce

1:45 **Forms of Industrial Cooperation: Case Studies**
Lansing R. Felker
Director, Industrial Technology Partnerships Program
Department of Commerce

2:15 **Industry/University Interactions**
John B. Wachtman, Jr.
Director, Center for Ceramics Research
The Rutgers State University

2:45 Industry/Government Interactions
Ora E. Smith
Senior Policy Analyst
Office of Science and Technology Policy

3:15 Break - reconvene for individual workshops

IV CONCURRENT WORKSHOPS ON INDUSTRIAL COOPERATION

3:30 Workshop #1 on Structural Ceramics
Chairman:
Joseph N. Panzarino
Director of Research
High Performance Ceramics Division
Norton Company

Workshop #2 on Electronic Ceramics
Chairman:
Robert J. Stokes
Principal Staff Scientist
Honeywell, Physical Sciences Center

5:30 Adjourn

7:30 Buffet Dinner
Gaithersburg Marriott Hotel

Thursday, July 11

V A NATIONAL AGENDA FOR ADVANCED CERAMICS

Chairman:
Richard M. Spriggs
Senior Staff Officer
National Materials Advisory Board

Panel Members:
Joseph N. Panzarino
Director of Research
High Performance Ceramics Division
Norton Company

Robert J. Stokes
Principal Staff Scientist
Honeywell, Physical Sciences Center

Lansing R. Felker
Director, Industrial Technology Partnerships Program
Department of Commerce

9:00 a.m. Reconvene; individual review of summary workshop statements

10:00 **Summary Remarks**
Workshop Chairmen

10:30 **General Discussion**

11:30 **Consensus Views and the Next Steps**
Panel Members

12:30 p.m. Lunch

1:30 Depart, or NBS Ceramic Laboratory Tours

BACKGROUND REPORTS

The following publications and documentation were provided to participants of the conference as being especially pertinent to the subject of the meeting:

The New Climate for Joint Research, Conference Proceedings, May 13, 1983. Sponsored by U.S. Department of Commerce, Office of the Assistant Secretary for Productivity, Technology and Innovation (1984).

Lansing Felker, Cooperative Industrial R&D: Funding the Innovation Gap, Bell Atlantic Quarterly I, No. 2, Winter (1984).

Large Scale Industrial Partnerships, U.S. Department of Commerce brochure prepared by the Office of Productivity, Technology and Innovation, (1984).

National Cooperative Resarch Act of 1984, Public Law 98-462, 98th Congress.

A Competitive Assessment of the U.S. Advanced Ceramics Industry, Industry Analysis Division, Office of Industry Assessment, Assistant Secretary for Trade Development, U.S. Department of Commerce, March (1984), NTIS Assession Number PB84-162288.

Technological and Economic Assessment of Advanced Ceramic Materials, Vol. I-VI, Prepared by Charles River Associated, Inc., August (1984); available NTIS-No NBS GCR 84-470-(1-6).

ERNEST AMBLER

Ernest Ambler is the eighth Director of the National Bureau of Standards. He joined NBS in 1953 and has worked throughout his career to make NBS an increasingly valuable scientific and technical resource for industry, business, government, education, and the public. As Director of NBS, Dr. Ambler leads the Nation's measurement Laboratory in the physical sciences and engineering. As a scientist, he has contributed directly to the state-of-the-art in measurement technology. His expertise in nuclear physics and cryogenics formed the basis in 1956 for a cooperative effort that disproved the law of parity conservation, a concept that nuclear scientists had adhered to for more than 30 years. This pioneering project confirmed experimentally the theoretical work of Nobel Prize winners T.D. Lee and C.N. Yang. As an administrator, Dr. Ambler has helped guide Bureau operations and policies to improve the efficiency with which NBS fulfills its mission. Dr. Ambler is a member of the American Association for the Advancement of Science, a fellow of the American Physical Society, and as Director of NBS, is ex officio President of the National Conference on Weights and Measures. He was commissioned by the Governor of Maryland in 1983 to serve on Maryland's High Technology Round-table. Dr. Ambler is the recipient of numerous honors, awards, and fellowships including: the Department of Commerce Gold Medal, the NBS Stratton Award, Nuffield Fellow of Oxford University, the John Simon Guggenheim Memorial Foundation Fellowship Award, the John Price Wetherill Medal of the Franklin Institute, the Washington Academy of Sciences Award, the Arthur S. Flemming Award, the William A. Wildhack Award, and the President's Award for Distinquished Federal Civilian Service. He authored 52 publications and holds a patent for low temperature refrigeration apparatus and processes.

Born in Bradford, Yorkshire, England, in 1923, Dr. Ambler earned his B.A., M.A., and Ph.D. in physics at Oxford University before coming to the National Bureau of Standards.

S.L. BLUM

S.L. Blum is Vice President at Charles River Associates. He has served as Vice President of Northern Energy Corporation and as Director of Advanced Planning at the MITRE Corporation. Prior to that he was Vice President of ITT Research Institute and Manager of Advanced Materials at Raytheon. He received his B.S. from Alfred University in ceramic engineering and his ScD. in ceramics from MIT.

He is now a Commissioner on the Commission for Engineering and Technical Systems of the National Academy of Science and Engineering and has served as Chairman of the National Materials Advisory Board of the National Academy of Science and Engineering. He has been on the Materials Board of the Office of Technology Assessment of the U.S. Congress, and the Visiting Committee of both MIT and ITT. He was a founder of the Electronics Division of the American Ceramic Society and served as chairman of various committees and as Vice President of the Society. Dr. Blum is well known in the ceramics industry and has about 35 years experience in technology, business and planning in the materials area. His experience ranges from research and development to plant operation and product market analysis. He has worked in electronic ceramics refractories, glass and advanced ceramics and has set up laboratories and ceramic production lines.

LANSING R. FELKER

Lansing R. Felker is currently Director of the Industrial Technology Partnerships Program, of the Office of Productivity, Technology and Innovation, U.S. Department of Commerce. Prior to this, he has had broad experience in Government: as a budget examiner in the Military Division of the Office of Management and Budget; as International Logistics Negotiator for the Office of the Secretary of Defense (where he focused on the export of aerospace equipment); as an international trade specialist for the Department of Commerce; and as a policy analyst in the Department of Energy. Outside the Government, he was an investment adviser to Wall Street for a number of years.

Mr. Felker was educated at the University of Chicago where he took his Bachelor's and Master's degrees, the latter in political science, specializing in military strategy and foreign policy. He is an ex-Naval Aviator.

JULIUS J. HARWOOD

Julius J. Harwood is Vice President of Energy Conversion Devices, Inc., and President of Ovonic Synthetic Materials Co.

He retired from Ford Motor Company at the end of 1983 as Director, Materials Sciences Laboratory, Research Staff, which he occupied since 1975. Prior to that he was Director, Physical Sciences; Manager, Research Planning; Assistant Director, Materials Sciences; and Manager of the Metallurgy Department with the Ford Research Laboratories. Before joining Ford in 1960, he was associated with the Office of

Naval Research as Head of its Metallurgy Branch, and with leaving ONR for Ford, the Advanced Research Projects Agency (DOD).

Mr. Harwood is a Fellow of the American Society for Metals, the Metallurgical Society of AIME, the AAAS, and the Engineering Society of Detroit. He served as President of the Metallurgical Society, President of the American Institute of Mining, Metallurgical, and Petroleum Engineers, and a past member of the Board of Directors of AIME. He has published over 70 articles and is the editor of 5 books in the field of materials management research.

Mr. Harwood is a member (and past Chairman) of the Board of Control of Michigan Technological University. He serves as a Professor of the Engineering faculty of Wayne State University and is a Chairman of the Board of Visitors to the Engineering College of R.P.I. In the past he served on Engineering Advisory Committees to the University of Pittsburgh, Carnegie Tech., Vanderbilt, M.I.T., and Pennsylvania.

Mr. Harwood was elected a member of the National Academy of Engineering in 1977. He was (1977-1979) Chairman of the National Materials Advisory Board. He also serves on the Science Advisory Council for the College of the City of New York. He was a member of the first metallurgical exchange delegation with the People's Republic of China (sponsored by AIME).

MICHAEL T. KELLEY

Michael T. Kelley is currently Deputy Assistant Secretary of Commerce for Basic Industries. Prior to this Mr. Kelley served as an Expert Consultant to the Assistant Secretary of Commerce for International Trade Development. Before joining the Department of Commerce, he served as Deputy Assistant Secretary in the Office of Congressional Affairs, U.S. Department of Energy (DOE), having responsibility for coordinating relations between DOE and the Congress.

Earlier, Mr. Kelley was Assistant to the Chairman for Government Affairs of the Houston Natural Gas Corporation. He has had extensive government relations experience with a number of corporate firms in Washington, DC. In addition to his work with the Houston Natural Gas Corporation, he worked for the Union Camp Corporation, the Babcock Wilcox Company, and as staff assistant to Rep. Silvio O. Conte (R-MA). Mr. Kelley received a B.A. in American History from Fairfield University in Fairfield, Connecticut, and he has done advanced degree work in U.S. diplomatic history at Georgetown University. He is married with two children and resides in McLean, Virginia.

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D. Bruce Merrifield is currently Assistant Secretary of Commerce for Productivity, Technology and Innovation. Most recently, he was Vice President of Technology and Venture Management for The Continental Group. He is a former Director and President-elect of The Industrial Research Institute; he also has been Chairman of the Board of the IRI Research Corporation and is a former Trustee and Chairman of the Research Council of The American Management Association. Currently, he is a member of The Directors of Industrial Research, and a Fellow of both The American Association for Advancement of Science and of The Institute of Chemists.

Dr. Merrifield also has been a member of the Advisory Board for the Binational Research and Development Foundation with Israel and of the U.S. Department of Commerce's Trade Mission to the People's Republic of China. He has served as a Science Advisor to the Jordanian government and as a member of the Department of Defense transition teams. Dr. Merrifield is a graduate of Princeton University and holds Master and Doctoral degrees in Physical Organic Chemistry from the University of Chicago.

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Before joining the DOC, Mr. Milbergs was employed by SRI International (formerly Stanford Research Institute) where he managed research and consulting programs in science and technology policy, commercialization of federally-funded R&D, and the strategic business environment. He led a major study of "Issues of the Eighties," and developed a nationally recognized presentation on the future business environment.

Prior to this, Mr. Milbergs served as a program and management analyst with the Office of Management and Budget and the President's Advisory Council on Executive Organization (Ash Council) to develop proposals for reorganizing economic, trade and regulatory functions. Mr. Milbergs received his degree from Harvard University where he studied public policy and economics. He is also a member of numerous organizations including the National Advisory Council on Continuing Education and the National Conference for the Advancement of Research.

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Joseph N. Panzarino is Director of Research and Development, High Performance Ceramics at the Norton Company. He received his B.S. from the U.S. Naval Academy in Electrical/Mechanical Engineering in 1958, and he received his Ph.D. from Ohio State University in Ceramic Engineering in 1967.

Prior to joining Norton Company, he held vaios positios with Corning Glass Works involving research on electronic materials, glass/ceramic materials, bio-ceramic materials, coatings, strengthening mechanisms.

He is a member of the American Ceramic Society, National Institute of Ceramic Engineers, and Society of Sigma Xi and has 7 publications and 10 patents.

DON RITTER

Don Ritter, first elected in 1978, is serving his fourth term in the U.S. House of Representatives, in which he represents Pennsylvania's 15th District.

He earned his master's and doctor of science degrees from the Massachusetts Institute of Technology, and his bachelor of science degree from Lehigh University, Bethlehem, PA. Before coming to Congress, he taught at Lehigh University and later managed the development of new research programs there.

Ritter belongs to the American Society for Metals (ASM), the American Institute of Chemists (AIC), and the National Society of Professional Engineers (NSPE). He was chosen in 1983 to receive the ASM's Distinguished Life Membership award and was named to the AIC honor scroll. In 1981 Ritter presented the Roy V. Wright lecture of the ASME. Ritter also is a member of the honorary societies Sigma Xi Tau Beta Pi and also is ex officio member of the board of associates of Muhlenberg College, and MIT's Political Science Visiting Committee.

Ritter serves on the House energy and Commerce Committee and two of its subcommittees: Commerce, Transportation and Tourism, and Energy Conservation and Power. He is the author of nationally-recognized legislation in the area of regulatory reform. Ritter serves on the executive committee of the House Steel Caucus and the steering committees of the House Travel and Tourism Caucus and the House Textile Caucus. He is a member of the American Security Council.

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In 1980 and 1982 the National Alliance of Senior Citizens inducted him into the Golden Age Hall of Fame for "concern, compassion and understanding of the unique problems of America's senior community." He is also a member of the American Association of Retired Persons.

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Samuel J. Schneider is Special Assistant to the Director, Institute for Materials Science and Engineering, National Bureau of Standards. He received a B.S. Degree and a (honorary) Professional Degree both in ceramic engineering from the University of Missouri at Rolla. His professional career began as a research engineer at Laclede-Christy Refractories Co. Following U.S. Army Service, he joined the National Bureau of Standards as a research chemist (ceramics) where he has worked on the phase equilibria and chemistry of refractory materials and on the techniques of measurement of high temperature materials. Before his present position, Mr. Schneider was Deputy Chief of the Inorganic Materials Division, NBS. He has served on many national and international committees and task forces, especially concerned with the behavior of refractories in energy applications. Mr. Schneider, a member of the American Ceramic Society, Keramos, NICE, and ASTM, has been the editor of two books, has organized 10 international conferences and has more than 50 technical publications and 40 invited lectures to his credit. He received the Department of Commerce Silver Medal Award, four NBS Special Achievement Awards, the ASTM Award of Merit, and the American Ceramic Society Refractories Award.

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Dr. Spriggs is the author or co-author of over 75 technical articles that have appeared in domestic and international periodicals, including chapters in ten books. In addition, he is co-recipient of three U.S. patents. He received his

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Dr. Spriggs is a Fellow of the American Ceramic Society and is currently serving as Immediate Past President of the Society. He is also past Vice President and former Treasurer of the Society and is a member of NICE and CEC. He is a former chairman and trustee of the Basic Science Division. He received the Ross Coffin Purdy Award of the Society in 1967 and the Hobart M. Kraner Award of the Lehigh Valley Section of the Society in 1980. Dr. Spriggs is also a Fellow of the (British) Institute of Ceramics, a former Trustee of the Federation of Materials Societies, and elect member of the International Institute for the Science of Sintering.

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Robert J. Stokes is Principal Staff Scientist in Honeywell's Physical Sciences Center, Bloomington, Minnesota. Dr. Stokes is responsible for diverse research on the behavior of materials in electronic and electro-optical devices.

From 1982 to 1984, as Section Head of the Materials Research Laboratory Section, Division of Materials Research, National Science Foundation, he was responsible for management of a large national research effort at fourteen major universities and four national research facilities. From 1977 to 1981, as Manager, Materials and Processes Department, Honeywell Corporate Technology Center, Dr. Stokes was responsible for materials--micropackaging, infrared optical materials, the electrochemistry of materials--energy storage, mechanical properties--electronic ceramics and the development of characterization tools for surface analysis.

From 1967 to 1977, as a Manager of the Materials Science Department at the Honeywell Corporate Research Center, he was responsible for research on projects on crystal growth, ceramic fabrication an the magnetic, mechanical, electrical and optical properties of materials.

Dr. Stokes joined the Honeywell Corporate Research Center in 1957. At that time he performed basic research studies on the mechanical properties of crystalline solids with emphasis.

In recognition of his outstanding contributions to ceramic science, Dr. Stokes received the Ross Coffin Purdy Award of the American Ceramic Society in 1965, and the H.W. Sweatt Award from Honeywell in 1967. In 1968 he was elected a Fellow of the American Ceramic Society. He has been named Sosman Memorial Lecturer, American Ceramic Society, 1976.

He has served as Editorial Chairman, Basic Science Division of the American Ceramic Society. He has served as Chairman, National Academy of Sciences Evaluation Panel for the Inorganic Materials Division, National Bureau of Standards and has served as a member of the NSF Advisory Committee for Materials Research. He is presently Co-Chairman of the Department of Energy Group on Future Directions for Structural Ceramics Research. He is Co-Chairman of the 1985 Materials Research Society Conference on Inorganic Materials. He is widely recognized as an authority on the mechanical and physical properties of ceramics and is frequently invited to present papers and seminars. He is the author of 60 publications.

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ALBERT R.C. WESTWOOD

Albert R.C. Westwood is Corporate Director--Research and Development for Martin Marietta Corporation. He received his B.Sc., Ph.D. and D.Sc. degrees from the University of Birmingham, England. He joined Martin Marietta Laboratories (then RIAS) in 1958, becoming its Director in 1974 and assuming his present position in January 1984. He has published well over 100 technical papers, mostly concerned with environment-sensitive mechanical behavior and, lately, R&D management, and has presented numerous keynote and invited lectures around the world. His scientific contributions have been recognized by a variety of awards and Fellowships, including the Beilby Gold Medal (1970) and election to the National Academy of Engineering (NAE) (1980). Current professional responsibilities include the Commission on Engi-

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11. ABSTRACT (A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here)

Advanced ceramics are a new generation of high performance materials, widely believed to hold promise of multi-billion dollar markets. The U.S. competitive position, however, has been eroded in recent years with the prognosis for the future equally dim. To address this problem, the Department of Commerce held an industrially oriented conference, July 10-11, 1985, at which leaders in the ceramic field assessed critical competitive issues from both a technological and business viewpoint and developed approaches for improved U.S. market posture. The Conference considered electronic and structural advanced ceramic markets, with focus on cooperative mechanisms for industrial R&D. A consensus was reached on the most critical areas for research and on the necessity for inter-and intra-industrial collaboration. Assistance from DOC was requested to facilitate the implementation of cooperative research ventures. This report constitutes the Proceedings of the Conference and includes the papers presented and summary of the workshop sessions.

12. KEY WORDS (Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons)

Advanced ceramics; Ceramic markets; Cooperative Industrial R&D; Cooperative research Act of 1984; Electronic ceramics; Foreign competition; Structural ceramics

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