A National Building Research Agenda: Starting the Process: Report of a Workshop (1988)

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Starting the Process

Report of a Workshop

Committee on a National Research Agenda
Building Research Board
Commission on Engineering and Technical Systems
National Research Council

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This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

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This report was prepared as part of the technical program of the Federal Construction Council (FCC). The FCC is a continuing activity of the Building Research Board, which is a unit of the Commission on Engineering and Technical Systems of the National Research Council. The purpose of the FCC is to promote cooperation among federal construction agencies and between such agencies and other elements of the building community in addressing technical issues of mutual concern. The FCC program is supported by 14 federal agencies: the Department of the Air Force, the Department of the Army, the Department of Commerce, the Department of Energy, the Department of the Navy, the Department of State, the General Services Administration, the National Aeronautics and Space Administration, the National Endowment for the Arts, the National Science Foundation, the U.S. Postal Service, the U.S. Public Health Service, the Smithsonian Institution, and the Veterans Administration.

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PREFACE

The United States has produced the world's greatest built environment, yet as we look toward the 21st century we see substantial challenges for our buildings and our infrastructure. If our future buildings are to contribute most effectively to a productive economy and enhanced quality of life of our citizens, we must strive to assure that our future design and construction actions serve well the changing needs of building users in the United States.

The Building Research Board is mindful of the important role that construction and buildings play in our economy and in our daily lives, and of how poorly this role is perceived by many of our fellow citizens and our leaders. Nevertheless we are heartened by the signs that change may be occurring, that people are becoming increasingly aware of their built environment and of the costs and consequences when that environment fails to meet the demands of our evolving society. While building research is only one of many elements that influence the capabilities of our building industry to meet our demands, it is an important one that needs greater national support.

This report presents the recommendations of a workshop that may be an early step toward building that support and assuring that the building research community responds effectively to that support.

Ross B. Corotis
Chairman, Committee on
A National Building Research Agenda

EXECUTIVE SUMMARY

Social, economic, and technological trends in the United States are likely to have profound impact on the nature of the services that buildings in the 21st century are called upon to provide. Well-directed research, effectively implemented, can make important contributions to the ability of the nation's construction industry to meet future demands for buildings, but mutual understanding is needed, among researchers and users of research results, regarding the opportunities and limitations of this contribution. Needed also is a substantially enhanced national commitment to conduct research in those areas most likely to yield positive results. A national building research agenda can help to meet those needs. However, a single agenda document can only temporarily reflect the diverse interests within the communities of building producers and users, and the consensus among those interests that is achieved in determining what specific research is to be undertaken.

Hence, in December 1987, 51 senior decision makers representing government, private sector, and professional organizations concerned with the future of the design construction and operation of buildings in the United States were invited by the Building Reserch Board to discuss the state of building research and its contribution to the goal of achieving better buildings for the 21st century (chapter 1). Workshop participants gathered in Washington, D.C. to address themselves to the process that can produce an agenda and maintain the agenda's currency and relevance.

Workshop attendees agreed that the process should embrace broad participation by building users and producers, representing both the myriad of special interests that characterize the nation's building industry and the common public interest (chapter 2). There was consensus that a permanent organizational focus is needed--a secretariat--within an existing institution or a new independent unit, to support and coordinate the process. Formal involvement of the building industry would assure that funds provided by research sponsors are directed to promising research areas. Experienced researchers would oversee the implementation of research projects to be undertaken by qualified private academic or government research organizations (chapter 3).

Workshop attendees recognized the challenges of establishing such an organizational focus and that a number of questions remain to be answered. The attendees proposed that the process should start with a national symposium to continue the workshop's discussions (chapter 4). This symposium would be the forum for developing goals for a national

building research program and the means for attracting broad national support for this program. The workshop attendees agreed that the symposium and the process for agenda building will yield valuable results for the nation.

INTRODUCTION

In December 1987, 51 senior decision makers representing government, private sector, and professional organizations concerned with the future of building and buildings in the United States gathered in Washington, D.C., to discuss the state of building research and its contribution to the goal of achieving better buildings for the 21st century. Hosted by the National Research Council's Building Research Board (BRB), these decision makers in the course of a two-day workshop participated in a wide-ranging discussion of the future of buildings and construction[1] in the United States, the contribution research can make toward achieving the greatest possible benefits from the nation's future building, and how building research may be directed toward assuring that this contribution is most effectively made. This document is a report of that workshop.

WORKSHOP OBJECTIVES

The workshop was a culmination of activity started eleven months earlier by the BRB. In sponsoring this activity, the primary objective of the BRB's Federal Construction Council (FCC) -- a group of 14 federal government agencies with substantial responsibilities for construction and facilities management -- was to gain understanding of how future changes in B&C may influence how these agencies pursue their basic missions, and how building research should be directed to help the agencies to capture the benefits of these changes.

Responding to the FCC sponsors' request, the BRB in January 1987 appointed a committee of 19 experts, representing a broad cross section of the building industry, to initiate a forum for establishing a building research agenda. The committee's discussions focused on the idea of

[1] The term "buildings and construction" in this context refers broadly to the processes of building planning, design, construction, operation, maintenance, and reconstruction, and to the products of these processes, that serve society as shelter and facilities for a broad range of social and economic activities. Building research is undertaken to gain better understanding of the performance expected of buildings and of how science and technology may be applied to meet these needs efficiently within the context of complex national priorities.

developing a definite agenda for building research, an agenda that could be used to direct agencies' research spending. Over an eleven-month period the committee reviewed more than 30 independently-prepared analyses of building research needs and lists of research topics (see Appendix A), assessed the current status of building research in the United States, and planned the workshop to involve a greater range of researchers and research users in the agenda-building process.

During the course of their discussions, the committee considered not only the form and content of a building research agenda, but also the desirable characteristics of institutional arrangements for effecting the agenda. Existing organizations in other fields, such as the Gas Research Institute and the Electric Power Research Institute, were considered as models to fill what the committee perceived as a void in the U.S. government-industry framework within which building research is directed and conducted and its results used.

The committee also considered the problem of defining the scope of an agenda responsive to the facts that B&C result in modification, repair, and removal of existing facilities as well as production of new ones; that the facilities comprise a broad range of infrastructure, administrative, commercial, residential, and other systems; and that materials, equipment, professionals and craftsmen, regulatory mechanisms, and financial arrangements all influence how facilities perform. Building research thus encompasses a potentially vast array of topics and applications. The committee concluded that no single agenda document can more than temporarily reflect the diverse interests within the communities of building producers and users or the consensus among those interests that is achieved in determining what specific work is to be undertaken An effective process of agenda development is therefore the most important element in directing research, rather than the agenda document. Thus, the committee viewed the workshop as an opportunity for participants to address themselves to describing a process that can direct research and maintain the currency and relevance of research to new concerns of building technology as they emerge.

The committee discussed several alternative themes to be adopted for the workshop, considering how research can improve the built environment, help to meet market-driven needs for this improvement, speed the rate of innovation in U.S. building, enhance the role of building in the U.S. economy as a whole, and set appropriate goals for the U.S. building research establishment. "Better Buildings in the 21st Century" was adopted as a forward-looking theme with appropriate appeal to both private and public interests and to both productive use or reuse of existing buildings and new construction.

THE WORKSHOP

The workshop was then planned to focus attention and discussion on two aspects of this theme: first, identifying the social, economic, and technological demands that may be placed on the buildings of the future, and second, devising and implementing a research agenda to assure the nation's ability to produce buildings to meet these future demands. Working groups of the workshop participants explored these two aspects

during several working and plenary sessions. (Key elements of the deliberations are summarized in chapters 2 and 3.)

Three keynote speakers addressed the participants at the opening of the two-day workshop: Mark Haynes, staff member of the U.S. Senate Committee on Environment and Public Works, Richard Wright, Director of the Center for Building Technology, National Bureau of Standards, and David Dibner, vice president of Bernard Johnson, Inc., and chairman of the BRB's FCC. (These keynote remarks are summarized in Appendix B)

The 51 workshop attendees together represented 35 private and 8 public organizations (see Appendix C). Meeting in Washington on December 3 and 4, 1987 at the offices of the National Research Council, this group drew strongly-felt conclusions, presented in Chapter 4, that a national building research planning process is needed and would yield substantial benefits to the nation, that there should be a clearly designated center of responsibility for implementing and maintaining this process, and that the workshop should be seen as an important first step toward establishing both the process and the center of responsibility for maintenance of the process.

2

IDENTIFYING DEMANDS FOR BUILDINGS OF THE FUTURE

Current trends of social, economic, and technological development in the United States are likely to have profound impact on the nature of the services buildings in the 21st century are called upon to provide. Public demands for safe living and working environments, combined with our improving ability to detect the presence of potentially damaging materials in the built environment, may require new capabilities for the materials and mechanical equipment in buildings. New technologies in such fields as medical research and treatment, electronics manufacturing, and biotechnology will demand greatly improved control of climate and vibration within buildings and safe and efficient handling of exotic wastes and by-products. Continuing change in communications technologies and transition of the U.S. economy to a post-industrial age will alter the patterns of space utilization and service access in offices and homes.

There may be a very large number of factors that will influence such trends. The workshop participants identified the following examples as particularly important:

- Emerging artificial intelligence technology that may be applied to building design and management
- Evolving technological efficiency of building construction, reconstruction, and retrofit activities
- Continuing depreciation and upgrading of the building inventory
- Commercialization of new building technology in materials, energy supply (such as photovoltaics), and telecommunications and controls (such as fiber optics)
- Changes in needs and demands building must fulfil, based on growth and aging of population, and shifting employment and social patterns of living and working
- Shifts in national priorities that lead to new energy, environmental, and conservation policies that influence building design and management
- Influence of concerns regarding crime and public safety on building design and operations
- Introduction of new technologies in such areas as health care and manufacturing that place new demands on building performance
- Shortages of urban land associated with increasing land values, development restrictions, and municipal infrastructure capacity

Workshop participants realized that we cannot know the future, and we cannot foresee with continuity the demands that will be placed on the buildings of the future. The working groups felt it is therefore essential that the research steering mechanism should be sensitive to emerging needs and technological trends. The working groups adopted the following premise as a guide to their deliberations and recommendations:

> "To identify the sociological and technological demands for buildings in the 21st century, the involvement of as many people as possible is needed to improve the accuracy of the identification and to promote awareness among these people, as users of buildings, that improved buildings are possible."

Involving a diverse group of building users, owners, and producers in the process of forecasting future needs will also help to build a constituency for building innovation and for support of private and public programs aimed at encouraging innovation.

Workshop participants noted that these people involved in identifying likely demands on future buildings are most likely to view trends in terms of major issues that begin to define areas warranting research. Working groups identified the following examples of such issues that are currently important:

- Improving existing buildings. A large portion of the country's existing building stock is in need of repair, remodeling, and renovation. A major effort is needed to make retrofit and modernization equally as attractive as demolition and re-building.
- Environments for the aged. With an aging U.S. population, there is a need for research into what may be the most appropriate housing and other environments to meet the specialized needs of an older population. This area could be expanded to cover the needs of other population groups that have special building requirements.
- Affordable housing. Housing problems affect all population types and income groups. There is a need to define the housing requirements of each distinct group, including the lowest income groups, and to develop appropriate housing forms and construction technologies to meet the current and projected housing needs. This must be done while maintaining the competitiveness of the U.S. housing industry.
- Rebuilding the infrastructure. The cost of rebuilding the nation's infrastructure with current methods and technologies is clearly prohibitive, and innovative approaches will be needed to satisfy the current and projected needs. This topic also is essential for maintaining U.S. competitiveness in global markets.
- Productivity and the work environment. There is strong evidence that improvements in the work environment, particularly in offices, can lead to significant increases in productivity. This will reduce costs and enhance the competitive position of U.S. products and services relative to foreign suppliers. Research is needed to determine the most appropriate forms for such environments and the most economical means of producing the components that are needed.
- Human health and the built environment. Evidence demonstrates that various elements in the built environment can have significant impacts on human health. At a time when much of the focus of medical activity has

shifted to prevention of health problems, it is important to insure that our environments are as safe and as health-promoting as possible. Additional research is needed to establish the extent of the relationships between human health and building components and to determine how to design and produce environments that are as healthy[1] as possible.

- Construction technology, products, and materials. While specific technologies, products, and materials will be needed to address the key areas of concern mentioned above, other more general research is needed to cover the broad spectrum of building concerns. Although cost reduction is always a major concern, improvements in performance and quality control are also important.

The workshop participants concluded that the process for developing and implementing a building research agenda should incorporate mechanisms for explicitly identifying such issues. These mechanisms are likely to depend on active participation of representative users and producers of building. Participants noted that building users are often poorly represented in current building research programs, and should be brought into the new agenda-building process. Workshop participants noted that the direct participation of the building research community will also be important to assure that research undertaken is directed toward issues of users' needs and national priorities, and that research results are put into practice.

[1] Building professionals have adopted the term "sick buildings" to refer to the problems associated with poor indoor air quality and similar health hazards.

3

DEVELOPING AND IMPLEMENTING A NATIONAL BUILDING RESEARCH AGENDA

The purpose of a national building research agenda should be twofold: First, the agenda should aid the community of researchers and users of research results to build mutual understanding of their potential contribution to improving the quality, efficiency, and value of the nation's buildings to our productivity and well being Second, it should serve to attract and direct resources to research in areas that have greater potential for making positive contributions to the quality of buildings in the 21st century.

The BRB committee's review of previous research agendas revealed a general tendency to focus on particular segments of the building industry, and on specific topics of building process and technology rather than on improvements in the abilities of buildings to meet society's demands. The committee viewed this tendency as an understandable consequence of the research establishment's dependence on support that is limited and drawn primarily from strongly mission-oriented private and public organizations. The great fragmentation and diversity that characterize the U.S. building sector make it difficult for any existing single organization to allocate resources sufficient to undertake broad programs of research, or to gain substantial benefits from pooling resources with other organizations. This situation also slows the adoption of innovation that may occur when research yields useful results.

The starting point for developing a national building research agenda must then be assembly of the relevant interests within an institutional framework capable of mobilizing resources and focusing those resources on high priority issues. The workshop participants were unanimous in their recommendation that a permanent organizational body -- a secretariat -- should be established. This organizational body might include the following functional components:

Constituents Representation would include both users and producers of buildings. Users have a myriad of special interests and needs, many represented by the 100 or more national organizations that take an active role in discussing building, such as the Urban League, the American Association of Retired Persons, and the National Organization of Women. Such organizations should be asked to formulate statements for needs they foresee for their constituencies in the 21st century.

Producers include labor, trade and professional organizations of those who plan, design, manufacture, build, and assemble buildings and components and systems for buildings. These groups also should be asked

to formulate statements of future needs and of technologies which they foresee may become standards in the 21st century.

In addition to their special interests, these two groups of organizations collectively represent the majority of the public, all of whom use buildings.

A Building Industry Panel within the secretariat would include members of those associations, societies, institutes, trade groups, etc., who represent the building industry (i.e., producers). It would be their responsibility to re-state the "needs," voiced by the constituents' group, in terms of possible technical solutions, that is to translate building needs to research projects.

Sponsors are those who control the sources of funds needed to make the program function. The secretariat should be established with ability to draw on private and public sponsorship, but to allocate funds without requiring direct links between sources and uses of funds.

A Research Steering Committee would include only a small group of experienced building research professionals whose task is to prioritize the projects generated by the Building Industry Panel, to seek funding approval from the sponsors and to let and monitor research contracts.

Researchers include colleges, universities, research firms, and private and government laboratories. Through competitive proposal preparation and bidding, researchers would be awarded research contracts, conduct the work, and report the results.

Existing Funded Research Organizations include these associated with manufacturing companies or with groups such as the National Association of Home Builders, who have their own research agendas that might contain projects which would satisfy project needs identified by the Building Industry Panel. Close involvement of these organizations in the national program is needed to avoid duplication of work and to encourage that the results of their internally-funded work is reported in a manner so as to benefit the public. Other organizations which fall within this group are the Gas Research Institute, Electric Power Research Institute, and the American Society of Heating, Refrigerating and Air-Conditioning Engineers.

The secretariat might have a small full-time paid staff to maintain communications and support the work of the building industry panel and research steering committee. One of the staff's functions would be the publication of a newsletter or other suitable periodical to keep the constituents abreast of progress being made.

Recognizing the challenges that might be faced in establishing such a new organization, workshop participants discussed the steps required and developed the recommendations presented in Chapter 4. Some workshop participants suggested that their agencies might be willing to support this new organization. Moreover, the workshop participants noted that the process for preparing a national building research agenda, regardless of the organizations that might be involved in the task, should include the following elements:

Review of background data on building-related research in the United States. This review would include information on which individuals and organizations participate in research, the types of projects they do, how well they are funded, how the research effort is organized, impact of

research on practice, etc. An examination should be conducted on organizations' previous efforts to develop research agendas for specific areas or sectors of the construction industry. Leaders of industry, professional organizations, and the public should be surveyed to identify societal and technological problems, solutions, and benefits. Some attempt should also be made to collect intelligence on likely technological changes that will affect the design and production of the built environment, and on the impact that demographic, social, and political changes are likely to have on the activities and performance requirements for buildings.

Symposium. A planning committee should be established to work toward a national symposium, with representatives of the building industry, users, and clients, including representatives from organizations sponsoring the planning committee's effort. The committee should address the commissioning of papers which identify national objectives and visions to serve as focal points for the national symposium; provide coordination of the broad input previously submitted so it can be translated into technical research issues; identify key national figures to participate in the symposium program; develop a list of industry, government, and academic person invitees; develop a method of inviting the public at large to participate; and make logistic arrangements for the symposium.

These efforts should yield several results:

- A highly visible event that gains the support of the public at large, and, through that, the attention of the Congress and the President.
- An indication of benefits to the nation resulting from public and private support for research on the built environment, including the international competitive advantage to the building industry itself.
- An ongoing cooperative process for maintaining national interest in the development of a building research agenda, and the establishment of a permanent secretariat.
- Guidance to research directors for programs and projects that would serve the needs of their organization. All material from the symposium should be assembled in a publication and widely disseminated.

The symposium should be a regular event, coordinated by the secretariat. The process overall would be a catalyst for change in the research culture of the building industry, to bring about improvements in the quality and performance of the nation's buildings and support the rebuilding of the nation's infrastructure.

4

TAKING THE NEXT STEPS

There was strong common understanding among workshop participants of the process they described and the organizational framework proposed for effecting the process and producing a research agenda. However, the participants agreed that questions remain to be answered:

Definition of "Building Research". It is important at an early stage in the process to define precisely "building research." Does it include only buildings, or does it include all construction, structures, infrastructure, etc.?

Source of funding. Since the sources of research funds inevitably will have a strong influence on how the money will be spent, it is critical to identify the sources early in order to evaluate how that influence might be felt.

Utilization of past studies. The building research programs of the past should be studied and evaluated, particularly those developed by the federal government; i.e., Operation Breakthrough, Douglas Commission Report, PBS Systems Buildings Program.

Additional academic research. Should more building research be conducted within colleges and universities, to enhance the educational experience of young engineers, scientists, and teachers by demonstrating the practical value of good research?

Using other countries' research results. Much important research in areas similar to U.S. areas of interest has been and is being conducted. A means to easily access the results needs to be developed.

Technological advances. Research, without implementation of the results, is a sunk cost earning no return on the funds invested. A study is needed to determine how best to enhance the incentives and reduce the barriers to early implementation of research results.

These questions should be answered as the next steps are taken to implement the process proposed by workshop participants for establishing a national building research agenda. The participants proposed that these next steps should include establishing the institutional focus -- the secretariat -- for creating and maintaining the agenda, and convening a national symposium to formally initiate the process.

There was consensus that this new organizational focal point would be best placed within an existing organization, taking advantage of ongoing support activities and established professional networks. The BRB was felt by many participants to be a logical host for this new activity,

although there now exists no government agency or program to stimulate initiation of the process.[1] It was recognized that such an activity might better match the institutional objectives of one of the several professional organizations that have interest in buildings and the building industry. Participants requested BRB to continue its efforts that led to the workshop and help to resolve the issue of location of the secretariat.

Preparation for a national symposium would include making inquiries of a broad range of public and private organizations to identify the content of their current building research programs and the methods they use to prioritize and select their research activities. The resulting comprehensive review of the building research establishment's research planning activities would be discussed at an early stage of the symposium.

The primary purpose of the symposium would be to develop and promote the goals and objectives of a national building research program, and in so doing enlist the support of industry, government, and labor, trade, and professional groups. While workshop participants expressed the hope that major funding for a national program would be forthcoming, they concluded that starting the process of agenda development will, in any case, build better communication and unity of purpose within the building community, and that this in turn will enhance our nation's ability to achieve better buildings for the 21st century.

[1] BRB is a unit of the National Research Council, which serves as an independent advisor to government on scientific and technical questions of national importance.

APPENDIX A: RESEARCH AGENDAS REVIEWED

SUMMARY OF SELECTED BUILDING RESEARCH AGENDA DOCUMENTS

The following documents were reviewed by the study committee to determine what elements past research agendas contained. These summaries are generally grouped by themes: construction research, architectural and environmental research, energy related, and others, e.g., aging, HUD, and NBS.

CONSTRUCTION R&D IN CANADA - Present and Potential

By Revay and Associates Limited
Montreal-Ottawa-Toronto-Calgary, 1983

Canada's construction program is over $55 billion accounting for 16% of its gross national products. Construction R&D amounts to 0.1% to 0.2% of the value of annual construction program. Construction R&D is uncoordinated; there are delays and shortcomings in the transfer of existing technology to practitioners engaged in the design, building and operation of construction facilities.

Contractors lack the resources to execute research work and generally "build to specification". Architects and Engineers are not afforded sufficient time or budgets to engage in research activities. The balance of R&D carried out in the private sector has been mainly conducted by manufacturers.

The lack of "market pull" is cited for the relatively low level of participation in R&D by the construction sector and why half or more of the total Construction R&D in industrialized countries is performed by governments.

The report noted that the changing nature of the industry has not been accommodated in areas as education and training, codes and standards and technology transfer. More emphasis is needed on building systems rather than on individual products, with a view to achieving an improved overall building performance.

The Federal government's program of research contracts and grants to universities, to research councils and to the private sector could be used as an effective medium for encouraging increased attention to building issues. Funding commitments for such activities and for special centers at universities devoted to construction studies should be sufficiently long-term to encourage the assembly of personnel and the development of worth-while results. Additional support for the operation of construction standrds and codes committees and establishment of a national system for the evaluation of new materials would be desirable with a view to overcoming the delays now encountered in the acceptance of new technology.

Expanded construction technology transfer programs are needed by means of seminars, workshops, demonstrations, manuals and other publications, audio/visuals and teletext. The Canadian Minister of Finance said "we must promote more actively the dissemination and application of technological advances in all sectors of the economy." New research centers, in Canada would influence "market pull".

CONSTRUCTION TRENDS AND PROBLEMS THROUGH 1990

By the Kellogg Corporation

The report, commissioned by the Construction Sciences Research Foundation (CSRF), was conceived to help optimize efforts in setting the future directions of CSRF's founding organization, the Construction Specifications Institute. However, it was apparent the study was not identifying unique or clear-cut issues which could be dealt with by a single organization or in isolation as separate problems. An entire spectrum of interrelated issues emerged which, when taken as a group, served as an action agenda by defining the dialogue within the fragmented construction industry over the next decade.

A review of concerns confirms the need for a joint effort by the construction industry:

- Increasing regulatory controls
- Poor management and supervision
- Rising costs
- Declining natural resources
- Low productivity
- Inequitable risk allocation
- Industry fragmentation

CONSTRUCTION TECHNOLOGY NEEDS AND PRIORITIES

By Richard L. Tucker
The University of Texas at Austin
The Business Roundtable, February 1982

As a part of the Construction Technology Study Area of the CICE project, a survey determined areas of technological need and advancement potential. The first phase was a questionnaire survey designed to determine areas of potential improvement within projects. The questionnaire mailed to selected owners, contractors and designers, provided data on project size and characteristics, and information about craft make-up of the work force and distribution of costs among 17 construction areas. The second phase involved job-site interviews to identify specific activities for priority within the more promising areas. Fifty-one craft superintendents and field engineers at fourteen job sites provided quantifiable, although subjective, data about inefficient construction activities and opportunities for improvement.

The survey results suggest that potential savings of more than $2 billion are possible through technological improvements of three construction areas; piping, mechanical equipment, and electrical, and improving them only to the same level of efficiency or difficulty as the remainder of the projects.

MORE CONSTRUCTION FOR THE MONEY

Summary Report of the Construction Industry
Cost Effectiveness Project
By Roger Blough
The Business Roundtable, January, 1983

This report summarizes progress of the Construction Industry Cost Effectiveness Project. The project's aim was to advance the market philosophy of production and distribution; to improve work methods to the end of creating more for more people.

The rationale for this effort is:

1. Construction is important to the economy as a whole and therefore to everybody. It affects costs, prices, and our international competitiveness both in our own and foreign markets.
2. Construction dollars are not being used effectively.
3. Declining cost effectiveness is not the fault of any one group. Owners, managers, contractors, unions, workers, suppliers, and governments all share the responsibility.
4. Cost-effectiveness in construction can be improved to the advantage of all without inequity to any group, if we recognize it as a national problem and seek cooperative instead of adversary solutions.

The report addressed its findings as two themes: What's Wrong and What Needs to be Done. For the former five subjects focused on the theme; The Myriad Cause of Declining Effectiveness, A Bizare Lack of Accurate Information, Shortcomings of Management, Problems Involving Organized Labor, and The Stultifying Role of Government. For the latter six subjects focused on the theme; Sharpening Management's Tools and Techniques, Plugging the Gaps in Training and Education, Harnessing Research and Technology, Maximizing Worker Productivity, Lifting the Clumsy Hand of Government, and Highlights of an Action Plan.

THE IMPACT OF THE WORK ENVIRONMENT ON PRODUCTIVITY

By Mary E. Dolden, and Robertson Ward, Jr.
Massachusetts Institute of Technology, 1985

The proceedings is a two day workshop on "The Impact of the Work Environment on Productivity." The workshop was organized by the Architectural Research Centers Consortium, Inc. (ARCC), representing 30 university-based architectural research centers, in collaboration with an interdisciplinary group of research and practice environmental professionals actively concerned with improvement of the work environment. Performance and productivity in the changing workplace were identified as key issues for environmental research in a wide-range agenda for building research recently compiled by a symposium of researchers brought together by ARCC, under a grant from the National Science Foundation.

ENHANCING CONSTRUCTION THROUGH STATE-OF-THE-ART RESEARCH

By David B. Ashley and Richard L. Tucker
The University of Texas at Austin, October, 1984

This report summarizes the proceedings of a workshop held in Austin, Texas on February 20-21, 1984. The workshop was funded by the National Science Foundation.

The workshop was designed to provide insight into the state-of-the-art of construction research and to identify topics of needed additional research. It also was intended to explore research methodologies and approaches and their particular applications to construction.

The workshop featured five topic areas.

- Industry wide research needs
- Design and procurement research needs
- Project management research needs
- Site activities research needs
- Construction technology research needs

WORKSHOP ON CONSTRUCTION ENGINEERING BASIC RESEARCH

By Robert I,. Carr and William F. Maloney
The University of Michigan, September, 1982

This workshop was sponsored by the American Society of Civil Engineers, National Science Foundation, and the Construction Research Council. Its five sessions addressed:

1. Definition of Basic Research in Construction Engineering and Management
2. Basic Research in Construction Engineering Management
3. Basic Research in Construction Engineering Analysis and Design
4. Basic Research in Construction Engineering Uncertainty
5. Basic Research in Construction Engineering Human Resource Management

RESEARCH FOR BUILDING CONSTRUCTION PRODUCTIVITY—REPORT ON THE JUNE 2, 1981 CONFERENCE

By National Bureau of Standards, August, 1981

The conference identified major research needs to improve commercial construction productivity. Twenty-six participants, from all sectors of the construction industry, met as a roundtable group. Five prepared papers stimulated wide-ranging discussion.

By the end of the day a consensus emerged around six primary research topics:

1. Develop a "family" of micro measures of construction productivity to assist individual firms in decision-making.
2. Improve macro measures of productivity to assist in understanding regional and aggregate industry trends.

3. Develop the methods needed to extend computer applications to all phases of construction decision-making.
4. Identify and develop methods to expedite the regulatory process.
5. Measure the relationships between occupant-user productivity and building design.
6. Produce the knowledge of physical properties of buildings needed to reduce risks of building failures and lower costs of designing for building safety.

Conferees further agreed that the private sector, not government, must take the initiative to formulate and conduct research. However, government should support and conduct some research.

PROCEEDINGS OF A WORKSHOP FOR THE DEVELOPMENT OF NEW RESEARCH DIRECTIONS IN COMPUTERIZED APPLICATIONS TO CONSTRUCTION ENGINEERING AND MANAGEMENT STUDIES

By C. William Ibbs, Jr.
The University of Illinois at Urbana-Champaign, July, 1985

A U.S. National Science Foundation Research Workshop was held in Urbana, Illinois on May 19-21, 1985 to provide a forum for information exchange and a review of research progress and needs. This workshop suggested how this community should conduct its research, with attention devoted to mechanisms of increased coordination between research units.

Panel discussions addressed:

Definition of Knowledge-Based Systems
Application Areas for KBS
Tools for Building KBS Applications
The Art of Building KBS (Knowledge Acquisition)
Standards for Testing and Validation of KBS
Philosophy for Guiding Research on KBS

Large group presentation and audience response addressed:

Creating and Enhancing Data Collection Tools and Analysis Technologies
Human and Organizational Aspects of Modeling and Simulation
Interface Among Tools and Applications

MEASUREMENT TECHNOLOGY FOR AUTOMATION IN CONSTRUCTION AND LARGE SCALE ASSEMBLY

By John M. Evans
Transitions Research Corporation, February, 1985

Fifty technical experts from business, industry, universities and government met in Washington, DC on February 5 and 6, 1985, to consider the issues of applying automation to construction and large scale assembly. This workshop, which was sponsored by the National Bureau of Standards and Transitions Research Corporation, concluded that:

- New technology achievable in the near term would have a major benefit in the construction and large scale assembly industries.
- The key to this benefit is the application of computers to data management and process control both off-site for design and planning and on-site for inventory management, production control and creation of an as-built data base.
- The achievement of this new technology requires research carried out on the integration of systems for measurement and automated control of on-site construction and assembly tasks.

Representatives of construction firms, heavy equipment manufacturers, shipbuilders, and related industries identified key technical barriers to the introduction of automated manufacturing technology to the building and assembly sites.

Specific recommendations for action included:

- Information transfer: a source of information on measurement technology that could be applied in construction and a major conference on this topic next year.
- A demonstration project to develop and demonstrate an as-built data base on a real construction project.

CORRECTIONAL FACILITY DESIGN AND CONSTRUCTION MANAGEMENT
By Dale K. Techrest and Shelley J. Price
U.S. Department of Justice, October, 1984

The objective of the project was to document, based on a one-year study of new facility construction in 15 states, attempts to plan, design and construct correctional institutions in environments that emphasize different objectives at different times. The report focused on an audience of correctional administrators and managers responsible for building new facilities, and architects, builders and others who create correctional institutions. Recommendations are:

1. The diffusion of authority and responsibility among government agencies, including complex approval processes, turnovers in agency personnel and failure to establish and maintain effective communication between decision-making authorities was identified as a primary factor in project delays and difficulties.
2. The lack of continuity in project planning and decision-making stands out as one of the most critical problems in correctional facility construction.
3. A critical issue during project planning and program development is the need for involvement of facility staff members and practitioners to identify critical operational and practical needs of the institution.
4. Many of the problems in facility operation can be traced to institutional use and operation different from the purpose for which it was originally designed.
5. There is a need to evaluate what has been done in an attempt to build on past experience rather than continue to repeat past errors.

ARCHITECTURAL AND ENVIRONMENTAL RESEARCH DISCUSSION DRAFT FOR ACSA/NSF MEETING

By Dean Richard Bender
University of California, February, 1977

Bender presented ideas on architectural and environmental research. He said the purpose of research is to systemstize the knowledge of a field through the discovery of order in seemingly random information. For an architect, it is essential that work develops from knowledge rather than speculation. The activity of research formalizes this record and renders explicit those areas where some degree of certainty may be achieved. Research, in its exploratory function, extends present knowledge into new areas. The field of research is the source of the professional's most reliable information, and provides a forum for the most advanced thinking.

It is difficult to draw well documented conclusions. Several conclusions can be drawn:

1. Most problems in environmental design require an interdisciplinary approach to be fruitful. Multidisciplinary research provides some insights, but interdisciplinary research approaches the field with the breadth it calls for.
2. Lengthy projects in environmental design, based on specific hypotheses, have not yielded satisfactory results. A search for balances rather than cures may be more fruitful. The relationship between concerns of the designer and the criteria of the evaluator has to be clear.
3. A search for an absolute "needs" basis for environmental design has been largely unfruitful. The dynamic relationship between an individual's perception of the environment, the repertoire of his environmental experiences, and changes in his expectations for the environment has been recognized. Increasingly, the environment will be called on to shape the individual's perceptions and to be responsive to the individual in precipitating growth and change.

Future planning can benefit from this experience. The professions and important national needs will be served by a program which is focused on this field and which recognizes the potential value of systematic environmental research.

ARCHITECTURAL RESEARCH PRIORITIES 1984

By the American Institute of Architects Foundation, 1984

The Architectural Research Council of the American Institute of Architects developed pricrity research needs as guidance to those responsible for planning and supporting architectural research. Each committee on the council prepared a list of the most important research needs in its domain. Research priorities includes:

Computers
Validity of Codes
Wet Smoke
Fire Safety Evaluation Systems
Fire Effects of Interior Finishes and Furnishings
Earthquakes and Nonstructural Building Components
Indoor Air Quality
Effects of Design on Operating Costs
Cost Models for Programming and Preliminary Design
Building Diagnostics
Integrated Building Systems
Emerging Trends in Technology and Pubic Policy
Building Obsolescence and Reuse
Maintenance and Replacement of Deteriorating Building Materials
Whole-Building Energy Performance
Demand-Based Building Technologies
Energy Crisis Management
Water Conservation
Quantifying Good Community and Building Design and Their Benefits
Design for Special Users
Infill Housing
Project Delivery Processes
Building Product and Materials Performance

Mechanisms must be established by which architects and researchers can collaborate in the transfer process. Recent developments in communications technology offer the possibility of greatly improving the way new information is disseminated to architects. Interactive video discs, teleconferencing, computer conferencing, key-word, in-context referencing, and remote database interaction may allow architects to expand tremendously their access to information of all kinds. The use of these technologies in disseminating new information warrants active investigation.

AN AGENDA FOR ARCHITECTURAL RESEARCH, 1982
By Michael L. Joroff, Massachusetts Institute of Technology
and John Templer, Georgia Institute of Technology, 1982
A project of:
The Architectural Research Centers Consortium, Inc.

This report identifies an agenda for fundamental research issues and research topics in architecture. It is an earlier version to the agenda above. It addressed five themes: the process of design and construction; building habitability; human security and safety; conservation of resources; structures, materials, and equipment systems.

ARCHITECTURAL RESEARCH
By James C. Snyder
The University of Michigan

This report is divided into two parts and 18 chapters. Part 1 is the context of architectural research, six chapters support this part; they are:

A Proposed Framework for the Emerging Field of Architectural Research
Research in Practice: Generation, Use, and Communication
An Overview of Sponsored Research in Schools of Architecture
The Question of Style in Research
Creativity in the Architectural Research Process
History of Technology

Part 2 is the substance of architectural research and 12 chapters support its heading; they are:

New Directions for Environment-Behavior Research in Architecture
Evaluation Research in Architecture
Research for Urban Design
Urban Planning within Architectural Design Research
Indoor Pollution: Lighting, Energy, and Health
The Architecture of Normalization: An Archaeological Discovery
Architectural Research and Life-Span Changes
Quads and Quality: Architectural Inquiry about Energy
The Narrow Shelf: Architectural Research on Seismic Hazards
Underground Architecture
Research in Architectural Communication
Building Economics: A Review of Value Engineering Research

RESEARCH AND DESIGN - SYMPOSIUM
American Institute of Architects Foundation, 1985

The American Institute of Architects presented a five day symposium on research and design to focus on technology for the practicing architect. Over 130 speakers in 29 sessions addressed current and potential uses of new research findings in energy, life safety, codes, redesign, design and facility types.

RESEARCH AND THE PRACTICE OF ARCHITECTURE
By Richard Bender, March 1976

A study was conducted to clarify the interrelated roles of research and the practice of Architecture. It attempts to explore the nature of research in Architecture, to examine objectives, methods and tools, and to make specific recommendations for the development of a research direction in the practice of an architectural firm, McCue Boone Tomsick, Architects.

EVALUATION OF ENVIRONMENTAL DESIGN RESEARCH DIVISION (EDRD) of CBT
By Richard Bender, March 1979

This memorandum by Bender discusses issues to consider when developing a research agenda. The case study in point is the Center for Building Technology (CBT) of the National Bureau of Standards. An issue surfaced as a result of creating a new division in CBT is related to a five year policy statement, one million dollars a year would be made available to NBS division build up a "scientific capability for long-term research efforts." What was at issue was how research was being defined by the leadership of NBS, a definition that had clear implications—most of them negative—for these who were engineers, behavioral scientists, i.e., psychologists, architects, planners, economists, and still others. While not explicitly stated, it was evident that "scientific competence" or "capability" was to be measured in terms of classical research in physics—sometimes called basic research—in which well articulated and developed theory guides a long-term systemstic research program. At most, engineers and others—unless they could conform to this model—would be concerned with applied research on highly specific issues that would be required once fundamental questions were answered and there was a need for "testing" and technical implementation in the "real world."

If this policy for planning how to build scientific competence for the future prevails, then a goodly part of the effort of CBT and other divisions will be rendered second-rate and auxiliary in nature. It is imperative that NBS be aware of the fact that what is being proposed—implicitly or explicitly—is unworkable if one indeed still seeks to use engineers, experimental psychologists, economists, planners, social psychologists, and others to solve a variety of problems in building safety, building economics, energy conservation and so on.

FUTURE RESEARCH DIRECTIONS IN ENVIRONMENTAL DESIGN: AN EXPLORATION USING THE EXPERIENCE OF UNIVERSITY OF CALIFORNIA'S COLLEGE OF ENVIRONMENTAL DESIGN

This project involved an exploration of the future of research in environmental design using the College of Environmental Design as a case-study. The College has a broad range of professional and research concerns in the field of environmental design including environmental planning, landscape design, urban design, land-use planning, architectural design, building science, energy analysis, computer-aided design, and visual communication.

Out of discussions with faculty and task groups, a listing of research topics emerged:

A. Case-Analysis Approach to the Study of Forces Shaping the Physical Environment
B. Integration of Health and Safety Criteria into Environmental Design
C. The Growth and Decline of Areas of Human Settlement
D. Taxonomy of Settings

E. Technology Transfer
F. Building Performance Evaluation
G. Futures Mapping
H. Design of Regulatory Systems for Design
I. Professional Media - Definition of Research Area
J. Research for Design Participation

CENTER FOR ENVIRONMENTAL DESIGN RESEARCH
ANNUAL REPORT, Fiscal Year 1985-86
By University of California, 1986

Broader faculty involvement in CEDR research activity has resulted in a substantial increase in extramural funding and support of graduate students in the College of Environmental Design's professional and doctoral programs during the 1985-86 academic year. The Center's research program continues to focus on design and planning of the built environment. Research over the next few years will build upon past research areas where CEDR established a position of national leadership, and emerging areas in design research. The four major research areas identified in the 1985-86 plan for CEDR research include:

- Information Technology in the Environmental Design Process
- Building and Site Diagnostics
- Environmental Hazards—Building and City Design
- Design of Health Facilities and Environments for the Elderly

Two new research seminars were initiated, greater faculty participation in seminars on Planning and Building for Seismic Hazards and on the role of Information Technology in the Environmental Design Process.

DIMENSIONS OF USER BENEFIT
An Overview of User-Oriented Environmental Design Criteria
By D. Michael Murtha, August, 1976

The author reviews the literature to develop sixty-eight user benefits applicable to environmental design. These benefits include: functional, physiological, psychological, and social aspects, in areas related to the efficiency and effectiveness of user performance, and user well-being, comfort, and safety. Individual benefits are operationally defined to represent continuums on which greater or lesser degrees of benefit can be determined. The benefits are organized to reflect logical systems of relationship and application. Supplementary material covers aspects related to benefit determination and application in rational design processes, including: the definition of user requirements, the formulation of design solutions, the comparative evaluation of design solutions, and the determination of levels of benefit in post-construction evaluations. Implications are presented for further research and development in the fields of environmental design and man-environment relations.

ASMER INFORMATION ACCESS PROJECT
SCOPE OF THE PROBLEM: REVISED LISTING
By D. Michael Martha, June, 1978

The report presents listing of information, definitions of major subject categories and subcategories, and specific items associated with each research disciplins category for human behavioral areas and built environment. The listings helped defins the scope of information access problem by identifying the types of information which are relevant to human health and well-being in the built environment and describe the various uses and users of this information in developing supportive physical environments.

THE RESEARCH AGENDA OF THE AMERICAN SOCIETY OF HEATING, REFRIGERATING, AND AIR CONDITIONING ENGINEERS
By ASHRAE

ASHRAE's research agenda includes:

- study indoor air quality; ventilation requirements and filtration
- energy conservation; simplified methods to estimate energy use, thermal storage systems, evaluating and determining cost effectiveness of energy conservation products and concepts
- chlorofluorocarbons; alternatives to CFC's and reclamation methods
- smoke and fire control; design criteria for using HVAC as part of solution
- legionnaires disease; operation modes of HVAC equipment
- computer applications for HVAC & R
- refrigeration systems
- thermal and moisture properties of building materials
- variable-air-volume systems
- development of design data and design methods
- research to support standards development

A SURVEY OF RESEARCH WORK IN THE UNITED STATES ON THE THERMAL ASPECTS OF BUILDING ENVELOPES AND MATERIALS
By P.E. McNall and P.R. Achenbach
Building Thermal Envelope Coordinating Council, May 1984

The Building Thermal Envelope Coordinating Council (BTECC) conducted a survey of R&D work, past, present, and future. Approximately 525 questionnaires were sent to selected individuals from a number of mailing lists of persons closely related to the building industry. The use of a survey to identify research showed that the instructions were interpreted differently by some respondents resulting in non-uniform answers. The survey technique provides an indication of the technical tasks that are being applied, indicates relative levels of effort and resources, could help determine what other research committees should be established.

A RESEARCH AGENDA: ENERGY CONSERVATION IN BUILDINGS AND COMMUNITY SYSTEMS FOR THE OFFICE OF BUILDING ENERGY RESEARCH AND DEVELOPMENT THE U.S. DEPARTMENT OF ENERGY
By the Advisory Board on the Built Environment
National Research Council
Washington, DC, 1982

This report presents an agenda on research needs in the field of energy conservation in buildings and communities to be supported by the federal government. The agenda is developed in a futures perspective, presenting material relevant for research and development five or more years from the present. A set of boundary conditions was created to help determine subject areas that should be a part of this agenda. Twenty-seven subjects are described as appropriate for areas of research. They are organized into six categories: Occupant and User Interactions in the Buildings and Community; Interaction Between the Built and Natural Environment; Basic Energy Processes; Energy Use and Control in Buildings and Communities; Community Infrastructure and Energy Conservation; and Research Information Dissemination and Technology Transfer. A description of each category and area is provided, with suggested topics of specific research projects.

APPLIED SCIENCE DIVISION
ANNUAL REPORT
ENERGY EFFICIENT BUILDINGS PROGRAM FY 1983
By Elton J. Cairns and Arthur H. Rosenfeld
Lawrence Berkeley Laboratory, 1983

This document presents six reports and a publications list. The reports are:

- Energy Performance of Buildings
- Building Ventilation and Indoor Air Quality
- Lighting Systems Research
- Buildings Energy Data
- Windows and Daylighting
- Building Energy Simulation Group

BUILDING ECONOMICS RESEARCH AGENDA
By David L. Hawk
School of Architecture
New Jersey Institute of Technology
June, 1986

The report presents conclusions of a Workshop sponsored by the National Science Foundation to clarify Building Economics and stimulate beneficial and exciting research in the area. The three traditional research concerns of What, Who and How provided an organizing structure for the Workshop and encouraged helpful responses to: 1) What are the Legitimate concerns of Building Economics? 2) Who is/should be concerned

with Building Economics? 3) How are Building Economics and related concerns addressed? These questions provided a forum for examination of what building economists were doing and could/should do.

RESEARCH PLANNING CONFERENCE FOR DEVELOPING A RESEARCH FRAMEWORK FOR ENGINEERING ECONOMICS
By Gerald J. Thuesen, Georgia Institute of Technology
March, 1986

This report suggests that new approaches and techniques must be developed for new manufacturing technologies, computer-aided design, and artificial intelligence in the field of engineering economics. Improvements in the field are being demanded. One response to those demands is to expand the research efforts in engineering economics and to focus on the problems of greatest concern. This realization that new research initiatives would be required began a series of events that eventually led to the effort represented through the completion of this report.

The purpose of the National Science Foundation sponsorship of this project was to assemble experts in engineering economics to develop a rational framework for future research. This purpose included the definition of the scope of the disciplins and a statement of the important interfaces with other disciplines. Additionally performed was development of taxonomies to facilitate an understanding of the field and the compilation of a glossary of standard terms and definitions. Five these areas were addressed:

Overview of the Field of Engineering Economics
The Interfaces of Engineering Economics
Taxonomies for Describing Engineering Economics
Classifying Future Research in Engineering Economics by Proposed Taxonomies
Terminology for Engineering Economics

A NATIONAL PLAN FOR RESEARCH ON AGING
Report of the National Research on Aging Planning Panel
By Public Health Service, National Institutes of Health, September 1982

This report presents the findings and recommendations of the National Research on Aging Planning Panel. The report comprises three sections: an introduction of the need for and significance of research on aging and highlights the panel's findings and recommendations; reports of the four subpanels; and appendices containing supplementary information. The panel finds that although significant research accomplishments have been made over the past five years, there remain many unanswered questions which may help advance our understanding of the aging process and the measures required to extend the vigorous and productive years of life.

A REPORT ON—A REVIEW AND STUDY OF THE PRODUCTS OF HUD'S TECHNICAL STUDIES PROGRAM, FY 1956 - FY 1972
By James R. Simpson and Mary S. Simpson
Simpson Associates, November 1975

The report commissioned by the U.S. Department of Housing and Urban Development is based on residual files of HUD's Technical Studies Program. A brief history of the program is given, including several administrative problems which persisted. A list of 228 significant research reports produced by the program is included. Other lists include reports recommended for deposit at NTIS, and for publication. A discussion of areas recommended for further research is provided with a listing of evaluation and inspection aids developed by the Program.

BUILDING TECHNOLOGY RESEARCH AGENDA
A Technical Report
National Institute of Building Sciences, May 31, 1985

The National Institute of Building Sciences (NIBS) developed recommendations for near term research based on compilation of building community research recommendations. The 16 recommendations were developed for the National Bureau of Standards Center for Building Technology and for Fire Research. NIBS suggested that emphasis be placed at CBT on research relating to building envelope systems with special attention to roofing performance and fastening devices. For CFR, emphasis is needed on research relating to residential sprinklers and other fire suppression systems, and to combustion toxicity of building materials and furnishings.

APPENDIX B: KEYNOTE PRESENTATIONS

PERFORMANCE REQUIREMENTS FOR BETTER BUILDINGS IN THE 21ST CENTURY

Remarks by
David Dibner
Senior Vice President
Bernard Johnson Architect/Engineers

Much of what I have to say today I was able to glean from the library of the World Future Society in Bethesda, Maryland. It is interesting to note that another person who was using their library at the same time, and whose subject was future occupations, was able to get five times as much material as I was able to get on future buildings. It was also interesting to note that their office building and office spaces were far from any architectural image I might have had of an appropriate setting for a World Future Society.

My assignment for this meeting was to speculate on what the future of buildings will be in the 21st century, and what will be the requirements of those who use buildings at that time.

People in the 21st century are most likely on the average to be older and healthier. There will be 35 million people over 65 with 5 million of them being over 85. This implies a concern for living spaces that serve the needs of this large sector of the population, such a congregate living, automated monitoring of life signs of the occupants, and communications links with health care centers.

Hospitals will change with changes in medicine and medical practice. For example, there will no longer be by-pass surgery needed, but more transplanting of human and animal organs.

The majority of people will be computer-literate and will have access to computers in their homes. Most peoples' work life will also be organized around computers. Computer-based communications systems will reduce the need for mobility....e.g., it is estimated that one out of every four trips currently made will be replaced by computer systems.

The movement towards the Sun-Belt will continue, as will the number of single parents. These new life styles will affect our design of houses.

Some of the major trends that will affect the built environment are:

New materials resulting from changes in scientific knowledge such as bio-engineering, physics, superconductivity, photovoltaics, etc. I recently heard about a new polymer glass that changes color as you change the electrical charge to the polymer, enabling light transmission to be changed or color of room to be modified. New production methods will increase the kinds of materials available, as well as their performance characteristics. Industry will become more international in character. The aging of our public works infrastructure will force the development of new technologies.

What then is likely to be the shape of this 21st century?

Here are some predictions:

Transportation distance will likely double in the next 30 years, and the demand for public transportation will double as well. Opposition to the building of freeways will increase 3 times. Moving sidewalks will be more common. Automated highways will come into common use by 2010.

Buildings will be constructed with more plastic materials, structural shapes made from filament wound systems will become more popular. Sprayed-on plastics will be used more commonly. Extrusion processes for whole building components could emerge. New kinds of systems that include such ideas as: plug-in structures, tensile structures, aero-structures (a big balloon which contains an entire building and allows the sun to provide heat by passive means), agricultural structures (created out of green plants growing and shaped by nets, and then carefully pruned), chemi-structures (formed by liquid materials which grow like crystals into rigid structures), video-structures (laser-projected images of spaces), media-structures (spaces completely covered with television screens), cryo-structures (water or other liquid sprays on a form), and the creation of spaces of projecting holographic forms into which one can walk.

The forms of such units will include ideas such as Budky Fuller's domed cities, or an overground network of megastructures, or megaliths (very tall structures), underground network structures, floating structures, underseas structures, and space structures (the concept of living out in space seemed to be the one most often mentioned in articles). There have even been attempts to evaluate the shape of spaces on the social structure of the group that uses them.

Much has been written about the home in the 21st century. There is an assumption that more work will be done in the home, so that homes can be located in more remote areas and connected to urban centers via communications networks. Homes will have media-rooms. Computers will provide a variety of controls and protection devices for homes. Houses are called by new names such as the "cybernetic house", or "the computer house", or "the sculptech house" (formed from plastic domes foamed in place), or "tele-text houses", and even "terratecture" (houses built into the sides of sand dunes).

I would like finally to return to telling you about my visit to the World Future Society. While I was there the woman who worked in their library admired a one-hundred-year-old locket being worn by the younger woman doing research on future occupations. When she discovered that there was no picture in the locket she suggested getting an ancient, brown photograph of some past relative. So, even those who look to the future, hark back to the past when their personal values are at stake. People have a strong need to identify with the past. Therefore as you move into the development of future concepts, I would ask that you always keep in mind human insights and intuitions and experiences. No matter what we do about the physical setting, <u>people</u> will still be living and working in these places. People will still be expressing their wishes, desires and hopes. So, that the one thing that we carry into the future is this important commodity called the "human preference".

THE ADMINISTRATION'S EFFORTS IN LEGISLATION AFFECTING BUILDING TECHNOLOGY

Summary of Remarks by
Mark Haynes, Staff Member
Senate Committee on the Environment
and Public Works

Mark Haynes made it clear at the outset that he was speaking as an observer of the process rather than on behalf of any member of Congress or any Congressional committee.

Haynes believes that as far as the future is concerned, there are few things as important as laying the groundwork for improved technological innovation and that there is hardly an area more in need of improved technology than public works infrastructure and buildings. He continued, it would seem that, from the standpoint of Congress, the idea of an accelerated program of research and development to improve the efficiency and technology of buildings and public works infrastructure should be very popular. It has all the earmarks of something very exciting and something members of Congress would want to get behind:

- It has competitiveness aspects because it directly relates to the competitiveness of the biggest industry in the U.S. construction industry;
- It has efficiency and budget savings aspects because about $100 billion is spent annually in the United States on infrastructure;
- It has obvious implications for both the economy at large and for the education community and future generations of engineers, architects, and so on; and
- Finally, a new program for research and development is a "clean" issue in that it does not have the classic symptoms of "pork barrel" legislation (although it could of course become "pork barrel" if not watched closely).

Given all of this appeal one would assume that legislation would be eagerly pressed forward, to be followed by hearing sand press conferences and speedy introduction into law. But this hasn't happened. There have been a few hearings and a lot of hints dropped to the Congress by OTA, the NRC and others including the Building Research Board. A lot of good questions have been asked by members of Congress during these hearings and a lot of interest expressed, but so far there is no action. Some sort of legislation might be introduced next year, but what that might look like or even if it will happen is far from certain.

Why is there so little action, not only by this Congress but by previous ones? Haynes suggested several reasons.

- This issue of construction and public works is just not a very exciting one for Congress because there is not much political payoff for members...except, of course, for specific projects done by federal agencies.
- There is also not a clear understanding by members of the Congress or their staff about the advantages of research and development in this field..."what's wrong with the way we are doing this now?"
- There is a good deal of uncertainty about what Congress can do about this problem, and consequently a tendency to lapse into more studies of the problem.
- Since many key members of Congress are up for reelection, they will tend to shy away from any new program that involves increases in the national budget.
- There does not seem to be a very vocal constituency for improved research and development in this field. To the extent there is, it is divided and uncoordinated. Further, the interest groups that are active in Congress have other issues besides R&D that are pressing.
- There is an attitude that suggests that Congress let the private sector fund such research, since they are the ones that are going to benefit. The Office of Management and Budget may be a particularly strong proponent of this position.
- There is, finally, the political question by members of Congress of "what's in it for me?", especially among those who are up for reelection.

None of these problems negate the fact that a new emphasis on R&D for construction and public works infrastructure is needed, nor is there any indication that all of these problems cannot be overcome.

If there is to be a major new national program of public works infrastructure research and development, there will need to be a major effort made to overcome the considerable inertia in the political system. It would seem that the potential results are well worth any effort it might take.

Because there is no public constituency for an improved research and development program, the burden is on the shoulders of those in the industry. Workshop attendees and their colleagues in industry and academia need to make enough of a showing to get some member of Congress to introduce legislation, and will need to keep the pressure on such members to see the legislative process through to the end.

IMPROVING U.S. COMPETITIVENESS IN THE CONTEXT OF BUILDING RESEARCH

Summary of Remarks by
Richard Wright
Director Center for Building Technology
National Bureau of Standards

Richard Wright said, at the beginning of his talk, that it was not about the political issues (which Mark Haynes had covered), but about technologies for the 21st century going beyond an earlier study of the 1990s. Wright continued, the CIB Congress, which will occur in Paris in 1989, will include a study of evolutionary trends in building construction worldwide that will emerge in the 1990s.

The demands for building performance in the 21st century are not likely to be dominated by mega-projects. There will be large projects, such as the proposed cleanup of the Boston Harbor, but the important technologies are likely to arise for ordinary projects. We will have to compete in an international arena, which means we will need to be competitive in terms of quality and costs. We will have to be at the state of the art technologically if we want to play effectively in this larger international game, and continue to dominate our domestic market.

The pressures on us from the demand side will include:

- The problems of building and rebuilding our infrastructure, the whole system of public works that supports our style of life.
- New styles of living and new kinds of industries that will require changes in our buildings and infrastructure.
- Steady pressure to improve safety and health aspects of our built environment.
- Needs to find better ways to conserve energy and preserve a livable environment.

We have substantial opportunities to make such improvements because of advances in our scientific and engineering skills, including advances in computer technologies. Advances in social, physical and engineering sciences will be available to be exploited in construction, including those ideas which flow from the international community.

The first sub-set of demand is the usefulness of constructed facilities:

Because the construction industry represents nearly 10 percent of the GNP it is a large factor in the economy, but the infrastructure built by our industry is the base for all other American industry. We have a large leverage on the balance of the economy depending on how well we perform, so that we affect the entire GNP. Our role is to help the users and owners of the facilities which we construct to be internationally competitive in their market sectors.

Wright noted that his own time at NBS has included the unfortunate demise of programs on architectural research and behavioral sciences that supported the creation of a built environment oriented to serving human needs. NBS was required to drop these programs in the face of economic constraints of the 80s, but this work seems likely, ultimately, to be the most important area of research to help us remain competitive in the world, to allow us to adapt the built environment to its human purposes, and to provide the users of buildings with substantial control of their own environments.

More intelligent facilities should become an important tool for a more productive built environment, providing we leave the controls in the hands of the users. Since any systems we develop will break down, we need always to keep in mind fail-safe procedures. Adaptive systems in intelligent buildings which can sense their own state, learn about their own parameters, and initiate action will be helpful.

We also will need new functions and new forms to provide for the new needs of organizations, which will emerge and evolve over time. We should be developing the knowledge base and skilled persons needed to respond to these changing situations.

We will need to keep our hardware and software systems as "open" as possible, in order to be conducive to innovations. Large scale, closed systems tend to discourage new concepts and incremental improvements.

The technologies that will be useful to keeping systems open include: public domain performance prediction techniques, interface standards that allow easier fit of novel components into larger systems, and test methods for evaluating the performance of the innovation.

The second impact of demand is the safety of constructed facilities:

Research is needed to give us a better understanding of human values as they relate to safety. We know people are much more concerned with an accident that takes ten lives, than with ten accidents that take only one life. But we ought to get a good quantitative understanding of values and respond to them in our designs.

We should be better able to predict the interaction of natural forces and responses of the physical systems. This area still needs much more work even though we have made much progress. We would understand how human occupants respond in an emergency, and design to encourage effective response.

The third subject of demand is the economy of constructed facilities. We need better methods and data to enable us to discuss life-cycle performance. Value engineering is a useful technique to avoid wasting money, but it is not always sensitive to costs and benefits over the whole life cycle.

Computer-integrated construction will provide technologies for an open, automated mode of design and construction which will have much more progress made in the 90s, but will still have much left to do in the 21st century. We likely still will have a construction enterprise that is made up of a large number of smaller sub-contractors who need to have their own software and hardware, but who need to be able to integrate their data bases across the board. Even by the 22nd century we are not likely to have a completely automated construction process. This means that we need to have partial automation (where it is cost effective), but allow automated exchange of information where needed. As in the other areas, we will need fail-safe technologies.

A research area where there is much going on now, but will still need much more work in the 21st century, is informing the early design decisions with intelligence about constructability and effects of alternatives on life cycle benefits and costs. Some eminent architects tell me that they rarely find an engineer who is helpful at the early design stages. For instance an engineer who is able to present the advantages and disadvantages of alternative structural systems or mechanical systems.

Summing up the technologies that will make us more competitive:

Performance modeling and simulation
Artificial intelligence and cognative sciences
Integration technologies that provide for open systems
Automated devices for measurement, design, and construction
High performance materials

We should be sensitive to the way that we respond to these new technologies, e.g., not just substitute the technology for the way we do things at the moment, but find ways to exploit the new techniques. We also need new organizational responses. For example, in major bridge construction today hardly anyone bids the original design. It is put out as a "bogey" for the creative firm to redesign a solution that is responsive to the same requirements but more efficiently constructable. More integration of design for end use and planning for construction is likely to be needed for effective automation in construction. Educational programs also will have to respond to new challenges, i.e., when every professional has a computer available, what is really necessary to understand in order to use such tools well? This educational rethinking seems equally important at elementary and secondary school levels.

Wright expressed his hope that in the 21st century we would see the user as an important component of the building design challenge, look to integration of our systems and methods, explore better knowledge systems, and constantly search for better ways of designing and constructing the built environment.

APPENDIX C: WORKSHOP PARTICIPANTS

WORKSHOP PARTICIPANTS
December 2-3, 1987

Gifford Albright
Program Director
Structures and Building Systems
National Science Foundation

George E. Baer
Policy Management Division 04M1B
Naval Facilities Engineering Command

Lynn S. Beedle
High-Rise Institute
Lehigh University

Richard Bender, Dean
College of Environmental Design
University of California, Berkeley

John K. Bowersox
Consulting Service
Construction Industry Affairs-
Government Relations

Liza K. Bowles
NAHB Research Foundation

Howard Brandston
Howard Brandston Design
Lighting, Inc.

Leslie Breden
Chemist
Department of Housing & Urban
Development

Doyle D. Carrington
Research Staff (088D)
Office of Facilities
Veterans Administration

Louis Circeo
Director
Construction Research Center
College of Architecture
Georgia Institute of Technology

Ross Corotis, Chairman
Department of Civil Engineering
Johns Hopkins University

K. Dean DeVine
General Engineer
U.S. Department of Energy

Charles Eastman
President
Formative Technologies, Inc.

John P. Eberhard
Executive Director
Building Research Board
National Research Council

Milon Essoglou
Naval Facilities Engineering
Command, Code 03

Deane Evans, Principal
Steven Winter Associates, Inc.

Charles Field
National Association of Home Builders

Geoffrey Frohnsdorff
Chief, Building Materials Division
Center for Building Technology
National Bureau of Standards

Dennis Gale
Associate Professor
Urban and Regional Planning
George Washington University

Michael Gaus
Program Director
Structural Mechanics
National Science Foundation

Albert A. Grant, President, ASCE
c/o Metropolitan Washington
Council of Governments

Douglas A. Greenaway
Vice President for Government
Affairs
Building Owners and Managers
Association International

John Hanson
President
Wiss, Janney, Elstner & Associates

George T. Jacobi
Vice President, Technology
Johnson Controls, Inc.

Rolf Jensen
Rolf Jensen & Associates, Inc.

Joseph E. Johnson
Chairman of the Board
National Fire Protection Association
Fire Protection Consultant

Richard L. Johnson
Manager, Corp. Properties
Caterpillar, Inc.

Tony Karwoski
Director of Technical Activities
Manufactured Housing Institute

Kenneth C. Kazmer
Manager Building Systems
Gas Research Institute

Arvo Lannus
Electric Power Research Institute

William B. Ledbetter
Department of Civil Engineering
Clemson University

Edward J. Lisee
President
ACEC/RMF

David MacFadyen
President
NAHB Research Foundation

Charles D. Markert
Deputy Assistant for Engineering
and Design
Naval Facilities Engineering Command

Ronald Marony
Director, Division of Innovative
Technology and Special Projects
U.S. Department of Housing & Urban
Development

Charles McGinnis
Construction Industry Institute

Dennis E. Miller
Manager, Controls Research
Johnson Controls, Inc.

John Millhone
Director
Office of Buildings and Community
Systems
Department of Energy

D. Michael Murtha
Director of Research, Association
for the Study of Man-
Environmental Relations (ASMER)

Joseph P. Murtha
Dept. of Civil Engineering
University of Illinois

John H. Myers
Assistant Dean for Research Admin.
College of Architecture
Georgia Institute of Technology

James M. Neil
Director of Cost Effectiveness
Morrison Knudsen

John E. Rasmussen
Vice President
Potomac Electric Power Co.

Arthur H. Rosenfeld
Director, Center for Building Sciences
Lawrence Berkeley Laboratory

William Seaton
Research Manager
ASHRAE

L.R. Shaffer
Deputy Director
U.S. Army Construction Engineering Research Laboratory

Maurice Sharp
Alcoa Laboratories

John Slayter
The Ryland Group, Inc

Alan J. Van Den Berg
Edison Electric Institute

Bruce Vogelsinger
National Institute of Building Sci

Jack Warner
ACEC Research Foundation

Forrest Wilson
American Institute of Architects

James Winger
Manager, Technology Transfer
Center for Fire Research
National Bureau of Standards

Leo Young
Director, Research and Laboratory Management
The Pentagon

Craig Zimring, Ph.D.
Visiting Scholar
Massachusetts Institute of Tech.

Keynote Speakers

Mr. David Dibner
Senior Vice President
Bernard Johnson, Inc.

Mr. Mark Haynes
The Committee on Environment
United States Senate

Dr. Richard Wright
Director
Center for Building Technology
National Bureau of Standards