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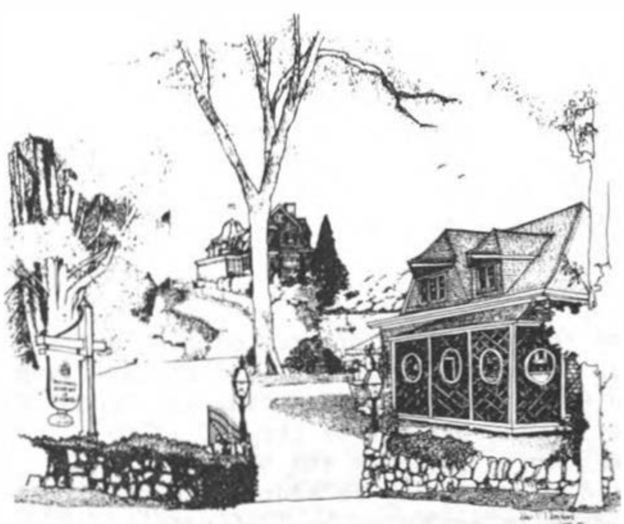

Committee on Advanced Technology for Building Design and Engineering
Building Research Board
Commission on Engineering and Technical Systems
National Research Council

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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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BACKGROUND

Since 1982 the Committee on Advanced Technology for Building Design and Engineering of the National Research Council's Building Research Board has been examining the potential for computer-based technologies in the building construction process. The purpose of the committee is to assess the long-range implications of how computer-based technologies will affect future design, construction and management of facilities. The committee's study was in response to a request from the thirteen agencies that comprise the Federal Construction Council to provide an informed assessment of the state of the art and its evolutionary direction.

1983 WOODS HOLE WORKSHOP*

The committee invited several other experts to join it at a workshop held in August 1983 at the National Academy of Sciences Study Center in Woods Hole, Massachusetts. Participants at this first workshop, charged with the challenge to develop a conceptual framework for the integration of computer-based technologies in the building process, found that "much valuable data associated with the design, construction and operation of a facility are lost during its life span." The workshop participants stated that these lost data could potentially be used to improve the building process by providing the information needed for improving the performance and responsiveness of future designs, and for bringing about a reduction in the life-cycle costs associated with new facilities. The workshop concluded that efforts should be made to explore the development of an integrated computer data base that would be available at all stages in the life of a building project.**

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*Although the proper title of the workshops is Workshop on Advanced Technology for Building Design and Engineering, they are known to workshop participants and committee members as the "Woods Hole Workshops."

**National Research Council, A Report from the 1983 Workshop on Advanced Technology for Building Design and Engineering, National Academy Press, Washington, D.C., 1984.

1984 WOODS HOLE WORKSHOP

This idea of an integrated computer data base became the core of the 1984 Woods Hole workshop. As in 1983, the committee invited other experts to Woods Hole to focus on the conceptual framework of an integrated computer data base that spans the life cycle of a building. Workshop participants generally agreed that there is a need for the development and implementation of an integrated project data base such as the model developed in Figure 1.

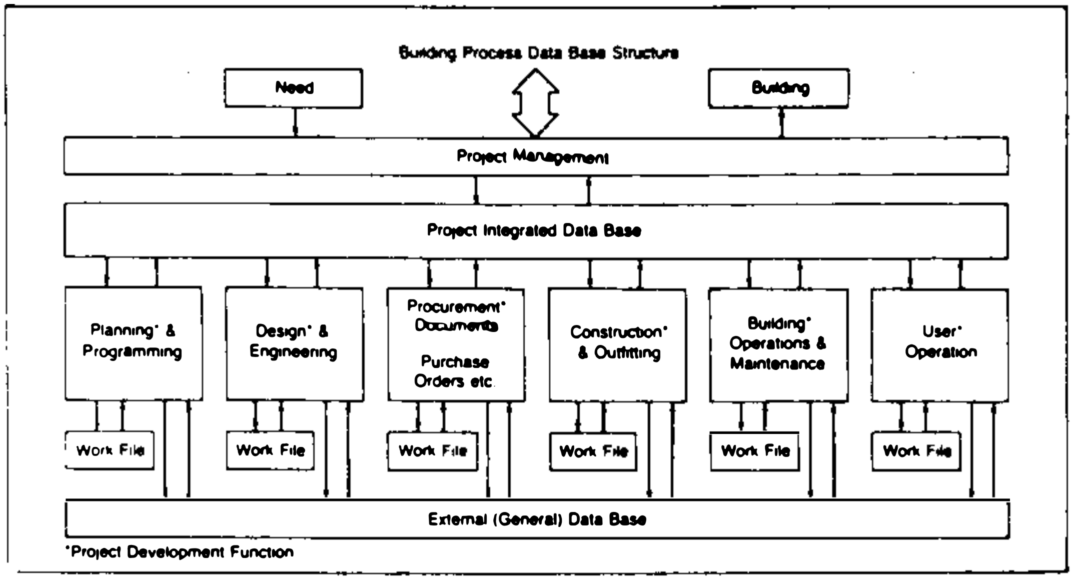

FIGURE 1 Integrated project data base.

The integrated project data base will support all phases of the building project and will involve new ways of representing and exchanging data (such as building geometry and protocols for data exchange). The participants concluded that life-cycle cost considerations should provide the economic rationale for the building owner to invest in the development of an integrated project data base. The availability of an integrated projected data base makes it possible to have more efficient facilities management that should result in savings to the building owner.*

1985 WOODS HOLE WORKSHOP

The 1985 Woods Hole Workshop--the subject of this report--addressed the developmental needs to formulate and construct an

*National Research Council, A Report from the 1984 Workshop on Advanced Technology for Building Design and Engineering, National Academy Press, Washington, D.C., 1985.

integrated project data base. The results of this exercise would be used to prepare a prototype for purposes of demonstration and research during 1986.

To do this, the workshop focussed on the interface between the design/engineering phase and the construction phase. The passing of information from one phase to another has been likened to trying to pass information over a wall. Each participant has a distinct view of what is useful information. The architect and engineer place their intentions into drawings and specifications, not passing on the programmatic information that has led them to their decision. The contractor, representing the construction phase, must extract from these documents explicit (e.g., materials and dimensions) and implicit (e.g., square footages, undocumented construction details, and construction sequences) information for bidding and construction. Often the contractor must recreate information not explicitly stated (i.e., not passed over the wall), though possibly explicitly available at previous phases in the building life cycle. Of prime concern, however, is not the information that is explicit or can be recreated, but the information that is lost.

The challenge presented to workshop attendees was to use the requirements for an integrated project data base developed in previous Woods Hole workshops to determine the data requirements and the conceptual representation of all data that pass through the integrated project data base. Chapters 1 and 2 of this report present the findings of the two working groups--Group A and Group B, respectively--that examined these considerations.

The group on "Data Requirements for the Integrated Project Data Base" (Group A) took a user's perspective of the information needs for the data base. The group identified user data needs, developed rules for data inclusion and exclusion, identified users and uses of data, and listed incentives for users to update and use an integrated project data base.

The group on "Integrated Project Data Base Conceptual Model" (Group B) focussed its efforts on identifying required data base characteristics and examples of how these characteristics would be used by the building industry. The group constructed a model of the conceptual view of the data base, developed a data model suitable for implementing this conceptual view, and described the relationship between the conceptual view and its physical implementation.

Chapters 3 and 4 of this report present proposals for different types of demonstration projects. In Chapter 3, the group on "Prototype Demonstration of an Integrated Project Data Base" (Group C1) developed a proposal for demonstrating the concept of an integrated project data base by means of a prototype system. The prototype would represent and exchange data in such a way that, regardless of the hardware and software involved, information generated in one phase of a facility's development would be available in later phases of the process.

Chapter 4 presents the findings of the group on "A Proposal for a Demonstration by Communication" (Group C2). This group examined the need for communication of the usefulness of an integrated project data base to all potential users by developing a proposal for a video disk demonstration.

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DATA REQUIREMENTS FOR THE INTEGRATED DATA BASE (GROUP A)

The working group on data requirements, Group A, was asked to explore the pragmatic information and knowledge necessary to describe an integrated project data base from the user's perspective. This section discusses the objectives of the integrated data base, the assumptions that would govern the user's view of an integrated data base, and the decision rules that would be applied to data for inclusion or exclusion in an integrated project data base.

Members of Group A were: Len Simutis (chairman), Harold Borkin, Pat Davis, Jack Enrico, Robert Furlong, Ron King, William McCormick, John Metzler, Shirley Radack and Peter Smeallie.

INTRODUCTION

The 1984 Workshop on Advanced Technology for Building Design and Engineering identified the need for an integrated project data base that would support all phases of the building process and that would involve new ways of representing and exchanging data. Participants concluded that life-cycle cost considerations would provide the economic rationale for the building owner to invest in the development of the integrated project data base. This conclusion was based on the assumption that building owners would benefit by more efficient facilities management and thereby achieve cost savings.

The 1984 workshop developed a model of the integrated project data base that covered six phases in the life cycle of a building project (see Figure 1). According to the model, each phase of the process uses its own working files or private data bases. The integrated project data base bridges all six phases and contains information to support functions in more than one phase. Since the model and its descriptions were concerned primarily with the various processes that make up the overall building process, it was necessary to develop a description of the data base itself.

This working group's charge was to develop the ideas and information that would provide the user's view of an integrated project data base. These ideas and information, blended with the other perspectives developed at the workshop, would help to guide the development of a demonstration integrated project data base in 1986.

ASSUMPTIONS

As a framework for its discussion of the classes of data that would be included or excluded in the integrated project data base, the following assumptions were made:

- Only necessary information would be contained in the integrated project data base. A great volume of data is collected and generated as a result of the building process. Many of these data are developed during one specific phase by one of the major participants in the process and may be lost, only to be recreated again by another participant. This was the significant factor driving the discussions held at the 1983 and 1984 workshops. However, some of the information collected may be of use in just one phase or of limited value during the life cycle of a building. Because the cost of collecting and storing this information would exceed the benefits of maintaining it in the integrated project data base, the group assumed that the data base would contain only the information that the facility owner or owner's organization decided was necessary and desirable to include.
- The integrated project data base should be designed to be independent of specific software and hardware configurations. Computer technology and hardware configurations are changing rapidly. Owners of an integrated project data base would benefit from the ability to change hardware and software when less costly and higher performance systems become commercially available. Design of the data base should enable the owner to accommodate changing technologies and should allow for the adoption of new methods of data entry, improved computer-aided design techniques, and the widespread use of computer workstations and networks with different capabilities.
- All of the data in the integrated project data base will not be accessed or used with equal frequency. Some of the data will be changed as the building changes and as requirements for information change. Some of the data will have historic value and may be stored in an archival file that is not part of the integrated project data base. However, the integrated project data base will contain a reference element to enable the user to locate the information that may be needed only infrequently.
- Data can be added to the data base as changes are made to the facility, or as data begin to be collected in different ways as a result of changing technology. The added information would update the information in the data base to reflect changes to the facility and its contents. It also might be desirable to add new classes of data to reflect changing information requirements for facility management. The integrated project data base should be sufficiently flexible to allow for these changes.
- Data available in the integrated project data base may be shared by those who use it and add information to it. A major benefit to be gained from the development of an integrated project data base is the improved quality of buildings, as well as more efficient facility management. Thus, the sharing of data may help building designers, who

can learn from operation and maintenance data collected for a specific project that are then applied to improve future design. Also, different participants in the building process should be able to respond to change and to exploit the data generated and collected by others.

- A data manager or data administrator will be needed to maintain the integrity, consistency, and security of the integrated project data base. It will be essential that the various users of the integrated project data base use information that is correct and up to date. Without assurance of quality and timeliness, users will lose confidence in the information that they access or decisions will be based on faulty data.
- Each integrated project data base will be unique, reflecting the needs of different owner organizations. Each organization will establish for itself what information is important for its goals and policies. Therefore, issues pertaining to user views apply to a class of data bases and do not describe a single type. There will undoubtedly be much of the same information collected by many organizations. However, individual differences must exist in order to serve the facility owner's organization best.
- Users will continue to maintain their own private data bases as they contribute to and access the integrated project data base. These private data bases will include the working files and data that support individual participants in the building process and that do not meet the criteria that facility owner establishes for inclusion in the integrated project data bases. However, the integrated project data base may contain references to these private data bases so that the facility owner may locate the information should it be needed.

OBJECTIVES

The objectives for determining data requirements for the integrated project data base are as follows:

1. **To identify user data needs for an integrated project data base.** The content and structure of a data base should be tailored to the needs of those who intend to use and benefit from it. To design the data base properly, it is necessary to examine in some detail the potential users and the organizations to which they belong.

When considering the needs of the users, the group recognized that those needs might be satisfied by a combination of data bases, some tied together to form an integrated project data base, and others independently accessible. Only those needs that justify the development of an integrated project data base were addressed. It was further noted that the user views the data base in the context of some specific application, and the data base must satisfy the various programs which it supports.

Lastly, it was recognized that the organization that owns the data base (and perhaps the facility) will most likely wish to impose certain special requirements. These requirements might stem from particular corporate objectives or policies.

2. **To develop criteria and rules for data inclusion and exclusion in an integrated project data base.** The feasibility of an integrated data base depends heavily on the selectivity applied in determining its content. Practical storage limitations and the perpetual cost of data maintenance dictate that only essential elements be included. A key objective of the group was to formulate criteria for determining rules for inclusion or exclusion of data. In approaching this task, it was necessary to address classes of data rather than specific project data. Given a well-conceived set of decision rules, one must only apply those rules at the project-specific level to determine which data elements to include. The criteria should reflect the user's needs and the principles of efficient data management.

3. **To identify users, uses of data, and the desired characteristics of an integrated project data base.** In addition to content and structure, the characteristics of the data base should be tailored to suit the potential user and intended uses. Potential users include planners and programmers, designers, constructors, operators, auditors, financiers, real estate brokers, and regulatory officials. In recognition of the wide spectrum of potential users and applications possible, it is important to include information from all phases of project development. Likewise, it is important to insure that the data be stored in forms most likely to serve potential users. Accessibility should be addressed in terms of frequency of need, convenience of data maintenance, and desired response times. The use of off-line reference files, working files or references to archived materials should greatly simplify the integrated project data base and not adversely affect its usefulness.

4. **To identify incentives for users to update and use an integrated project data base.** The initial development and maintenance of the data base will require the dedicated and disciplined efforts of those who use it and contribute to it. Assurance of quality over the life of the data base will require that each user be interested in data quality. For those users whose participation is temporary or relatively short-term, it will be necessary to provide other forms of incentives. The most likely form will be contract provisions with appropriate fee allowances. Other incentives might include free access to the data base for use in other business ventures or use by governmental bodies in their development of criteria for standards and codes.

These objectives should serve to improve the building process in all of its phases, but more importantly to improve the end product, i.e., the constructed facility. If pertinent information is captured, properly communicated and retained throughout the process, each of the phases will more effectively achieve its objectives and the completed facility will not suffer in quality as a result of poor communications.

At the multi-project level, similar improvements should result. Intelligence gained from better records and feedback on lessons learned will contribute to improved planning, better design, more efficient construction and more enlightened facilities management.

DECISION RULES

The following decision rules for inclusion and exclusion of data are based on discussions held at the 1983 and 1984 Woods Hole workshops. It was found that the problem of what items to be included in the integrated project data base was too complex a problem to be assessed by just listing the individual data elements that would be necessary. Two concepts emerged to assist in solving this problem. The concept of data classes that would include several elements or even subclasses of elements allows for a flexible data base that might include a class of data, but would not necessarily include all elements that make up a class. This would allow development of a comprehensive data dictionary, but not necessitate the inclusion of all dictionary items in a data base. The second concept concerns inclusion and exclusion rules and provides general principles for development of both a comprehensive data dictionary and for the development of a specific data base. The following rules are presented with data classes rather than specific data items in mind.

Inclusion Rules

1. **Life-cycle use data.** Data that affect the life cycle of the facility should be included in the integrated project data base. Data elements that influence the facility's life-cycle costs are items chosen during the design and construction phases and have the greatest effect on the maintenance and operation phase. The cost implications of these early decisions must be recorded in the integrated project data base. It is within the major building systems that the life-cycle use becomes most important and can have the greatest influence on the final product.

2. **Multiple use (long term and short term).** Data valuable in more than one phase is considered a multiple use. However, a data element used several times in any one phase, such as design and engineering, is not considered necessary for inclusion. Such data would reside in the work file. A typical multiple use element is the allowable floor area of a facility, used in the planning and programming phase, the design and engineering phase, and finally in the operation phase. This is an example of a long-term multiple use data element. Short-term multiple use implies that the integrated project data base serves as a pass-through medium, for example, at the transfer of an equipment list from the specifications list to those which are eventually installed in the facility. Such data can be removed from the data base after their last expected use.

3. **Physical description.** Data that describe the physical attributes of a facility should be included in the integrated project data base. This class of data will provide the basis for deriving much of the data to be used later in the building process. Examples of these elements include facility dimensions (length, width, height), material types (concrete, steel), and inventory of equipment. The list of physical description elements should be limited to the major building components.

4. **Intention.** Performance expectations of the programmer and designer will provide useful data at the facilities management phase, for example, the reasons why a sloped roof was chosen over a flat roof.

5. **Historical references.** The data class comprising historical references that relate to past uses should be included in the integrated project data base. These elements can provide the user with the information needed to make decisions on future uses. The elements can also aid the user in determining the outcome of changing the intended use.

6. **Major system components.** Major system components should be incorporated as separate data classes in the integrated project data base. This rule ensures that data relating to major building systems are retained within the data base. The building's physical description should include many of the major components, but may not include all of them. Examples of major components include foundations, superstructure, roofing, mechanical, and exterior utility locations.

Exclusion Rules

1. **Derived or generated data.** The exclusion of derived or generated data removes from the integrated project data base any element that is redundant since it could be recreated from one or more elements (however, the derivation algorithm must be preserved if the derived data is ever to be accurately recreated). This rule will help reduce the size of the integrated project data base. It also reduces the chance of recording conflicting data. An example of this rule is that a room area need not be included when the room dimensions are in the data base. The room area can be derived from the room dimensions.

2. **Data in the external data base.** An external data base includes items that are contained in industry standards and other generally available generic sources. The integrated project data base should not contain data that reside in the external data base (such as the specific steel members used in the building design itself), although the source of the reference should be captured if the reference is ever to be recreated.

3. **Insignificant data.** Insignificant data must be defined and then excluded from the integrated project data base on a project-by-project basis. This exclusion is directly related to the facility owner's organizational policies. Some owners are interested in retaining information on all building fixtures, furniture and maintenance items. To another owner, such data may be considered of such insignificant value that they are not important to track. Based on the policy of the owner, the integrated project data base can be reduced in size when the accounting of insignificant data is not considered important to the future use.

4. **Value to other data bases.** Data whose value are greater in another data base should be excluded from the integrated project data base. This exclusion is directed primarily at the operation and maintenance phase. For example, maintenance records on equipment would be better kept in a working file than in the integrated project data base.

Data Dictionary

Preparation of a data dictionary of standard definitions that are clear for all the users of a data base will be a difficult task. Common definitions should be used where possible. The development of the dictionary will require considerable effort from all disciplines of the organization. Unfortunately, there are numerous examples of data bases within an organization using different definitions for the same element.

A comprehensive data dictionary is desirable for elements used in work files and in the integrated project data base. The test for element inclusion in the integrated base will rest with the owner organization. However, the development of rules to enhance the consistency of evaluation should prove helpful in eliminating unnecessary elements from the integrated project data base. While broad areas of agreement will be reached upon classes of data for inclusion, however, a clear dictionary will assist in avoiding misunderstanding of the meaning of data elements.

While all phases of the building cycle will exert influence on the data elements to be included, the planning and design phases may exert the greatest initial influence. However, facilities management functions will most likely move into the most influential position in the future since it is at this phase that the greatest potential benefits of the integrated project data base will accrue.

Existing data bases, even though not as comprehensive nor integrated as those assumed in this report, require maintenance over the life of the building. The resources for this maintenance can be easily underestimated. Lack of proper maintenance could result in out-of-date and poor quality data. Experience has shown that once data are perceived to be of poor quality, a prejudice is developed that becomes extremely difficult to overcome.

It should be recognized that data collection techniques can significantly influence the elements to be included. For example, current standard electrical meters are not conducive to automatic collection of data on electrical energy consumption. This has the capability to change not only the quality of data but to alter the application programs used. It is not too difficult to imagine that other forms of technology might be combined to change the whole magnitude of data quantity and possibly to enhance the quality.

USER VIEWS OF THE DATA

The concept of user views of the data recognizes that the data which are to be part of an integrated project data base will have different uses for different participants in different phases of the design, construction and management of a building. Consequently, either the integrated project data base must be created in such a way to anticipate these various uses and needs, or the data base must be structured to accommodate a variety of queries by different users to meet varying needs.

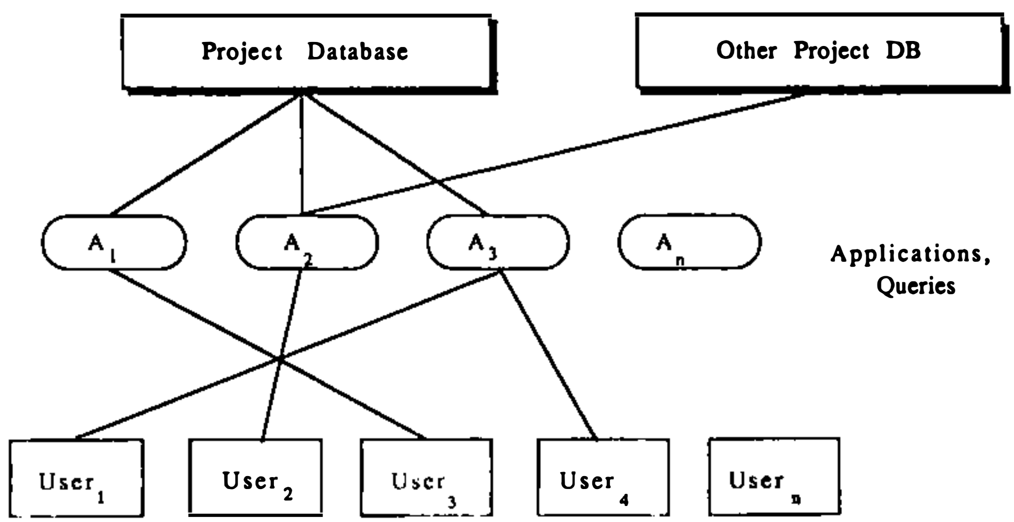
For example, data describing the structural elements of a roof will be used in the original form-giving design phase, and again in the calculations necessary for structural analysis. Also, the structural elements will be components to be priced, ordered and stored on-site prior to construction; they will be components in the construction process and will need to be sequenced in building assembly. Finally, they will be components requiring periodic inspection, maintenance, and perhaps replacement. Thus, information describing the same building component depends on its function for the various participants in the different phases of the building process.

It is now possible to define user views of the data in a variety of ways since data base technology is developing the appropriate flexibility and resources to allow for fewer structured queries and more ad hoc analysis. Until recently, it has been difficult, sometimes impossible, to query or analyze data in ways not anticipated in the original design of the data base. The analysis capability was dependent on the limits imposed by the structure of the data base and the mathematical or statistical methods incorporated into the data base computer programs. With these limitations becoming less significant through the development of more powerful software and hardware environments, it is now possible to enhance significantly the way the information stored in a data base is accessed and analyzed.

For an integrated project data base, a number of alternative views of the data may be envisioned. One view of the data might include verbal descriptions and text that capture the purposes of the project, the designer's intentions in proposing a particular solution, as well as transcriptions of meetings among the client, designer, and developer. This same view of the data might also include copies of the program, bids, and contracts for the project. From this view of the data, information in the data base would be retrieved and analyzed primarily using textual tools for analysis, such as keyword searches or content analysis.

Another view of the data might be spatial descriptions of the facility--its form and volumes. This view could be constructed graphically or geometrically from descriptions of the structural elements. This same information might be used for planning of interior spaces, for estimating requirements for heating, ventilation and air conditioning, and for meeting fire codes. In each instance, the basic data elements are shared by a number of different users, but the analysis done with these elements will be diverse.

Figure 2 gives some examples of how various views of the data can link user requirements to an integrated project data base. As depicted, project data bases are linked to users through a variety of applications or queries which access the data bases for particular purposes. For example, $User_1$ and $User_4$ both employ an application program which processes updates to the data base. $User_3$ employs an application program which conducts an energy analysis of a prototype design, while $User_2$ does a facility management analysis comparing utilization patterns in two different projects.



$User_1$ processes an update to the database.

$User_2$ does a facilities management analysis comparing utilization patterns in two different projects.

$User_3$ does an energy analysis of a prototype design.

$User_4$ processes an update to the database.

FIGURE 2 User views of the data.

These examples stress that the desireability of application programs and queries being constructed independent of the software and hardware on which the integrated project data bases may reside. Thus, the application program, A_2, may reside on a microcomputer in an engineer's office, but will link to two data bases that themselves may be located on separate computers in different locations. Similarly, the energy analysis program, A_3, might reside on a computer in a research laboratory at a university which is accessed via telecommunications by an architectural firm in another city, with the integrated project data base itself in still another location.

USER INCENTIVES

Because the largest benefit of an integrated project data base will accrue to the facility owner, incentives to assure that users participate and provide useful data will have to be devised and promoted by the facility owner. Since most owners are unaware of the potential benefits involved, facilities management organizations will have to educate the owners in order to get the necessary support. Such organizations have the greatest likelihood of becoming the managers of the integrated project data base.

How the owner proceeds to deliver a facility determines what incentives need to be applied. For example, if the owner uses in-house resources to program, design, construct, and operate a facility, he must be willing to issue appropriate policies and provide necessary support of the data base. On the other hand, if the owner contracts out the programming and design phases, it would be in his best interest to: (1) hire a consulting facilities manager at the earliest possible time, (2) assure that the facilities manager or appropriate data base manager inputs the requirements into the early phases, and (3) pay extra fees, e.g., to members of the design team to install data into the data base that they would not normally provide.

Initially, because of cost, only owners with long-range strategic plans or similarly interested buyers will have the incentive to use an integrated project data base, although a facility that contains such a data base may increase its re-sale value.

FINDINGS AND RECOMMENDATIONS

The data requirements group concluded that an integrated project data base will permit more economic and efficient facility management and improve the quality of a facility, in terms of its responsiveness to user needs, by providing useful and timely data for all participants in the building process. In order to realize these benefits, the data base must be planned, designed, and maintained with these objectives in mind. The needs of facility management should have a strong influence on the content of the data base. Consequently, it may be necessary for owners to offer incentives to other participants in the process to ensure that necessary data are captured, maintained, and updated as necessary.

Facility management is emerging as the facility owner's organizational element which will benefit the most. Facility management, as defined by the International Facility Management Association, is concerned with the tasks of design, construction, maintenance and management of the physical environment as it relates to people and work processes--the practice of coordinating the people and the work of an organization into the physical workplace. This process involves such disciplines as architecture, building engineering, interior planning and design, construction, finance, leasing, maintenance, communications, information management, personnel management, purchasing, and worker comfort and safety. In view of this broad scope of involvement, it is clear that facility management will have a strong influence over the content of the integrated project data base.

The integrated project data base serves as the primary interface among all aspects of the project. The internal structure of the data base serves as a major vehicle for communications. Consequently, the content of the data base must be organized in a standard way, possibly using Uniformat or some other appropriate format. Exactly which data or data elements will be included in the data base will be determined primarily by the facility owner's views and policies; however, there will be broad areas of agreement for inclusion of classes of data. Users of the data base should be able to retrieve data from the data base in any one of a number of views--words, numbers, graphical, or the three mixed in a single view--whichever combination meets their needs.

Maintenance of the data base over the facility's life will require a significant commitment of resources. Consequently, it is essential that a data manager or administrator be designated to insure that the data base is properly maintained, and the data are consistent and reliable, since inaccurate information is usually worse than no information at all. Changes in data collection techniques (such as diagnostic sensors and voice-activated data input devices) will have a major impact on the data requirements, especially in the facility management area. The introduction of these devices should make it easier to capture essential data at a much lower cost and minimize the human error factors.

The group believes that facility owners who commit the necessary resources required to establish and maintain an integrated project data base can realize a return on their investment. Table 1 shows various types of cost savings which can be realized in the facility management area through the use of an integrated project data base. Further, certain intangible benefits can also be realized. For example, the integrated project data base:

- provides continuity of data, thereby reducing chances of human error,
- integrates the tracking and planning activities,
- provides a tool to manage change,

- generates multiple alternatives rapidly, and
- enables decisions to be validated.

Also, the data base's usefulness is not limited to one project. The data are readily accessible for comparisons with other projects or for consolidation in summary facilities management reports.

TABLE 1 Areas of Potential Cost Savings: Return on Investment in Facility Management Area

I. Occupancy cost savings
   A. Ongoing renovation
   B. Inventory
      1. Equipment
      2. Furniture
      3. Space--Excess space control
   C. Lease management
      1. Option tracking
      2. Analysis, i.e., expiration review

II. Productivity-related savings
   A. Procurement
   B. Project management
   C. Drafting production
   D. Presentation preparation
   E. More efficient use of O&M building service equipment and personnel

III. Growth/change cost savings
   A. Recapture
   B. Moving
      1. Construction
      2. Dislocation
   C. New space
      1. Cost-effective standards
      2. Workload analysis

IV. Maintenance-related savings
   A. Downtime
   B. Replacements
   C. Responsiveness
   D. Purchase order generation

Recommendations

The data base envisioned contains a large number of data items that have to be associated and accommodated in the proposed data base structure. How to input, update, and manage this usable data is important because of the multi-phase, multi-participant use envisioned. Critical to its success is end user satisfaction. If user needs are not served, there is little, if any, incentive to participate.

Data integrity, security, and maintenance will play a critical role in the quality of the information provided. Traditional and enhanced rules for these items should be automated and embedded in the data base structure. A data dictionary that covers all possible participant groups will also be needed to insure the integrity, security, and maintenance proposed. The dictionary should be an active, integrated part of the data base.

The data requirements working group believes that a research project should be undertaken to determine specific data elements and their value over the life cycle of the data base. A part of this recommendation is that new methods for data base administration will also have to be developed to manage the complexity of the data base proposed.

The group specifically recommends research and development in the following areas:

1. Data base administration procedures that match the complexity of the data proposed,
2. Data capture procedures that separate the participants from the data input and maintenance process,
3. Intelligent data editors to preserve data base integrity,
4. Data base transition standards that accommodate various levels of user sophistication and data use,
5. Analytical tools to determine the real value of data to a single user and subsequent value to downstream users, and
6. Incentives to ensure user participation in the data base.

Finally, the group encourages the continued support of research in the area of user interface and support problems as they relate to the integrated project data base. An understanding of user needs, their use of the data, and what incentives are required for their participation is essential to this project.

As a general recommendation, the group suggests that the decision rules developed in this workshop be tested in demonstration activity in the context of a real organization and a real project.

2

INTEGRATED PROJECT DATA BASE CONCEPTUAL MODEL (GROUP B)

Previous workshops identified the importance of an integrated project data base to participants involved in different phases of the building process. While these workshops addressed the high value of the integrated project data base, they did not develop criteria for qualities that are necessary to make this data base responsive to the many different demands that participants in the building process place on data. Therefore, the group on integrated project data base concepu̇tal model, Group B, focused its attention on identifying required data base characteristics and developing examples of how these characteristics would be used by the building industry. These provided more detailed specifications for the integrated data base.

Members of Group B were: Bob Tilley (chairman), Charles Atwood, Terry Longstreth, Blake Mason, Kent Reed, Dan Rehak, David Skar, and Christos Yessios.

INTRODUCTION

In order to develop a conceptual model, the group followed a "blue sky" approach in describing a rich structure capable of meeting the complex data needs of the building industry. First, the integrated project data base model from the 1984 workshop was recast into a state machine model. This model emphasized that anyone in the building process could initiate an action against the current state of data describing a facility. Given this model, the group focused on describing the conceptual views of the data at a level between a user's view and the physical level where data is stored. To support the integrated project data base, the group identified four major objectives of the conceptual model: data independence, data dynamics, data consistency, and multiple data views. At the conceptual level, it must be possible to define different data types such as geometry and text, to develop relationships between types of data, and to conduct operations such as storage and retrieval on the data. These features at the conceptual level were modeled as a conceptual specification for data space contents. Finally, this model was applied to eight user views of a detailed design data space (see Figure 3).

Stored Data	Operations		Meta data		Meta Operations	Meta Data Operations
	Program	Dataspace	Program	Dataspace		
Numeric data numbers	+, -, *, / sort(?)	store	<>=	structure definition	Define data dictionary (new class)	Apply constraints
Text sets of bytes	assign concatenate sub-string	retrieve replace convert sort(?)	lexical	constraint definition	Define new structure	Define dictionary entry
Geometric data surfaces points lines solids holes planes polygons	intersect join weld difference project size	relational calc predicate calc	null intersect relationships	data dictionary relationships predicate calc expressions		
Image data bit maps	clip composite convolution					
Relationships between specific entity instances			precedence relationship			

FIGURE 3 Conceptual model: abstract examples of content specification.

ASSUMPTIONS

Traditionally, the term "data base" denotes a specialized structure of data which provides for the storage, retrieval and maintenance of data in a uniform and consistent fashion, within a given data processing environment. In the case of the integrated project data base, the term "data base" takes on a much broader definition. It refers to the totality of both stored and implied data which might be encountered in the varied and dissimilar processes of building design, construction and maintenance. In this sense, the integrated project data base is not easily definable in terms of a single system view. Both the data sources and their associated applications vary considerably by virtue of the range of participants in the overall building process. Accordingly, for the purpose of referring to this expanded data environment, the term data base is replaced by the term "data space," to refer to the multitude of data bases and possible non-data base data contained in the total building process environment.

The underlying challenge of the conceptual modeling group is to produce a certain consistency of data representation at the conceptual level, so that, regardless of specific applications needs, a single unified view of data can be maintained. In an effort to provide such consistency and to adhere as closely as possible to the few generally recognized models for representing an overall data environment, the ANSI/SPARC 3-Schema Architecture has been adopted for use in illustrating an overall model of data.

The conceptual schema of the ANSI/SPARC model implies two important characteristics, both of which are retained by implication in the work of the conceptual modeling group:

1. The conceptual schema is functionally independent from the internal and external schemas, i.e. changes made to the physical storage of data in the internal schema or in the user views of the external schema should not require changes in the conceptual schema.
2. The conceptual schema itself is never accessed or manipulated directly by the user, but serves only as an overall representation of data, from which all user views are extracted. It is, in essence, a super-set of all possible data contained in the integrated project data base.

OBJECTIVES

1. **To build on the goals and recommendations of the 1984 Woods Hole Workshop.** The 1985 workshop represents the continuation of a three-year process of evaluating the implications of advanced technology on the design, construction and management of buildings. Much valuable and important work emerged from the 1983 and 1984 Woods Hole workshops that should be recognized as a foundation on which the work of the 1985 workshop should build. The first objective of the conceptual modeling group is to address the needs identified by the 1984 workshop and to advance further developments in solving those needs.

2. **To construct a model of the conceptual view of the data base.** Building on the needs identified by the 1984 Woods Hole Workshop, the second objective is to construct formally a conceptual representation or model of all data which pass through the integrated project data base. It should describe how data are viewed at the conceptual level and should define the conceptual data model.

3. **To develop a data model suitable for implementing the conceptual model.** The data model developed should describe the characteristics that data may possess, and should include definitions of the

relationships and operations allowed between and on the data, respectively.

4. **To describe the relationship between the conceptual view and its physical implementation.** The last objective of the conceptual modeling group is to describe clearly how data defined at the conceptual level are extracted to form external views by various users, and how the data are passed to the internal level for physical storage, retrieval and maintenance.

EVOLUTION OF THE CONCEPTUAL MODEL

The 1984 Woods Hole Workshop defined the integrated project data base as the conceptual model of the building process (see Figure 1). In this representation, three elements are labelled "data base". The role of the project data base is to provide formalized interfaces between the functions comprising the building process.

The group developed a conceptual model of the integrated project data base representing the state of the project. In this perspective, formalized interfaces are no longer viewed as being between functions, but as being between each individual function and the system. All responsibility for consistency between the functional view rests with the data system. Insofar as the information supplied by a function is internally consistent, the data system will insure that consistent information is supplied to all other participating functions.

A state machine (more properly, a finite state machine) representation was chosen as the vehicle for communicating and refining this view of the project integrated data system. State machines are used to model computer-based processes which must modify their behavior based on past execution schedules. A state machine is composed of two major elements: the machine state, which contains the "memory" of past events, and a set of transition functions which can examine and modify the state.

The state contains the data space and can be accessed and manipulated by the state machine operations of the data system. Transition functions contain encapsulated sequences of operations which must be treated as a unit by the state machine. Once a transition function gains access to the data space, through any of the operations on the state, the state machine must guarantee that the transition will complete a sequence of operations which results in a consistent state at the termination of the transition function. The transition function must be guaranteed a consistent state upon gaining first access to the state, and the state machine must guarantee that all schedules of parallel executing transitions appear externally to have been executed in some serial order. Since external users of the system can only view or modify the data space through the intercession of a transition function, consistency of user views is guaranteed.

STATE MACHINE REPRESENTATION OF THE INTEGRATED DATA SYSTEM

Figure 4 shows the group's view of the integrated construction program data system. The state contains the data which model the dynamics of the construction functions, and include descriptions of allowable determination generations. The list of transitions is equivalent to the set of project functions depicted in Figure 1. The representation is not a strict interpretation of the state machine theory, since in that theory each transition must have a specific triggering input and a precisely defined set of associated inputs and outputs. The work files and external data bases depicted in Figure 1 are transition functions as appropriate.

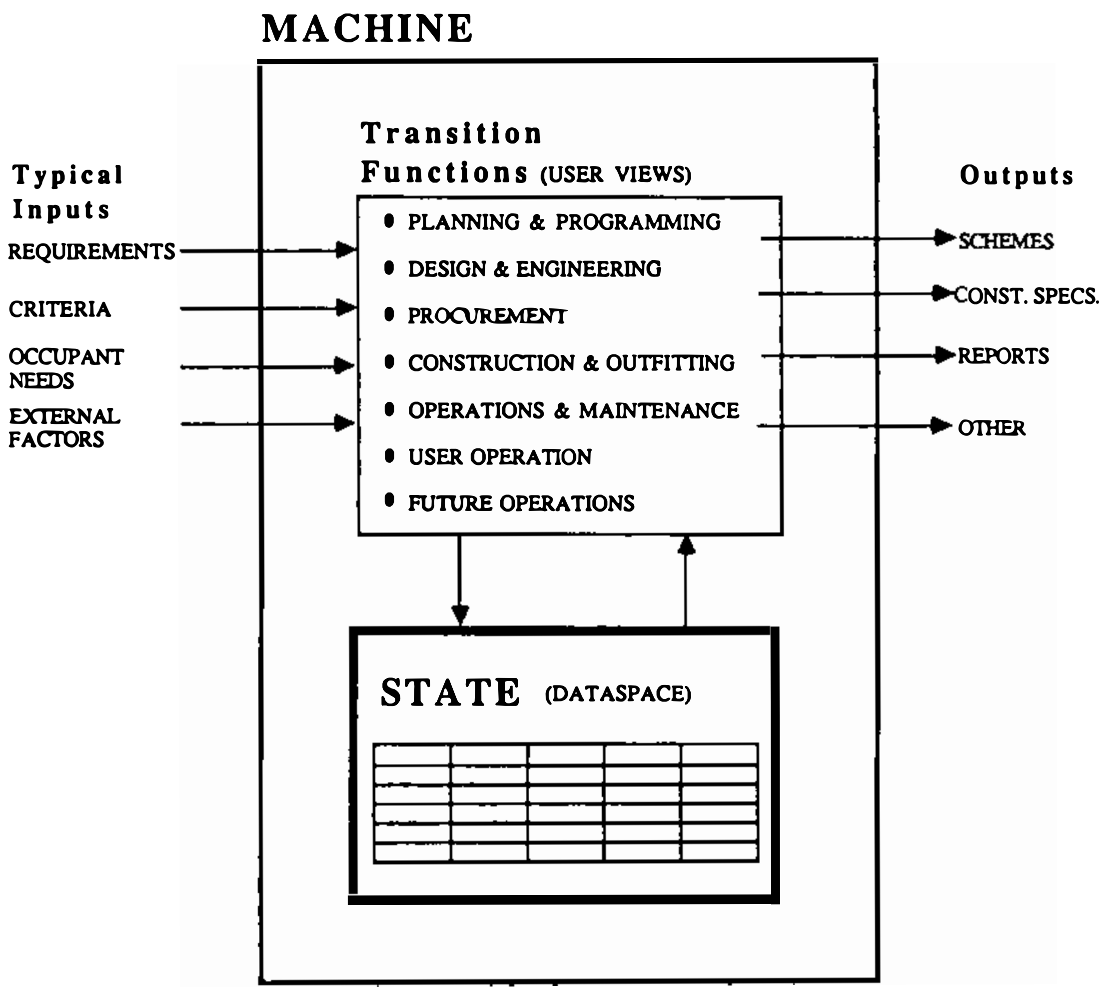


FIGURE 4 State machine model of the building life cycle.

The state machine diagram is a starting point for the design and development of an integrated data system, but it requires substantial refinement before it can be used as a basis for computer software development. In particular, the nature of the data and operations must be specified, and the transition functions must be subdivided into much smaller, independent components. The general level of these functions would imply that the planning process could not supply a consistent change of the state until all planning had been completed.

By further refining the definition of the planning process, the state transitions could represent discrete elements, such as one day's schedule, which could be entered into the state by a single transition, adding that one day's information as a consistent unit.

THE CONCEPTUAL MODEL FRAMEWORK

Contents of the Conceptual Model

The conceptual model must be sufficently rich in content to support the creation of the many required user views of the project data. User views, identified by Group A, include verbal descriptions, spatial descriptions, elements of construction, the process of construction, and the process of management and use. Three generic items that must be contained in a conceptual model emerge from a first analysis of various user views. They are data entities, relationships among data entities, and operations.

Data entities are objects about which factual information is to be recorded; they are either atomic or nonatomic. An atomic data entity represents an irreducible piece of information whose value may be textual, numerical, or geometric. Associated with an atomic data entity is its domain, which is the set of all legal values. An example of an atomic data entity is a TASK-START-DATE, which has a single value. Its domain is the set of dates from project inception to current date, as well as null. An example of a nonatomic data entity is a logical collection of data entities representing various electrical and mechanical properties of a pump. It must be emphasized that data entities have no intrinsic semantic meaning. Relationships capture the semantic meaning of data entities in terms of dependency structures, which may be of the form 1:1 entities, 1:m entities, or m:n entities. These dependencies are not inherent in the entities, but are defined externally. They can be expressed as rules which are executable constraints. An example of a semantic dependency expressed as a rule is: "if x is a physical object, then x has weight." This relationship is imposed by the semantic meaning of "physical."

Operations are actions that are taken on as parts of the conceptual model or the model itself. Operations on the data include storage, retrieval, updates and deletion. Operations on the definitions of the data entities include changing descriptions or creating new ones, changing relationships, and defining new operators. In addition, there are operations to execute (enforce) the rules that express relationships. Operations on the conceptual model itself include changing the underlying logic system.

The contents of the conceptual model can be specified now in the terms discussed above. Abstract examples are illustrated in Figure 3. The stored data types needed to provide a variety of user views for a facility project include numeric, textual, geometric, image, and relationship data. The stored data types differ in terms of which types of operations can be performed on them at the program level, that is, within the activity functions or transition functions described earlier. For example, arithmatic operators are defined with respect to numeric data but not to textual data, or concatenation is defined with respect to numeric data but not to textual data. As shown in the third column of Figure 3, there are primitive operations that can be performed on all the stored data types. These operations include storing an item, retrieving it, and replacing it. Collectively, such operations form a relational algebra or relational calculus such as predicate calculus.

As in the case of the operations, it is useful to separate the higher level or "meta" data relationships that are applied at the program level from those at the data space level of the model. Again, the stored data types are differentiated by the kinds of meta data relationship at the program level. For example, numerical equalities and inequalities apply to numeric data, while lexical qualities apply to textual data. At the data space level, the meta data are shared by all the stored data types and include defined structures and constraints (rules), expressions in the calculus of the operations defined in the data space, and relationships in the data dictionary.

The meta (higher level) operations and meta data operations illustrated in the last two columns of Figure 3 complete the specification of the content of the conceptual model. Meta operations include defining a new class of data dictionary and defining a new structure. Meta data operations include defining an entry in a data dictionary.

General Concepts

The preceding section has illustrated a wide variety of types of data, operations and other similar components which are the required items of the general conceptual model of the integrated data space used in the building process. A cursory overview of these items may lead to the idea that no unifying or abstract structure of the model is present. On closer examination, the conceptual structure illustrated in Figure 3 and discussed below may be inferred. The purpose of this conceptual structure is to reduce the variety of items presented above to a handful of well defined, but abstract, concepts.

The basic hierarchy of conceptual model concepts is divided into two components: "data" and "operations." The data component represents <u>all</u> the information which describes the building and building process. The integrated data space exists to hold all of these data; alone, however, data are meaningless. A set of mechanisms to access and manipulate the data is needed. These collectively can be denoted as data operators or, simply, operations.

The data portion of the model can be split into two parts. The first part, denoted "stored data," is used to represent the "factual" description of the building. Typical examples include items such as "beam 17 has length 25'-0"" and "project start-up date is 8/11/85." In addition to these facts, there is a large body of higher level information which describes the nature and characteristics of the data. We refer to these data as meta data. Some typical examples include statements that "beam lengths are constrained to be positive numbers" or "start date for an activity must precede finish date." These meta data are important in that they define the meaning or semantics of the stored data. They provide the information which permits the operations to manipulate and understand the stored data in a meaningful fashion.

Similarly, the operations can be split into those operations which work on the data and those which work on other operations. Operations on the data can be further split into those which operate only on the stored data denoted the "stored data operations" (such as fetch, store, delete, etc.) and those which operate on the meta data which are denoted "meta data operations." Examples of meta data operations include "define a new constraint on some data item" or "define a new type of relationship." In this way, the data operations provide mechanisms to manipulate and act on all the types of data stored in and defining the data space. Any given set of operations, however, may not be complete or correct. Thus, manipulating the operators is also required. For example, introducing a new data type may require changing the data access operation. Any operation that manipulates the current set of operations is an operation on an operation, or a "meta operation."

By analogy, one may consider extending these general concepts with additional items such as meta-meta data (i.e., information which defines the meta-data) and meta-meta operations. A clearer method, however, is to introduce recursion into the concepts of the model. Consider only the data portion of the model. The two basic concepts are the stored data and the meta data. The meta data component, however, must be stored in the data space. Rather than treating meta data as a special set of data with special rights and privileges, consider it to be yet another type of stored data. Thus, the meta data which are related to these stored meta data become the meta-meta data. Admitting such recursive definitions permits us to simplify the model to only those few concepts. In its most general terms, the model must support only stored data and operations on the stored data, with all other components being treated as one of the classes (basic or meta) of these two items.

This concept, while abstract, is very powerful and general, admitting a self-defining view of the conceptual model of the integrated data space.

An Example: From the Conceptual Data to the User View

The intent of this example is to illustrate how a user view can be extracted from an internally stored conceptual data base. That is, how the "image" in Figure 5 is generated from information stored in the data base.

In general, what is contained in the data base is not necessarily in the form needed by the user. Therefore, a set of actions must be applied on the information contained in the data base to transform it into a user view. The exact characteristics of these actions are implementation dependent. They depend on both the implementation of the data base and the implementation of the programmatic procedures which execute the actions. Consequently, to be able to present an example, certain assumptions about the implementation are required. They are:

1. The user view coincides with currently acceptable standards for communicating detailed design documents. The word "document" does not imply paper and can be any medium made available by the electronic technologies.
2. The user may be a person or a program.
3. The implementation of the conceptual data base contains information which may be extracted through a more or less direct retrieval operation.
4. Three-dimensional informationally complete models are used for the representation of the physical entities of a building. An informationally complete model is defined to be a relational network that includes spatial semantics and attributes.

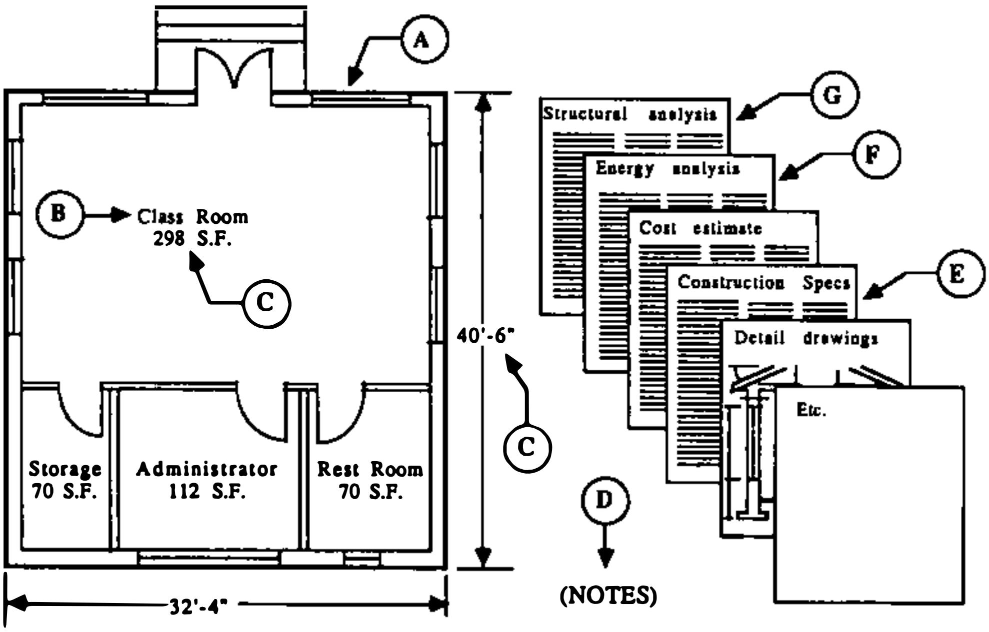
Given the above assumptions, the derivation of a partial user view of detailed design documents from a hypothetical data base for a one-class school building would be as follows (see Figure 5):

A. Floor-Plan. The geometry of the plan is extracted by taking a horizontal section of the three-dimensional geometric model. Symbolic representations of elements such as doors and windows are extracted by processing the semantics of elements encountered by the reference (cutting) plane. Interior details (such as furniture layouts and fixtures) are derived through vertical orthographic projections of elements associated with respective interior spaces. Other details of a user view of a floor plan are extracted in a similar fashion and (as already pointed out) dependent on the particular implementation.

B. Text Labels. Assuming that the text label is not just an annotated note (if it is, see item D below), but a semantic attribute associated with an element, then the respective relationships need to be traced and resolved to retrieve the label and its association, for incorporation in the user view.

C. Numeric Labels. Assuming that the numeric label is not an annotated note, but a value (quantity) which can be inferred from the information in the data base, the relevant knowledge is processed and the value calculated. Two categories of numeric values are shown in the example. The first consists of the areas of the rooms. The geometry of each room is processed and its area is calculated. The

Detailed Design



	User View	Actions on Conceptual Data
A	Floor Plan Image	Section of 3D model by reference plane, and projection.
B	Text labels	Resolve relationships to retrieve relevent attributes.
C	Numeric Labels	Dimension line, take resulting intersection and get end points, size.
D	Annotations	Retrieve and/or infer alphanumeric and/or symbolic notes, to be attached to floor plan.
E	Construction Specs	Possibilities: Various data as is; Inferred from data and meta data; Combination of both.
F	Energy Analysis	Develop surface areas, spatial volumes, resolve relations, get characteristics, provide to energy analysis program
G	Simple Frame Structural Analysis	Extract relevent geometry, provide to structural analysis program.

FIGURE 5 Partial user view of detailed design documents from a hypothetical data base for a one-class school building.

second category consists of dimensional information. Any pair of point coordinates (in the two-dimensional plan section) can be processed and their distance calculated. Both categories of numeric labels are incorporated in the user view.

D. **Annotations.** Defined to be alphanumeric and/or symbolic notes attached to a drawing as part of a user view, annotations may be retrieved directly or inferred after processing relevant knowledge contained in the data/knowledge base.

E. **Construction Specifications.** As with the annotations, they consist of various data retrieved directly as well as information inferred from knowledge in the stored data and/or the meta data.

F. **Energy Analysis.** Relevant geometric information (such as areas, volumes, spatial relations) and non-geometric attributes (such as material types) are retrieved and/or inferred from the data base and transmitted to an energy analysis program. The data given to the program as well as its output constitute the user view of the energy analysis.

G. **Structural Analysis.** This is similar to the energy analysis, except that the relevant geometric and non-geometric data extracted from the data base are now transmitted to a structural analysis program. It should be noted that structural analysis programs of variable complexity have to be employed depending on the structural requirements of the building in question.

CONCLUSIONS

Having continued the refinement of the model presented in the 1984 workshop at the conceptual level, the group concluded that an integrated project data base can be developed which is distributed, dynamic, and respond to multiple users. It is distributed across geographic and organizational boundaries. It accommodates the demands of multiple views of the same data by different users for different purposes. It dynamically responds to changes in the content and definition of the state machine. The technology to develop such a data base is currently at the state of the art. The group recognizes that significant software development is needed.

The group has developed a conceptual model which will probably be implemented as a meta language. Possibly, this might be achieved by using entity-relation, object-oriented or artificial intelligence frame-based techniques which can be built as extensions of a conventional data base machine state. The group has not at this point defined the conceptual model to the point that it imposes a single implementation.

The technologies exist that could be used to implement the conceptual model, although the tools, techniques and procedures are not widely available or understood. Emerging technologies (such as automatic program generators) will facilitate implementing the conceptual model in the future. The programs developed must understand and express this conceptual model to take maximum benefit of it. Existing programs may be included over this transition period, but only at arm's length through translation programs which cannot take full advantage of the model.

RECOMMENDATIONS

The specific recommendations of the group are:

1. Efforts should continue to refine aspects of the conceptual model and transition functions before attempting implementation.
2. Existing systems should be evaluated in the light of the conceptual model presented here. Because the conceptual model is not fully developed, efforts should be made to examine the parts of the model that are known and understood.
3. Research and future workshop discussions should continue on the following topics:

- interface of levels (external, conceptual, and internal, especially user view to conceptual model),
- definition of transition functions,
- data capture procedures,
- consistency issues, and
- data base administration issues.

Efforts should be supported to link the needs of those in the building industry with those doing work on artificial intelligence. The role of artificial intelligence in the development of the integrated project data base should be further explored.

3

A PROPOSAL FOR A PROTOTYPE DEMONSTRATION OF AN INTEGRATED PROJECT DATA BASE (GROUP C1)

During the course of the workshop, Group C split into two sections, C1 and C2. Group C2 concentrated on the development of a proposal to communicate the usefulness of a integrated project data base (see Chapter 4). Group C1 saw its charge as doing the preliminary planning for a prototype demonstration of an integrated project data base including developing high-level functional requirements, definitions, and the scope of the effort (cost and manpower requirements). The group consisted of Jim Burrows, Ken Reinschmidt, Fred Kitchens, Bob Heterick, Dick Zitzmann and Paul Scarponcini.

INTRODUCTION

Computer-based technologies have had a significant and positive impact on the existing building process. While the result is an advancement of the building process, it has created islands of automation involving individual data bases without (in most cases) communication and transferability between different computer systems and between phases of the building process. Therefore, the building process is fragmented, and there is continued segmentation of the professionals and functions involved.

The ever-increasing cost of design, construction, operating and maintaining facilities demands a more efficient approach to the overall building process. While the cost of design and construction is quite high, it is estimated to average only between 7 and 17 percent of the total life-cycle cost of a facility; the remaining 83 to 93 percent of the total cost is in operation and maintenance.*

Some of the costs incurred throughout the life cycle of the building process are due to the fact that information generated in one phase of the building process is not available in subsequent phases and must be regenerated. Much of the data needed are lost or

*National Research Council, A Report from the 1984 Workshop on Advanced Technology for Building Design and Engineering, National Academy Press, Washington, D.C., 1985, pp. 3-4.

discarded simply because the various participants do not coordinate; however, even with the best of intentions to transfer data, there is no generic means of integrating information generated on incompatible software and hardware utilized in the process.

An approach is needed that provides a means of representing and exchanging data in such a way that, regardless of the hardware and software involved in the life cycle of a facility, information generated in one phase of development is available in subsequent phases of the building process. The approach currently being investigated in this (and previous) workshops is termed the integrated project data base.

The general goal of the group was to develop a proposal for demonstrating the concept of an integrated project data base by means of a prototype system. The prototype could be used to identify design problems, to work out solution strategies, to test data base integration and structural concepts, and to obtain feedback from representatives of the potential user community on the principles in the prototype, and on improvements in the extended system.

The components of the prototype design include the following:

- a relational data base management system (DBMS) and query language,
- two or more software applications systems,
- computer hardware capable of supporting the selected DBMS and applications,
- engineering workstations with graphics capabilities, and
- integration software.

OBJECTIVES

The major objectives of the prototype study are:

- To evaluate the suitability of a general relational data base management system as the foundation for the integrated project data base,
- To explore the requirements for data sharing and integration among dissimilar functions operating across discipline and organizational boundaries,
- To study the requirements for access to external data bases and methods for providing such access through the project data base,
- To develop project data dictionaries and directories,
- To evaluate the practical difficulties and requirements for the integration of industry standard applications software without modifications to this software,
- To explore the requirements and methods for the design of the project data base integrator functions, including the data dictionaries, communications, translations, access, and security,
- To demonstrate the proof of principle that such an integrated project data base system is workable,

- To evaluate the costs and benefits of the integrated project data base system,
- To obtain feedback and evaluation from the users of the prototype system in government and industry,
- To establish functional specifications for the design of an enhanced system covering a broader range of applications, and
- To establish standards for data bases, query languages, and applications software development.

Data Base Management System (DBMS)

The DBMS used for the prototype will be a commercially available relational system with a user accessible query language, such as RIM (Relational Information System), SQL (Structured Query Language), DB2, Oracle, or others. The research team will evaluate all existing relational systems and select that one which is most compatible with the objectives of the study.

Applications Software

The applications software for the prototype system will be selected from the most widely used computer-aided functions in the building industry. The applications will be selected from different disciplines so that the issues of the integrated data base extending across traditional discipline, function, and organizational boundaries can be fully explored.

The following suggestions constitute several examples of possible sets of applications software that could make up the prototype. The final selection of the applications software will be made during the study phase from among these and possibly other examples.

The nature of the building function is such that geometric data are critical to the entire design and construction process. Therefore one of the selected applications areas will be computer graphics; more specifically, a computer-aided design (CAD) system capable of use by architectural and engineering organizations. This CAD system might be drawn from the following set of commercial vendors: Applicon, AutoCAD, Autotrol, CADAM, CALMA, CATIA, CD-2000, ComputerVision, GDS, Intergraph, or others. The chosen system must provide an interactive computer-aided design and drafting interface, and a computer data base capable of on-line storage and retrieval of two- and three-dimensional objects, symbols, and text.

Example 1: Architectural and mechanical design data.

In this example, the prototype will consist of the integration of architectural and mechanical design functions. The mechanical design function will be energy analysis, and heating and air-conditioning system design. The software application will be an energy analysis system such as BLAST. The integrated project data base function will be to access architectural spatial and functional design data stored in the CAD data base, to access climatological data stored in external data bases, to store mechanical and thermal properties of architectural and structural elements (thermal conductivity, thermal capacity, air infiltration, etc.), to make these data available to the energy analysis applications, to store the results of the energy analysis and design calculations, and to make these results available to the architectural CAD system for graphical display and evaluation by the architectural designers.

Example 2: Architectural and structural design data

In this example, the prototype will consist of the integration of architectural and structural design functions. The structural functions will include structural steel frame analysis, a selection of rolled and built-up steel sections, and structural detailing and connection design. The integrated project data base function will be to access architectural spatial design data stored in the CAD data base, to access building code data stored in external data base (allowable flow loads, wind loads, etc.), to format these data in a way suitable for access by the structural analysis and design software (for example, STRUDL), to store member sizes, end forces, moments, and deflection calculations for access by the CAD system used for connection detailing and structural shop drawings, and to store private structural member size data for use by architectural and mechanical designers.

Example 3: Building design data, material quantities, and construction management data

In this example, the prototype will consist of the integration of architectural and engineering design functions, quantity tradeoffs, construction planning, and construction scheduling. The integrated project data base will access geometric data stored in the CAD data base. Material quantities (lengths, areas, volumes, and numbers of items) will be extracted from the geometric data and computed by the CAD system. The integrated project data base will contain relations mapping the design entities onto construction work packages and construction field activities using the project construction work breakdown structure. These quantity data would be made available through the integrated project data base to contractors, would compute construction labor hours for each work package and activity from the quantities and the unit rates for production. Durations of construction activities would be derived from the computed labor hours and the desired construction manloading. These data would be made available through the integrated project data base to network scheduling programs for computation of the critical paths and floats. Material quantities distributed over activities would also be used to compute material costs as a function of time; the combination of material and labor costs with the construction network schedule would generate project cash flow projections. The integrated project data base would greatly facilitate optimization of the design and construction planning process, as the effects of design changes or construction schedules and costs would be readily propagated through the construction planning system.

EXISTING SUPPORTING TOOLS

There exist useful supporting tools with or without general data base management capabilities that could form a more coherent, but loosely coupled, set of supporting tools if an integrating component were available.

Data in the system that have a useful life are variables which may need to be used at a later date. Data will be captured in a data base or data bases (there will probably be more than one) which is described by a standard format data dictionary directory. There is such a standard being processed now.

I. A routine process with input and output only and no problem-specific associated data, would need to have a machine-readable description of its data needs in dictionary form (format, coding, etc.) and a machine-readable description of its output in dictionary form. This would allow a DBMS which could get the data to prepare an input to the routine; in addition, it would know that the output was available for other routines or processes or for extraction of data to be input to another file for further processing.

II. Data associated (DA) with a series of processes and which stay near those processes will not be available to the system (except through standard reports as in I) unless:

1. The data are available through an associated data base management system (ADBMS), and a central standard dictionary is available and a centrally prepared query language statement (standard if possible) can be sent to the ADBMS to extract the requested data and send it to the central intelligence for further processing (possible reformatting and translation) to the requestor.
2. A standard request will trigger the DA being sent to a central process for further selection and processing.
3. A standard request will trigger a transformed version of the data to be prepared and transmitted.
4. Other schemes which preserve the ability of transmitting a data sequence which can be understood by the recipient.

III. General reports (not precanned reports) beyond the capability of any of the individuals of the confederated systems to produce will only be available if the data needed for the report are available centrally.

IV. Specific reports currently available from any of the associated processes will still be available without translation, if possible. If a standard transformation, such as IGES, will make the report available to another locale, such a transformation will take place. If the standard reports can only be made available through a process as in I above, that will be possible.

V. Text files will be available in ASCII. If formatting codes are needed to preserve the ability to word process the text, a solution similar to the Navy's Document Interchange Format (DIF) will be used.

VI. It has been shown (see ANSER by Informatics) that several mainframe data systems (IMS, IDMS, TOTAL, MARK IV) can make data available to PC systems, DBASE II and LOTUS 1-2-3. Possibly a similar system with more generality should be available.

VII. A query language against the central files should be selected. It is hoped that a national standard QL will be available. Thus, the data accessibility would be similar to the diagram in Figure 6.

CONCEPTUAL MODEL

The problem examined in the previous workshops involved representing and exchanging data in such a way that, regardless of the hardware and software involved, one could look at the entire life cycle of the facility and the information that was generated in one phase could be carried into another phase. The conceptual model developed was called integrated project data base (see Figure 1).

There are applications that are either existing now or will be written later to perform some task by the architect, engineer, contractor or facilities manager. These applications may be working off a data base management system, they may simply have some type of external file structure for storing their data, or they may be of a closed architecture whereby their data storage mechanism is inaccessible from external hardware.

The group introduced the concept of a transition data base (see Figure 7). Because certain applications are shorter than the life cycle of the entire project, one cannot always count on the fact that the data are available from that application. The capability is needed to take the common data that are needed for different applications and store them in the transitional data base.

The central function of the integrated data base approach is termed an integrator (see Table 2). The first part of the integrator is the communicator which allows the data to flow. It will consist of hardware, software and protocols, and will exist physically to move data within the system.

The accessor is the method of obtaining those data from the various data repositories. The sum collection of all relevant data existing in all these data repositories constitutes the integrated project data base.

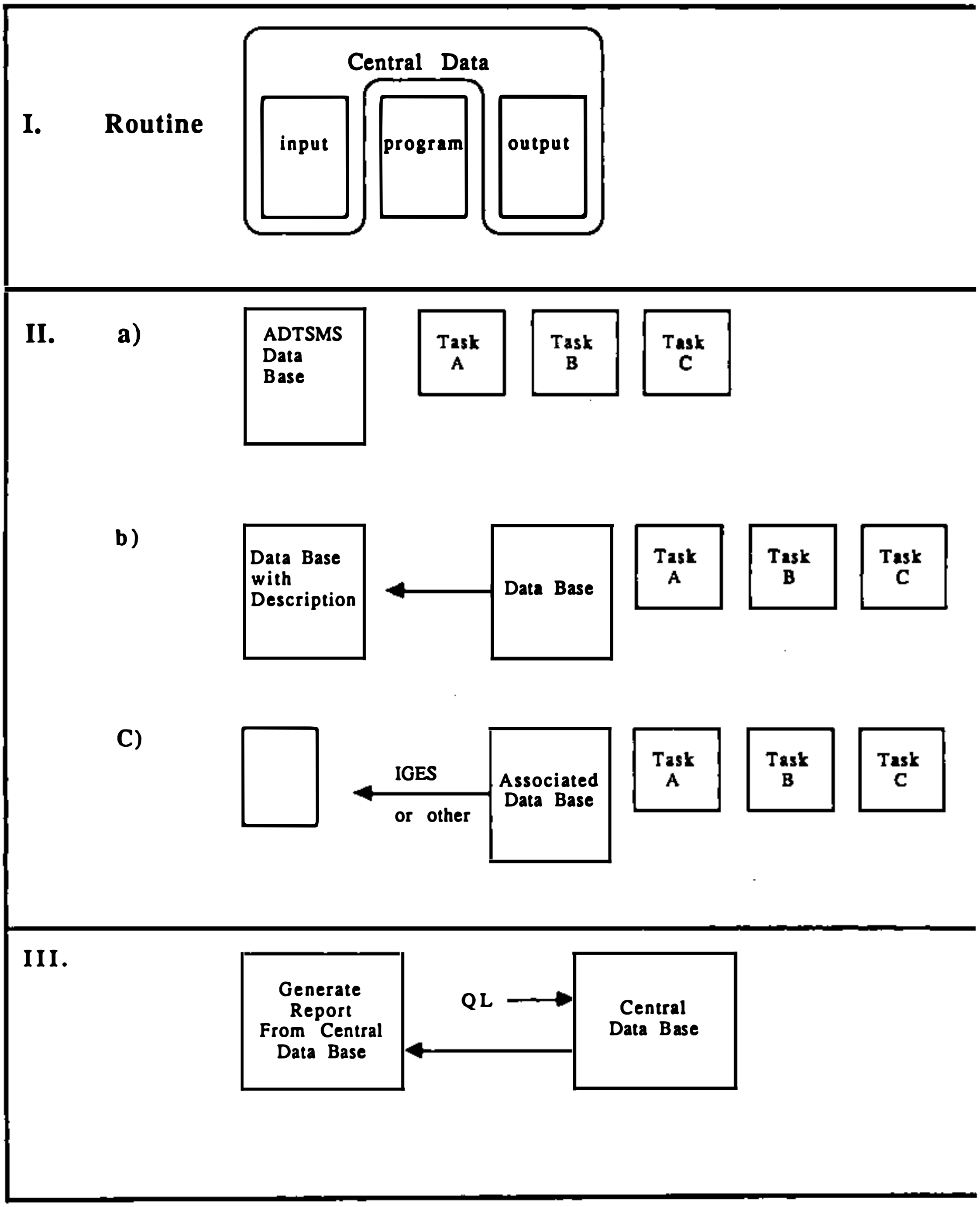
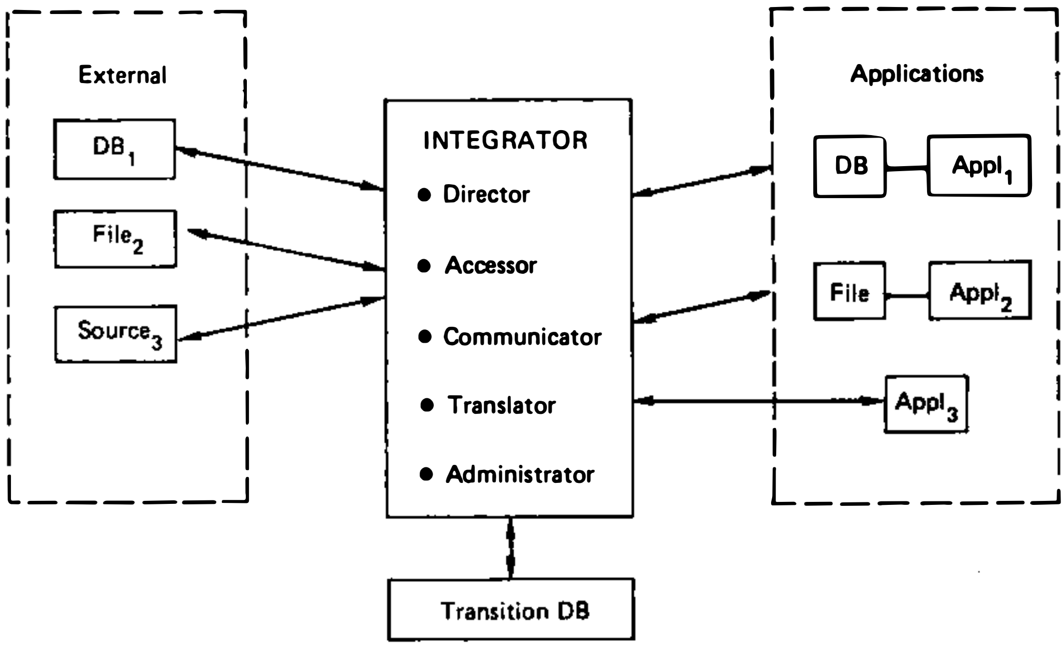


FIGURE 6 Data accessibility.



DATA SOURCE	DESCRIPTION
• External	Data not unique to a particular project
• Application	Data created by project participant—graphic models, schedules, etc.
• Transition	Data whose life cycle extends beyond participant's role—equipment specs, design loads, etc.

FIGURE 7 Integrated project data base components.

The translator understands the format the data are in, both from the source and the target, and has to be able to translate that information. The director has knowledge of where the data are stored and an indication of whether the data are limited in scope to a particular application or should be considered part of an integrated data base. The administrator maintains the consistency of the data and addresses issues such as security and permission to access the data base.

TABLE 2 Role of the Integrator

Component	Role
• Communicator	Hardware, software and protocols to transport data physically
• Accessor	Data manipulation functions required to query or store data anywhere in the integrated project data base--perhaps as a SQL model, understanding data semantics/ equivalences
• Translator	Understands and translates source and target data formats
• Director	Knowledge of where data can be found, if it needs to be translated, how accessed, etc.
• Administrator	Rules for inclusion in transition data base, consistency requirements, read and update authorization, integrity requirements, etc.

IMPLEMENTING THE PROTOTYPE DEMONSTRATION

To implement this concept, the group decided to look at the objectives of putting together a prototype system, and then use these in terms of designing that system, and validating the integrated project data base concept. The group believes that this new approach should be validated as to whether it is cost effective to develop it and the benefits that can be gained from it.

The group decided to explore heterogeneous integration because the software is available today, and certain types of hardware address different applications better than other types. It is important to assure that the integrated project data base will support a heterogeneous environment. In addition, there are existing standards of protocol. The role of the external data base, in terms of a source of information to the project, has to be understood.

It was suggested that relational data base management systems be used for the integrated project data base. The group decided to explore this option, and evaluate whether this type of management system is feasible.

The components of the initial prototype will be a relational data base management system with query language. The computer hardware is capable of receiving the selected data base management systems and the applications. The computer hardware should vary to be able to show the heterogeneous nature. There are certain needs for graphics that may be different from other industries that are developing similar types of concepts.

PROPOSAL FOR A DEMONSTRATION PROTOTYPE

The group discussed what it would take to put together this type of prototype demonstration from a management point of view. It became evident to the group that a project manager would be needed to control the development, to understand the concept, and to be able to formulate it in terms of detailed design and implementation. A perspective manager should be made available as soon as possible to drive the design of the project. This is most likely a full-time person, directly reporting to the Building Research Board.

Project Organization

The proposed organization will be staffed initially to prepare the design requirements and project plan. The organization will be expanded to accommodate subsequent implementation and testing activities upon receipt of approval to proceed. Figure 8 illustrates the initial project organization required to support the proposed activity.

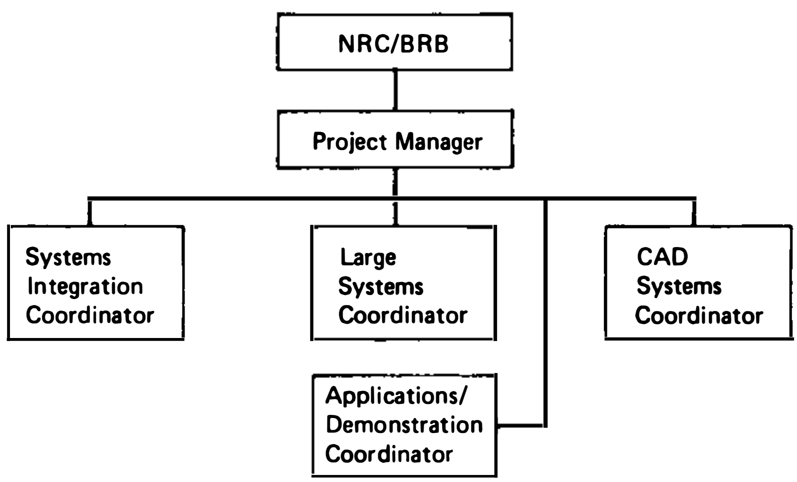


FIGURE 8 Demonstration project organization.

Program Manager

The program manager will have overall program responsibility including coordination of all administrative, technical and logistics activities. The program manager will be responsible for preparation and submission of the proposal for the implementation of the integrated data base demonstration. The program manager will report to the Building Research Board of the National Research Council and will be dedicated on a full-time basis through project completion.

Systems Integration Coordinator

The systems integration coordinator will be responsible for integrating all of the hardware, software and applications required to implement the demonstration. This coordinator will be responsible for the overall technical design and eventual implementation. The systems integrator will be knowledgeable in architectural applications, as well as in the use of computer technology to solve relevant problems in this area through the design phase. This person will be available on a half-time basis.

Large Systems Coordinator

This individual will provide the necessary technical support in the areas of mainframe hardware, operating systems software, product set and applications. This coordinator will be responsible for participating in the overall design of the demonstration and coordinating additional support resources associated with the sphere of responsibility. This person will be available on a quarter-time basis through the design phase.

CAD System Coordinator

The CAD system coordinator will provide the necessary technical support in the area of workstation hardware, software, product set and applications. This coordinator will be responsible for participating in the overall design of the demonstration and coordinating additional support resources associated with the sphere of responsibility. This person will be available on a quarter-time basis through the design phase.

Applications/Demonstration Coordinator

The applications/demonstration coordinator will be responsible for the selection of the applications to be demonstrated and the operation of the demonstration. This individual will represent the architectural/engineering community and will ensure that the overall intent of the applications demonstration is addressed. This individual will be available on a half-time basis through the design phase.

Table 3 shows the proposed project milestones, man months and costs.

TABLE 3 Proposal for a Prototype System: Project Milestones and Costs

Project Milestones	Dates
o Draft proposal	6/21/85
o Team identified	8/85
o Proposal to candidate sponsors	9/85
o Award	11/85
o Design complete	3/86
o Review with NRC/sponsor	6/86
o Proposal for implementation	6/86
o Award	7/86

Project Costs	Man Months (MM)
o Project manager	12 MM
o Integration coordinator	6 MM
Technical support	12 MM
o Large systems coordinator	3 MM
Technical support	6 MM
o CAD system coordinator	3 MM
Technical support	6 MM
o Applications/demo coordinator	6 MM
Technical support	12 MM

Project Cost Summary

Labor	66 MM @ 10,000	$660,000
Travel/per diem		40,000
TOTAL		$700,000
Participants Share		$350,000
Requested Funding		350,000

4

PROPOSAL FOR A DEMONSTRATION BY COMMUNICATION (GROUP C2)

Group C2, consisting of Walter Day, Kaimen Lee, Earl Mark, and Janet Spoonamore viewed the overall goals of the demonstration project as the communication of the usefulness of an integrated project data base to all potential users. The group selected the interactive video disk as the demonstration medium and developed a proposal to accomplish this project.

DEVELOPMENT OF THE STORY BOARD

The purpose of the story board approach is to represent as completely as possible, with words and sketches or drawings, what will be or can be an interactive video disk that will run on a micro terminal as a demonstration of the usefulness of the integrated project data base. The video disk would illustrate through a simple example project (in this case, a one-room schoolhouse) the buildup of data within the integrated project data base, and how the data contained therein would be of use to those involved in the building process--including the owner and user of the facility.

The story board approach consists of at least four parts:

1. An activity/outcome outline that spans the entire building process,
2. A frame-by-frame sketch of picture representations of what is envisioned as the video media to show,
3. A miniature model that would be included in all video frames and would graphically (by color scheme or pointers, or some other scheme) show the viewer using the video where in the process he or she is at any time, and
4. A written narrative description of the process that would be recorded with the video.

During this workshop the group was able to accomplish only a portion of the above. The group agreed on a conceptual model of the building process and on the use and storage of data. It had difficulty representing that concept on paper so that it would be understandable and acceptable to the remainder of the workshop participants.

However, the group used the concept of the model to outline the activities and outcomes for the example through the operations and maintenance phase of the building process. It also sketched frame-by-frame representations of the video covering planning, pre-design, and design developments.

The group plans to commit to completing the four parts outlined above, without outside fiscal or contractor assistance. The group will try to incorporate the results of Groups A, B, and C1.

The group proposes to use the publication of the results of this development process as the basis for preparation of a video disk for use as a demonstration at the 1986 workshop.

APPENDIX 1

BIOGRAPHICAL BACKGROUND OF PARTICIPANTS

CHARLES L. (CHUCK) ATWOOD is a registered architect with a certificate in data processing. He received a master of architecture degree from the University of Illinois combining architectural engineering, civil engineering, and computer science courses into an independent study option. He worked 5 years in the Chicago office of Skidmore, Owings and Merrill, developing software for structural, project management, graphic, data base, and program development applications. For 3 years he was corporate director of computer services for Hellmuth, Obata, and Kassabaum (HOK), a St. Louis-based architectural and engineering firm. Since January 1985, he has been president and CEO of the HOK Computer Service Corporation, a subsidiary of HOK, specializing in computer software for the AEC marketplace, specifically professional design and facility management systems.

HAROLD BORKIN is an architect and professor of architecture and urban planning at the University of Michigan. He is director of several computer-aided design research projects for the U.S. Army Corps of Engineers. He is also the director for the development of the ARCH, a model computer-aided design system. Professor Borkin has authored numerous articles and papers on advanced technologies for housing and computer-aided design. He received his bachelor of architecture from the University of Michigan.

DONALD D. BOYLE is senior staff engineer and acting deputy director, Division of Management Services, Food & Drug administration. He is also a licensed architect and a licensed engineer. Mr. Boyle has previously worked with the Naval Facilities Engineering Command and in the private sector.

JAMES H. BURROWS has been the director of the Institute for Computer Sciences and Technology, National Bureau of Standards, Department of Commerce since 1979. The Institute manages the government-wide federal computer standards program, provides technical assistance to federal agencies in the use of computer technology, and conducts related computer science research. These activities are aimed at improving economy and effectiveness in the procurement and use of computers by the federal government. Prior to 1979, Mr. Burrows was associate director, Office of Computer Resources, U.S. Air Force. As the Air Force's senior civilian manager for data automation, he was responsible for developing and implementing policies for ADP management, operations, procurement and standards utilization. Before this, he directed the development of large information systems and data management projects for the Mitre Corporation and the Lincoln Laboratory in Massachusetts. Mr. Burrows received his B.S. in engineering from the Massachusetts Institute of Technology in 1949 and his M.S. in mathematics from the University of Chicago in 1951.

C. PATRICK DAVIS has been the chief of the Technical Engineering Branch with the South Atlantic Division of the U.S. Army Corps of Engineers since 1978. In this position he is responsible for planning, organizing, directing and coordinating the work of the mechanical, electrical, structural, hydraulics, environmental, architectural and cost engineering disciplines for a wide variety of Army and Air Force projects and civil works projects in seven southeastern states, Puerto Rico and the Virgin Islands. Mr. Davis is interested in optimum computer system development and utilization for the division and five district offices. Particular areas of current emphasis include cost estimating and design systems to improve design review quality and to shorten design time. He is a registered professional engineer and a graduate of the University of Mississippi and the University of Texas.

WALTER C. DAY is the assistant chief of the Engineering Division, U.S. Army Corps of Engineers, South Pacific Division located in San Francisco. His published technical papers are in the radiation safety field and in the use of explosives (both chemical and nuclear) in civil engineering applications. He is currently the South Pacific Division's point-of-contact with CERL for technology transfer and field testing of R&D products in the area of "automation in the building process." He received his A.B. in physics from Earlham College in 1956 and his MSCE from Stanford University in 1975.

H. LAWRENCE DYER is a senior consultant with the Environmental Technology Center for professional services at the Control Data Corporation with responsibility for product development and marketing. Current projects include the design of an integrated computer system for use by water utilities, water management agencies, and their engineering contractors. His past experience includes water resources development at Argonne National Laboratory and environmental engineering for Science Application Inc. Mr. Dyer holds membership in the American Society of Civil Engineers and other honorary and professional societies. He is a mechanical engineer with degrees from Wentworth Institute, the University of Arkansas and Purdue University.

JACK F. ENRICO is manager of cost and schedule for Bechtel Power Corporation's Los Angeles Power Division where he has the responsibility for implementing and administering cost and schedule services on both international and domestic projects. For more than fifteen years he has supervised the development and implementation of automated cost, schedule and material systems for use in the engineering/construction industry. At Bechtel, he has served on a number of related committees including the Computer Applications Committee and as chairman of the Los Angeles Power Division's Project Control Advisory Group. Mr. Enrico is a member of the American Association of Cost Engineers, where he serves as national director for project management; the Project Management Institute; the Los Angeles Council of Engineering Societies; the Planning and Scheduling Study Team of the Business Roundtable; and part-time lecturer at the University of Southern California Graduate School Department of Civil Engineering.

ROBERT J. FURLONG has been a civil engineer with the U.S. Air Force on the staff of the Directorate of Engineering and Services since 1982. Prior to this position, he was a project engineer with the Naval Facilities Engineering Command. He is responsible for developing and maintaining civil engineering criteria for all types of Air Force facilities. Mr. Furlong has several years experience in the use of computer-aided design and management information systems. His current interest is in the use of computer systems to manage the design and construction process. He is a registered professional engineer who received his B.S. in civil engineering from Columbia University and his M.S. in geotechnical engineering from the George Washington University.

JAMES R. GOODLAND works with the Control Data Corporation where he currently manages a group of consultants, program managers and analysts. The past five years have been spent in the application and industry related areas--developing markets and products where industry problems can be tied to computer technology. One key area of interest is in the integration of applications, data bases, workstations and mainframes to solve industry requirements. His background includes 23 years in the computer industry.

ROBERT C. HETERICK has been with Virginia Tech for twenty-three years. He now serves as professor in the College of Architecture at Virginia Tech. He received from Virginia Tech a B.S. in civil engineering in 1959, M.S. in structural engineering in 1961, and Ph.D. in engineering in 1968. Mr. Heterick has several publications, reports, reviews, and technical notes. He has also received many honors.

RONALD KING is area manager for design, construction, and building operations and maintenance systems in the General Government Division, Civil Procurement and Property Management Group of the General Accounting Office. Prior to this, he was project manager for GAO's study of computer-aided design. Mr. King has a degree in accounting and holds a California CPA certificate.

FRED KITCHENS currently serves as assistant chief, Engineering Division, Savannah District, U.S. Army Corps of Engineers. Prior to this assignment, he was chief, Military Program and Management Branch and assistant chief of the Design Branch. Mr. Kitchens has more than 25 years experience in the field of engineering and design, and computer applications in both the technical and managerial areas. He is a registered professional engineer in Georgia and South Carolina and holds a B.S. and M.S. in civil engineering from the Georgia Institute of Technology.

KAIMAN LEE is the head of the Computer Graphics Branch and systems manager, Design Division, Naval Facilities Engineering Command at San Bruno, California. He has four degrees, including a doctorate in architecture. He is a registered architect and licensed in three other areas as well. He started his computer graphics career in 1969 with the architectural firm of Perry, Dean, and Stewart in Boston. As the computer architect coordinator, he developed and implemented the ARK-2 system, the first interactive computer graphics system designed specifically for architectural practice.

W. I. (TERRY) LONGSTRETH has been with IBM's Federal Systems Division since joining the company in 1967. He has been primarily involved in support of federal agencies. In May 1967, he went to Vietnam and Germany on several assignments that combined data base, systems and applications development and programming responsibilities. In 1973, he went to work at Lowry AFB in Denver to support development of a training system for intelligence analysts. Since 1976 he has been involved in data base systems research and development, working on government contracts, proposals and government supported projects. He is currently an advisory programmer, responsible for defining and monitoring software engineering and design practices for a large shared data base on a classified government project. He graduated from Drury College, Springfield, Missouri in 1966 with a B.A. in French.

EARL MARK is a senior analyst programmer for Computervision Corporation. He received a B.A. in architecture, a master of science in computer graphics applications to architecture, and a master of architecture. He also teaches CAD/CAM at Massachusetts Institutes of Technology, Architecture Department.

BLAKE J. MASON is a practicing architect with 10 years experience in the design and management of residential, commercial and industrial building projects. He received his undergraduate degree at Berkeley in 1976 and attended University of Manchester, England for graduate research on a Paul Harris Fellowship in 1981. His work in computer science dates from 1974. He has developed numerous software systems which utilize relational DBMS products for analysis and management of building projects, as well as for corporate clients such as VISA, USA, and Tetley Tea.

WILLIAM N. McCORMICK, JR. is chief, U.S. Army Corps of Engineers of the Engineering Division charged with responsibilities for the planning and execution of engineering and design activities in support of world-wide construction programs for the Army's Civil Works program, the U.S. military, other U.S. government agencies, and foreign governments. He holds a Bachelor of Science degree in mechanical engineering from Auburn University and has 27 years experience as a professional engineer.

JOHN F. METZLER is a projects manager in the Office of Project and Facilities Management in the Department of Energy. He is responsible for the Department's General Design Criteria (GDC) Manual, the GDC Planning Board and the Design Information Exchange System. Prior to his current office, his experience in the design and construction industry included employment with general contractors, architect-engineering firms, naval architecture firms, interior design and construction projects for the Department of Energy. He received a Bachelor of Architecture degree from The Cooper Union, the Architectural Association Diploma and a Master of Architecture in Urban Design from the Harvard Graduate School of Design.

BARRY MILLIKEN is associate partner and systems manager for the New York office of Skidmore, Owings and Merrill where he has been involved with computer applications to architecture over the last fifteen years. He was involved with a wide range of data base systems supporting application needs from space programming to cost estimating. Since the 1970s computer graphics and computer-aided design have been an ever increasing focus of their development work. He received his B.A. in architecture from the University of Toronta and his M.B.A. from Columbia University.

JOHN MORRIS is an architect, a past associate professor of architecture and engineering, and a computer hacker by advocation. He is currently a doctoral student in the School of Architecture, University of Michigan, specializing in the introduction of artificial intelligence principles into computer-aided architectural design. He returned to the student chair after nine years of teaching architecture and architectural engineering at Oklahoma University, Tulane University, and the University of Kansas. Mr. Morris continues to be actively involved in the architecture/engineering profession by consulting on the development and implementation of computer based A/E aides.

SHIRLEY RADACK is on the staff of the Institute for Computer Sciences and Technology of the National Bureau of Standards. At the institute, which provides technical support to the federal government in the management and use of information technology, she is responsible for developing reports, special studies, and analyses of institute activities. Mrs. Radack has a B.S. in microbiology.

KENT REED is the leader of the Computer-Integrated Construction Group in the Center for Building Technology at the National Bureau of Standards. He is responsible for research on the information interfaces needed for integrated computer-aided design, construction, and operation of buildings and on the technologies needed to implement computer-based building standards and expert systems. Dr. Reed was educated as a physicist at the College of Wooster, Ohio, and the University of Chicago, Illinois. He was first exposed to computers in the early 1960's; he has since written systems and applications levels software for all size machines. He is particularly interested in increasing the effectiveness of computers in the engineering professions by making them intelligent assistants.

DANIEL REHAK is an assistant professor of civil engineering at Carnegie-Mellon University. He received a BSCE and MSCE from Carnegie-Mellon University, and a Ph.D. in Civil Engineering from the University of Illinois in 1981. He also serves as a co-director of the Civil Engineering and Construction Robotics Laboratories at Carnegie-Mellon. He is a member of Sigma Xi, Chi Epsilon, Phi Kappa Phi, the IEEE Computer Society, and the Association for Computing Machinery.

KENNETH F. REINSCHMIDT is vice president and manager for the consulting group at the Stone and Webster Engineering Corporation in Boston. Prior to joining Stone and Webster, he was an associate professor of civil engineering and senior research associate at the Massachusetts Institute of Technology. Dr. Reinschmidt has consulted on problems in construction management, seismic analysis of nuclear piping, project management, and probabilistic fracture mechanics. He has been active in computer-aided engineering and design since 1960 and was associated with the development of such systems as STRESS (Structural Engineering System Solver) at MIT. Currently, he is chairman of the Stone and Webster computer oversight committee and sponsors developmental work in computer graphics, CAD/CAM, expert systems, data base applications in engineering, microcom- puter applications, financial analysis, and risk analysis. Dr. Reinschmidt received his S.B., S.M. and Ph.D. in civil engineering from the Massachusetts Institute of Technology.

PAUL SCARPONCINI is project manager at McDonnell Douglas AEC Co. He is a registered professional engineer and current Ph.D. candidate in computer science. He received his bachelor of arts in civil engineering at Rutgers University in 1973 and his masters degree in architectural engineering at Pennsylvania State University in 1981. Mr. Scarponcini has served as project engineer in charge of computer-aided design of civil projects for Aurora, Colorado and product manager for lighting design computer programs for Computing Sharing Services.

LEONARD SIMUTIS was associate dean for academic affairs, College of Architecture and Urban Studies at Virginia Tech until May 1984. He became the dean of the Graduate School of Research at Miami University in Oxford, Ohio on July 1, 1984. At Virginia Tech he served as assistant dean and chairman of the Division of Environmental and Urban Studies from 1975-1982, and as director of the Computer Applications Laboratory in the College of Architecture and Urban Studies from 1973-75. He received his bachelor's degree from the University of Illinois, and his M.A. and Ph.D. degrees from the University of Minnesota. His major teaching and research interests are in computer-based approaches to design and planning with special interest in heuristic approaches employing computer graphics and information systems.

DAVID SKAR is director of the Naval Facilities Engineering Command's Engineering Systems Management Division, responsible for planning, developing and managing the use of advanced technology for engineering and design in Headquarters and its Engineering Field Divisions. This responsibility includes justifying resources, developing requirements for equipment, software, telecommunications and training, and managing system development and installation. These systems support all phases of construction contract document development, criteria development, consultation and management.

JANET SPOONAMORE is operations research analyst and team leader for the facilities system division with the U.S. Army Construction Engineering Research Laboratory. She has a bachelor of science in teaching of mathematics and a master of arts in mathematics. She is a member of the Association for Computing Machinery and the International Planning Committee.

ROBERT F. TILLEY, SR. recently joined a small consulting firm in Maryland specializing in large scale data base systems. As senior consultant, he intends to use this new position to supplement his present understanding of CAD with a detailed knowledge of data base management technology. He started as an interior designer with the General Services Administration where he acquired an appreciation for the needs of the building owner and tenant during the facility management process. Later, as program officer with the Veterans Administration, he designer, developed and implemented several computer-aided design systems with an emphasis on design review along with supporting the more traditional building design applications. In the future, he hopes to return to the CAD/AEC environment and continue with his interest of developing a fully integrated facilities management system.

DALE WADE is a registered architect and a certified planner, and is a senior consultant in the Facilities Decision Group, an Interspace Company. An expert in facilities planning, Mr. Wade brings over twenty years of experience in a variety of consulting services including urban and regional planning, new town development, project planning, design and management of complex healthcare, laboratory and office projects, site planning, environmental impact analysis and advanced computer operations for facilities and organizations. He is a graduate of the University of Pennsylvania with a Masters of Architecture and a Masters of City Planning. He is currently overseeing the development of the facilities management software project for the joint venture of the Wharton School and Interspace.

CHRIS YESSIOS is currently a professor of architecture and computer-aided design and the director of the Graduate Program in CAAD. He holds a Ph.D. in computer-aided design (1973) from the Carnegie-Mellon University, B.Arch (1967) and a Diploma in Law (1962) from the Aristolian University in Greece. He has published over 30 articles and research reports, and has designed and implemented a variety of CAD systems. He occasionally practices architecture and consults in computer-aided design applications.

RICHARD F. ZITZMANN has over 25 years of experience in the computer and communications fields. Former employers include Bell Laboratories, IBM Comsat and AT&T Information Systems. Previous technical management positions have included vice president of teleconferencing system design and construction (ISACOMM/United Telecom), division manager for advanced systems development (AT&T-IS, System 85 and System 75), assistant director of engineering for systems engineering (Satellite Business Systems), director of the analysis and evaluation division (COMSAT). Holding B.E.E. and M.E.E. from the Polytechnical Institute of New York, he is a professional engineer licensed in Maryland.

APPENDIX 2

WORKSHOP AGENDA

National Research Council
Building Research Board

1985 WORKSHOP ON ADVANCED TECHNOLOGY FOR BUILDING DESIGN AND ENGINEERING

National Academy of Sciences Study Center
Woods Hole, Massachusetts
June 16-21, 1985

Sunday, June 16

6:00 - 7:00 pm	Welcome Reception Study Center.
7:00 - 8:30 pm	Introduction to the Workshop John Eberhard and Jim Burrows.

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Monday, June 17

7:45 - 8:30 am	Breakfast Study Center.
8:30 am	Presentations on Working Group-Themes, Goals and Objectives Group A: Bob Heterick Group B: John Morris Group C: Larry Dyer
10:00 am	Case Study Presentation C. Patrick Davis, The Corps' Project Management System (AMPRS).
11:00 am	Working Group Sessions
12:30 - 7:30 pm	Free Time Unstructured time set aside for discussion, relaxation, or exploration of the region. Meeting rooms are available at the Study Center. Lunch is provided at the Study Center.
7:30 - 10:30 pm	Working Group Sessions

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Tuesday, June 18

7:45 - 8:30 am	Breakfast Study Center
8:30 am	Brief Reports from Working Group Chairmen
9:15 am	Case Study Presentation Douglas Stoker, SOM, Architecture/Engineering
10:30 am	Working Group Sessions
12:30 - 6:00 pm	Free Time Lunch is provided at the Study Center.
6:00 pm	Clam Bake
7:30 - 10:30 pm	Working Group Sessions

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Wednesday, June 19

7:45 - 8:30 am	Breakfast Study Center.
8:30 am	Brief Reports from Working Group Chairmen
9:15 am	Case Study Presentation Jack Enrico, Bechtel, Construction.
10:30 am	Working Group Sessions
12:30 - 7:30 pm	Free Time Lunch is provided at the Study Center.
7:30 - 10:30 pm	Working Group Sessions

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Thursday, June 20

7:45 - 8:30 am	Breakfast Study Center.
8:30 am	Brief Reports from Working Group Chairmen
9:15 am	Case Study Presentation Dale Wade, Facilities Decision Group, Facilities Management.
10:30 am	Working Group Sessions
12:30 - 6:00 pm	Free Time Lunch is provided at the Study Center.
6:00 pm	Cook-Out
7:30 - 10:30 pm	Working Group Sessions

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Friday, June 21

7:45 - 8:30 am	Breakfast Study Center.
8:30 am	Working Group Summary Presentations
11:30 am	General Discussion, Concluding Remarks
12:30 pm	ADJOURN. Lunch is provided at the Study Center.

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APPENDIX 3

PARTIAL GLOSSARY (DEVELOPED BY GROUP B)

- **ANSI/SPARC**--American National Standards Institute/Standards Planning and Research Committee

- **Conceptual view model (conceptual level)**--A view of the total data base content as seen by the data base designer. The conceptual view is not directly accessed or manipulated by the user, but serves only as an overall representation of data, from which all user views are extracted.

- **Conceptual data model**--A concise representation of data as contained in the conceptual view model. The conceptual data model describes the type.

- **External level or view**--An individual user's view of the content of the data base. The content of the data base as seen by some particular user. To that user, the external view is the data base.

- **Internal level or view**--A very low-level representation of the entire data base, dealing with the physical storage of data within a hardware storage device.

- **Schema**--A representation or view of data, expressed at any level in the data base.

- **State machine model**--A finite state machine model represents a computer system as a set of functions, performed upon retained memory through deterministic operations.

- **Data space**--A term suggested by the conceptual model group to depict the total environment of individual, possibly dissimilar, though integrated data bases throughout the building design and construction environment.

- **Data independence**--The immunity of applications from changes in storage structures and access strategies. The provision of data independence implies that changes in the external data schema or internal storage data schema should not require changes in the conceptual data schemas.

- **Entity**--The smallest unit of data that implies meaning without depending upon other entities or attributes for its description.

- **Domain**--A pool of data values from which the actual data values appearing in a given column of a relation are drawn.