First Workshop on the Building System Integration Laboratory

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FIRST WORKSHOP ON THE BUILDING SYSTEM INTEGRATION LABORATORY FEASIBILITY STUDY

1.0 INTRODUCTION

The Whole Building Systems Integration Laboratory (WBSIL) feasibility study was initiated by the U.S. Department of Energy (DOE) to determine the feasibility of constructing a laboratory dedicated to the investigation of whole-building system-integration issues. The Pacific Northwest Laboratory (PNL) is conducting this study. To ensure the feasibility study receives a wide range of input, an advisory committee has been formed to assist in establishing the functional criteria for the WBSIL.

The advisory committee consists of nationally recognized experts in a variety of disciplines related to building research, design and operation. The original plan was for the advisory committee to provide guidance for the study in three forms. First, the advisory committee was to complete a questionnaire on whole building research issues and products. This was to be followed by the first workshop where the advisory committee would provide information on the need for the WBSIL and on its required design features. Finally, the advisory committee was to meet a second time to provide a review of the conceptual design of the facility and the functional criteria.

The first workshop was held on April 5 and 6, 1988, in Washington, D.C. The specific goals for the workshop included the following:

- Identify and rank whole-building research issues.
- Translate issues into research products.
- Identify and rank functional requirements needed to complete the research products.
- Identify existing facilities that may meet some of the functional requirements.
- Identify possible synergistic uses.

It was intended that results of the workshop would be used in three ways. First, the results would be used to evaluate the need for the WBSIL. Second, the list of high priority functional criteria would be used to guide the design process. Finally, the workshop participants would provide information about existing facilities.

This document will report the results of the workshop. Section 2.0 will discuss the procedure used in the workshop. Section 3.0 will present the results of the workshop. Section 4.0 summarizes the important findings from the workshop, while Section 5.0 presents modifications to the study based on the results of the workshop.

2.0 WORKSHOP PROCEDURE

The original workshop agenda was designed to produce a list of high priority functional criteria that could be used to direct a preconceptual design conducted by an engineering firm. The suggestions from the participants resulted in significant modifications to both the workshop and the project methodology.

The workshop participants were selected to provide a wide range of opinions. Participants included representatives of industry, academic researchers, and national laboratories involved in building science research. The participants in the first workshop are listed in Appendix A.

The workshop consisted of five major activities:

- identification of relevant issues
- identification of research products
- identification and ranking of workshop-suggested research
- identification of existing research facilities
- general discussion.

2.1 IDENTIFICATION OF RELEVANT RESEARCH ISSUES

The initial activity consisted of identifying research issues that would need to be addressed by a WBSIL. This activity consisted of three steps; high priority issues from the questionnaire were presented, the participants added issues to questionnaire results, and the participants determined which of the high priority issues would benefit from the WBSIL.

The questionnaire was prepared from the results of previous studies identifying important research issues. The questionnaire was sent to the workshop participants, who were asked to indicate the importance of 40 issues and 36 research products divided into eight research areas. The results were used to identify high priority issues and products. The results of the questionnaire were presented to the workshop, and the high and medium priority issues formed the basis for subsequent discussion.

After the high and medium priority issues from the questionnaire were presented to the workshop, the participants were asked to add new research

areas and issues. In addition to adding new issues, the participants were free to include low priority issues from the questionnaire if the workshop concluded that these issues were indeed important.

Following the addition of issues, the workshop participants were divided into four groups. Each group was assigned a fraction of the issues and was asked to separate the issues into three categories:

1. Issues best addressed by field studies - This category consisted of issues that would be most efficiently addressed by field studies in existing buildings. Issues in this category would not require the WBSIL.
2. Issues best addressed by separate effects tests - This group of issues did not strongly involve building system interactions and could be studied at facilities that lacked the ability to simulate the simultaneous interaction of multiple building systems. Issues in this category would not require the WBSIL.
3. Issues best addressed by the WBSIL - Issues in the group would require the WBSIL for efficient investigation.

Each group presented its conclusions to the workshop, and the workshop participants were free to suggest alternative characterizations of issues.

2.2 IDENTIFICATION OF RESEARCH PRODUCTS

Following the identification of WBSIL research issues, the workshop participants were again divided into the same four groups and were asked to identify research products that would address each of the research issues. It was suggested that the research products should be deliverables that would be of direct interest to buildings designers, builders, and owners.

At this point, the intent was to develop and rank functional criteria based on research capabilities required to produce the research products. The workshop participants felt that the list of research issues requiring the WBSIL was sufficiently compelling to support the need for the facility and that it was premature to identify and rank specific research capabilities because the research agenda for the facility would change dramatically during the facility's life. In addition, any list of research capabilities could only address "known unknowns" while the most important issues may currently be "unknown unknowns."

As an alternative to producing a list of high priority functional criteria, the workshop suggested that time be spent on generating creative preliminary designs for a flexible research facility. This recommendation was accepted, and an additional meeting was arranged for April 25 and 26. This meeting was to consist of an interactive design process involving two four-person groups formed from interested workshop participants.

2.3 IDENTIFICATION AND RANKING OF WORKSHOP SUGGESTED RESEARCH

While a list of high priority functional criteria was not developed, it was still important to have some indication of what type of research was viewed as a high priority by the workshop participants. Consequently, the participants were asked to suggest topics for a research agenda for a WBSIL. These were recorded and, after the list was completed, the participants were asked to rank the topics. This was done by giving each participant ten votes that could be distributed among the topics. One participant could assign 0, 1, or 2 votes to a topic. No more than two votes could be assigned to any one topic.

As part of this process, the participants were also asked to identify the impact of not proceeding with the WBSIL. These items were also recorded.

2.4 IDENTIFICATION OF ALTERNATIVE FACILITIES

The final activity consisted of producing a list of research facilities that could perform some fraction of the research proposed for the WBSIL. Various members of the workshop were then asked to develop a description of the relevant facilities.

2.5 GENERAL DISCUSSION

At various times during the workshop, the meeting became a general discussion of the WBSIL concept and the proper method to be used in the feasibility study. The results of these discussions proved to be quite useful and were recorded. Several of the suggestions made during the general discussions have been incorporated in the project.

3.0 WORKSHOP RESULTS

The results of the workshop consists of four components: a list of research issues and products that would benefit from a WBSIL, a workshop-suggested research agenda for a WBSIL, a compilation of the impacts resulting from not proceeding with a WBSIL, and suggestions and comments presented during general discussions.

3.1 RESEARCH ISSUES AND PRODUCTS

The workshop participants used the results of the questionnaire as a starting point to produce a list of issues that would benefit from the WBSIL. The participants then identified research products that would address the various issues. The research issues and products are listed in Appendix B. A review of the issues shows the following trends:

- usefulness of WBSIL - The issues presented in Appendix B shows that there are a substantial number of research issues that would benefit from a facility with the capabilities of the WBSIL.
- research areas requiring WBSIL - The workshop participants indicated that issues in seven research areas would benefit from the WBSIL. Research areas with multiple issues include HVAC systems, control systems, building physics, and whole building envelope.
- additional study required to define research products - Based on workshop comments, it appears that additional research is required to define research products that would be useful to building designers and operators. This conclusion is reinforced by a review of the suggested research products which tend to be quite general.

3.2 RESEARCH AGENDA SUGGESTED BY PARTICIPANTS

The WBSIL research agenda items suggested by the workshop participants are presented in Appendix C. The items have been divided into six areas: coordination and technology transfer, technology development, building physics, guideline development, field testing, and productivity. The ranking assigned to the various items is also presented. A review of these results shows that the following research activities are important.

- coordination and technology transfer - The workshop assigned a high priority to the coordination and technology transfer role of a whole buildings research program. This area received 19% of the votes assigned by the participants. Particular importance was attached to facilitating communication between researchers and industry users.
- technology development - The workshop indicated that the WBSIL should serve as a test bed for technology development. This area received 20.5% of the votes assigned by the workshop. Particular importance was assigned to having the facility serve as a test bed for new product development.
- building physics - Items related to developing a better understanding of basic phenomena were grouped together in the building physics area. This area received 20.5% of the votes assigned by the workshop. High priority research included validation of simulation codes, identification of optimum operating conditions, and development of an understanding of multiple system interactions.
- guideline development - A number of the research activities suggested by the workshop involved the development and testing of guidelines for design and operation. This research would use the WBSIL as a test bed to evaluate and develop new guidelines and rules of thumb. Seventeen percent of the votes were assigned to this area.
- field testing - Research items suggested by participants included a number of WBSIL research topics that are related to field testing. High priority research in this area includes the development of building diagnostics and instrumentation and test protocols for field data collection. This area received 16% of the votes assigned by the workshop.
- productivity - The workshop indicated the importance of research on productivity by the priority assigned to this item and in comments made during the general discussions. Seven percent of the votes were assigned to this topic.

3.3 IMPACT OF NOT PROCEEDING WITH WBSIL

Participants' comments concerning the impact of not proceeding with the WBSIL are summarized in Appendix D. A review of these comments indicates that there will be a substantial adverse impact associated with not proceeding with the WBSIL.

3.4 WORKSHOP COMMENTS

Many useful comments were provided by the workshop participants during general discussions. These were documented during the meeting and were subsequently reviewed. Where appropriate, these suggestions have been incorporated in the discussion of the workshop procedures and in the summary of major findings discussed in Section 4.0.

4.0 SUMMARY OF MAJOR FINDINGS

The various products from the workshop were reviewed. The major conclusions and findings were compiled and are summarized below.

4.1 WHOLE BUILDINGS RESEARCH CENTER

The committee strongly recommended that the WBSIL be considered as one component of a research program that concentrates on whole building research. In addition to a WBSIL, a center would coordinate research and concentrate on putting research products in a form that would be useful to industry. This technology transfer role would include evaluation of existing data, review of foreign developments, development of design guidelines, and review of codes and standards.

4.2 ROLE OF WBSIL

Whole building research can be divided into four types of activities:

- research that uses existing data
- research that uses existing research facilities
- research that can be conducted in occupied buildings
- research that requires the controlled conditions that would be available in a WBSIL.

The WBSIL should be focused on the issues that require the special capabilities of a dedicated whole buildings research facility without the difficulties associated with conducting research in an occupied building.

4.3 NEED FOR WBSIL

When attention is limited to those issues requiring a WBSIL, the workshop concluded that a facility with the capabilities hypothesized for the WBSIL is needed. This conclusion is provisional because the detailed evaluation of existing facilities is not completed.

4.4 ALTERNATIVE CONCEPTS

The workshop participants suggested several alternative approaches to conducting whole buildings research. These include using several facilities located in a variety of climates; using multiple structures at the same site to allow side-by-side comparisons; and using a variety of new buildings for 1 or 2 years as whole building test facilities with the owners being compensated with low cost loans.

4.5 COMMERCIAL SECTOR PRODUCTIVITY

The participants strongly recommended that enhancing productivity should be a major goal of the research conducted at the WBSIL. The workshop concluded that the promise of improved productivity will greatly improve the likelihood of successful technology transfer and will enhance the international competitiveness of the commercial sector in the United States.

4.6 WBSIL CAPABILITIES

A review of the high priority research activities recommended at the workshop suggest that the WBSIL should have capabilities in the following areas:

- technology development - The WBSIL should have the capabilities required to serve as a test bed for product development and evaluation of design procedures and codes and standards.
- building physics - The WBSIL should include capabilities that allow the investigation of fundamental processes in commercial buildings. Investigations could include validation of whole building simulation codes, building systems interactions, whole building ventilation, electrical system interactions including power quality issues, and the development of procedures for integration of building systems.
- guideline development - The WBSIL should have the capability to test and develop design and operational guidelines and rules of thumb.
- field testing - The WBSIL should be able to support field testing in occupied commercial buildings. Activities could include serving as a test bed for the development of advanced data acquisition systems and diagnostic procedures. The laboratory should include computer facilities for field data reduction and data base management.

- productivity - The WBSIL should support research on the factors affecting human productivity in commercial buildings and on methods for enhancing productivity without adversely impacting energy consumption.

4.7 IMPACT OF NOT PROCEEDING WITH WBSIL

The workshop identified the consequences of not proceeding with the WBSIL. These include the loss of innovation that would benefit from the test bed capabilities of the WBSIL, continued fragmentation of buildings research, reduced energy efficiency, reduced technology transfer, and an adverse impact on international competitiveness.

5.0 MODIFICATIONS TO STUDY

The results of the workshop have been used to modify the feasibility study. Modifications will be made to the project scope and methodology. These include:

- whole building research center - The recommendation to expand the WBSIL concept to include the development of a whole building research center will be included in the feasibility study. The WBSIL will be presented as one component of a larger research effort and the proposed design will include facilities for coordination and technology transfer activities.
- role of WBSIL - The workshop recommended that research activities on whole building issues be divided into those issues that can be studied in existing buildings, those that can be addressed in existing facilities and those that require the WBSIL. The feasibility study will be directed to concentrate on research that will benefit from the WBSIL.
- design workshop - The workshop participants recommended that the two advisory committee workshops currently planned should be augmented with a smaller design meeting. The goal of the design meeting was to define the capabilities of the building and to generate creative approaches to the design of the facilities. The design workshop was included in the feasibility study and was held on April 25 and 26 in Washington, D.C.

APPENDIX A

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APPENDIX A

WORKSHOP PARTICIPANTS

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APPENDIX B

SUGGESTED RESEARCH ISSUES AND PRODUCTS

APPENDIX B

SUGGESTED RESEARCH ISSUES AND PRODUCTS

The workshop participants produced a list of issues that would benefit from research conducted in a WBSIL. They then identified research products that would address those issues. These suggested research issues and products are listed in this appendix, organized according to specific research area.

HVAC SYSTEMS RESEARCH

Issues

- Many of the problems encountered in buildings involve the distribution system and the interaction between the distribution system and the occupied space. This can result in inefficient operation (such as when overcooling occurs), inadequate space conditioning, or undesirable dynamic interactions.
- HVAC components are a mature technology and improved energy efficiency is more limited by economics than technology. The greatest potential for major performance improvements is in the development of innovative systems concepts, particularly integrated building systems.
- One of the major reasons for the failure of modern HVAC systems to perform up to expectations is the inadequate initial setup and adjustment of the system's components. The evaluation of commissioning practices will require facilities and procedures appropriate for this type of activity.
- Innovative distribution system designs are required.
- Innovative methods of incorporating thermal energy storage in either the distribution system, occupied space, or as a separate component are required.
- Humidity control and the impact of humidity levels on other building systems needs additional research.
- Innovative designs that combine features of the HVAC system and domestic hot water system are required.
- The fire prevention system should be integrated with the HVAC system.

Products

- An understanding of distribution system interactions.
- Distribution system designs that minimize outside air use while meeting human comfort conditions.
- Commissioning protocols.
- Reports and data bases on HVAC systems commissioning.
- Transient condition analysis of new building systems and envelope.
- Guidelines and new design factors for system integration effects.
- Results of analysis of technical data for system interactions.
- Innovative HVAC systems conversions for existing buildings.
- Innovative data acquisition systems and interfaces for existing buildings including improved and cost-effective diagnostics and protocols for data acquisition.
- Distributed thermal energy storage designs that incorporate thermal energy storage in the distribution system.
- Optimum heat recovery systems for integrated lighting and HVAC systems.
- Designs of systems that utilize exhaust air for snow and ice melting.
- Designs of HVAC systems with local temperature control for individual occupants.

WHOLE BUILDING VENTILATION

Issues

- Often available ventilation is not efficiently used. Poor ventilation efficiency will increase the requirements for ventilation air.
- Interzonal air flows are difficult to predict and not well understood.

Products

- Validate design and simulation methodologies for interzonal air flows.
- Develop ventilation designs that provide effective ventilation for different spacial configurations such as open rooms versus open plan offices and widely varying uses and loads.

WHOLE BUILDING LIGHTING RESEARCH

Issues

- Understanding interactions between the lighting system, electrical system and the HVAC system.
- Understanding interactions between daylighting and other building systems such as the HVAC system and artificial lighting system.

Products

- Design and evaluation tools for the integration of daylighting and HVAC systems.
- Design guidelines and recommendation for integrating the lighting HVAC and other building systems for energy efficiency and load management.

ELECTRICAL SYSTEM RESEARCH

Issues

- Integration of electrical system with the HVAC system including heat recovery from electrical equipment.
- Impact of other building systems on electrical system power quality.
- Impact of other building systems on electrical system power factor.
- Integration of communication systems with other building systems.

Products

- Design tools, technical assessments, and operating manuals for integrating heat recovery from electrical equipment into the mechanical system.
- Design tool to evaluate the impact of equipment selection on power quality.
- Design tools for the configuration of systems to provide good power factors and specifications for device or systems to control power factor.
- Recommended practice and design and operation guidelines for integration of building control and communication systems.

CONTROL SYSTEM RESEARCH

Issues

- Adaptive and predictive control systems offer the potential for significant improvements in a building's energy efficiency and can compensate for component degradation and occupant modifications to the conditioned space. To achieve this potential, these concepts must be developed and field tested.
- HVAC systems are seldom at steady-state operating conditions. Control systems need to be able to control for efficient part-load and transient operation.
- It is recognized that comfort depends on more than just air temperature and humidity. Air velocities and radiant temperature also affect comfort. For maximum comfort and productivity, the control system should monitor and control other factors affecting human comfort.
- Control systems should be designed with maintainability as a major design goal.

Products

- Design guidelines to achieve energy efficiency and comfort using adaptive and predictive controls.
- Selection of control systems to match HVAC designs.
- Design and operation strategies for providing human comfort in an energy efficient manner.
- Design information regarding transient and part-load operation of equipment and their effect on equipment selection, operation and control.
- Workbook on using the control system to assist in monitoring maintenance issues.

BUILDING PHYSICS

Issues

- The verification of simulation codes, for both zonal and overall building performance, is challenging. A standard benchmark procedure for verification is required.
- Simulation tools for modeling HVAC system performance, particularly transient effects and HVAC system/building interactions, are required for system development and research.

- An adequate understanding of key system level physical phenomena does not exist. Examples include impact of a building's thermal mass on energy consumption, interzone air flows, and convective heat transfer.
- Methods for using metered data and billing data to calibrate existing simulation models are required.

Products

- Statements on the accuracy and limitations of simulation codes. Improved and ASHRAE approved whole building simulations.
- A systematic comparison of simulated and experimental results for HVAC systems.
- Improved HVAC systems simulations.
- Data on system level parameters.
- A determination of the feasibility of using metered and billing data to calibrate existing simulation codes.

WHOLE BUILDING ENVELOPE RESEARCH

Issues

- Impact of fenestration on whole building performance is not well understood. Issues including the distribution of absorbed radiant energy the internal heat transfer induced by absorbed radiant energy, and interaction of the fenestration with the HVAC system, lighting system and system controls.
- Whole building heat transfer is not well understood. This involves the heat transfer mechanisms in the building in addition to heat transfer through the envelope.
- The impact of a building's thermal mass on the thermal performance of the structure (both in the envelope and within the building) is not adequately understood. There are competing methods for modeling thermal mass, and it is unclear how sophisticated this modeling needs to be.
- Infiltration of air moisture is not understood.

Products

- An empirically-verified data base of fenestration and perimeter space characteristics together with validated methodology for predicting space conditioning demands as a function of climate, orientation, and design.
- Diagnostic tools for evaluating heat transfer during commissioning

- HVAC diagnostics
- Predictive load control
- Design guidelines for the placement of thermal mass
- Determination of the impact of air and moisture infiltration on energy performance.

OTHER ISSUES AND PRODUCTS

Issues

- Widely used "Rules of Thumb" need to be field tested.
- Codes and standards need to be evaluated in the field.
- Energy systems need to be able to adapt to changes in the occupied space caused by occupants or remodeling.
- The complete building design and construction process needs to be evaluated because many of the problems occur due to the fragmented nature of these activities.
- The domestic water and fire prevention systems need to be integrated with other building systems.
- The impact of site-specific factors, such as climate and orientation, on the performance of building systems needs to be determined.

Products

- The evaluation of "Rules of Thumb", codes and standards, and the building design process should be included in all testing areas.
- The development and testing of innovative adaptive energy systems.

APPENDIX C

WORKSHOP-SUGGESTED RESEARCH AGENDA

APPENDIX C

WORKSHOP-SUGGESTED RESEARCH AGENDA

<u>Agenda Item</u>	<u>Number of Votes</u>
COORDINATION AND TECHNOLOGY TRANSFER	
Research life cycle of R&D product must go from problem identification to commercialization.	0
Conduct surveys of foreign developments in an open forum.	2
Help U.S. building industry compete internationally.	0
The WBSIL should be a research "center" with technology transfer and coordination responsibilities.	6
Improve HVAC design process.	3
Enhance exportability of U.S. products.	3
Serve as a clearing house for communication between researchers and the building industry and facilitate technology transfer.	9
TECHNOLOGY DEVELOPMENT	
Develop building instrumentation.	4
Develop new controls systems.	3
Establish component design needs.	1
Test bed for new construction methods.	0
Test bed for development of new products.	10
Development of easily maintained control systems.	2
Control systems that allow easy modification of the control strategy.	3
Building system designs that support flexibility in building use.	2

<u>Agenda Item</u>	<u>Number of Votes</u>
BUILDING PHYSICS	
Methods for identifying optimum operating point for energy, comfort and cost.	8
Combine computer added design with load prediction programs.	0
Validation of whole building simulation codes.	6
Develop an understanding of how multiple systems interact.	5
Develop a systematic way of integrating component research into a whole building design.	3
Develop updated algorithms for building simulations.	3
GUIDELINE DEVELOPMENT	
Guidelines for minimizing owning and operating costs.	4
Reduce commissioning and operating costs through the development of commissioning protocols.	1
Test design "Rules of Thumb" and design guidelines.	7
Develop and test new concepts and develop amendments to codes and standards.	4
Guidelines for evaluating lighting and HVAC interactions.	5
FIELD TESTING	
Develop building ratings. What are achievable energy goals and how to achieve them.	3
Instrumentation and test protocols for field testing using a small number of data sets over a short time period.	6
Provide data bases on field performance in a useful format and with easy accessibility.	3
Develop diagnostics for building system malfunctions.	8

<u>Agenda Item</u>	<u>Number of Votes</u>
PRODUCTIVITY	
Building research must consider factors that impact productivity and have productivity as a valid objective.	8

APPENDIX D

IMPACT OF NOT PROCEEDING WITH WBSIL

APPENDIX D

IMPACT OF NOT PROCEEDING WITH WBSIL

One way of evaluating the need for the WBSIL is to consider the consequences of not building the facility. Toward this end, the workshop participants were asked to suggest lost opportunities that would result from not pursuing the WBSIL concept. The suggestions include:

- The nation will lose a showcase for new approaches in building systems, particularly those that don't meet existing building codes. This will result in reduced innovation in the buildings industry.
- Not establishing a center for whole buildings research will result in a continued fragmentation of whole buildings research with a loss in coordination and inefficient use of available funds.
- Not establishing a center for whole buildings research will result in a loss of value from existing data because of a lack of a coordinated effort to analyze existing data sets.
- Without the WBSIL we will "stay dumb."
- The nation will lose opportunities for energy savings in buildings.
- The nation will lose opportunities for peak electricity generating capacity limitations.
- There will be a loss in communications, technology transfer, and other clearinghouse functions associated with a whole buildings research center.
- There will be a loss of opportunities for cross-fertilization between researchers in various branches of buildings research.
- International competitiveness will be adversely affected by the lack of information on economical building design practices.
- Not establishing a center for whole building research will result in avoidable negative environmental impact and use of nonrenewable resources.

- The lack of design data available from the WBSIL will result in the continued overdesign of building systems that, in turn, requires capital that could be more productively used elsewhere in the economy.
- Failure to pursue the WBSIL concept will contribute to the United States becoming a technological backwater.

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