Report From the 1986 Workshop on Integrated Data Base Development for the Building Industry (1987)

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Report From

The 1986 Workshop on Integrated Data Base Development for The Building Industry

Woods Hole, Massachusetts
June 1986

Committee on Integrated Data Base Development
Building Research Board
Commission on Engineering and Technical Systems
National Research Council

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OVERVIEW

BACKGROUND

This report, the fourth in a series, presents the findings of a workshop held at the National Academy of Sciences' Study Center in Woods Hole, Massachusetts in June 1986.[1] The workshop's purpose was to present a demonstration of a prototype integrated data base that would support a facility throughout its life cycle and to recommend further activities to move forward the concept of the integrated data base. Particular attention focused on the requirements of the integrated data base at the facilities management phase of the building life cycle.

This workshop on the development of an integrated data base is part of a study program of the National Research Council's (NRC) Building Research Board (BRB) to assess the long-range implications of computer technologies on future design, engineering, construction, and management of facilities.[2] Since 1982, an NRC-appointed committee has been examining the potential for computer-based technologies to improve the building process. This committee's study is in response to a

[1]The other reports in the series are as follows: National Research Council, A Report from the 1983 Workshop on Advanced Technology for Building Design and Engineering, National Academy Press, Washington, D.C., 1984; National Research Council, A Report from the 1984 Workshop on Advanced Technology for Building Design and Engineering, National Academy Press, Washington, D.C., 1985; A Report from the 1985 Workshop on Advanced Technology for Building Design and Engineering, National Academy Press, Washington, D.C., 1986.

[2]Although the proper title of the 1986 workshop is "Workshop on Integrated Data Base Development for the Building Industry" (the 1983, 1984, and 1985 workshops were titled "Workshop on Advanced Technology for Building Design and Engineering"), they are referred to in this report as the "Woods Hole Workshops." The change in titles reflects the change in emphasis by the committee and in the Woods Hole Workshops from the implications of computers in general to the development of an integrated data base for the building industry.

request from the 13 agencies of the BRB's Federal Construction Council to provide an informed assessment of the state of the art and its evolutionary direction.

The committee has conducted four Woods Hole Workshops from 1983 through 1986. These week-long sessions, attended by experts in computer technology and in facility design, engineering, construction, and management, have each contributed to the further development of the conceptual and the prototype integrated data base. The following is a brief review of each of the previous Woods Hole Workshops.

1983 WOODS HOLE WORKSHOP

The committee invited several other experts to join it at a workshop held in August 1983. 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, engineering, construction, and management of a facility are lost during its life span. The workshop participants concluded that these lost data could potentially be used to improve the building process by providing the information needed to improve the performance and responsiveness of future designs, and bring about a reduction in the life-cycle costs associated with new facilities. Workshop participants recommended that efforts be made to explore the development of a computer-based integrated data base that would be available at all stages in the life of a building project.

1984 WOODS HOLE WORKSHOP

This idea of an integrated 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 data base that spans the life cycle of a facility. Workshop participants generally agreed that there is a need for the development and implementation of a project integrated data base such as the model developed in Figure 1.

The project integrated data base would support all phases of the building project and 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 data base. The availability of an integrated data base would make it possible to have more efficient facilities management that should result in savings to the building owner.

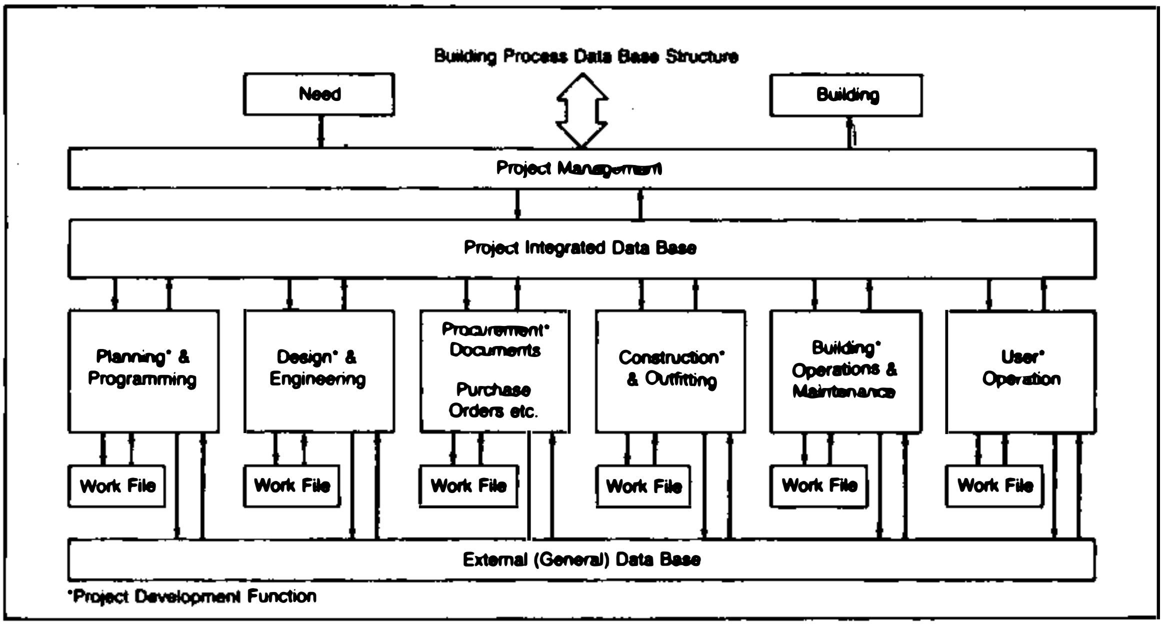

FIGURE 1 Project integrated data base developed at the 1984 Woods Hole Workshop.

1985 WOODS HOLE WORKSHOP

The 1985 Woods Hole Workshop addressed the developmental needs to formulate and construct an integrated data base. The results of this workshop were used to develop the prototype integrated data base that was demonstrated at the 1986 Woods Hole Workshop. The 1985 workshop focused on the interface between the design/engineering phase and the construction phase.

The challenge presented to workshop participants was to use the requirements for an integrated data base developed in previous Woods Hole Workshops to determine the data requirements and the conceptual representation of all data that pass through the data base. Workshop participants 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 data base.

Efforts also focused on identifying required data base characteristics and examples of how these characteristics would be used by the building industry. A model of the conceptual view of the data base was developed, and the relationship between the conceptual view and its physical implementation was described.

In addition, workshop participants developed a proposal for demonstrating the concept of an integrated 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, data generated in one phase of a facility's development would be available in later phases of the process.

Workshop participants concluded that the concept, if successfully implemented, offers the promise of improving building performance and reducing operating costs of the facility. It also would improve communication among the many participants who use data in the building process.

THE 1986 WOODS HOLE WORKSHOP

The 1986 workshop, the subject of this report, involved 42 individuals invited by the Building Research Board and the Committee on Integrated Data Base Development to the National Academy of Sciences' Woods Hole Study Center from June 15 to 20, 1986. Workshop participants were invited from industry, government, and academia; they represented the building industry as well as computer fields appropriate to this effort. Biographical sketches are given in Appendix 1, and a workshop agenda can be found in Appendix 2.

The centerpiece of the 1986 workshop was the prototype integrated data base demonstration that took place early in the workshop and served as the basis for much of the discussion and work that followed. The demonstration used heterogeneous hardware and software to show a typical sequence of tasks that take place between the design and construction phases of the building process. Chapter 1 describes in detail the integrated data base demonstration.

A group of workshop participants concentrated on identifying data that need to be obtained from the integrated data base for the eventual management of facilities. This task analysis group extended the work of previous Woods Hole Workshops to the facilities management phase of the process. Chapter 2 details the findings of this group and includes a listing of tasks needed in the facilities management phase.

Data modeling of the integrated data base at the conceptual level was the subject of another working group. This group concluded that it is possible to begin building a more comprehensive model. Chapter 3 presents the report from the data modeling group.

Chapter 4 concerns the integrator description and functional specification. The integrator is the functional capability of an integrated data base. It contains elements that administer, direct, translate, access, and communicate data within the environment of an integrated data base. The working group developed design objectives for the further development of the integrator.

Chapters 5 and 6 examine future directions of the integrated data base and the implications of introducing the data base into the building process. The two working groups developed comprehensive lists of issues requiring attention by the committee and others. Of principal concern is moving the integrated data base concept to organizations that can help implement it and leverage the results of the four Woods Hole Workshops.

1

INTEGRATED DATA BASE DEMONSTRATION

BACKGROUND

At the 1985 Woods Hole Workshop, participants investigated ways of developing a prototype integrated data base demonstration. Workshop participants recommended that a special demonstration prototype project team be formed to develop the concept during the next year.[1] The project team was subsequently organized and held its first meeting in October 1985.

The objectives of the demonstration prototype project team were to design and implement a demonstration prototype of the integrated data base (IDB) that would be available as a research tool for three to five years and could be used by the committee, project participants, and their representatives to (1) gain a better understanding of how the IDB will be used in the future building process and the resulting requirements that the IDB will have to satisfy, and (2) investigate alternative technical solutions to IDB implementation problems of linking data files and data bases of multiple computer systems through a common (integrated) data base for use throughout the life cycle of a facility.

At the second meeting of the project team in December 1985, it was decided that an initial prototype IDB demonstration should be available at the 1986 Woods Hole Workshop. The initial prototype was planned as a tool for both the invited participants at the workshop and for the demonstration prototype project team.

The concept was to use the initial prototype at the workshop to walk through a typical scenario in the building process so that workshop participants could use that example to address specific questions relative to the IDB, as well as to future enhancements of the prototype. The team would seek feedback from workshop participants on questions such as: Is this the kind of prototype required to resolve the issues that now delay the introduction of the IDB technology in the building process? What kinds of changes are desired in the prototype over the coming year? What resources are needed to extend the prototype further, and how will those resources be obtained?

[1]Members of the demonstration prototype project team are listed in Appendix 3.

CONFIGURATION OF THE PROTOTYPE IDB DEMONSTRATION

The configuration of the prototype IDB demonstration is planned as the first phase of a multi-Phased approach to the implementation of the prototype. The central processor is a DEC MicroVAX II, with a 5 megabyte MOS memory plus three 71 megabyte fixed Winchester disk drives with controller, a VT240 terminal and an LA100 printer/terminal. The operating system is MicroVMS, configured for eight concurrent users. The permanent prototype configuration will include the Tektronix high resolution color graphics terminal, Model 4125 (the terminal used at the 1986 Woods Hole Workshop was a borrowed Tektronix 4111). An IBM PC/AT equipped with Enhanced Graphics Adapter (EGA) was also used during the demonstration.

The Data Base Management System (DBMS) was ORACLE, and the applications software included AUTOCAD, GDS, STRUDL and STAAD III.

Vendors generously donated the equipment and software required for the prototype, or loaned it to the Building Research Board for an extended period. The configuration was assembled and integrated by demonstration prototype project team members Paul Scarponcini and Jim Greetham at McDonnell Douglas AEC Systems Company in St. Louis, Missouri. Building design data were prepared by Gary Seibert of the U.S. Army Corps of Engineers, Savannah District; he also played a key role in preparing the initial data model. Other data were prepared by team members David Kalish and Malcolm McCullough of Autodesk and Jack Enrico of Bechtel Power Company. Jim Anderson, consultant, CDC Information Analysis Services, provided expert advice on the design of the conceptual data model for the initial prototype using the NIAM data modeling method (see Chapter 3). Richard Zitzmann, a consultant to the Building Research Board, provided the overall project team management.

SCENARIO

At the workshop the prototype was used by team members to walk through a typical sequence of tasks that occur between the design and construction phases of the building cycle. To keep the implementation of this initial prototype to a manageable size, the team decided to restrict the effort to the various tasks and activities involved in the design and construction of a wood truss. The building design selected for the case study was a mobilization administration and supply building for which the Corps of Engineers had an existing design.

Although this snapshot of the building process is just a small portion of the entire cycle and addresses only the structural subsystem, the team found that the lessons learned from this effort can be extended to other subsystems and phases and can go a long way toward addressing issues related to global data modeling and desired characteristics of the IDB. Future research efforts could broaden the scope of investigation.

During the demonstration, Fred Kitchens of the U.S. Army Corps of Engineers described the steps that the client would follow in establishing requirements for the building, including preparation of Form 1391, a standard form of the Corps of Engineers that is used to initiate a construction project. Data required for subsequent tasks in the scenario were stored on the MicroVAX using ORACLE. Mr. Kitchens also explained the owner's view of data throughout the whole building process.

Malcolm McCullough, the architect for the demonstration, explained how he used the owner's requirements to drive his activities, which involved the use of AUTOCAD to generate the architect's view of the building floor plan and a cross section of the roof. These data were stored in the demonstration IDB for use by the structural engineer.

Gary Seibert, the structural engineer for the demonstration, walked through the steps of the design task in detail. He retrieved the architect's view from the demonstration IDB, generated a design, analyzed it using STAAD III, and accessed a simulated on-line external data base for physical properties of wood materials. He then prepared a drawing of the wood truss design that was loaded into the demonstration IDB.

Jack Enrico played the role of general contractor. He used requirements and design data on the wood truss to prepare the work breakdown and the contractual requirements for the fabricator/subcontractor. The resulting data were included in the demonstration IDB.

The fabricator role was played by Jim Greetham who worked through the task in detail, retrieving data from the demonstration IDB, preparing a detailed fabricator's view using GDS, and performing structural analyses using STRUDL. His results also were stored in the demonstration IDB.

At one point in the scenario, the flexibility of the IDB concept was illustrated by showing how the client could make a change in requirements. The other participants demonstrated how the new data could be accessed directly, and how design and contract changes can be made quickly.

Throughout the demonstration, the progression of the scenario was illustrated using a projected graphic display from the Tektronix 4111 terminal. Figure 1-1 shows the prototype configuration in the lower left-hand corner, the flow of the scenario at the top, including the current step being presented and the data base functions required to support that step. The latter information was given in the lower right-hand corner of the graphic display which also illustrates the general notion that the IDB consists of data distributed among external, transition, and application data bases.

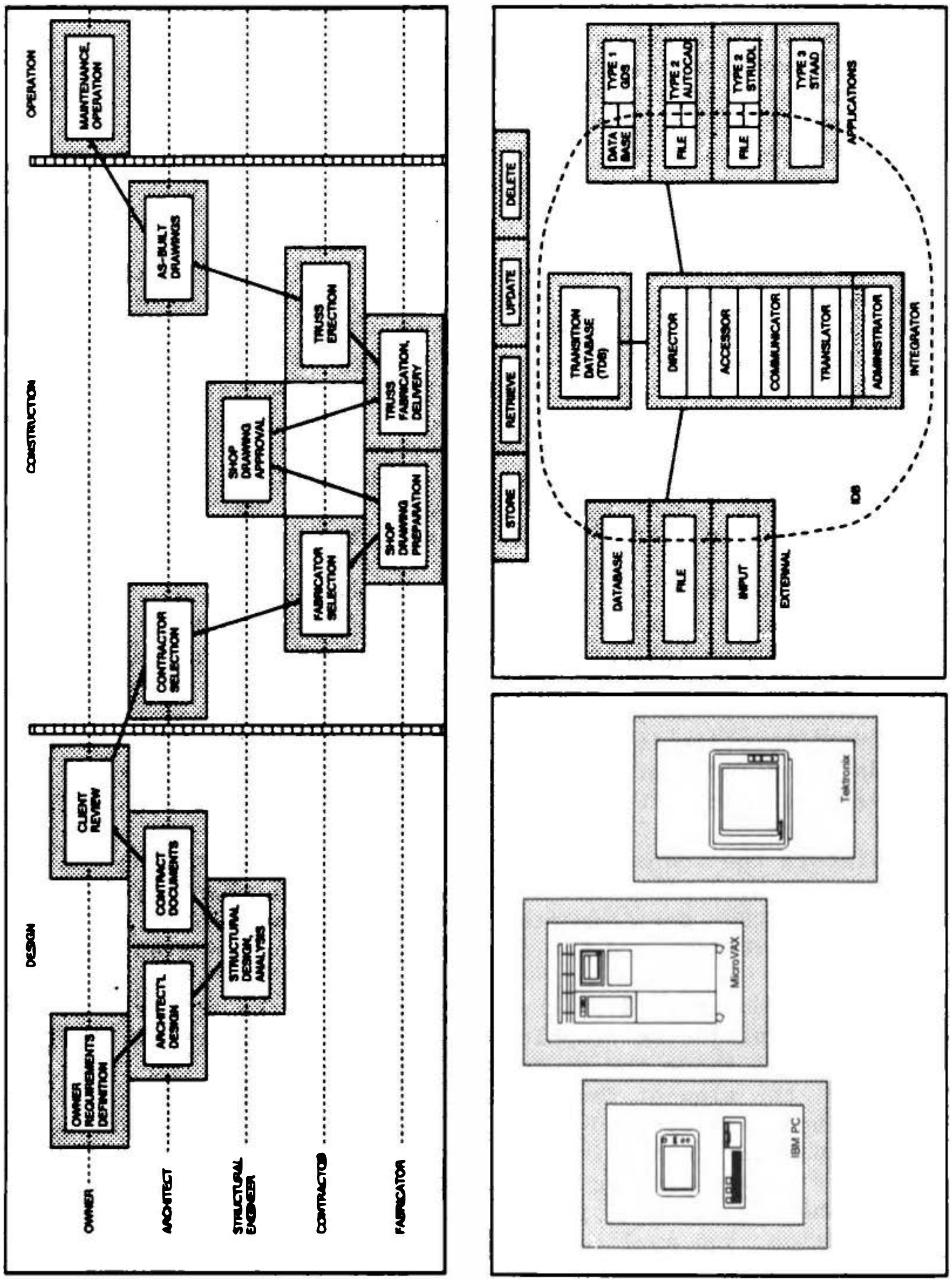

FIGURE 1 Integrated data base prototype diagram.

CONCEPTUAL DATA MODEL

The structural engineer's task and the fabricator's task were presented in detail during the demonstration, as summarized in the above scenario description. To ensure that the demonstration IDB contained the necessary data entities and attributes and that the data base was populated with the data required for these two tasks, Gary Seibert and Paul Scarponcini, aided by Jim Anderson, performed detailed task analyses and initiated the design of the IDB conceptual data model as the prototype IDB demonstration configuration was being assembled prior to the workshop.

Two goals of the demonstration were to explain how the tasks were analyzed and the data modeling methodology used. That work was used as a starting point for the task analysis working group (see Chapter 2) and the data modeling working group (see Chapter 3).

INTEGRATOR

At the 1985 Woods Hole Workshop, the concept of the integrator was introduced. The integrator represents a composite of the functions necessary to support an IDB in a distributed, heterogeneous hardware and software environment.

There have been a significant number of research projects in the computer industry and at universities that have addressed at least some of the technical issues that derive from achieving an integrated data base in a distributed, heterogeneous environment.[2] These issues include data integrity, query processing, catalogue management, concurrency, fragmentation, transparency, recovery, and others. In treating these issues, a lexicon of terms has been developed by researchers to describe requisite data base functions; for example, they include "global data management," "distributed transaction management," and "global-local subqueries."

The integrator concept was defined at the 1985 workshop without regard to specific implementation of functions, the data base management system to be used, or even the potential segmentation of issues as other researchers may have done. Instead, a conceptual structure was established for the integrator, consisting of five components:

1. *The Director*. Includes the data dictionary, information on where data are stored, file formats, access authorization, current status, specific physical implementation information,
2. *The Accessor*. Determines access strategies, creates files, removes files, adds data, deletes and retrieves data,
3. *The Translator*. Contains knowledge of requirements for different views of data, formats of sources and targets, and performs conversions,

[2]A list of sample projects is given in Appendix 4.

4. *The Communicator*. Provides data transfer between hardware and systems, and

5. *The Administrator*. Ensures security of data (controls read, update, delete), integrity, consistency, currency; provides for concurrency, recovery, backup; and enforces inclusion and exclusion rules.

During the detailed demonstration of the structural engineer and fabricator tasks, an explanation was given about the components of the integrator necessary to support the two tasks. In essence, the structural engineer task illustrated a store-data operation while the fabricator task illustrated an operation of retrieving data from the IDB for analysis.

Although this initial prototype was not capable of executing most functions of the integrator, the demonstration was designed to show the sequential steps of the integrator for the two tasks that were demonstrated in detail.

At the workshop, a working group was asked to prepare a plan for further developing the concept of integrator that could form the basis for a future implementation of integrator functionality (see Chapter 4).

LESSONS LEARNED

Following the demonstration, the project team conducted a panel discussion that addressed the lessons learned by the team while implementing the prototype IDB demonstration. A summary of key points follows:

1. Not only was the equipment configuration a prototype, but the project team was a prototype of an organization necessary to implement an IDB. As a result, the team went through a learning experience on the implementation process itself.
2. Although it was learned that use of a thorough, well-structured methodology was essential to design the logical data model, it did not seem that there was any one method that was significantly better than any other well-established method for use with the building process.
3. The lack of a formal project organization, similar to a project for a software development, was an impediment for the volunteer IDB demonstration prototype project team. Progress was hindered because of the dependence on voluntary resources.
4. Even though the prototype IDB demonstration effort was limited in scope intentionally, it became obvious that the volume of data for the building process is large; some effort is required to make wise decisions on exactly what data to include in the transition data base over time. However, it may be that this problem will be less severe in the future as new, automatic ways to capture data are discovered.
5. The question of the proper level of detail for the data model was debated. Some team members advocated a high-level model. Others

held that data modeling is a never-ending, evolutionary process, and that the model should be developed in bite-sized pieces.

6. Future prototype IDB demonstration efforts should include the facility management phase of the building life cycle where there are many existing management problems for the owner, and where large cost savings are likely to be achieved.

2

TASK ANALYSIS

INTRODUCTION

Previous Woods Hole Workshops concluded that the development of an integrated data base (IDB) would mitigate the loss of data and the need to re-create data in the building process. Because the greatest loss of data occurs at the interfaces between the phases in the building process (see Figure 1), the task analysis group was asked to concentrate on the interfaces or boundaries between construction and facility management, and between facility management and the start of a new cycle for a new building loop. Discussions focused on identifying data which (1) need to be obtained from the IDB, and (2) are generated during the facility management phase that have use in evaluating past performance and improving future facilities.

The working group was chaired by Jack Enrico and included Clyde Arnold, Frederick Busch, Ronald King, Malcolm McCollough, Lee Nason, Richard Person, Peter Smeallie, Janet Spoonamore, and James Walton.

Approaches

Figure 2-1 illustrates the approach used by this working group to determine the general characteristics of data required for facility management from the IDB. Five broad categories of facility management functions or tasks have been determined. Four relate to tasks at individual facilities--operations, maintenance and repair, facility improvement, and space management. One category--asset planning--applies as a multi-facility management function. The IDB given to the facility owner, and passed to its management units, then was considered to be screened by the application of inclusion/exclusion criteria to develop the three general types of data required to be included in the data base: performance, physical characteristics, and components. This exercise developed the need for the group to focus on definitions, rules for inclusion/exclusion, and the five broad task groupings.

It is important to note that facility management activities generally produce analyses and surveys that lead to (1) owner decisions on the need for new or modified facilities, and planning and programming input, and (2) new information inputs into the IDB. A more detailed functional view of typical facility management activities and

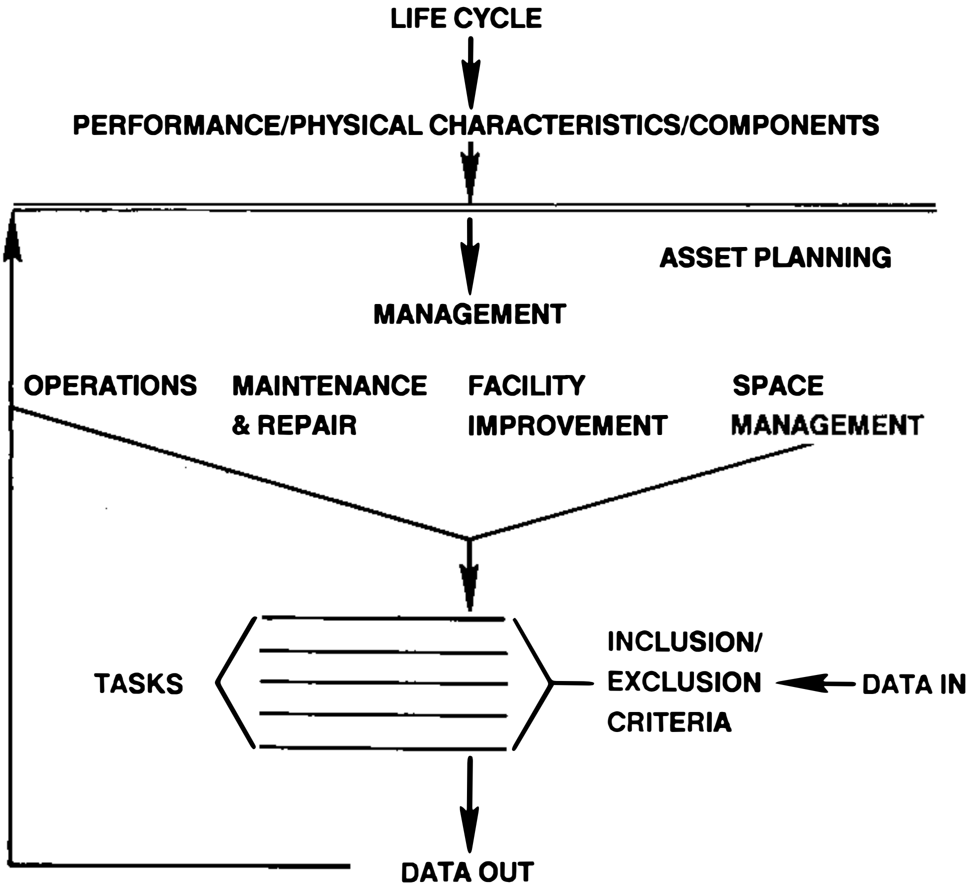

FIGURE 2-1 Task analysis approach (single project).

relationships is shown in Figure 2-2. Taken from a U.S. Army Corps of Engineers management activities model, the exhibit clearly shows the role of planning/evaluation and work management activities in operating and enlarging a multi-facility installation.

Assumptions

The primary target of the task analysis group was the facility management phase of the building process, with a focus on benefits, such as improved management control and decision making. The working group reviewed the assumptions from the 1983-85 Woods Hole Workshops about data needs and data element issues, and agreed that the assumptions made at these workshops are still valid. Briefly, these assumptions were as follows:

- The IDB concept will drive the technology.

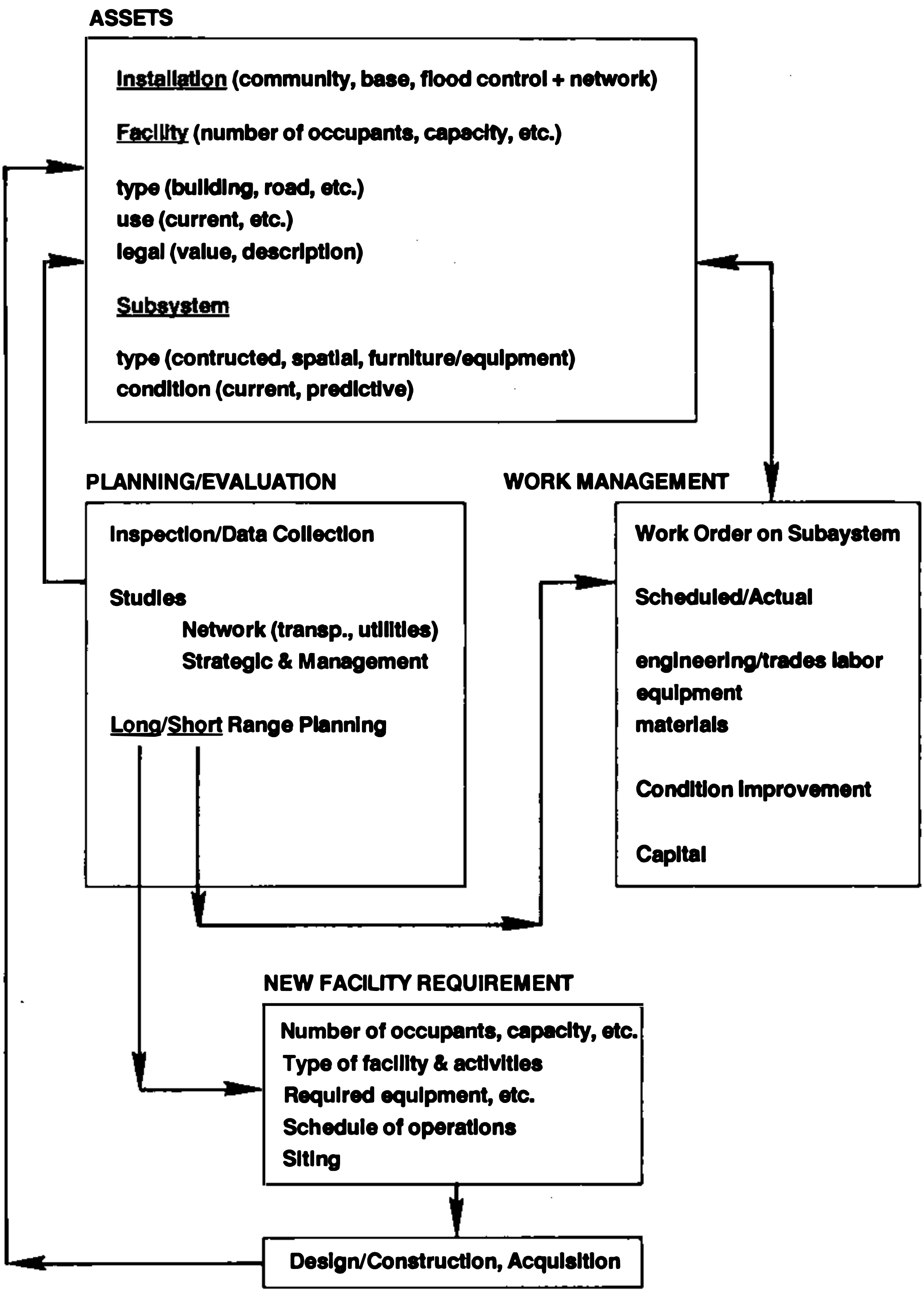

FIGURE 2-2 Model of relationships.

- Only data that facility owners and their organizations decide are necessary and desirable will be contained in the IDB.
- The IDB will consist of heterogeneous hardware and software, and will accommodate changing technologies over time.
- The IDB will contain pointers or reference elements to enable users to locate data that are not used frequently, such as data of historic value, which may be stored outside the IDB in an external file.
- The content of the IDB will evolve. Some of the data will be changed over time as the building changes, and new data will be added as needs are identified or data requirements change.
- Data in the IDB will be shared by all participants in the building process and will be an essential element in the owner's management control system for facility management activities.
- A data manager or administrator will be needed in order to maintain the integrity, consistency, and security of the IDB. By ensuring data integrity and consistency, and possibly eliminating redundancies, the IDB will have economic advantages over existing practices.
- Each IDB will be unique, reflecting the needs of different owner organizations. Each organization must establish for itself what information is important in view of its goals and policies. Individual differences must be allowed in order that the IDB best serves the owner's facility management needs.
- Other data bases, including working files and data not meeting the IDB inclusion criteria, will continue to exist. The IDB will contain references to these data bases so that information contained in them can be quickly located, should it be needed by the owner or others.
- Effective interfaces between cost accounting and other data systems, and the IDB are in place (or will be) to ensure that decision makers receive complete information on status, condition, and cost.

Definitions

In order to place the work of the group into the proper perspective and to ensure a clear understanding of the working group's findings, the following definitions are offered.

<u>Asset Planning</u> Asset planning is the long-range, integrative strategic planning function for a multi-facility owner. It considers the costs and functional attributes of possible alternative actions and recommends optimal directions based on experience, life-cycle economics, organizational policy, and responsiveness to the owner's requirements. Its recommendations are affected by some information from all phases of a facility's life.

Construction The building of a new facility; the replacement of a facility; or the modification, alteration, addition to, or conversion of a facility so that the facility may be more effectively used.

Facility A building or structure which makes possible some activity. A facility can consist of a group of buildings or structures that are considered a single unit or entity, such as a military facility (e.g., base, fort, station, or installation).

Facility Improvement Process The modification, alteration, addition to, or conversion of a facility so that it may be more effectively used. Responsibilities in this area include the following: proposed design changes to facilities; award of contracts and management of construction; design and procurement of specialized technical equipment, such as security systems; development of cost estimates; and monitoring of costs during projects.

Facility Management The International Facility Management Association (IFMA) describes facility management as follows: It coordinates the physical workplace with the people and work of the organization. Its goal should be to combine the best management practices with the most current professional and technical knowledge to provide humane and effective work environments.

Furnishings and Equipment Major parts or subsystems of a building. Examples are the foundation, superstructure, roof, mechanical systems, transportation systems (elevators and escalators), and telecommunication systems.

Maintenance/Repair The work required to keep and/or restore a facility in such condition that it may be used for its intended purpose. This includes ensuring an efficient, safe, and cost-effective facility and its daily operation through the following functions: proper maintenance, both preventive and breakdown; housekeeping; trash disposal; maintenance of the building shell and grounds; monitoring and reporting maintenance costs; and managing cost reduction efforts associated with maintenance and repair functions.

Master Planning The determination of new facility requirements to include type, size, number, and location to satisfy a strategic plan usually over a two- to three-year period. Master planning considers mission requirements, existing facilities, available utilities, and environmental requirements, and includes a cost analysis.

Operations The day-to-day use of a facility, its systems, and related supporting activities, exclusive of those activities considered to be maintenance or repair functions.

Performance The measure of how well a building, structure, subsystem, or material does what it was designed to do; or how well a person executes specified or assigned tasks.

Physical Description Data that describe the physical attributes of a facility. Examples include room dimensions (length, height, and width), material types (concrete, steel, and wood), and major building components and equipment included in each building.

Space Management Efforts required to provide an efficient and functional workplace to accomplish economically and effectively the organization's objectives within budgetary constraints. This includes: (1) developing and implementing space use policies and standards, (2) developing short- and long-range space use plans based on future operational expectations, (3) allocating and reallocating available space among competing requirements, (4) monitoring assigned space to ensure that it is being effectively and appropriately used, (5) overseeing all interior moves, additions, and changes, (6) maintaining space and furnishings inventories for management control and evaluation purposes, and (7) gathering historical data on space allocations and use, growth rates, and costs for use in revising policies and standards, and for forecasting future needs.

Space Planning Planning for the effective use of existing spaces and facilities within requirements and budget constraints.

DATA REQUIREMENTS FROM THE IDB FOR FACILITY MANAGEMENT ACTIVITIES

The working group's first task was to provide guidance on information required from the IDB for facility management activities by the owner, and to identify priorities for use of facility management data.

The owner operates (or designates others to operate) the individual facility. The information generated during the development process contains considerable data regarding life-cycle costs for the facility--costs which normally dwarf design and construction expenses. The term owner covers a broad classification of organizations responsible for the construction and use of the facility. These organizations differ in terms of organizational structure, goals and objectives, reporting methods, and facility evaluation techniques.

The content and structure of the data base provided would have to be tailored to the individual user, but generally would contain information in the following general categories:

- *Performance*. Design assumptions and intent of the architect/engineer, estimated system functional abilities, and costs.
- *Physical characteristics*. Physical description of the actual facility, systems, spaces.
- *Components*. Movable, relocatable, and often user-specific equipment such as lighting, furniture, and so forth.

User Views and Perspectives: The Private Sector

Previous Woods Hole Workshops identified the diversity of views held by the many participants in the life cycle of a facility. This diversity was well illustrated using floor space data as an example. The real estate manager is most interested in rentable areas, the architect is most concerned with gross square footage, and the owner may want to know only about net square footage.

The view of this diversity must be expanded to place appropriate emphasis on the operations and maintenance phase of the life cycle. Focusing on organization and management, both time and function can dramatically affect the data needs of a facility manager.

Time

An essential parameter missing from the workshop's prototype IDB demonstration was time. The architect, engineer, contractor, and related participants perceive the facility as a project; that is, they see that their purpose is to complete the facility and move on to the next job. The facility manager's purpose is to extend the life of the facility to the point of economic feasibility.

The facility manager is therefore concerned with issues such as the time value of money, durability of products, life expectancies of facility components, deterioration of materials, and performance of materials over the life cycle of the facility. This observation implies that further development of the prototype IDB should incorporate time-dependent variables in order to bring potential owners to the realization that the IDB can cope with the subtle changes that occur in the life cycle of a facility.

Examples of features that show concern for this issue are the following:

1. Incorporation of the <u>ENR</u> "Construction Cost Index" in all costing functions. Historical records could be used for costing to present day levels, and projections could be used to calculate future costs.
2. Incorporation of component life expectancies to help predict maintenance and repair costs and to help facility managers to more easily schedule periodic inspection and maintenance needs . Design analysis in accordance with value engineering principles would help facility managers to schedule and budget major maintenance, such as roof or cooling tower replacements and would help avoid catastrophic component failures.

Function

Facility managers perform a wide variety of functions in their day-to-day jobs; their data needs vary accordingly. For example, when involved with a repair on a fan coil unit, the facility manager needs part numbers and perhaps an air-distribution diagram in order to arrange emergency air conditioning to critical areas of the facility. When involved in a furniture inventory, the manager needs the plan showing desk locations. When completing an energy usage study, equipment heat loads and the facility component U-factors become important. In fact, there exist so many data on any given facility that concocting a single textual or graphical representation for a facility manager would be impossible and counterproductive. This observation implies that future prototype IDB efforts should incorporate task-oriented data access systems with hierarchical levels of detail.

Examples that show concern for this issue are the following:

1. Establishment of user software to block out space usage, square footages, occupancies, and schedules on a high-level floor plan which, upon request, can be magnified to show needed floor plan detail and dimensions, and
2. Establishment of user software to show mechanical equipment layouts and required temperature and humidity requirements on a high-level floor plan which, upon request, can be magnified to show air-balancing detail or controls.

These functional, task-oriented "slices" through the IDB may consist of derived data for higher level information or primary data for more detailed views. A comprehensive mapping scheme might be developed that would allow users to pick and choose the areas where they are willing and able to purchase and maintain pertinent "slices" of the IDB.

User Views and Perspectives: The Public Sector

Functional Processes

In the public sector, major aspects of the IDB that are related to the operations and maintenance phase include information on real-property related assets that are added to the building stock in the earlier design and construction phases. The major data elements for installations, such as those that the U.S. Army owns, are the facilities themselves, their use (e.g., barracks and hospitals), and specific legal description and capitalization information.

Within each facility, the operational and supporting subsystems of the facility are categorized. For example, the constructed elements consist of the mechanical, electrical, and structural subsystems. The spatial elements consist of the available floor space and usable areas of the facility. The related functional components consist of the furnishings and equipment. The operations/maintenance functions address that part of the IDB associated with the in-place facilities (associated through a network) of the owner's installation.

Specific attention is made to the subsystems of the facilities that must be maintained. For example, the facility manager assumes that the HVAC systems are maintained, keeps records of fuel usage, and plans for upgrades and replacements of equipment.

Work Functions

In the operations and maintenance phase, work functions include two major categories: planning/evaluation and work management. The planning/evaluation functions include tasks related to the inspection of the condition of the subsystems of the facilities. Studies are conducted to assure that functional space is adequately allocated and used, capacities of roads are not exceeded, utilities are adequate, and methods of work are cost effective. Short- and long-range planning for preventive maintenance, enhancements, and new facilities to accommodate future needs is conducted. The work management function concerns the repair, maintenance, operations, and improvements to the subsystems of the facilities. Since the work involves labor, materials, and equipment, the operations and maintenance budgets and costs are accounted by the facility subsystem. The condition of the subsystem is updated by the work process, i.e., repair work to restore a subsystem to operating order. Value added through work can also be associated with the facility (e.g., adding air-conditioning).

Integrated Data Base Needs

The data elements necessary for the planning/evaluation function of the operations and maintenance phase include the assets information, in addition to other data about the organization's needs. Long-range planning may result in future new facilities to be acquired or designed and constructed. New facility requirements are described to the construction or acquisition agent. This information includes the desired type of facility, capacity (number of occupants, beds, etc.), types of activities to be performed in the facility (classrooms, laboratories, etc.), equipment to be housed, and potential siting requirements with respect to other facilities on the installation.

Although the work management function uses many sources of data, the only elements used from the IDB are the performance and physical characteristics of the assets information.

Data Population

The important question related to the assets part of the IDB is how this assets data base can be populated with data. Given the slow turnover of facilities (it is estimated at 1 percent per year), the most likely manner of population is through the inspection and data collection tasks of the facility manager. Further, the work performed on the facilities could likely be used to update the information in the assets data base, which is part of the IDB. This view of the assets part of the IDB will dictate that the data delivered from the earlier phases (design and construction) must be translated to conform to representation needed in the operations and maintenance phase.

DECISION RULES

The working group attempted to reassess, modify, or add to the inclusion/exclusion decision rules for the IDB developed at the 1985 Woods Hole Workshop. These inclusion/exclusion rules are important to determine the information requirements for facility management, as shown in Figure 2-1. Again, the exact nature of the information required is highly dependent on the type of facility and the owner's needs, but general guidelines can be established.

The decision rules are used to screen and group data requirements for various facility management tasks, then identify data needs that the IDB would fill. With a well-conceived set of decision rules, development of information requirements at an owner or project-specific level can occur. The review and adaptation of the inclusion/exclusion rules for facility management information will also provide guidance to modeling efforts associated with the future evolution of the prototype IDB.

The following decision rules for inclusion and exclusion of data, based on the 1985 Woods Hole Workshop, are meant to be used to determine what data will be furnished to the owner. It should be noted that the ability of the owner to use data may vary. Some owners may be able to use the raw data, while others may require that the data be processed and furnished as information. This decision should be established early during the project.

It is recognized that the owner must be provided guidance about which data should be contained in the IDB. The following concepts of inclusion and exclusion can be used to provide guidance on items to be included in the IDB. In assisting the owner, it is important to review all of the tasks that the owner must perform and to establish which tasks can be enhanced by use of the IDB.

Inclusion Rules

1. Life-Cycle Use Data Data that affect the life cycle of the facility should be included in the IDB. The elements should be chosen as early as possible. Cost estimates of owning and operating the building should be made available to the owner as early as possible. Changes made to the project that would affect the life-cycle cost should be reported to the owner so that program changes can be made during the design and construction phases.

2. Multiple Use Data Data that are valuable in more than one phase of the building process are considered multiple use data and should be included in the IDB. However, a data element used several times in any one phase is not considered necessary for IDB inclusion. Data valuable only to the owner should not be kept in the IDB, but provided to the owner by another method. An example of multiple use data is the allowable floor area of a facility used in the planning and programming phase, the design and engineering phase, and finally in the operating phase.

3. Physical Description Data that describe the physical attributes of a facility should be included in the IDB. This class of data should describe the building attributes and the building component systems. Building attributes include facility dimensions (length, width, height) and material types (such as concrete or steel). Examples of the building component systems are the foundation, superstructure, roofing, mechanical, and exterior utilities location. The building component systems should be described in enough detail to allow the owner to evaluate the component for future building requirements.

4. Intention Performance expectations of the programmer and designer should be included in the IDB for use by the owner. The intention should describe how the facility is to be used, and should also provide a description of how the major building components and systems will operate. It should include design assumptions used in developing the major building components and systems, and any limitations the owner should know. Examples of intentions might be the assumptions used in designing the air-conditioning system, and limitations as to the number of personnel and amount of equipment that can be accommodated in the building.

5. Historical Reference This data class comprises information on the facility that can be useful in determining future uses for the facility. This information may also be a legal reference. Examples of this class of data include codes used during the design and construction phase, and legal limits placed on the facility use by governing authorities.

6. Major Equipment Major equipment should be incorporated as a separate data class in the IDB. This rule insures that descriptions of major equipment furnished with the building are available for the owner's use. Typical of this class is specialized user equipment and furniture. This type of equipment is normally movable in nature and is not an integral part of the building.

Exclusion Rules

1. Derived or Generated Data This rule states that data that can be derived or generated from other data should not be stored in the

IDB. This rule helps to reduce the size of the data base. For example, a room area need not be included when the room dimensions are stored in the IDB. This rule should not preclude the owner from receiving calculated or generated data. The building owner may not have the software to derive or generate the data and may request that the derived or generated data be furnished when the building is complete.

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 IDB should not contain data that reside in the external data base, although the source of the reference should be captured if the reference is ever to be retrieved.

3. Insignificant Data Insignificant data must be defined and then excluded from the IDB 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 IDB 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 IDB. 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 IDB.

IDENTIFICATION OF USER BENEFITS

The working group identified important beneficial and demonstrable aspects of the IDB. Specific facility management tasks, notably in maintenance, repair, and operational activities can realize easily comprehended and quantified cost savings. Another highly visible benefit is the information that can be maintained for systems analysis or future programming use. To achieve maximum positive impact in future prototype IDB demonstration efforts, emphasis should be placed on working examples that best display the benefits to the owner.

The greatest benefit of an IDB will accrue to the facility owner. In evaluating the benefit-driving mechanism, one must recognize that 80 to 90 percent of a facility's life-cycle cost is attributable to the operation and maintenance of the facility. Furthermore, facility managers have the greatest likelihood of becoming the managers of the IDB.

In spite of the promise of computer technology, data base development and ownership have often been perceived as high-risk undertakings with a questionable return on investment. However, the rapidly growing use of computers by facility managers throughout government and industry to assist in the operation and maintenance of facilities indicates that the benefits from computerized information are becoming more apparent. Table 2-1 summarizes some of the benefits of an IDB that the group identified.

The IDB offers a vehicle for encouraging innovation. The following list is an indication of some potential opportunities.

- Greater understanding of data base technology by facility managers and owners,
- Greater ability to correlate questions of quality and life-cycle costs,
- Better continuity of data over the physical life cycle of a facility, possibly resulting in a 100-year useful life,
- More integration during the planning phase of a facility,
- Better tools to manage change rather than only react to change,

TABLE 2-1 Benefits of the IDB to the Owner and/or Facility Manager

A. Occupancy- (operations-) related benefits:
   1. Equipment, furniture, and space inventories
   2. Replanning, redesign, and drawings
   3. Project management and procurement
B. Maintenance-related benefits:
   1. Availability of detailed data about physical characteristics and components of facility
   2. Structure for creating customized maintenance procedures to track individual components over time
      a. Maintenance history
      b. Automatic work/purchase order productions
C. Better information to make decisions about the types of maintenance to be applied to each component:
   1. Preventive maintenance to reduce the need for future, more expensive rehabilitation or replacement and extend component life
   2. Rehabilitation/modification
   3. Replacement
D. Decisions based on analyses of physical characteristics, maintenance history, and condition indicators (diagnostics)
E. Fine tuning of maintenance functions over time can lead to:
   1. Reduced costs for labor, materials, and equipment
   2. Reduced down time
   3. Increased responsiveness
F. In the design/construct feedback looping:
   1. Performance of original design concept
   2. Performance of original and replacement components
   3. Improved knowledge base to draw on for future projects

- Generate multiple alternatives rapidly and employ sensitivity analysis to guide decisions,
- Greater ability to validate the decision-making process,
- Manage the information explosion more efficiently,
- Greater reduction in the time differential between basic facility research and wide dissemination,
- Stronger encouragement of a multidisciplinary approach to facility management,
- Increase the intelligence level of the lowest common working medium, as work moves from drawings to the computer, and
- Develop a creative model for export to other industries.

FINDINGS

The working group reconfirmed many of the findings of previous workshops, particularly in the area of data requirements and data inclusion/exclusion rules. This group extended these findings to the facility management phase, and the identification of the principal functions or tasks that require data from the IDB. In addition, the views of the facility manager were addressed and findings were identified for this area.

Data

The 1985 Woods Hole Workshop inclusion/exclusion design rules were validated and extended to include the facility management phase. Data requirements established in previous workshops continue to apply. Other data-related findings are the following:

- Facility management data can be categorized and assigned to a specific area of responsibility.
- A problem of populating the data base exists due to the exceedingly long life cycle of a facility. For this reason, the time value of data becomes an important issue.
- Facility management data contained in the data base fall into the general categories of performance, physical characteristics, and components.

Facility Management Data Requirements

The group identified five broad categories of facility management functions or tasks that require data from the IDB: (1) operations, (2) maintenance/repair, (3) facility improvements, (4) space management, and (5) asset planning. Table 2-2 lists tasks under these five categories.

The group also identified the facility manager as a multi-disciplined participant in the process needing data from every phase of

TABLE 2-2 Facility Management Tasks.

Tasks	Multi-Facility Assets Planning	Single Facility Operations	Mainten. and Repair	Facility Improvement	Space Management
1. Minor changes		X		X	
2. Planning	X				X
3. Replanning	X				X
4. Furniture installation	X		X		
5. Space inventory					X
6. Major changes	X				X
7. Furniture moving		X			
8. Operating budgets		X	X		
9. Furniture		X			X
10. Furniture maintenance	X	X			
11. Finish maintenance			X		
12. Preventive maintenance			X		
13. Furniture inventory		X			
14. Furniture purchasing		X		X	
15. Furniture disposal		X			
16. Space standards					X
17. Code compliance		X	X	X	X
18. Housekeeping			X		
19. Security		X			
20. Telecommunications		X	X	X	
21. Design evaluation		X	X	X	
22. Space forecasting	X				X
23. Construction management			X	X	
24. Breakdown maintenance			X		
25. Trash removal	X				
26. Furniture budgeting	X				
27. Capital budgeting	X	X		X	
28. System design			X	X	
29. Energy manager		X			
30. Architectural/design			X	X	
31. Grounds			X		
32. Exterior maintenance			X		
33. Long-range planning, 1-3 years	X				
34. Building programming	X				
35. Satisfaction evaluation		X			
36. Long-range planning, 3-10 years	X				
37. Long-range planning, 10+ years	X				
38. Hazardous waste removal		X			
39. Utility services		X			
40. Space allocation		X			X

the building process that precedes the operation of the facility. The facility manager also needs time-dependent views based on the state of the facility at a queried point in time.

Based on its application experience in facility management, the group reconfirmed the opinion that an IDB could provide a significant cost benefit to existing practices in facility management.

RECOMMENDATIONS

The task analysis group recommends that the prototype IDB demonstration continue to be developed over the coming year with the effort refocused to an area which meets the following criteria:

1. Allows demonstration of a full life-cycle concern. Design and construction data are forwarded to a facility manager for use in operations. Operational data are forwarded to a design/construction team to improve the economic or functional aspects of the facility during rehabilitation.
2. Obtains high value from a potential owner. Owners must be given sufficient incentive to participate in the design and, eventually, to purchase the system. Therefore, the "slice" of the IDB which should be developed must be highly valued because of substantial economic, function, or policy benefits.
3. Applies to a low-technology, well-understood problem area. This criterion not only supports easy comprehension and acceptance by potential owners, but might allow the demonstration prototype project team to build on existing software thus reducing the cost and work effort involved from the volunteer team members.

The task analysis group feels that two slice areas meet all of these criteria: (1) energy management and (2) space usage management.

A user task force can be convened using task analysis group members as a core, but expanding membership to include a wider variety of multi-facility owners from both the private and the public sectors. Their charter would be to validate (or redirect) efforts toward the establishment of an appropriate slice of the IDB. They would then complete task and information modeling on the slice that they had chosen and pass on their analysis to the demonstration prototype project team which would design and complete an applicable portion of the IDB. If clarification was needed by the team on any functional issue, the task force would be available for advice.

This plan would correctly involve potential users in the design process and create a market to which interested vendors may respond. It would enable the demonstration prototype project team to avoid working in a vacuum, uncertain of requirements. As envisioned, it would involve a wide enough representative sample of the owner population so that the results would be generally applicable, regardless of the idiosyncratic requirements of any individual owner.

3

DATA MODELING

INTRODUCTION

The working group on data modeling focused on the modeling of building project data at the semantic, or conceptual, level. At this level of abstraction, an enterprise can be described directly and naturally in terms of the objects, attributes, and relationships important to the enterprise.

By comparison, the data model that evolved during the 1985 Woods Hole Workshop identified the basic data types, relationships, and attributes that a building data base would have to support and that could be used to express the contents of the semantic model. Thus, in an overall framework, the previous data model fits between the semantic model developed this year and a physical data base implementation.

This working group on data modeling was aided materially by the limited semantic model that had been developed for the prototype integrated data base demonstration. Through a critique of the prototype model, the group was able to identify key missing concepts, as well as to generalize existing concepts to higher levels of abstraction.

In the following sections, the relevant results of the 1985 Woods Hole Workshop are summarized, the current conceptual model is assessed, the process and methods of modeling are discussed, and a strategy for implementation of the data model is presented.

Members of the working group were Len Simutis (chair), Jim Anderson, Per Christiansson, Bob Fulton, Kent Reed, and Dave Skar.

RESULTS OF THE 1985 WOODS HOLE WORKSHOP

At the 1985 Woods Hole Workshop a working group on conceptual modeling constructed what it called a conceptual model of the integrated data base, representing it as a finite state machine (FSM). This representation allowed the group to express clearly the idea that the current state of a project is reflected in the current state of its corresponding FSM-data space. The various user views of the data base are then represented by transition functions that can examine and modify this state. Data consistency is enforced within the transition functions themselves rather than by any external process.

The group developed a data model that described the characteristics that data may possess and defined the relationships and operations allowed between and on the data, respectively. Treated in this model were data and meta data, as well as operations, meta operations and meta-data operations.

Finally, the group developed several examples of how a user view can be extracted from the data base according to the conceptual model. It should be noted that, in its work, the working group indicated only the kind of semantic information that was needed and did not try to develop a supporting semantic model.

ASSESSMENT OF CONCEPTUAL MODEL

In assessing the IDB conceptual model developed to date in the Woods Hole Workshops, the group identified several areas that the model needs to address, or which require clarification. Most fundamentally, the model views the building as the sum of its parts. The design, assembly, and operation of the building are processes that depend on information about the building parts and spaces.

For the conceptual model to be sufficiently robust, it was concluded that the model must include part-to-part relationships as data attributes. The building parts themselves must contain information on revisions made during design, construction, or operation since these changes will have cascading effects on other aspects of the building process.

Further, the concept of shape, as used in the model, needs to be expanded to incorporate a full description of part geometry. This information was viewed as vital to address the issue of connectivity between parts so that assembled components could be identified and analyzed. Also, connectivity of parts may be used as one way of defining spaces. Rather than giving names to a particular space, thus complicating nomenclature and leading to ambiguity or error, the geometry that gives the location and extent of a space can be determined by identification of its interconnected components. Parts have three-dimensional shapes, and the parts, when connected, identify three-dimensional spaces.

The group considered how best to incorporate architectural and construction drawings into the conceptual model. For some, the drawings could be seen as graphic representations of building design and construction--a sequence of increasingly detailed information about building components required for construction and building operation. For others, drawings were simply another way of providing a report of a building's "state" of architectural design and construction as it evolved and developed over time.

While the notion of drawings as important summary documents in their own right is critical to many computer-aided design (CAD) systems currently in operation, the group concluded that drawings are simply another way of representing or reconfiguring the relationships among elements in the IDB. In short, a drawing is not different conceptually than a tabular summary from the data base; it is another kind of report.

THE PROCESS FOR DEVELOPING DATA MODELS

A structured approach to the development of data models in support of administrative data bases has evolved over the previous decade. The first steps in this approach, contained within the box in Figure 3-1, are (1) definition and analysis of the tasks that must be supported by the data base, (2) analysis of the information flows that are required in these tasks, and (3) definition of the elements of a semantic model that will support this information flow.

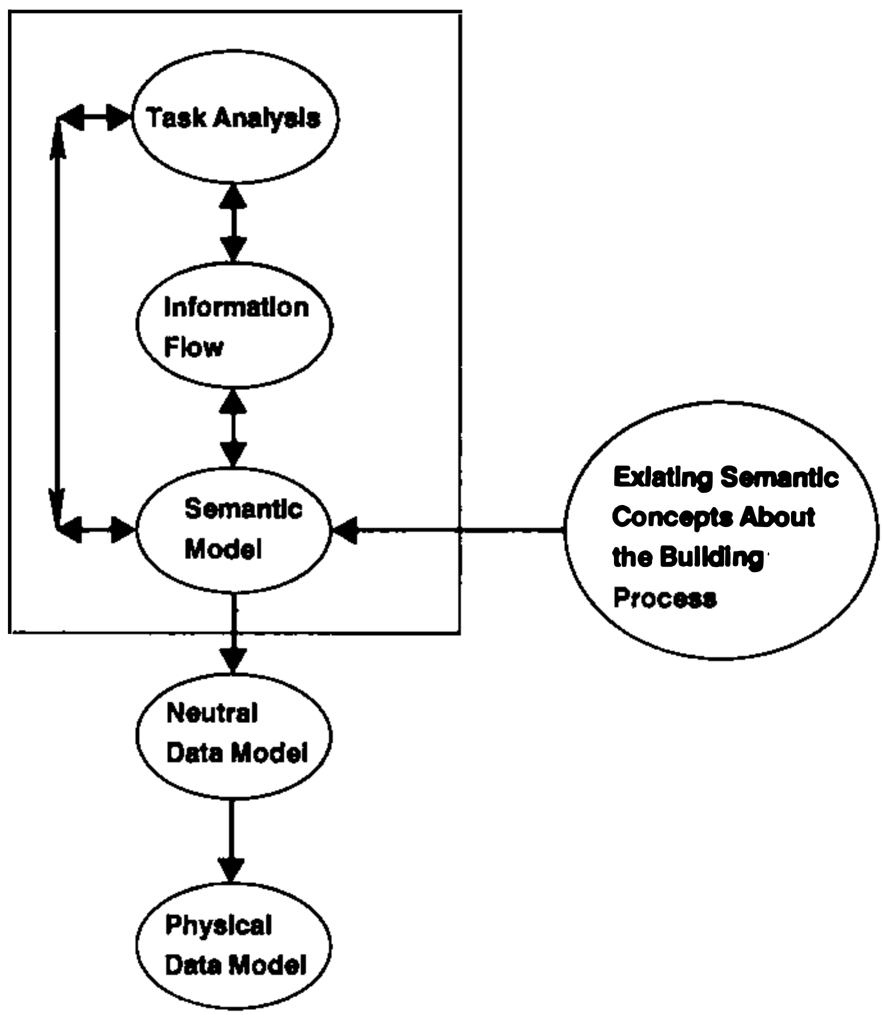

FIGURE 3-1 The process for developing a data model.

Unlike administrative data, buildings have been the subject of conceptualizations for centuries. A large body of semantic concepts already exists, and a modification of the above modeling process is proposed. As shown in Figure 3-1, the existing high level concepts and derived conceptual models are refined and integrated into a draft semantic model. This model encapsulates agreements in areas such as shape and structural grammars, building part descriptions, building process activity descriptions, and so on. The draft model is then tested against the task and information flow analyses described previously, and modifications are made as needed.

It should be apparent that desirable characteristics for a semantic model include extensibility, since it is a certainty that the model will be neither complete nor immutable. As new tasks are defined and analyzed, new features or modifications to existing features in the semantic model will be required. The methodology chosen for developing the model should support this and other characteristics such as simplicity, since the model must be understandable if it is to be useful, and consistency, since the model must provide meaningful and unambiguous responses to queries.

DATA MODELING METHODOLOGIES

Bringing about a successful integration of information depends largely on business functions and the size and complexity of the organization. Information integration requires rigorous, analytical techniques, backed up by powerful tools and a methodology that oversees the total life cycle of an entire project.

Methodologies providing these capabilities have been, or are being, developed for different types of data models that capture semantic information including the entity-relationship model, the extended relational model, the functional data model, the semantic association model, the semantic data model, and the semantic hierarchical model. It is not clear which, if any, of these models provides the best fit to building project information. Therefore, a particular methodology--NIAM (Nijssen Information Analysis Methodology)--was selected by the working group based primarily on the availability to the group of tools and information. This decision will almost certainly be revisited as more research results become available about the nature of building project information.

The Methodology Used on the Prototype IDB Demonstration

The NIAM methodology describes the relationships of objects and the roles of these objects to support the views for the prototype IDB. NIAM uses a three schema/view architecture. The first view is the Semantic Information Model. This view uses the identified information flows to develop the information structure model. The Semantic Information Model identifies all information elements, relevant semantics, and constraints required for information integrity.

The diagram for the Semantic Information Model, Figure 3-2, is made up of (1) objects, (2) roles, and (3) uniqueness constraints. Objects take on two forms: the non-lexical object type (NOLOT) and the lexical object type (LOT). Roles that form the relationship between two NOLOTS are ideas, while the roles that connect a NOLOT to a LOT form a bridge

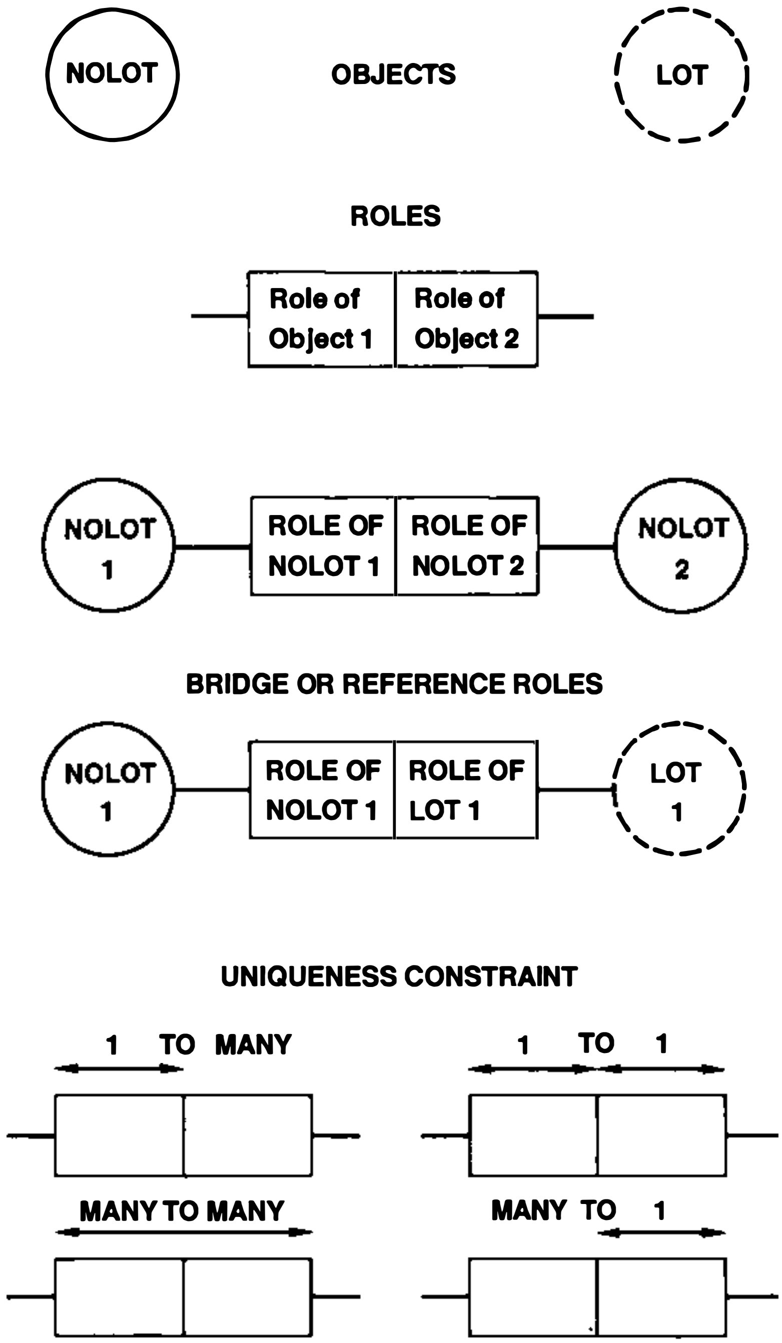

FIGURE 3-2 The semantic information model.

or reference. The uniqueness constraint defines the cardinality of the objects role in a relationship, or joint relationship.

After developing all the relationships for the Semantic Information Model, a Neutral Data Model can be defined. The Neutral Data Model specifies record types and their elements, and the behavioral constraints on the elements of each record type.

The NIAM methodology starts with the Functional Model and the information flows that connect the functions to create the Functional Flow Model. The Functional Flow Model, Semantic Information Model, and Neutral Data Model are combined with a definition of the detailed logic of each of the lowest level components of the Functional Flow Model to produce a Logical Process Model for the information system.

From the resulting models, one or more prototypes are built based on the requirements model. The validation prototype is performed without hardware and software restrictions. These validation prototypes are used to validate the contents of the models and identify necessary modifications.

The final outcome of the NIAM methodology is a design specification that can then be used for building the sections that will be supported by a heterogeneous environment.

The Semantic Information Model is also known as a conceptual model. From the conceptual model the logical data base schemas, the program views for each of the physical data bases, and the logical internal schema for the computerized parts of the information system can be determined.

VALIDATION PROTOTYPE IMPLEMENTATION

The work to date on the IDB has provided good insight into the potential of a future IDB to support the building process. The prototype's focus, however, is on the storage and management of data associated with the structural design and construction process. The data models appear to represent adequately the entities at that stage of the building process.

It is recommended that a second prototype IDB implementation be carried out to validate selected areas of data modeling associated with the maintenance and operation phase of a building. The specific focus of the application should be based on the recommendations of the task analysis working group (see Chapter 2), which considered data such as those associated with the operation and maintenance of the building, its contents, and its subsequent modification or rehabilitation.

The goal of this validation prototype system should be to both validate data model issues and to provide an illustrative example to help a federal agency take the next step toward development of a usable prototype IDB.

Scope of the Validation Prototype System

The development of a prototype system can be a major undertaking. The following discussion is to focus attention on the key data modeling thrusts to be addressed. Figure 3-3 shows a functional view of the system from the perspective of data modeling. At the top are the various types of data to be managed for the user shown at the bottom. The user is provided a set of tools and menus to facilitate the query and use of the data. The data base is composed of a conceptual model

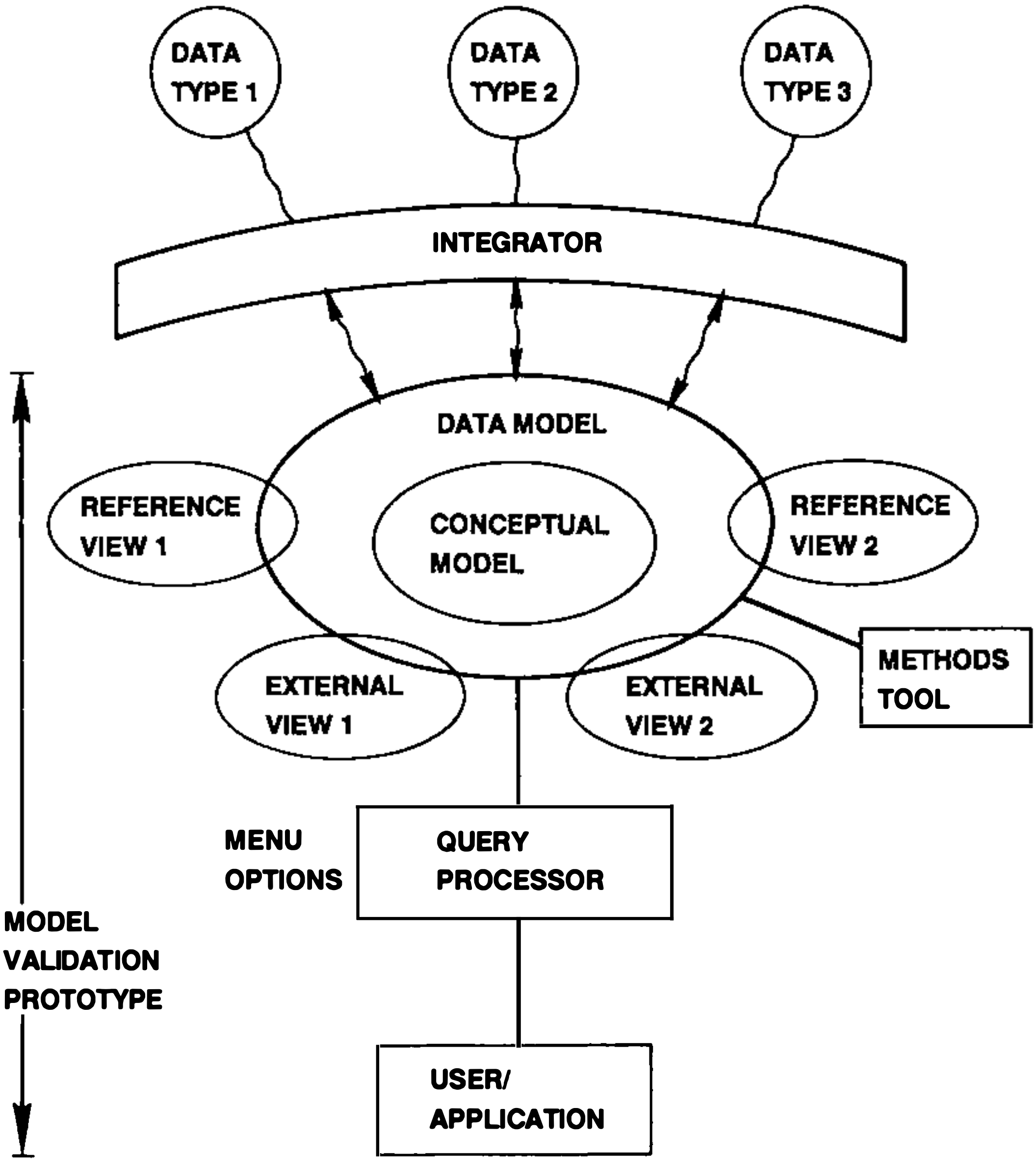

FIGURE 3-3 Data model view of the IDB.

together with various specialized views of the data. A set of software utilities serves as the integrator between the data model and the various data types.

As the figure indicates, the system should concentrate on data model issues rather than on displays of application tasks. While the other parts of the system may be useful for other purposes, it is felt that the above limitations will be sufficient to address data modeling issues and to illustrate the benefits for building maintenance and operation. Purposefully omitted are the interfaces to the model of specific application systems since such interfaces are expensive. They also tend to focus effort and attention on the application capability rather than on the data base issues.

Characteristics of the Validation Prototype

The validation prototype should be focused on facility management issues as developed by the task analysis working group. A high-level data model should be established containing a view of the important characteristics of the facility covering all phases of its life cycle.

One section of the high-level model should be decomposed into a more detailed model of those data involved in the facility management area. Two key characteristics should be visible in this: (1) the thread of the data model between the high-level model and the detailed model, and (2) the interrelations among the entities within the detailed model.

At the detailed level, the data model should be established that will support selected realistic user queries representative of facility management functions, the scenarios established, the data models used and the data base management approach implemented. It should be designed to address some of the key data modeling questions identified in the next section. The scenarios tested should be sufficiently illustrative to allow a facility management executive to understand the development risks and the associated benefits of an integrated data management system. It is anticipated that through a validation prototype, a reasonable subset could be implemented with a relational data management system operating on a personal computer.

Scale of Effort in Data Modeling Task

Future work on the data model should be aimed at extending the model to cover the needs of the building owners. Three criteria must ensure that this objective is met. First, the data model must be complete, containing information the building owner needs. Second, the data base design must ensure responsiveness, and the time required to retrieve information from the data base must meet the owners' needs. Finally, the data model must be adaptable to the changing information needs of the building owner.

Tasks

As Figure 3-4 illustrates, the existing data model for the wooden truss used in the prototype demonstration must be generalized, and the generalized model must be expanded to accommodate other tasks. Figure 3-1 identifies the steps that must be followed to extend the generalized data model to include the additional tasks highlighted by the task analysis working group.

Resources

The following considerations are important in estimating the resources required to revise the data model:

- The effort will require an interdisciplinary team consisting at least of a functional expert and an analyst. The functional expert must identify the functional data requirements such as data required in making maintenance or repair decisions. The analyst's knowledge of data modeling is instrumental in efficiently representing the data relationships in the data base.

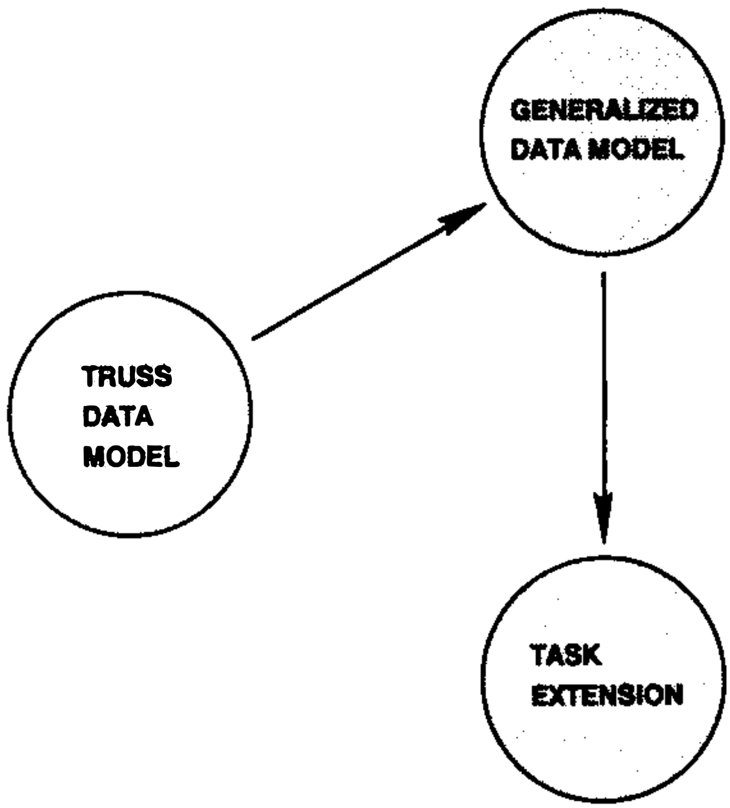

FIGURE 3-4 Generalized data model.

- Work done by the demonstration prototype project team provides an excellent starting point for revising the models since many important facility management concepts are already developed. The interdisciplinary teams are already high on the learning curve and can be expected to increase their capability as they expand the data model.
- A rule of thumb for the time required to test the validity of a data model is shown in Table 3-1.

TABLE 3-1 Rules of Thumb for Testing Data Model Validity

Time Units	Step
1	1. Task Analysis
4	2. Information Flow Analysis
4	3a. Semantic Model (using data modeling tools)
6	3b. Semantic Model (not using data modeling tools)
4	4. Validity Prototyping

Table 3-1 shows that if task analysis takes 1 week, then information flow analysis will take 4 weeks. The time to develop the semantic model will vary from 4 to 6 weeks depending on whether or not computerized modeling tools are used to ensure integrity in the model. Validity prototyping will ensure that questions concerning data model completeness, responsiveness, and adaptability are successfully answered.

FINDINGS AND RECOMMENDATIONS

The data modeling group concluded that the data modeling activity should continue, with or without a working prototype in an actual project setting. It recommended that a validation prototype of the IDB be developed, and that the validation prototype be distributed initially to workshop participants and to the client organizations they represent for analysis and evaluation. Finally, the group recommended that the prototype IDB, if developed further, take into account advances in data base technology developed in other areas so that the IDB prototype is acknowledged to contain state-of-the-art characteristics and refinements which will enhance its acceptability and appeal to the building community.

4

INTEGRATOR DESCRIPTION AND FUNCTIONAL SPECIFICATION

INTRODUCTION

The 1985 Woods Hole Workshop introduced the concept of an integrator as the central function of an integrated data base (IDB). The purpose of this working group is to further extend and describe the integrator. The group reviewed and validated the 1985 workshop concept of the integrator--validated it against the literature in the field and against the work undertaken by others. The group also assessed the status of the prototype IDB as it relates to the function of the integrator, extended the concept of the integrator, and proposed a direction for implementation of the integrator.

This chapter summarizes the findings and recommendations of the working group. First, the IDB and integrator concepts are outlined, and the integrator concept is then viewed in the context of architecture models resulting from other outside research. Practical technology and user considerations that influenced the group's recommendations for integrator implementation are then described, followed by a discussion of considerations for implementation. Finally, the group's proposal for extending the prototype IDB in 1987 is presented.

Members of the working group were: Bob Mahan (Chair), Larry Dyer, Jim Goodland, Bob Heterick, Marie Roberts, Paul Scarponcini, and Dick Zitzmann.

IDB CONCEPT

The IDB for a building project will exist from the very start of the programming and planning phase of the building process when the idea for the building originates. The IDB will be an active element of the process through the operational and facility management phase (when large cost advantages are expected to result). It may even survive the demolition of the building, since the data would have experiential value to future building projects.

The quantity of stored data will vary over the span of the life cycle. As activities and tasks are completed, the amount of stored data will increase with time, at least in the early phases. Since some data will not have to be stored for the full cycle, and others will be added as time goes on, it could be that the total size of the stored data may stabilize at some point in time.

It is convenient to envisage the IDB as consisting of three broad components:

1. Data distributed among currently active files and data base systems of current participants in the building process, but limited to data elements and instances of data elements that are prescribed in advance to be valid parts of the IDB (i.e., subject to inclusion and exclusion rules),
2. A transitional data base that holds data resulting from the tasks of participants no longer active in the process; over time, this collection of data will grow as the building project proceeds, and, eventually, is expected to comprise essentially all of the data of the IDB, and
3. The functional components of the IDB which, collectively, is called the "integrator."

INTEGRATOR CONCEPT

The conceptual view of the integrator developed at the 1985 Woods Hole Workshop contains the five components: administrator, director, translator, accessor and communicator.

Administrator

The administrator is responsible for the area of data security and includes functions to control reading, updating, and deleting of data. It also ensures the integrity, consistency and currency of the data. It includes the management function for concurrent queries or updates, and for recovery and backup in case of system failure. Rules are contained within this component to govern the inclusion or exclusion of data resulting from building process tasks.

Director

The director contains the global data dictionary, information on where IDB data are stored, file formats, access authorizations, data currency status, and information about the specific physical implementation of the data model.

Translator

The translator contains information on requirements for different views of data for authorized users of the IDB as well as the formats of data sources and targets. This component contains the functionality to perform necessary format conversions.

Accessor

The accessor determines optimum strategies for accessing data in the IDB, which may be distributed. It creates files, deletes files and data, adds data to existing files, and retrieves files and data.

Communicator

The communicator provides for the physical transfer of data among IDB components and between the IDB and user systems.

ARCHITECTURE OF THE INTEGRATOR

At the 1985 Woods Hole Workshop, the concept of the integrator was introduced as the central function of the IDB conceptual model. The five components or subfunctions of the integrator are, in fact, distributed among several components of a distributed data base. Therefore, it is more meaningful in a description of systems architecture to redistribute these subfunctions to reflect architectural components that are conventionally part of a distributed data base management system (DBMS).

Architectural Model[1]

Three groups of design goals are commonly applied to distributed, heterogeneous data base systems. The first seeks transparent local DBMSs. This implies a common, global user view of all data to be shared in the distributed system, a common data manipulation language, and a system-wide data dictionary.

The second group, which seeks to maintain autonomy of all DBMS sites, requires that the local operation of a site be unaffected by global operations and that the addition of new sites or DBMSs be facilitated. Local DBMS optimization and data base organizations should be unaffected by global operations.

The third group, which deals with communications among sites and DBMSs, suggests the use of standard communications protocols over conventional communications networks or facilities. However, special data base-oriented protocols may be necessary to preserve semantic integrity among some heterogeneous DBMSs.

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[1]This section is an abstract of the article "Interconnecting Heterogeneous Database Management Systems," Virgil D. Gligor and Gary Luckenbaugh, University of Maryland, authors, published in the January 1984 issue of COMPUTER, the Institute of Electrical and Electronics Engineers, Inc. The article is a result of an analysis of existing approaches to interconnecting heterogeneous DBMSs.

The architectural model for the integrator, which is illustrated in Figure 4-1, consists of three sublayers of the application layer of the ISO reference model plus the data communication protocol layer. A summary description of the three sublayers follows.

Global Data Manager

The global data manager (GDM) maps local data views into the global data view and vice versa, and performs all associated input/output (I/O) operations. An input to the GDM is a query or transaction based on the global model that the GDM transforms into the query language of the local DBMS or into a set of subqueries in appropriate query languages when more than one site is involved. In fact, the output of the GDM is a plan of subquery execution which the GDM passes to the sites involved via the communications network. Responses to the subqueries are then assembled by the GDM and returned to the user in global schema terms. Five functions are required by the GDM: (1) global data model analysis, (2) query decomposition, (3) query translation, (4) execution plan generation, and (5) results integration.

The global schema may be stored in a distributed data dictionary along with the local schemas. Global query translation may include the translation of a query based on a particular user's view of the data into a query based on the global schema; then, another translation based on the local schema may be performed.

Distributed Transaction Manager

The distributed transaction manager (DTM) receives subqueries from the execution plan generator of the GDM and controls the execution of those queries and transactions so as to ensure the consistency of the data base by providing a hierarchy of concurrency control and recovery control by utilizing a two-phase commit protocol. For reliable recovery control, the coordination process that supports the two-phase protocol must be crash resilient. In most cases, the local DBMS will have to be modified to support the "prepared state" of the two-phase protocol.

Structured Data Transfer Protocols

Structured data transfer protocols (SDTPs) support the services of the DTM and require the services of the data presentation protocol and of other application layers such as those of the file transfer protocol. They are application-level protocols required for the interconnection of remote heterogeneous DBMSs. The SDTPs themselves use the data communications protocols and can be regarded as extensions of such protocols.

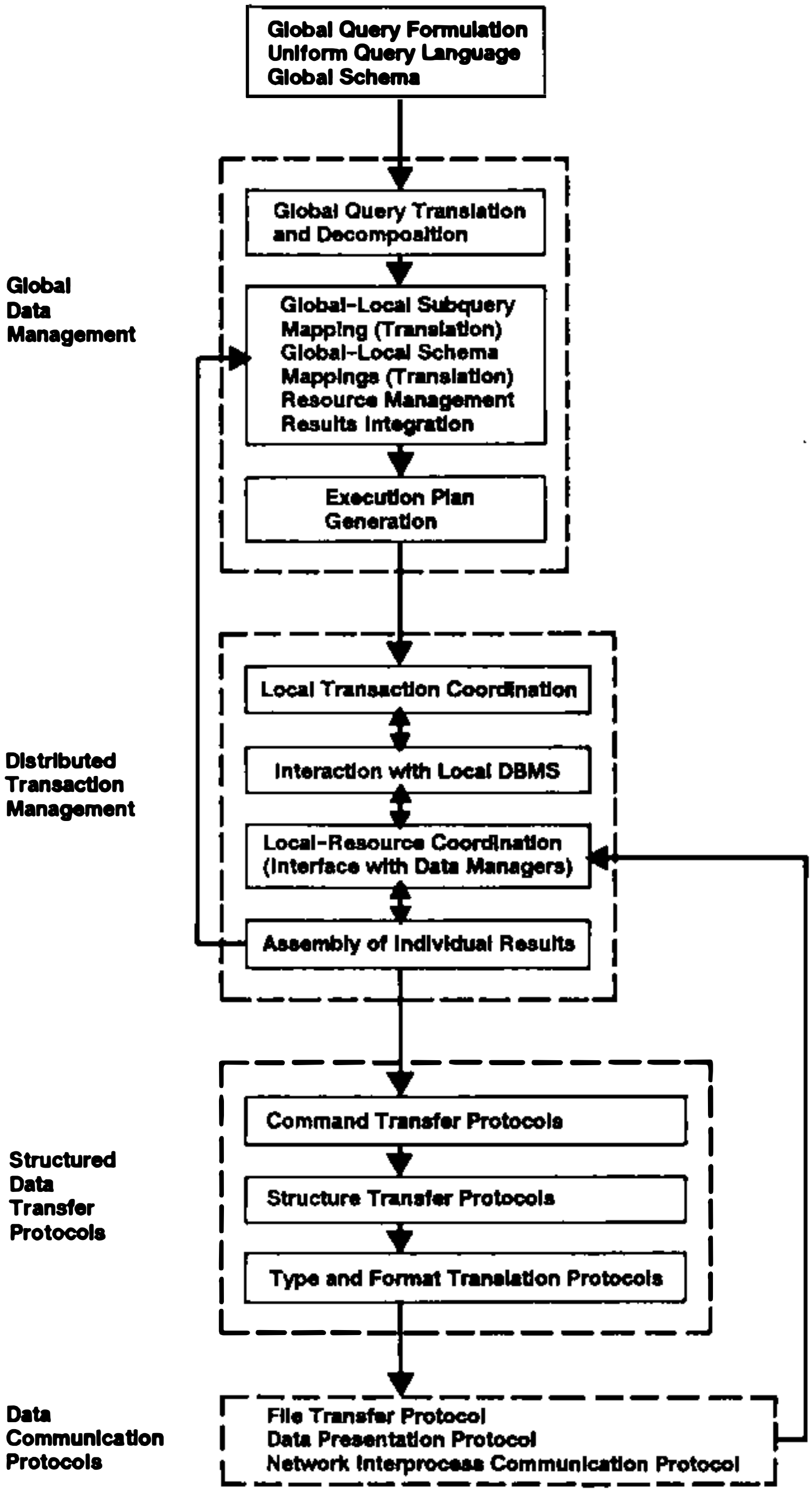


FIGURE 4-1 Functional requirement areas.

PRACTICAL TECHNICAL AND USER CONSIDERATIONS

Several practical considerations exist that could affect the integrator implementation plan. Some of these are:

1. Integrators that enable heterogeneous hardware, applications, and data bases to operate together in a coordinated fashion may exist in other areas of industry and could have applicability to the needs of the building industry.
2. Some pieces of the integrator in a distributed, heterogeneous environment are resident in the various hardware and software components comprising that environment.
3. A key purpose of the integrator functionality is to provide the user with an interface to the available information at any stage in the life cycle of a building. Its function in this role is to answer user queries. Transparency to the user is an ultimate goal. Available information is that which has been released by the professional involved in each step of the building process. The integrator is the mechanism for the owner to affect program management.
4. A logical sequence of steps to design an IDB shows that it is not until the last two steps that the integrator can be functionally specified. The steps are as follows:

    a. Identify data items required by every application and define the data item relationship,
    b. Identify source and format of data in every application,
    c. Define a conceptual data base to satisfy data requirements of all applications,
    d. Define user requirements for data update and selection to and from the data base,
    e. Based on (c) and (d), define necessary software for data base update and selection,
    f. Identify the hardware and operating software under which the data base must be operational, and identify the data base manager to be used,
    g. Design the data base and the integrator, and
    h. Develop integrator and any support software required.

5. The actual implementation of the integrator depends on the hardware, software, communication, applications and data base components available throughout the building life cycle. The cost to produce an integrator is a function of these components and will likely decrease with the adoption of building industry standards and protocols for communication and translation functions (i.e., common languages, translation to neutral file formats, and communication protocols). The adoption of standards in these areas would directly affect the cost and performance of implementing the communicator, the accessor, and translator functions. The functions of the administrator and the director will remain dependent on the needs of individual owners and operators.

6. The integrator should be viewed as a platform on which various functional modules can be added. It should be flexible, programmable, and data-driven (i.e., hard and fast linkages should not be defined or developed).

7. The role of the prototype IDB demonstration has been to help understand the integration needs of the building industry. The development of a fully operational integrator is beyond the scope of this working group. The prototype IDB demonstration was instrumental in showing requirements for data exchange, but the integrator functions were not directly addressed.

8. An extended prototype IDB demonstration for the 1987 Woods Hole Workshop should superimpose the owner's needs through an integrator. The extended prototype should use the existing prototype's hardware, software and applications, and augment these with other products, if appropriate. It should isolate and demonstrate integrator functions. An extended prototype must be able to demonstrate to participants in the building process that there is a direct benefit. To do this, the following are suggested:

a. Clearly, concisely, realistically present the strategy for development, implementation, utilization, maintenance, and growth of the IDB. Show immediate possibilities as well as the future potential, and

b. Demonstrate by prototype the possible system functions at critical junctures in the building process with an emphasis on benefits.

IMPLEMENTATION CONSIDERATIONS

Neutral File Concept

The introduction of an exchange file concept that converts data into a neutral file format addresses the problem of multiple translators at each node in the IDB network. The integrator would activate the appropriate translator program to convert unique application data files into the neutral file format. Applications requiring these data would then connect from the neutral file format into their own format. This would be done by the application interface portion of the integrator, not the application itself. This could also be used by the IDB for global data base activity.

Menu Implementation

The integrator should provide all interactive user options in menu format. Menu selection will result in application to application interaction, data interchange including translation, output functions to be executed, and utility and support functions to be performed.

Application Interface

The application interface is the user's view into the IDB; it is a part of the integrator. The application interface responds to all menu prompts, processes command language requests, and enables the appropriate operating system functions to be accomplished. The application interface is functionally part of the integrator, but is physically evident to the user.

Translator

The translator is activated by the integrator in response to a request issued by a menu prompt from the requesting application. The translator converts data into or from the neutral file format from or to the specific format of the application issuing the request.

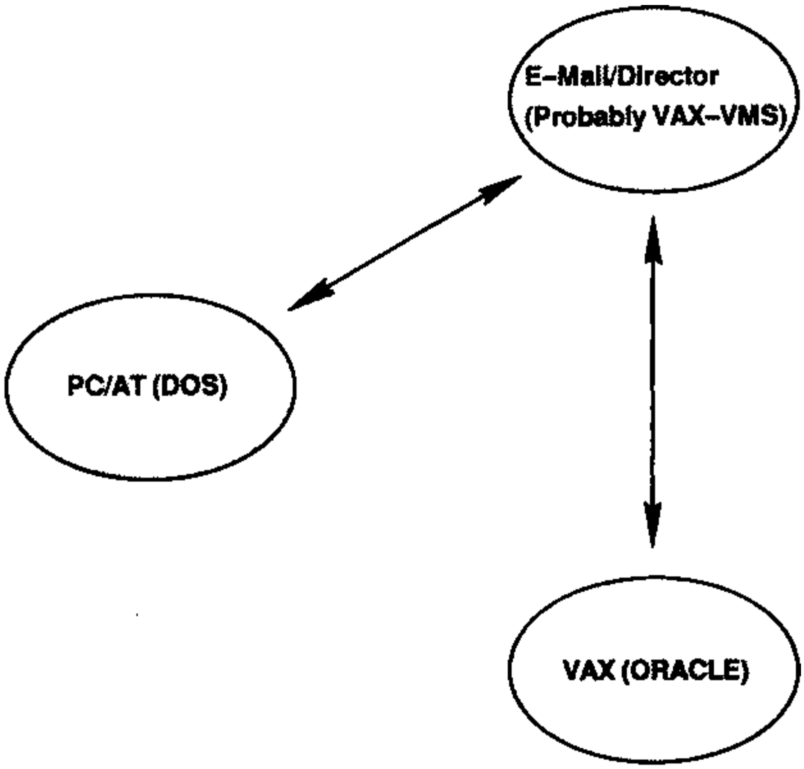
PROPOSED PROTOTYPE IDB EXTENSION

The 1986 prototype IDB demonstrated the capability of interaction of dissimilar systems in the architect-engineer-constructor continuum. The connections between systems were customized and made no attempt to use generic integrator concepts. Further expansion of the prototype should attempt to incorporate some integrator approaches.

Perhaps the simplest technically-meaningful demonstration of integrator concepts occurs relative to a query for data. For purposes of the prototype IDB, incorporation of integrator concepts can be demonstrated with the existing prototype's hardware. It may be clearest to view the inter-system communication as an extended electronic mail system. Even at only this single level, all five components of the integrator are present.

Queries are dispatched via mail and responses are returned via mail. The communicator, for demonstration purposes, is then only the linkage between the two systems. The administrator is likely to be quite complex (and beyond the scope of next year's prototype), perhaps evolving into a knowledge-based system. The focus is then on the director, accessor, and translator functions.

Conceptually, the IDB might appear as



One possible scenario would involve:

1. The composition of a mail item on the AT which covered a data base query,
2. Dispatching that item to the mail system,
3. Routing that item to the director,
4. Fowarding the item from the director to the ORACLE data base,
5. Translating the query to well-formed ORACLE commands,
6. Accessing the ORACLE data base,
7. Reformating the response to the interchange specification,
8. Enclosing the responses in a mail item directed to the mail system, and
9. Forwarding the mail item to the AT.

In order to implement this scenario it is necessary to operate a mail system (probably on the VAX). The envelope of the mail item and where in the contents is the accessor command need to be determined. The director (one or more pieces of software, probably resident on the VAX) needs to receive the mail item and pass the accessor command (written in SQL as a canonical language). The director will ascertain the appropriate destination (an ORACLE data base on the VAX) and forward the item to a translator (an ORACLE front end) which will again pass the command and reconstruct it as a well-formed ORACLE command(s).

The ORACLE data base is queried and the response is passed to a translator (an ORACLE back-end) that reformats the response to the global data interchange specification. That specification would need to precede the response with information such as the number of records, number of fields, and field delimiters of the response in something like row major order. This response is then placed in the appropriate mail envelope and sent back to the requester via the mail system. The requester (the PC/AT) then needs to receive the mail item, strip the mail envelope, and translate (the DOS front-end) the response to an appropriate format for the application executing on the AT.

In this simple scenario it can be assumed that the director has knowledge of all the files and fields of the ORACLE data base and can ascertain that the canonical query refers to known files and fields. If it does not, the director needs to be capable of returning a mail item to the sender indicating the offending syntax (such as an undefined variable or an ill-formed canonical statement). Since the sender may be a process operating asynchronously with the "end user," the mail item containing the error diagnostic needs itself to be in some well-defined format. If the ORACLE data base front-end is not able to deal successfully with the canonical query, it needs to be able to return a similar diagnostic.

Similarly, if any one of the partners to any exchange is not able to participate, the director needs to know this and incorporate a strategy for handling the situation (such as to hold the communication until the situation is resolved or abort the process with an appropriate diagnostic).

Updating functions present a host of concurrency and integrity issues that are beyond the level of the proposed demonstration. It is estimated that each translator (there are three of them in this scenario) will take six man-months to construct. Effective error handling will likely require as much effort as a translator.

5

FUTURE DIRECTIONS FOR THE INTEGRATED DATA BASE

INTRODUCTION

The working group on future directions for the integrated data base (IDB) reviewed the prototype IDB demonstration and concluded that, while it serves an educational mission, it does not convey the abstract, decentralized communications concepts inherent in the IDB. The group believes that the demonstration does not epitomize the essence of an IDB, nor does it validate key IDB issues. The group recommended that the Woods Hole Workshop activities conducted since 1983 should be brought to closure, and the results should be communicated to industry and the public sector with a view to obtaining commitments for future work. The group stressed the need to leverage the IDB work being carried out by other industries. Consequently, the group developed:

A. An outline of the IDB concepts with the intent that they be developed by the Committee on Integrated Data Base Development for communication to industry and the public sector,

B. An explanation of some key issues that need further work and validation prior to development of an IDB, and

C. A description of some new processes that would be possible as a result of an IDB.

Members of the working group were: Mary Oliverson (chair), Harold Borkin, Earl Mark, Dan Reynolds, and Si Simonsen.

A. INTEGRATED DATA BASE CONCEPT

System Architecture

Potential users of the IDB will not have a common set of hardware or software, nor will they be willing to acquire or convert to a common system. They will be geographically dispersed, and to centralize their data bases at some distant location would mean loss of control. They may look to the IDB as a means of improving productivity, but a major conversion investment (before any benefits are realized) would be considered too high a price to pay. Therefore, the concept of a centralized, homogeneous (one type of hardware and software) IDB is virtually impossible.

Achievement of a conceptual IDB in a heterogeneous, distributed environment will place significant demands on effective communications to provide linkages between the many sources of information viewed as logical parts of the IDB. This is consistent with and evidenced by the emerging technological evolution of local and wide area networks to integrate heretofore islands of automation. This type of communications will also offset much of the manual re-entry of data produced by one system into another, so that a particular phase of the building process can be accomplished more effectively.

User Organization Size

The IDB must offer benefits to all types and sizes of organizations. Elimination of small professional firms, for example, would have a detrimental effect on the creative and competitive aspects of building design. The small architectural firm need not be precluded from participating even if its total automation capability is limited to a microcomputer or a single graphics workstation. The heterogeneous, distributed nature of the IDB provides a means of including all interested organizations as participants and contributors.

Data Base Management Facilities

The IDB is based on the concept of a comprehensive set of data base management capabilities including, but not limited to:

- Data security--means to control access and use of data, and monitoring threats to data in the IDB by unauthorized persons; no data are lost or changed,
- Privacy--controlled access to data that are used to develop aggregate data,
- Data integrity--that quality of data, and the associated processes that ensure the consistency, reliability, accuracy, and preservation of data maintained by the IDB; data derived from information in the IDB may be stored or rederived, depending on the complexity of derivation and likelihood of downstream use; stored or computed data that accurately reflect the state of the project at that time,
- Configuration control--the set of processes that address maintenance of integrity and control of information as they evolve throughout the building process; included are currency, version control, revisions, authorization, approval reviews, and release status (the as-designed, as-planned, and as-built sequence), and
- Dictionary/directory--that capability that defines the "meaning" of data items and provides a means of locating needed information; it must include resolution of the thesaurus, as well as the multiple occurrence of a given name phenomena (such as homonyms and synonyms) that will occur.

These data base management capabilities are considered an essential part of the environment in which applications will be developed, but should not be considered part of the applications.

Data Deterioration

Since the IDB must exist over a long period of time, provision must be made for the fact that the quality of data deteriorates over time. This deterioration can take several forms. The most common form concerns stored data that does not reflect the current condition of the facility. For example, in a case where office partitions have been moved and space assignments have changed, the designed performance values no longer reflect the current performance of the actual building system.

Another type of deterioration occurs when changes in computer hardware and software require input data that are not stored in or accessible by the IDB. Data in the IDB must be maintained by new input or by data transformation procedures to ensure more than historic value.

Distribution

In the heterogeneous environment envisioned by the IDB, the ownership of data can be independent from the distribution of the data. Such "owned" data that are distributed must contain ownership characteristics as an inherent part of the data. For example, the size of a structural element can be owned by the structural designer until the final structural design is completed, but the current size of the member may be transmitted to others so that they may use it without waiting for the formal structural design. In this case, the fact that the member is owned by the structural designer should be part of the data on the member.

User Interface

The user interface to the IDB should not impose a uniform grammar on users but should accommodate expansion and collection of interactive styles as common features. For example, commands need multiple definitions to reflect the popular usage. Text should be displayed and edited on a "what you see is what you get" basis. Graphic input should be used. Natural language data inquiry that reflects the user's vocabulary should be implemented.

Application Services

Applications constructed for or operating in the IDB environment should be based on a set of application services (or system facilities) common to all users. These services will, in time, reduce the complexity and size of applications (as depicted in Figure 5-1) and will minimize the impact of evolutionary changes such as new operating systems, upgraded version of support libraries, new storage hardware, and revised standards.

Integrator Concept

The integrator, as developed at the 1985 Woods Hole Workshop, is a combination of application services and system utilities. As such, it is a logical, rather than a physical, concept. It is not a monolithic "chunk" of software or hardware that performs a set of functions for applications in the IDB. It must be adaptable to a variety of heterogeneous environments and needs with capabilities invoked as required. As evolutionary technology changes occur, the integrator must be capable of incorporating these changes without major redesigns and conversions of user applications. In short, it is based on a set of modular capabilities with well-defined interfaces.

Atomic Data Types

The IDB must support high-level atomic data types. These data types and a set of operations on them represent the normal functions on

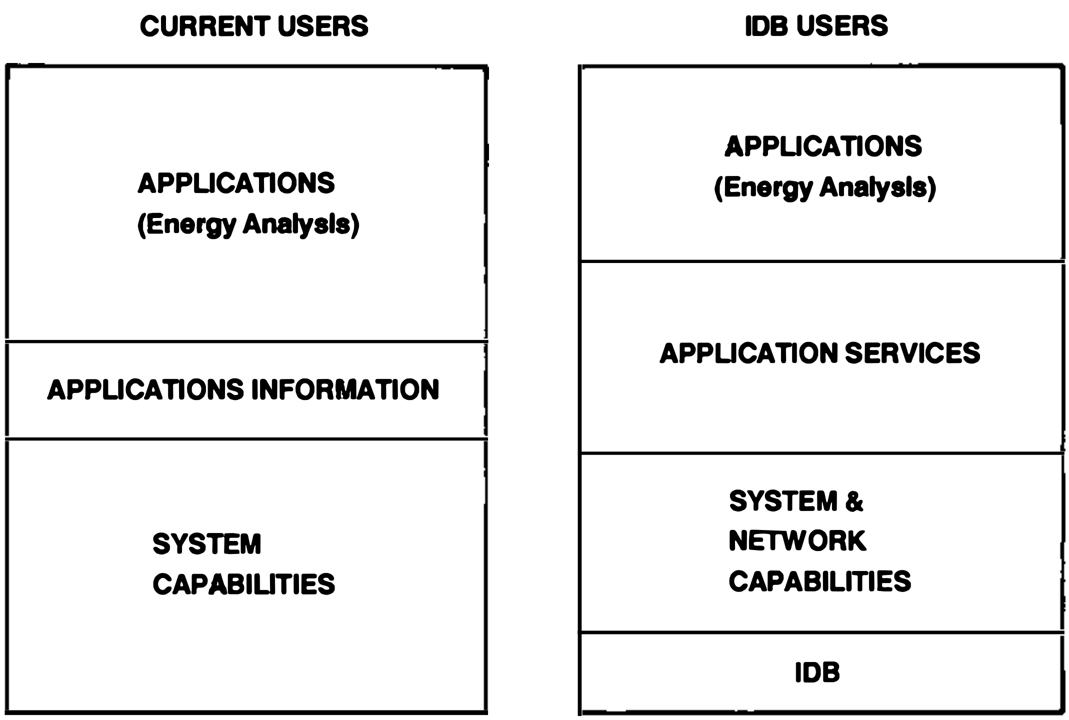


FIGURE 5-1 Application services current and IDB users.

which new user views or applications can be built. Atomic data type means the lowest level of appropriate data that can be accessed as a clump. These would include, but not be limited to: geometry types, images, text, numbers, documents, operations, and rules and relationships. The operation on each must include input and output, and transformations.

User Migration

The IDB concept will not be implemented at one time. Even if users and their applications fully embraced the concept, the transition period will be significant. Many users already have major investments in large data bases and application software. Therefore, the IDB concept must support a productive migration to this new environment. The users must be able to recover their investments in current capabilities while initiating programs to take advantage of the IDB. Current data bases may support or become part of the IDB. Security provisions must be addressed, and accounting and networking capabilities must be upgraded. User training and retraining cannot be implemented instantaneously.

Therefore, the IDB must not only offer attractive capabilities but must provide a practical migration path for its adoption.

IDB Standards

The IDB concept is a major undertaking with significant benefits. Each element in the heterogeneous environment will likely undergo changes. To ensure that ongoing developments will not become "dead ends," consideration should be given to the adoption and use of standards in existence or evolving throughout the industry.

B. VALIDATION OF ISSUES

Diverse Flexible User Interface

The man-machine interfaces within a global IDB environment may consist of any number of a large assortment of hardware devices or user languages. The range of hardware interfaces, for example, can support interactive cursor control (pen, mouse, joystick), eye movement recognition, voice recognition, or gesture recognition. The range of user languages can emulate high level "natural" languages, such as English, and those languages that more closely resemble the lowest level binary instructions to a computer. The range of user skill levels can also vary widely. The development of the global IDB environment, therefore, should not impose limitations on this great variation in hardware interfaces and user languages.

Application Services

In order for the IDB to develop, it is essential that several key application services be provided. These services include a means to provide consistently and comprehensively interchange of geometric data that is well defined, complete, and interpretable by various users. Data maintained in various data management systems must be transformed in a similar fashion while maintaining structural relationships, content, and semantics between the source and sink nodes. Data structured in the hierarchical and network methodologies must be usable in a relational form (DIF and translators will assist this process).

The ISO open system environment local area network (LAN) standards provide multiple vendors the ability to plug their offerings into LANs in existence. Adoption of such standards will greatly facilitate effective integration of an organization's automation centers providing electronic mail, voice/digital messaging, calendaring, word processing, and so forth.

An important service to be provided is various levels of convenient user interfaces, including voice interaction, HELP and training capabilities, menu procedures, and flexible command language services.

These application services may necessitate investigation and even prototyping to ensure their availability and understanding. It is the definition of this set of application services required by the IDB and the assurance that they can be provided that must be validated.

Integrator to Operate within a Heterogeneous Hardware and Software Environment

The data formats, processes, and machinery of the IDB exist within a distributed computing environment. Functioning at this level, the IDB handles communications between each local computing system. However, the data format used within a local system may be closely related to a uniquely local interpretation. This may not be similar to the format and interpretation of data used within another local system. The IDB is concerned with the integrity, consistency, and translation of data between computing systems in this heterogeneous global environment.

The role of the IDB in translating between local systems is, in part, like that of a data base exchange standard. A data base exchange standard acts as a common denominator in the transfer of data between dissimilar systems in a heterogeneous computing environment. In the transferring of data through a common denominator, some of the higher level interpretation may be lost. However, the IDB must also ensure that when these data arrive at the receiving computer system, it is possible to restore the highest level interpretation of their contents. In other words, there must be some mechanism within the IDB that will restore the semantic meaning of the data after they are translated to the receiving computing system.

The difficulty of translating data between heterogeneous systems and at the same time supporting the highest levels of local interpretation of those data makes a number of possible techniques for achieving this seem unfeasible. For example, the approach of building a high-level translator of data for every two dissimilar components of the IDB would require an exceptionally large number of translators. It also results in the unacceptable scenario of an exponentially rising number of translators for every new computer introduced into the system. Another unacceptable approach is to attempt to gather all possible data types and incorporate them into a monolithic common data base that would serve all systems within the IDB. As an illustration of how such a large data base would be unmanageable, one workshop participant speculated that a comprehensive data base for a building would need to consist of at least three gigabytes of data types. This does not yet account for the amount of data types required to support all possible formats used by different computing systems.

Alternative approaches to these monolithic schemes were identified at the 1985 Woods Hole Workshop. One approach envisions a "loose coupling of expert systems" performing the data translation between local computing systems, so as to reduce the number of translators required between the individual components of the IDB environment.[1] A second, and not necessarily separate scheme, envisions a data dictionary existing at a level of abstraction so as to support a wide variety of multiple views (local computing system interpretations) of data.[2] There is a recognition inherent in these approaches that the IDB environment must adopt and pioneer new strategies to reduce the load imposed by its data handling responsibilities.

Data/Software Migration within a Heterogeneous Environment and Over Time

Within a heterogeneous hardware/software network, the transmission of information from one component to another risks the separation of semantic meaning from "raw" data. For example, a cube may be represented as a set of related polygons, each describing one of its faces (front, bottom, left, right, top, and rear faces). This raw geometry, however, may alternatively be used to describe either a box (a hollow container), or a block (a solid container). In general, it may be used to describe any enclosed or partially enclosed form having similar surface characteristics, but subject to different interpretation.

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[1] H. Craig Howard and Daniel Rehak, "Expert Systems and CAD Databases," Carnegie-Mellon University, a paper presented at the Woods Hole Workshop, June 1985, p. 3.

[2] National Research Council, A Report from the 1985 Workshop on Advanced Technology for Building Design and Engineering, National Academy Press, Washington, D.C., 1986, pp. 15-26.

A distributed IDB environment imposes a risk for inconsistency of semantic interpretation when data are moved from one computing system to another. A similar risk of inconsistent interpretation exists when moving data between successive generations of hardware and software separated by the date of their introduction into marketplace. This risk can exacerbate the difficulty of interpreting the original intentions of a set of data (such as required for "audit trails" during litigation). The question arises as to what extent it is reasonable for the IDB to support consistent interpretation of data at different places and times, and correspondingly, to what extent the end user bears this responsibility.

Data Consistency

Issues of data consistency and integrity offer compelling reasons for developing the IDB. That users view one representation of data for multiple purposes rather than store the multiple representations is an important component of maintaining data consistency and integrity. Rule systems for both spatial or property consistency are required if data integrity is to be enforced. The maintenance of these properties is a formidable challenge in homogeneous data base systems. The possibility of including these concepts in a heterogeneous distributed system needs to be investigated and demonstrated.

Data Transformations

The transformation of data in a distributed IDB must preserve the context and meaning of information. This requirement has proven to be difficult to achieve and is an important characteristic to be demonstrated. The current work on the IGES translation for drafting systems is an example of the loss of meaning when translations are made from one system to another.

C. NEW PROCESSES ENABLED BY IDB

Performance Validation During Warrant Period

The IDB can be used to validate the performance of the facilities and support systems by monitoring the usage and actually measuring the operational performance of the individual materials, components and assemblies. The measured values can be compared with the original performance criteria. It should be noted that these validation procedures may require change in contract documents.

Evaluating Compliance with Expected Performance

The computer model of a building's life cycle provides documentation on the causes and effects of building performance. A continually passing chain of events is viewed within one panorama. This type of comprehensive documentation that captures the chronologically linked data stream of a building's life cycle can serve as a predictive model of building performance. These models can be used to determine if the original design criteria for a building's design have been satisfied. They also can be used to inform the formulation of new design criteria.

RECOMMENDATIONS

Recommendations of the working group follow.

1. It is time to take the IDB concept beyond the the Woods Hole Workshops. The four-year workshop efforts should be brought to closure.
2. The Committee on Integrated Data Base Development should report the IDB concepts and issues formally to agencies of the Federal Construction Council through a committee report. Efforts should be made to communicate beyond the construction industry to organizations working in similar areas such as computer integrated manufacturing.
3. The committee and the Building Research Board should work toward enlisting the support of multiple agencies and industry to sponsor and support IDB development. The levels of effort and resources now required for IDB development go beyond what is achievable by volunteers.
4. Further expansion of the IDB prototype demonstration is not recommended. Future prototyping must address key human and technical issues.

6

DATA BASE IMPLICATIONS

INTRODUCTION

The working group on data base implications was asked to discuss issues associated with the building process that are likely to result from the introduction of the integrated data base (IDB). The group addressed legal, organizational, and other barriers that could inhibit the use of the IDB. The group also examined incentives for implementing the IDB and developed recommendations to begin this process.

Members of the working group were Fred Kitchens (chair), Gifford Albright, Eric Dluhosch, Robert Furlong, Rick Martin, Harry Mileaf, Jack Phillips, Shirley Radack, and Pete Ruhlin.

VALUE OF THE IDB

As pointed out at the 1984 Woods Hole Workshop, only 10 to 15 percent of the overall life-cycle cost of a building can be attributed to the design-construction phases. The other 85 to 90 percent is spent on operation, maintenance, and periodic rehabilitation, and must be taken into account in terms of the benefits offered by the proposed IDB system.[1]

However, the benefits to be gained by the sharing of data and the access to a comprehensive data base in the operation and maintenance phase will not be apparent early in the use of any computer driven data base, including the proposed IDB. Experience has shown that the initial costs associated with the installation of computerized preventive maintenance systems (and facility management systems) are relatively high and increase during the early years of operations, before dropping to a level below that of the preceding manual operation costs.

Figures 6-1 and 6-2 represent a schematic representation of the relationship between cost and time for a computerized operations and maintenance facility system (for example, a maintenance management system for a statewide computer-supported facility) and the distribution of various cost elements associated with the ownership, and operation and maintenance of building equipment.

[1]National Research Council, A Report From the 1984 Workshop on Advanced Technology for Building Design and Engineering, National Academy Press, Washington, D.C., 1985, p. 3.

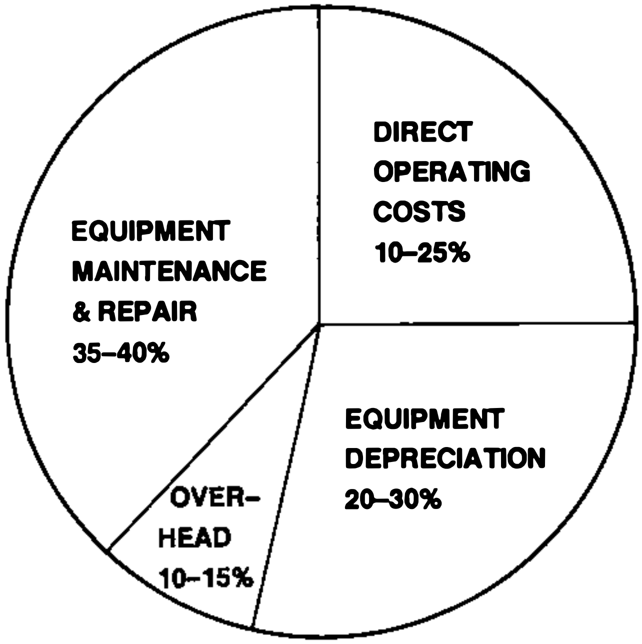

FIGURE 6-1 Relationship of the various cost elements associated with the ownership and operation and maintenance of building equipment.

SOURCE: Division of Capital Planning and Operations, Commonwealth of Massachusetts, "Conceptual Design Report," prepared by Roy Jorgensen Associates, Inc., April 1986.

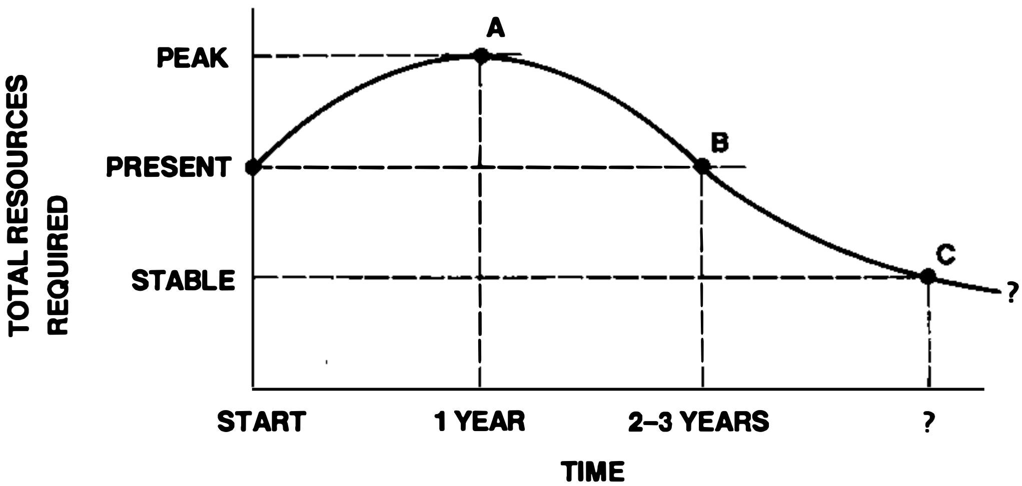

FIGURE 6-2 Schematic cost curve of resource requirements of computer-based operations and maintenance program.

This cost curve may also be viewed as a learning curve. The installation of the IDB may be expected to pass through a similar path of initial high front-end costs, before a clear economic benefit will be realized. This has serious implications on the types of incentives that will drive implementation.

The value of the proposed IDB is actually of a dual nature: One is broadly societal in that better communication and an enriched information environment will lead to a higher level of understanding of overall trends, productivity assessment, and related statistical and analytical operation. These currently suffer from a lack of precise data, covering the whole universe of new and existing facilities, and particularly the lack of precision of data available for operation and maintenance. While various heterogeneous data bases dedicated to facilities management are currently available on a stand-alone basis, the proposed IDB may overcome these barriers which preclude regional or even national integration.

Assuming the general desirability of an IDB, users will be able to:

1. Access data from a common pool, while at the same time contributing to and maintaining the integrity of the IDB,
2. Concentrate their own data with those extracted from the IDB for purposes of comparison and evaluation, apart from verification of standards, norms and state-of-the-art practices, as contained and shared in the IDB, and
3. Obtain "bonus" information as a result of data recovery for generic design, procurement, and operations tasks.

This implies that the final version of the IDB will provide data transfer not only from design to construction to operation and maintenance, but also from operation and maintenance back to design.

The major value of the IDB in the operations and maintenance phase lies in addressing the problem of managing facilities more efficiently and using resources more effectively. The possibility of "catching-up" and bringing even a part of poorly maintained and aging facilities up to acceptable standards of performance should recommend the initiation of pilot projects as test beds for the implementation of the IDB concept.

Therefore, the IDB raises the true value of existing facilities in terms of the following:

1. Lower operation and maintenance costs over the long term,
2. Higher actual value per square foot or service rendered (equivalent to higher real estate valuation in the private sector),
3. Better management of inventories, labor, spare parts, procurement, space utilization, and
4. Better communication and more accurate reporting that improve management practices.

VALUE OF THE IDB TO THE RENOVATION MARKET

Financial incentives exist to implement the IDB as quickly as possible. Commercial, institutional, and industrial building renovation is the largest construction market in the U.S. today. Each year, more money is spent to renovate the existing inventory of these buildings than is spent for new construction.

There are 4.5 million commercial, institutional, and industrial buildings in the United States today. Over 75 percent, or 3.4 million, are 17 years of age or older.

During the past four years, the new construction of commercial, institutional, and industrial buildings averaged 68,500 buildings per year which is equivalent to 1.5 percent of today's existing building inventory. Almost ten renovation projects are completed for each new structure built. In 1986, it is estimated that more than 674,000 commercial, institutional, and industrial buildings will be renovated.

The relationship of the relatively small number of new buildings being constructed each year to the large, aging inventory of existing buildings explains why the total dollars spent in the renovation market are increasing faster than the total dollars spent on new construction. Table 6-1 summarizes the impacts created by renovation.

Both the construction of new buildings and the renovation of existing buildings share the same basic design and construction technology. However, building renovation projects are more difficult to design, construct, and budget because some decisions regarding retention, repair, or replacement of building components must be changed during the actual renovation. Moreover, as previously unknown conditions are discovered during renovation, they very often require custom solutions at greater cost.

The key to successful building renovation requires precise diagnoses of existing building components and systems (what to retain and what to replace) and the optimum integration of old and new building components within budget constraints.

The unique problems encountered in the renovation process require that building owners, architects, engineers, and contractors maintain an attitude of open-mindedness and that they be receptive to the

TABLE 6-1 Total Dollar Expenditures for Commercial, Institutional, and Industrial Buildings (Dollars in Billions)

	Renovation	New Construction
1983	58.7	54.5
1984	67.5	62.7
1985	79.4	66.1
1986 (est.)	87.0	70.0

examination of all possible solutions for a given project. Very often, out of necessity, owners can initiate creative solutions to unique retrofit problems which are later applied to their new construction projects.

ENHANCING THE VALUE OF THE IDB

Other economic benefits will accrue in the mature phases of a continuous IDB project. The monitoring and evaluation of pilot or test bed projects over a three- to five-year time period is necessary for testing different models or versions of the IDB before full implementation. Government owners of public facilities tend to manage these facilities over the full life cycles, and, since the investment in public facilities is significant, the best candidates for a pilot to test the IDB concept will be found in the public sector.

Since most public agencies employ private firms to install their facility management systems, the likelihood of technology transfer from the public to the private sector is considerable, provided that legal barriers can be removed. In addition, initial research and development costs need to be prorated with respect to the number of buildings to be served (or the number of owners using the system). The need to provide the IDB with the capacity to capture, translate, and integrate data from new and old construction, and to facilitate multiple feedback loops is a necessary condition for enhancing its value to the owners.

If it is true that, at least initially, the greatest benefits of using the IDB will accrue to owners of large facilities (e.g., public sector agencies and large corporate owners), the benefit to small or individual building owners may become apparent only in terms of "secondary" market effects, such as:

1. Subscription to limited or scaled down versions of the IDB,
2. Creation of associations of individual owners, sharing access to the IDB,
3. Formation of architectural and engineering service capabilities that would use the IDB on behalf of individual users or user associations, and
4. As a public service, to be provided on a fee-for-service basis by governmental agencies.

Steps that could be taken to ensure success during the transition phase to full implementation of the IDB include:

1. Articulate a clear rationale for selling the IDB concept by judicious dissemination of information, contact with potential clients, IDB demonstrations, and inclusion of all participants in the building process as potential IDB clients,
2. Elaborate explicit and reasonably transparent rules for the use and operation of the IDB in terms of technical, operational, and legal matters (including constraints),

3. Select candidates for pilot or test bed projects including the mobilization of legislative, financial, and human resources prior to installation,

4. Assure peer group control in terms of impartial evaluation of test bed cases, including publication of results and communication with professional associations,

5. Monitor benefit and cost aspects of installed IDBs, both in terms of base line costs before and comparative cost levels after, including comparison of benefit/cost curves between users of the IDB. Consider using control buildings for comparison (i.e., non-IDB projects).

THE LEGAL BARRIER

Emerging technologies create new uncertainties which inevitably result in added legal risks and liabilities. The patchwork of tort laws in the United States has slowed the growth of emerging technologies, but has not yet stopped this growth. An IDB, like any emerging technology, will increase legal liabilities in unforeseeable ways. New legal and insurance reforms will be put into place because of the IDB. These reforms may include shared insurance risks similar to commercial airlines. Federal products liability reforms to standardize commerce among the various states will almost certainly become a reality. The successful implementation of the IDB will depend on the reduction of legal barriers to emerging technologies. Further detailed legal research will be needed into best case scenarios for reducing the legal risks implied in a full blown IDB implementation.

CULTURE SHOCK

The implementation of the IDB will precipitate a number of organizational, economical, and physical changes to the building community. Some of these changes can be anticipated; others are quite speculative, and their effects could be confirmed through the test bed approach. The culture shock implications have been segregated into four basic areas where change is expected: (1) business and professional service organizations, (2) structure of the architecture, engineering, construction community, (3) procurement, and (4) the use of external data bases. These implications are discussed below without any attempt to assign priorities.

Organizational

Small business

It is perceived that the average architecture and engineering (A/E) firm may have difficulty participating in projects requiring the use of the IDB because the condition of a small firm's capitalization, the mix of its work, and the lack of diversity in its staff may preclude small A/E firms from applying the IDB to their client's requests.

However, under proper circumstances, small A/E firms may be encouraged to enter into use of the IDB because of economic incentives to the firm, such as decreases in workstation costs, reduced communication time, and accommodation of change orders more rapidly.

Work Force

Innovation provided through the IDB should significantly affect the composition of an A/E firm's staff. With many para-professional and routine tasks being directed by senior staff through the IDB, a decline in jobs at entry level and low tenure positions will occur. A similar decline in the more junior staff in the owner's organization is also predicted.

Work Space

The IDB will change the A/E firm's work facility. Drawing boards and desks will be replaced by electronic workstations; storage of hard copy project documentation might be eliminated; and the A/E community working with the IDB may be motivated to merge their resources.

Job Profiles

Within the professional services community, project architects and engineers will assume much of the lower staff level tasks, relying on automation relating to the IDB and associated hardware for the production of contract documents. Within construction firms, technical staff will be upgraded as a result of their interface with the IDB. Contractors and fabricators will be required to deal with electronic rather than hard-copy information. In all elements of the project, users of the IDB will require skills related to data management and communication.

Education

The IDB will change the education of technical staff throughout the building process. Both undergraduate and postgraduate levels of curricula must include opportunities for students to be trained in the use of the IDB. Aside from the present day architectural and engineering subjects being presented, students anticipating careers in building-related disciplines will be required to be familiar with skills demonstrated by the para-professionals.

Project Modification

The IDB will foster faster and better communication between the A/E firm and the owner organization. This should create a deliverable at less cost with a shorter construction time. On the other hand, with the owner having continuous access throughout the building process, there could be a tendency for the owner to interject more changes into the project process. Although project redirection could be considered positive, it may lead to delays in completion of the necessary contract documents.

Federal Budgeting Process

Through the IDB, an agency will have timely access to more detailed data for preparation of budget requests related to new construction, renovation, and facility operations. Less manpower should be required to produce the budgetary supportive documentation. In addition, funding for organization- and maintenance-related activities should be more easily defined.

Industry Structure

Reduction of Professional Service Firms

The availability of an IDB, in concert with a possible decline in new building projects, may cause a decline of professional design firms. Projects will be completed in less time than today by those firms using the IDB concept, forcing those not using the IDB to leave the field or to perform and concentrate on services other than design.

Modify Design Services

The use of the IDB could change how design professionals perform. Access to an IDB could make it easier and more economical for construction firms to provide more detailed design; design professional deliverables could be limited to those of a design development nature. Without an IDB, design services are currently apportioned this way in other countries (especially in Europe).

Professional Expressionism

Construction firms supporting the design phase could assume, through the IDB, a greater role in the design of projects. This will require construction firms to upgrade their skills to the levels necessary to facilitate the design process. A greater number of junior professionals will enter the industry in this manner. This shift in employment of professionals to the construction sector will very likely affect the reduction of junior professionals in the A/E community.

Procurement

The procurement of design, construction, and facility services in the current building process, has been traditionally driven by first cost. Such a system does not lend itself to the life-cycle approach that is evident in the IDB concept. The procurement of design, construction, and facility operation and maintenance services is generally independent, each predicated on the cost at the time of contract.

Since the IDB is based on the life cycle of the facility, then the services that make up the pieces of the facility procurement must be looked at and developed on a life-cycle basis. Design development options, the choice of construction materials and techniques, and facility management decisions must be made on a life-cycle basis. Without such an emphasis during procurement, the development of the IDB will be hindered. The sooner the procurement process recognizes this required change the easier the transition process.

Although there is concern with the culture shock that such changes will have on the industry, such concepts are new, but not totally adrift, of some present day thinking. An example of this occurs in the design/construction phases and the use of value engineering to make decisions based on life-cycle costing. The use of such concepts, though limited, does indicate that life-cycle thinking can and does occur today.

How to procure a facility is not as important as what to procure and when to allocate monies to support the procurement. The IDB process will help prove to building owners that the first cost should not be the sole priority.

Today's procurement process can support the IDB development. It is the decision makers within the procurement process that need to accept the life-cycle concept before the benefits of an IDB will be realized.

External Data Bases

Most of the data and analyses created and used during design are based on data derived from published sources, which can be in either traditional printed media as well as in some form of electronic media. Examples of the traditional printed data are published handbooks in tabular, graphic, or nomographic formats. Examples of electronic data bases are Masterspec, Electronic Sweet's Product Data, Dodge Cost Systems, Steel Beam Design Data, as well as other planned activities dealing with graphic details, building codes, and a variety of engineering data.

The specific data that are used from the external data bases to make critical design determinations must be recorded in the IDB for future reference. With data sources that exist only in traditional printed format, manual gleaning and input would be required, which is not as efficient or reliable as the automatic input that could be arranged with a computerized data base.

There must be inducements for organizations to convert traditional data bases to electronic form, which is essentially a new technology publishing function. This function could be provided in some cases, where the data are in the public domain, by organizations that have no revenue interests, such as government or military agencies, or associations with special interests, such as the Steel Institute. The data can be provided in the new media by the traditional commercial publishers as extensions or replacements for their traditional publishing efforts. In actual practice, data bases will likely be provided by a combination of sources, with commercial publishers being relied on most heavily, as is currently the case.

In their current mode of operation, publishers and, more importantly, authors rely heavily on unit sales to produce revenues. The application of electronic data bases could impact heavily on the unit sales formula because larger numbers of individuals could employ the data base than do now with individual printed materials. There is always the specter of illegal copying which is often impractical with an entire book. Protection and pricing schemes must be arranged which might differ considerably from the publisher's traditional schemes.

Traditional publishing treats revisions and updating of data lightly, often letting long periods go by before aged data are revised. In effect, the publisher is passing the responsibility on to the users to rely on their own expertise and judgment in how the data are used. This cannot be tolerated in automated systems where the age or validity of the data might not be obvious to the user. Incentives and controls must be established to assure that the content of an external computer data base be more dynamic than the relatively static printed material.

Because of the permanent nature of printed materials, they are conducive to archival storage after revisions are made, so that they can be retrieved and referred to for review. The more dynamic computer data bases and, in particular, on-line data bases do not lend themselves readily to this kind of archival storage. A special effort must be made to retain the data base in an as-used state for the purposes of review and evaluation.

In summary, the issues regarding external data bases might require the following:

1. Providing incentives and protection to both the publisher and author to create and supply the external data bases,
2. Establishing standards and controls to assure the dynamic updating of the data, and
3. Establishing a methodology of archiving an external data base in its as-used state.

STRATEGIES TO IMPLEMENT THE IDB

Many of the direct and indirect benefits to be gained from implementation of the IDB are long-term, life-cycle cost benefits. In order to implement the IDB, many changes will evolve in the structure of the building industry and in the business, professional, and legal arena over a period of years. It is recognized that the effective utilization of the IDB might evolve in a transitional mode over the next 15 years. For that reason, it is important to recognize a transitional period and the need for articulation of that transitional phase, rather than delaying implementation or developing an IDB within the framework of specific current professional, business, and legal practices and procedures.

Transition

Given current, traditional procurement practices, the implementation of the IDB will have to occur in an environment that permits and encourages innovation. It will not be enough for implementation to follow today's practices and procedures with the added presence of an IDB.

Use of an IDB Test Bed

During the transition phase, implementation should occur in a test bed which should be in an innovative environment and should include a group of similar new projects within a single federal agency (a single federal agency ideally would represent a continuous owner). This test bed should include new facilities being planned and built during the next 15-year period as well as certain existing facilities.

These facilities should be designed and built faster, and at a lower cost than today due to the increased efficiency of the project team and the improved communications between the owner and the project team. Owners will receive a majority of the data to load their facility management systems.

Existing Facilities

Today's existing building stock will largely remain in place well beyond the year 2000. This older portion of the building stock will put the most demands on the owner for the continuing need to manage, repair, and rehabilitate these buildings, and to plan for phase out and replacement as the cost to maintain approaches the cost of replacement.

The life-cycle issues being addressed are replacement; minor repair; major repair; operation and maintenance of building systems; modifications to building systems; space planning, inventory, and cost allocation; capital asset inventory and allocation; and facility reconfiguration or replacement.

Currently available facility management software addresses the needs of both the lowest level (minor repair, operation, and maintenance) and the middle level (space planning, inventory, allocation) with varying degrees of success. The needs of the highest level (replacement, major repair, modifications, reconfigurations), however, are inadequately addressed. The IDB, with project by project data input and multi-project logical combination and query capability, should address the needs of managers to answer questions such as the following:

- Since the tenant has only nine months left on the lease, can we defer major repairs, thus avoiding unnecessary temporary relocation?
- Rather than repair, should we replace?
- Of all the owner's facilities, what facilities occupied or unoccupied are suitable for this new tenant?
- Is this facility suitable to be modified economically for this new function?
- Where do agency-wide energy costs appear to be problems?

To answer these questions, existing facility data must be available as well as new facility data. Since the IDB is not a facility management system and since it must exist in a heterogeneous hardware and software environment, standards must be developed. The challenge is in the communication between software packages. The ability to extract and store data in various software packages without knowledge of the vendor proprietary data base will become critical to the long-term success of the IDB. For the near term, intermediate solutions can be created to accomplish the task.

CONCLUSIONS

Reduced costs for facility management is the area of biggest payoff resulting from the development and implementation of the IDB. A major incentive to adopt IDB technology lies in the capability to capture data about existing facilities and to use those data for improved management and planning. The potential opportunities for reducing these costs should be emphasized in efforts to stimulate further development of the IDB.

Significant benefits should accrue to the manager of large and diverse facilities resulting from the ability to make comparative analyses of similar building functions. While software may be available to carry out facility management functions, the needs of higher management responsible for overall planning and resource allocations, are not adequately served by current approaches and technology.

The widespread use of computers by the building community and by building users is a potential force that could bring the various disciplines together and accelerate the implementation of the IDB. The IDB concept has survived four years of critical review and discussion through the Woods Hole Workshops, and has been sharpened in focus. The next step would appear to be either a pilot implementation of the IDB or an incremental step toward the implementation. The organization most likely to benefit from such a project appears to be a federal or other public agency with a large inventory of existing buildings and with plans to construct new buildings. The pilot project would not only provide experience and knowledge to building owners, but would also enrich the building community by encouraging the development of a capability that would enhance its international competitiveness.

The changes in the IDB concept that have occurred as a result of the workshop discussions suggest that continued development could further enhance the usefulness of the concept and its applicability to solve real-world problems. The orientation toward providing a tool for facility management appears to be a useful direction for future discussions and demonstrations.

It is evident from the foregoing discussion of legal, cost, and implementation issues that there are a number of issues that could, if not addressed, inhibit the implementation of the IDB. Generally, the issues are of no more magnitude than is being experienced in other areas of technological change. Some of the risks could be exacerbated with the advent of the IDB; however, these risks must be weighed against the many benefits to be gained including lower costs for building construction and maintenance, improved communications between building owners and the building community, and improved capabilities for managing buildings.

In summary, the effect of implementation of the IDB will be positive and a major improvement in the working environment of the entire building community. It is essential that steps be taken to initiate the transition phase to ensure that known impediments are dealt with systematically and in a timely manner. Adoption of the recommendations outlined below will aid in that effort.

RECOMMENDATIONS

The working group recommends that the Committee on Integrated Data Base Development form a task group to carry out an outreach program. Information about the IDB concept should be transferred to potential implementors and to organizations that could leverage the workshop accomplishments. Presentations and discussions could be initiated with groups of large buyers of buildings such as the Business Roundtable. Professional organizations such as the International Facility Management Association, the American Association of Engineering Societies, Building Owners and Managers Association, and the American Institute of Architects could also be targeted for information exchanges.

A large federal agency should be asked to sponsor a pilot project as a research effort that can apply creative and innovative techniques to procurement and other administrative requirements and to barriers to the IDB. The project should be monitored by the committee and analyzed for its potential extension to larger scale projects. In particular, the techniques developed for reducing barriers should be evaluated.

The existing prototype IDB demonstration project should be expanded to carry out facility management functions. Options for loading already available data, using facility management software, or developing suitable operation and maintenance applications should be considered.

APPENDIX 1

BIOGRAPHICAL BACKGROUND OF PARTICIPANTS

Gifford H. Albright
Program Director
Structures and Building Systems
National Science Foundation
1800 G Street, NW, Room 1110
Washington, DC 20550

Gifford Albright is program director for structures and building systems in the Engineering Directorate of the National Science Foundation (NSF). The Structures and Building Systems Program provides support for fundamental research in structures, building systems and construction processes including computer-aided design of integrated building systems. Construction automation research-information processing, equipment automation, and computer-integrated construction is a major thrust area in the NSF program. Mr. Albright is professor of architectural engineering (on leave) at Penn State University where he served as founding head of that department in 1963 and was instrumental in establishing in 1965 the AE Cad Lab at Penn State for instruction and research on the "MODCON" System--A Man-machine Optimum Design Construction and Operation Network System. Since that time he has actively participated in computer-aided design and construction developments.

James G. Anderson
Consultant
Facility HQB01D
Control Data Corporation
8100 34th Avenue South
Bloomington, MN 55420

James Anderson began his career with the computer industry in 1969. He has worked in several areas including operations, programming, analysis, physical specifications, systems implementation, applications design and implementation. Mr. Anderson is currently working with data base development methodologies. Since 1982, he has been involved with data base technology. During this time he has designed and implemented data base driven applications for the engineering areas. A recent development effort produced an integrated data base for use by the utilities industry for design of the piping structures. His fields of expertise are data base development using a three schema architecture and integrated of information required for processing user requirements.

Clyde L. Arnold, Ph.D.
Economist, Facility Systems Division
Code L53
Naval Civil Engineering Laboratory
Port Hueneme, CA 93043

Clyde Arnold has a Ph.D. in economics with fields in computer applications, statistics and environmental systems. In the past he has been a research scienist on loan from University of Oklahoma to the Corps of Engineers, assistant professor at Washington-Jefferson College; he has worked in the Apollo program at NASA doing electronic repair and calibration. He received his bachelors and masters degrees in economics from the University of Houston.

Harold Borkin
College of Architecture and
Urban Planning
The University of Michigan
Ann Arbor, MI 48109

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.

Frederick R. Busch, Airport Planner
Dade County Aviation Department
Miami International Airport
14232 S.W. 76 Street
Miami, FL 33183

Frederick Busch is an airport/aviation planner in the Planning and Programming Section of Dade County Aviation Department. He works closely with the department director and senior staff responsible for development of conceptual plans and programs for improvement projects at Miami International and five other county-owned airports. His activities range from studies of the roles of each of the airports, formulating overall airport development "master plans," airport land-use and noise analysis to specific facility planning and various special projects which may be assigned. Recently, he has been involved with airfield, aircraft parking and access planning activities. Prior to joining the county staff, he worked as a national airport engineering consultant, playing key technical roles in state airport system planning, and individual airport master plan and noise studies. Mr. Busch received his B.S. in air commerce from the Florida Institute of Technology.

Per Christiansson, Assoc, Prof., Ph.D
Department of Structural Engineering
Lund Institute of Technology
Lund University, Box 118, 221 00 Lund, SWEDEN

Per Christiansson is associate professor at the Department of Structural Engineering, Lund Institute of Technology and holds a Ph.D. in structural engineering. Besides his own research, teaching and research supervision, he is scientific advisor to the Swedish Industry Research Council, BFR, within the field of computer use in the building industry. For 10 years he has been head of the Civil Engineering Computer Center in Lund. He is a member of the BFR/BST CAD-Committee, a Swedish steering and coordination group for the use of computer aids in the building process, and Swedish representative in NBS-DATA, the working group for information technology of the Cooperation Organization of the Nordic Building Research Institutes. He is also a member of CIB W78, the working group for integrated computer-aided design within the International Council for Building Research, Studies and Documentation and of ECAADE, Education in Computer-Aided Architectural Design in Europe, and the International Editorial Board of Design Computing (John Wiley & Sons).

Eric Dluhosch, Ph.D.
Associate Professor
Departmentof Architecture
Massachusetts Institute of Technology
5 Fairfield Street
Boston, MA 02116

Eric Dluhosch is currently a consultant to the Division of Capital Planning and Operations of the Commonwealth of Massachusetts, setting up state-wide computerized facility management for preventative maintenance. His general research aims are the integration of design with technologocal factors, innovation and evolution of systems. Dr. Dluhosch has participated in research activities including industrialized building (system building and prefabrication), modular coordination, and housing systems (developing countries, and U.S.) He was educated in Czechoslovakia, Canada (McGill) and the United States (M. architecture, Cornell); he received his Ph.D. from the University of California, Berkeley.

H. Larry Dyer, Manager
Mail Code ROC320
Control Data Corporation
6003 Executive Boulevard
Rockville, MD 20852

Larry Dyer is a senior consultant with the Environmental Technology Center for professional services at 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
Manager Technical Services
Bechtel Power Corporation
12440 E. Imperial Highway
Norwalk, CA 90650

Jack 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 E. Fulton
Professor of Mechanical Engineering
Georgia Institute of Technology
Atlanta, GA 30332

Robert Fulton joined Georgia Tech in 1985 to lead a new initiative on the application of computers to engineering. He has also led a joint university/government research program, Finite Element Machine (FEM), to develop technology for applying concurrent processing and future super computers to solve solid and fluid mechanics problems. He is the author of over 100 technical publications in areas such as finite element methods, numerical methods, static and dynamics analysis of shell structures, dynamic stability, and the use of computers in engineering analysis and design. Dr. Fulton has served on the faculties of George Washington University, Old Dominion University, North Carolina State University, the University of Illinois, and Virginia Tech. His professional society affiliations include active leadership roles in the National Computer Graphics Association, the American Society of Civil Engineers, the American Society of Mechanical Engineers, the American Society of Engineering Education, the American Academy of Mechanics, and the American Institute of Aeronautics and Astronautics. He has served on several National

Academy of Sciences and NSF committees to help identify critical technology needs associated with computer applications to engineering. Dr. Fulton received his B.S. in civil engineering from Auburn University, and M.S. and Ph.D. in civil engineering from the University of Illinois.

Robert Furlong
AF/LEEES
Bolling AFB
Washington, DC 20332

Robert Furlong is a registered professional civil engineer with the U.S. Air Force on the staff of the Directorate of Engineering and Services. Prior to this, 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 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
Manager, Special Systems
Control Data Corporation
4105 North Lexington Avenue
St. Paul, MN 55126-6197

James Goodland currently manages a group of consultants, program managers, and analysts at Control Data Corporation. The past five years have been spent in 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 more than 20 years in the computer industry.

Robert C. Heterick
Vice President for Information Systems
201 Burruss Hall
Virginia Tech
Blacksburg, VA 24060

Robert Heterick has been with Virginia Tech for more than 20 years. He recently served as professor in the College of Architecture at Virginia Tech. He received a B.S. in civil engineering in 1959, M.S. in structural engineering in 1961, and Ph.D. in engineering in 1968 from Virginia Tech. Mr. Heterick has several publications, reports, reviews, and technical notes.

Ronald L. King
Group Director in Civil Procurement and
Property Management Group
U.S. General Accounting Office
General Government Division
Washington, DC 20415

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
U.S. Army Corps of Engineers
P.O. Box 889
Savannah, GA 31402

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.

Robert E. Mahan
Battelle Northwest
P.O. Box 999
Richland, Wa 99352

Robert Mahan is manager, Computer Systems Support at Battelle Pacific Northwest Laboratories. He is an adjunct lecturer in computer science at the Joint Center for Graduate Study at the University of Washington where he teaches digital design, computer architecture, and data comunications. Previous positions at Battelle include manager, Electro-Optics Systems Section and associate manager, Computers and Information Systems Section. His research interests are in the areas of strategic planning, technology forecasting, and management systems. Mr. Mahan received his bachelor and master of science in electrical engineering from Washington State University.

Earl Mark
Senior Analyst Programmer
Computervision Corp.
100 Crosby Drive
Bedford, MA 01630

Earl Mark is a research affiliate at the Massachusetts Institute of Technology, in addition to being a senior analyst programmer at Computervision Corp. His recent project at Computervision includes CV Genesis/3000 Workstation: Project Leader on the implementation of AEC application software. The application areas include architecture, visualization, mapping, site, and plant design. He is also system manager for AEC CV-4000 systems and implementation of CDSM local area network (between super-mini and mainframe computers). Mr. Mark is currently involved in the study of the design process and the related assessment of CV's product offerings to architects. At MIT his research is on "Project Athena," concerned with linking together expert system, videodisc visual information system, CAD, and a data base manager for the purpose of maintaining data and reference information through the life-cycle phases of a building design project. Mr. Mark has a B.A. in architecture and mathematics, a master in architecture, and an M.S. in computers and architecture.

Rick Martin
Attorney
Oltman and Flynn
915 Middle River Drive
Ft. Lauderdale, FL 33304

Rick Martin writes patents and prosecutes intellectual property litigation in federal courts. He is a guest speaker at the University of Miami's Honors Course for Entrepreneurship and has published numerous articles centering on proposed government reforms to encourage American entrepreneurship. His recent "Lawsuits May Choke U.S. Software Industry" urges a cap for jury awards in products liability cases. His fields of expertise include computer software systems design, high-tech marketing and business planning, products liability, corporate and patent law. Mr. Martin's workshop contribution includes forecasting immediate legal effects on builders using the proposed integrated data base development and proposed legal reforms to ease implementation of advanced technologies into American commerce. He has a B.S. in physics from Bucknell University, 2 years of business training at IBM, Honeywell and NCR, and a juris doctor of law from Nova University.

Malcolm McCullough
AEC Applications Product Manager
Autodesk, Inc.
2320 Marinship Way
Sausalito, CA 99965

Malcolm McCullough has been with Autodesk since 1983. Prior to joining Autodesk, he was an architectural designer/drafter at Jung/Brannen Associates, one of the largest and most progressive design offices in New England. Mr. McCullough has recently completed his master of architecture at UCLA, where he was the recipient of numerous academic honors. He also has a B.A. in engineering and architecture from Yale University.

Harry Mileaf, Vice President
Planning, Electronic Products (CIG)
McGraw-Hill Information Systems Company
1221 Avenue of the Americas
New York, NY 10020

Harry Mileaf is vice president, planning for electronic products for the Construction Information Group (CIG) of the McGraw-Hill Information Systems Company. The CIG unit encompasses Sweet's, Dodge, and the five major magazines in the consruction industry. He is the developer of Sweet's mechanical, electrical, and civil engineering catalog files. Mr. Mileaf directs CIG'S long-range technology program and has conducted in-depth research on the use of computers in construction for the last several years. He has authored articles and lectures on this subject at major conferences. He is editor and publisher of "TechPointers," a newsletter on computer use in construction, and is chairman of the Coordinating Council for Computers in Construction. Mr. Mileaf is the developer and initiator of Electronic Sweet's, a data base of building products; and the author of 16 high school and junior college text books on electricity and electronics, as well as the computer program, "The Research Reporter."

F. Lee Nason
New England Telephone and
Telegraph Company
245 State Street
Boston, MA 02109

F. Lee Nason is district manager, real estate-engineering staff for the New England Telephone and Telegraph Company. In this position she is responsible for all intercompany contracting issues involving leased or owned facilities, lease administration, and all furniture and office equipment corporate capital investments. She received a B.S. in industrial engineering from Northeastern University and her master of architecture from the Massachusetts Institute of Technology.

Mary Oliverson
IBM-AEC Product Administrator
Engineering Systems Market Development
IBM 12/69a
400 Columbus Avenue
Valhalla, NY 10595

Mary Oliverson is with Engineering Systems Market Development at IBM as a product administrator for architectural and engineering CAD software. Before joining IBM in 1984, Mrs. Oliverson was president of both the U.S. and Canadian subsidiaries of Applied Research of Cambridge Ltd., which was subsequently purchased by McDonnell Douglas. As an architect/planner, she has previously worked for Skidmore Owings and Merrill, and as a consultant on urban projects for the World Bank. She has over 15 years' experience in the application of computers to architecture and engineering, with special emphasis on CAD techniques.

Richard Person
Project Manager
Infrastructure Management Program
St. Paul Department of Public Works
St. Paul, MN 55102

Richard Person is project manager for the infrastructure recommendation program which includes computerized inventories of streets, sidewalks, sewers, water mains, signs, lights, and bridges; computer-aided mapping; and computerized maintenance management systems. He is also an instructor at the University of Minnesota for public works management information systems.

Jack Phillips
AEC Applications Marketing Manager
Digital Equipment Corporation
Marlboro, MA 01752

Jack Phillips has a B.S. in civil engineering from the Lehigh University. His experience includes 16 years with a central engineering department (E.I. DuPont DeNemours Inc.); field engineering in the construction division; AEC estimating group supervisor, senior systems analyst design division; 2 years as industry manager for AEC for AutoTrol Company.

Shirley Radack
Program Analyst and Group Leader
Institute for Computer Sciences and Technology
National Bureau of Standards
Gaithersburg, MD 20899

Shirley Radack is program analyst for the Institute for Computer Sciences and Technology of the National Bureau of Standards. She is responsible for studies, analysis, and plans for Institute programs in standards development, technical assistance, and research in computer technology. Her interests include the role of standards in the effective use of computers, impact of technology on organizations, and development of government policies to advance the use of computers. Mrs. Radack has a B.S. in microbiology from the University of Maryland.

Kent A. Reed
Group Leader
Computer Integrated Construction Group
Center for Building Technology
National Bureau of Standards
Gaithersburg, MD 20899

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. He was first exposed to computers in the early 1960s; 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.

Kenneth F. Reinschmidt
Vice President and Manager
Consulting Group
Stone & Webster Engineering Corp.
Boston, MA 02107

Kenneth Reinschmidt is a vice-president and director of the Stone & Webster Engineering Corporation. He has been active in the development of computer-aided engineering and design systems for more than 25 years. He received SB, SM, and Ph.D. degrees in civil engineering from the Massachusetts Institute of Technology. Following two years on active duty with the U.S. Army Transportation Corps, he returned to serve as a member of the faculty in civil engineering at MIT until 1975, when he joined Stone & Webster. At SWEC he is currently senior consulting engineer, manager of the consulting group, and chairman of the advisory committee on technology development. His current work at SWEC includes consulting; management of corporate microcomputers; and development of new applications in computer-aided engineering and design, expert systems, construction automation, and integrated data bases. For the past several years he has been directing the development of an integrated data base for facilities engineering, design, construction and operation using IBM mainframe systems, the relational data base system DB2, and 3D geometric modeling (CATIA and CADAM). He serves as the chairman of the Committee on Integrated Data Base Development of the Building Research Board of the National Research Council and is a member of the Panel for Building Technology of the Board on Assessment of NBS Programs of the NRC.

Daniel W. Reynolds
U.S. Army Corps of Engineers
Sacramento District
Sacramento, CA 95814-4794

Daniel Reynolds received his B.S. in civil engineering from the University of Wyoming. He is a registered professional civil engineer in California and has more than 25 years experience as a structural engineer in building design review and construction with the Corps of Engineers. Presently he is supervisory structural engineer and chief of military design section B in the Sacramento Corps District. Mr. Reynolds is chairman for Computer-Aided Building Design Task Group, one of ten CASE Computer-Aided Structural Engineering task groups sponsored by the Water Ways Experiment Station at Vicksburg, Mississippi. He is a member of the teaching team on computer-aided building design, presented at Vicksburg each January. In addition, he is the Sacramento Corp District Alpha test coordinator for CAEADS, Computer Aided Engineering Architectural Design System sponsored by CERL. Mr. Reynolds is co-author of Stiffness Methods, Frames, and Military Engineering published on Corps-wide Conference on Computer-Aided Design in Structural Engineering prepared for Office Chief, Engineering, U.S. Army, Washington, D.C., August 1976.

Marie D. Roberts, CDP, CSP
Operations Research Analyst
U.S. Army Construction Engineering
Research Laboratory
Champaign, IL 61820-1305

Marie Roberts is an operations research analyst and principal investigator on the Design Systems Team, Facility Systems Division, U.S. Army Construction Engineering Research Laboratory. Ms. Roberts has worked for the Corps of Engineers since 1977 as a mathematician and computer specialist. In Savannah District and Europe Division, ADP Centers, she specialized in scientific and engineering applications development and implementation. She wrote the Harris Computer Users' Manual for the Europe Division. In Savannah District, Engineering Division, she was the PRISM-RA/PM (Project and Resource Information System for Management) Coordinator and provided division-wide computer applications assistance. She has designed and conducted classes in computer and application program usage for more than 350 Corps employees. She taught various computer courses for City College of Chicago in Frankfurt, Germany. From 1966 to 1972 Ms. Roberts was a mathematician for the U.S. Naval Oceanographic Office, Ocean Surveys Program, where she designed (with two others), programmed and implemented the OSP Information System. She was the first woman to work aboard a NAVOCEANO deep ocean hydrographic survey ship as a regular member of the scientific team. From 1972 to 1977 she worked as a programmer/analyst for Sperry Microwave Electronics and as the data processing manager, assistant business manager for a large law firm in Florida. She is certfied as a systems professional (CSP) and as a data processor (CDP), and she is listed in Who's Who of American Women. Ms. Roberts holds a B.S. in mathematics from the University of Georgia and she did graduate work there in mathematics and art. She also did graduate work at American University in the technology of management, specializing in computer science and STINFO (scientific and technical information systems).

Robert R. Ruhlin
Senior Vice President
Syska & Hennessy
New York, NY 10036

Pete Ruhlin is a senior vice-president of the international consulting engineering firm of Syska & Hennessy. He heads the facility management division which offers services in the field of energy conservation, operations and maintenance manuals, work measurement, preventive maintenance, organizations and staffing, inventory control, and facilities condition studies. He received a BSEE from the University of Notre Dame and is presently completing the MBA requirements with the University of New Haven. Instrumental in developing both mainframe and micro-based computerized maintenance programs, he implemented the use of CAD in the development of O&M manuals produced by his firm. Mr. Ruhlin is a registered professional engineer and president-elect of the Institute of Plant Engineers. He has authored a number of magazine articles on the subject of facility management and currently has three texts in print on the same subject.

Paul Scarponcini, PE
McDonnell Douglas AEC Company
P.O. Box 516-303/4W-0994
St. Louis, MO 63166

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.

Gary M. Seibert
CADD System Manager
U.S. Army Corps of Engineers
Savannah District
Savannah, GA 31402-0889

Gary Seibert is a registered structural engineer with the U.S. Army Corps of Engineers, Savannah District. He is assigned to the engineering division where he is responsible for the integration of computer activities with engineering and serves as system manager for the CADD system. He received his bachelors' and masters degree in structural engineering from the University of Florida and is currently a Ph.D. candidate. Mr. Seibert's areas of interest include integration of data base system with design programs and expert system for design review. He currently is a member of the AEC Subcommittee of IGES.

R. H. Simonsen
Manager of Integrated Systems Engineering
Boeing Computer Services
Government Information Services
Seattle, WA 98124

Si Simonsen is the manager of Integrated Systems Engineering for the Government Information Services Division of Boeing Computer Services. His responsibilities include the technical and architectural aspects of system integration technology and its application to the design and development of distributed computing systems. He has been the program manager on several large contracts concerned with the development of integrated information systems spanning a dispersed, heterogeneous computing environment. Mr. Simonsen's areas of technical and management experience includes data base integration, systems modeling, data security, computer-assisted instruction and man-machine interfaces. His primary management experience has been in the development of strategic technology and practical application of advanced computing technology directly related to information systems. He has published and presented many papers in these areas and holds several patents related to the use of associative memory to address problems of data management. Mr. Simonsen holds an M.S. in applied mathematics from the University of Michigan and a B.S. in aeronautical engineering from Rensselaer Polytechnic Institute.

Leonard J. Simutis
Graduate School and Research
102 Roudebush Hall
Miami University
Oxford, OH 45056

Leonard Simutis is dean of the Graduate School and Research at Miami University in Oxford, Ohio. He also serves as a special assistant to the provost for academic information systems; in this position he has overall coordinative responsibilities for academic computing and for the university's libraries. Prior to joining Miami in 1984, he was on the faculty in the College of Architecture and Urban Studies at Virginia Tech for 13 years and served as assistant dean for the Division of Environmental and Urban Studies, and associate dean for academic affairs. His current research interests include the use of video in computer-based instruction and the use of heuristic approaches in computer graphics and information systems. He received his bachelor's degree from the University of Illinois, and his M.A. and Ph.D. degrees from the University of Minnesota.

David Skar
Director
Engineering Systems Management Division
Naval Facilities Engineering Command
Alexandria, VA 22332

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
U.S. Army Construction Engineering
Research Laboratory
Champaign, IL 61820

Janet Spoonamore has been involved with architectural and engineering computer applications since 1973, starting with the work of MIT's IMAGE program and working with Bruce Dains and Dale Bryant at CERL in writing SEARCH (architectural review). In 1980, CERL's Computer-Aided Engineering and Architectural Design System (CAEADS) got off the ground, starting with Carnegie-Mellon's and the University of Michigan's efforts. For the past 5 years, she has been working as team leader of the design systems team, focusing on bringing together stand-alone tools, e.g., CADD, BLAST, cost estimating, etc. The major long-term goal of the CAEADS project is the integration of the design tools used throughout the design process, taking advantage of a "common" building design description accessible to all participants in the design process.

Robert F. Tilley, Sr.
Senior Consultant
Computech Inc
Bethesda, MD 20814

Robert Tilley 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 designed, 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.

James M. Walton
U.S. Army Corps of Engineers
Vienna, VA 22180

James Walton graduated from Texas Tech as a mechanical engineer. He spent four years in the Army where he was assigned as the engineer for Brooke Army Medical Center. He worked two years as a mechanical engineer, six years as an air-conditioning specialist, and three years as the chief mechanical engineer. Since July 1976 he has been assigned to headquarters of the U.S. Army Corps of Engineers as the chief air-conditioning and refrigeration engineer. During his current assignment, he is testing a computer-based scheduled maintenance program.

F. Richard Zitzmann
Colvin Run Consultants, Inc.
1304 Colvin Forest Drive
Vienna, VA 22180

Richard Zitzmann has over 25 years of experience in the computer and communications fields. Former employers include Bell Telephone 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 Polytechnic Institute of Brooklyn. He is a professional engineer registered in Maryland. Since October 1985, Mr. Zitzmann has been an independent consultant and has managed the Prototype Integrated Data Base Demonstration Project for the Building Research Board.

APPENDIX 2

WORKSHOP AGENDA

National Research Council
Building Research Board

1986
WORKSHOP ON INTEGRATED
DATA BASE DEVELOPMENT

National Academy of Sciences
Woods Hole Study Center
June 15-20, 1986

Sunday, June 15

6:00 - 7:00 pm	Welcome Reception Study Center Sun Porch.
7:00 - 8:30 pm	Introduction to the Workshop John Eberhard and Ken Reinschmidt.

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Monday, June 16

7:45 - 8:30 am	Breakfast Study Center.
8:30 am	Report from the Integrated Data Base Prototype Demonstration Team Carriage House.
12:30 - 8:00 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.
8:00 - 10:30 pm	IDB Prototype Demonstration Carriage House.

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Tuesday, June 17

7:45 - 8:30 am	Breakfast Study Center.
8:30 am	General Discussion--Prototype Demonstration Carriage House.
9:30 am	Panel Discussion--Lessons Learned Jack Enrico, Fred Kitchens, Ken Reinschmidt, Paul Scarponcini, Gary Siebert, Dick Zitzmann, and others.
11:00 am	Working Group Sessions
12:30 - 6:00 pm	Free Time Lunch is provided at the Study Center.
6:00 pm	Cook-Out Study Center.
7:30 - 10:00 pm	Working Group Sessions

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Wednesday, June 18

7:45 am - 8:30 am	Breakfast Study Center.
8:30 am	Brief Reports from Working Group Chairmen Carriage House.
9:30 am	Presentation on NASA Technical and Management Information System (TMIS) Larry Dyer.
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

****

Thursday, June 19

7:45 am - 8:30 am	Breakfast Study Center.
8:30 am	Brief Reports from Working Group Chairmen Carriage House.
9:30 am	Working Group Sessions
12:30 - 6:00 pm	Free Time Lunch is provided at the Study Center.
6:00 pm	Clam Bake Study Center.
7:30 - 10:30 pm	Working Group Sessions

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Friday, June 20

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

APPENDIX 3

DEMONSTRATION PROTOTYPE PROJECT TEAM

ALTON BRADFORD
Naval Facilities Engineering Command

JACK ENRICO
Bechtel Power Corp.

JAMES GOODLAND
Control Data Corporation

JAMES GREETHAM
McDonnell Douglas AEC Company

ROBERT HETERICK
Virginia Tech

DAVID KALISH
AutoDesk, Inc.

FRED KITCHENS
Corps of Engineers

ROBERT MAHAN
Battelle Pacific Northwest Laboritories

BLAKE MASON
ARCH.1 Architects

MALCOLM McCULLOUGH
AutoDesk, Inc.

MARY OLIVERSON
IBM Corporation

MARK PALMER
National Bureau of Standards

JACK PHILLIPS
Digital Equipment Corporation

KENT REED
National Bureau of Standards

KENNETH REINSCHMIDT
Stone and Webster

MARIE ROBERTS
U.S. Army CERL

PAUL SCARPONCINI
McDonnell Douglas

GARY SEIBERT
U.S. Army Corps of Engineers

JANET SPOONAMORE
U.S. Army CERL

SHAD STEVENS
Control Data Corporation

JOAN SULLIVAN
National Bureau of Standards

JOHN EBERHARD
Building Research Board

PETER SMEALLIE
Building Research Board

DELPHINE GLAZE
Building Research Board

DICK ZITZMANN
Consultant to BRB

APPENDIX 4

SAMPLE DISTRIBUTED DBMS PROJECTS AND PROTOTYPES

MULTIBASE

Computer Corporation of America. Read-only queries. Does not support concurrency control and transaction management. Heterogeneous system.

DDTS (Distributed Data Base Testbed System)

Honeywell research prototype. Five-level schema architecture, specified using the Entity-Category-Relationship (ECR) model. Supports concurrency control and transaction management. Heterogeneous system.

SIRIUS-DELTA

French research project. Limited transparency. Essentially a framework for cooperating data base systems. Heterogeneous system capability.

DDM/ADAPLEX

Computer Corporation of America. High degree of transparency. Adaplex interface language has the data base sublanguage DAPLEX embedded in general-purpose programming language Ada. Project sponsored by DARPA and NAVELEX.

SDD-1

Computer Corporation of America research project (1978). Addresses DDB problems of concurrency, recovery, consistency, fragmented data, redundant copies.

DISTRIBUTED 204

Computer Corporation of America commercial product resulting from SDD-1 research system.

R*

IBM Research follow-on to System R which led to DB2. Multiple cooperating copies of System R on IBM mainframes, advanced catalog management. Reportedly has moved out of research and into development recently.

DISTRIBUTED INGRESS

Researched at Berkeley; commercial product of Relational Technologies, Inc. Supports abstract data types and indices to CAD data.

IISS (Integrated Information Support System)

GE as prime contractor, plus 10 subcontractors involved in construction of test bed that will migrate to an integrated heterogeneous distributed system for factories. USAF/Wright-Patterson sponsor.

PROTEUS

Research project involving several British universities. Initial prototype has star configuration with switch at center and front-end interfaces at distirubted nodes. A heterogeneous distributed data base system.

CSIN (The Chemical Substances Information Network)

Designed and implemented by Computer Corporation of America. Interconnects heterogeneous systems. Somewhat limited; not fully integrated. Global model does not include all data in component data bases.

ICAM/PDDI (Integrated Computer-Aided Manufactring/Product Definition Data Interface)

McDonnell Douglas contract with USAF/Wright-Patterson. Major emphasis on definition of long-range manufacturing needs and a prototype demonstration of PDDI. Employs IDEF methodology for data definition.

IDS (Integrated Design Support System)

Charter is to assemble off-the-shelf tools and to add technology to manage technical data for the B-1B aircraft. Rockwell prime contractor with DACOM, SDRC and CCA for USAF/Wright-Patterson.

EXPERT SYSTEMS RESEARCH RELEVANT TO IDB

For example, ongoing work at Carnegie-Mellon.