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PROMOTION OF THE DEVELOPMENT AND USE OF THE SUBSYSTEM CONCEPT OF BUILDING CONSTRUCTION

BRAB-Federal Construction Council
Technical Report No. 62

Prepared by the Subcommittee on
Promotion of the Development and Use of the
Subsystem Concept of Building Construction
of the
Federal Construction Council
Building Research Advisory Board
Division of Engineering
National Research Council

NATIONAL ACADEMY OF SCIENCES
Washington, D.C.
1972

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of the
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In this pursuit, its specific objectives include: Assembly and correlation of available knowledge and experience from each of the agencies; elemination of undesirable duplication in investigative effort on common problems; free discussion among scientific and technical personnel, both within and outside the Government, on selected building problems; objective resolution of technical problems of particular concern to the Federal construction agencies; and appropriate distribution of resulting information.

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The Council directs the conduct of technical investigations and surveys of practice, holds symposium/workshops, arranges for interchanges of information and for monitoring of research and technical projects.

BRAB/FEDERAL CONSTRUCTION COUNCIL

Subcommittee* on

PROMOTION OF THE DEVELOPMENT AND USE OF THE SUBSYSTEM CONCEPT OF BUILDING CONSTRUCTION

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FOREWORD

The Building Research Advisory Board (BRAB) approves this report developed by its Federal Construction Council (FCC), endorses its findings, and encourages implementation of the recommended program. Development and widespread use of dimensionally and functionally precoordinated building subsystems appears to offer the nation the greatest opportunity to maximize the benefits of increased industrialization while satisfying the desire of individuals and organizations--public and private--for freedom of expression in creating facilities that are responsive to their needs.

The proposed program is comprehensive and could have a profound effect upon the building community and the nation, and it need not cause harmful disruptions. As a continuing program, initially directed toward those building owners/users having a substantial annual demand for physical facilities, it has the capability of creating a response from the building community adequate to set the desired changes in motion and serving the smaller user and involving him in time. Further, the program deals positively, realistically, and sensitively with the constraints that have discouraged--often for sound reasons--other proposed and pursued forms of industrialization. The effect of these two primary aspects of the proposed program would be to accelerate the current trend toward the development and use of a greater number of subsystems in the building process, and to shorten the time required to reap the potential benefits of initial cost and time saving, increased quality, and extended functional life of facilities that are inherent in this technological concept.

A special note of appreciation is due to the FCC Subcommittee, whose members spent many hours exploring the subject, conducting meetings with the several sectors of the building community, and developing the conclusions, the proposed program for the next phase of this study, and the supporting material contained in this report. The Building Research Advisory Board is prepared to lend its full support in achieving the goals outlined.

JOSEPH H. NEWMAN, Chairman
Building Research Advisory Board

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I
INTRODUCTION

A. Background

In the late 1960's, federal construction agencies, like most organizations responsible for the procurement of facilities, encountered a serious cost-budgetary squeeze. As a result, these agencies increased their individual efforts to find new and better ways to enhance the efficiency and effectiveness of the construction process. Many new concepts relating to the basic construction process have been investigated and tried at least experimentally. However, it was realized that maximum benefit could probably be achieved only if a single approach could be identified as most desirable and the resources of all agencies could be combined to stimulate its implementation. The administrators of the Federal Construction Council's supporting agencies asked the Council to review all concepts, experimental efforts, and experience gained, and if appropriate, to recommend a course of cooperative action to the agencies.

In response to this request, FCC made a detailed analysis of the current and projected facilities needs of the agencies in light of the various concepts identified. On the basis of this analysis, it was concluded that many of the concepts not only had validity, but had already achieved a degree of acceptance and use, and could be expected to contribute to improvement in overall efficiency and effectiveness in the construction process. However, the concept that appeared to offer greatest potential for further significant progress was that of employing dimensionally and functionally precoordinated subsystems as the basic building blocks in construction, within an overall open-system framework.* Such an approach, it was believed, could reduce the amount of on-site cutting and fitting of materials and assembling of individual products that is consistent with the type and volume of construction involved and the degree of individuality needed or desired.

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*The term "system," as used in this report and by many writers on industrialized building, means an entire building; a system is considered "closed" if it is designed around the use of a specific set of subsystems, and no other subsystems can be substituted; a system is considered "open" if it permits many different types of subsystem to be used interchangeably.

As envisioned by the Council, such dimensionally and functionally precoordinated subsystems would be preengineered and prepackaged, and might include such major building elements as ceilings and floor/ceilings (including lighting); partitions; exterior walls and skins; and heating, ventilating, and air-conditioning. Such subsystems need not necessarily be fully assembled in the factory for shipment to the site; however, they would be preengineered, pretested, and so marketed that in-place performance could be assured.

Convinced of the desirability of this basic approach, the FCC formulated a two-phase program to encourage its further development and use throughout federal construction and, hopefully, the building industry. The program was presented to the administrators of the supporting federal agencies in October 1970. The administrators endorsed the program and committed funds for the execution of Phase I. This is the report on that Phase I effort.

The objectives of Phase I were to investigate the feasibility of the concept and, if indeed found feasible, to develop a plan for its implementation. Phase II was envisaged as the implementation of that plan, if desirability of the concept was established.

B. Purpose of this Report

1. To present the results of an in-depth investigation into the desirability and feasibility of the concept of using precoordinated subsystems as the basic building blocks in building construction, and of means of implementing the concept.

2. To present a feasible and comprehensive action plan for: (a) stimulating the development, marketing, and widespread use of a broad range of precoordinated subsystems; (b) minimizing legal and institutional constraints on the use of subsystems.

C. Conduct of Study

The study on which this report is based was carried out under the direction of a special Federal Construction Council Subcommittee comprising: Mr. George B. Begg, Jr., Public Buildings Service, General Services Administration (Chairman); Mr. Cameron L. Davis, Miller-Davis Company; Mr. George E. Distelhurst, Office of Construction, Veterans Administration; Mr. Leander Economides, Economides and Goldberg, Consulting Engineers; Mr. Louis A. Nees, Directorate of Civil Engineering, Department of the Air Force.*

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*Professor Jack B. Blackburn, Department of Civil Engineering, Kansas State University, also served on the Subcommittee up until the time of his retirement from the Building Research Advisory Board and the Federal Construction Council.

The Subcommittee first gathered together information, data, and opinions from knowledgeable persons in various segments of the building community on systems building in general, and on the FCC subsystems concept in particular. This information and opinion gathering part of the project was conducted in close accord with the plan of action for Phase I developed by FCC prior to initiation of the project. Basically, this part of the project involved a preliminary investigation of the feasibility of employing subsystems in federal construction programs and a series of meetings with representatives of various segments of the building community.

To carry out the preliminary investigation, the Subcommittee assembled a panel of representatives from the various agencies that participate in FCC, each having broad knowledge of his agency's construction program and of building technology in general. The panel was assisted in its efforts by specialists from the respective agencies in the fields of architectural, structural, electrical, and mechanical engineering. In carrying out their investigation, panel members devoted virtually full time to the project for a period of two months; the team of technical specialists contributed additional man-months of effort.

The panel first identified and classified a number of building subsystems that appeared to be suitable for functional and dimensional standardization. It then developed, in general terms, the functional and dimensional requirements that the identified subsystems would have to satisfy to be suitable for use on federal government projects. Next, it assessed the market potential within the agencies for the identified subsystems, and it outlined in general terms mechanisms for specifying, prequalifying, contracting for, and designing with subsystems.

Concurrent with this effort, the National Bureau of Standards made a preliminary survey for the panel to identify existing criteria and test methods that could form a basis for the evaluation and certification of subsystems identified by the panel. (The results of the panel's investigation are presented in Appendix A.)

The meetings with representatives of various segments of the building community were conducted by the Subcommittee itself. The groups with which the Subcommittee met were, in chronological order:

a. The Building Industry Manufacturers Research Council of BRAB

b. A group of some 200 individuals broadly representative of the building community, at a conference held under the joint sponsorship of the Producers' Council Inc. and Building Research Institute of BRAB

c. Representatives of various large public and private owners/users of building

d. Selected representatives of labor unions

e. Selected individuals affiliated with the contracting segment of the building community

f. Selected individuals concerned with building codes

g. Selected individuals affiliated with the design segment of the building community

h. Selected specialists in labor law and labor relations not affiliated with labor unions

i. Selected representatives of manufacturers of building materials and products

The BRAB staff arranged all meetings except for the conference sponsored by the Producers' Council and the Building Research Institute. All meetings followed the same general format. Mr. Begg, the Subcommittee chairman, began by briefly summarizing the objectives of the FCC project; he then directed a general discussion of the probable impact of implementation of the subsystems concept on the particular segment of the building community involved. (The results of these meetings are summarized in Appendix B.)

Finally, the Subcommittee prepared a report draft based on the results of the information and opinion gathering part of the study as well as the general knowledge and judgment of Subcommittee members. The Subcommittee's report draft was then submitted to the full FCC for review and approval.

D. Organization of Report

This report is divided into four main sections plus three appendixes: Section I, "Introduction"; Section II, "Conclusions," in which is presented without elaboration the conclusions of FCC regarding the feasibility and desirability of the concept of using precoordinated subsystems as the basic building blocks in building construction, and regarding means of implementing the concept; Section III, "Proposed Program for Phase II," in which is presented a comprehensive plan of activities for the implementation of the concept; Section IV, "Discussion," in which is presented the rationale supporting the conclusions; Appendix A, in which is presented the results of the preliminary investigation of the feasibility of employing subsystems in federal construction programs; Appendix B, in which the results of the meetings with the different segments of the building industry are summarized; and Appendix C, in which recent and current activities related to industrialized building are described.

II
CONCLUSIONS

The Federal Construction Council, on the basis of its analysis of information and expressions of views obtained through the investigation conducted during Phase I of the study reported here, has arrived at the conclusions presented below regarding: 1) the desirability and feasibility of the general concept of employing subsystems as basic building blocks in building construction; 2) the prerequisites to successful implementation of the concept; and 3) a strategy for implementation. A proposed program for Phase II of the project--developed by the FCC on the basis of the following conclusions--is presented in Section III, page 15.

A. Desirability and Feasibility of the General Concept of Employing Subsystems as Basic Building Blocks in Building Construction

1. The Need for New Initiatives to Achieve Adequate Productivity and Performance Gains in Building Construction

Dissatisfaction with the rate of productivity and performance gains in building appears justified. Building has not kept pace with developments in other producing segments of the economy, with the result that costs have risen dramatically and necessitated cancellation or drastic reduction in the scope of many construction projects. The inability to complete most construction projects within a time frame consistent with present-day demands of owners, and the inability to satisfy the demands for increased physical and functional performance of facilities, are increasingly calling the more conventional construction practices into question. The time required to design and construct facilities must be further reduced and significant performance gains must be realized, even while containing cost rises, if the building community is to meet contemporary demand.

2. Building with Subsystems: The Most Promising Alternative to the Traditional Process

A variety of new concepts for modifying both the technology and the processes of building have emerged in recent years. Many of these have been implemented at least to a limited degree and have been found to offer significant potential for improving productivity and/or performance. Of these, the one that appears to hold greatest promise of maximum benefit with fewest undesirable side effects is the concept of building with subsystems--wherein buildings are designed and erected using subsystems, supplied by manufacturers as preengineered, precoordinated packages, as the basic building blocks of construction.*

A number of subsystems are already available on the market and some buildings have already been constructed using subsystems almost exclusively. Such experience demonstrates that the concept is valid and that, given the proper circumstances, quality buildings at competitive and even lower costs can be produced in less time than with traditional processes; further, that the desired productivity and performance gains, and construction-time reductions, can be realized if there is more universal acceptance and implementation of this concept.

3. The Desirability of Widespread Implementation of the Subsystems Concept

Widespread implementation of the subsystems concept would require significant changes in the traditional practices and relationships in the building process. Effecting such changes would be both difficult and costly unless accomplished under a well-conceived coordinated plan. With such coordinated implementation, the benefits from the concept would, however, more than offset the cost penalties associated with the temporary disruptions these changes might bring about. Therefore, if coordination can be accomplished, widespread implementation of the concept would be in the best interests of the federal construction agencies, the U.S. building community as a whole, and the nation.

B. Prerequisites to Successful Implementation of the Concept

1. The Key to Successful Implementation: Owner/User

Successful implementation of the concept requires that it be accepted by all participants in the building process: owners and users of buildings, building designers (architects and engineers); manufacturers (particularly manufacturers of subsystems); contractors; code authorities; and labor unions. The

*In terminology frequently employed in the past by writers on industrialized building, under this concept the system (which is the building) would be considered "open" while most subsystems would be considered "closed."

key participant, however, is the owner/user; indications are that if the owner/user were convinced of the desirability of the concept, he would prevail upon his building designers to apply it, thereby creating a demand for subsystems to which manufacturers and contractors would respond. Then, through the joint efforts of manufacturers, contractors, designers, and owners/users, labor and code obstacles to implementation could be overcome.

2. Convincing the Owner/User of the Desirability of the Concept

The primary requirement for successful implementation is therefore to convince owners/users of the desirability of the concept. In order to be convinced, owners must be assured of cost, time, performance, and quality benefits from use of the concept.

3. Requirements for Ensuring Beneficial Results

To ensure beneficial results in terms of cost, time, performance, and quality, the concept must be implemented in such a way as to assure that:

a. Primary emphasis is placed on use of stock* subsystems so that the cost of developing a subsystem and tooling for its manufacturer can be distributed over a large number of projects.

b. There is significant direct competition among subsystems suppliers.

c. Contractual arrangements for and administration of projects involving subsystems are relatively uncomplicated.

d. There is widespread availability of subsystems that meet a broad spectrum of functional, dimensional, and aesthetic requirements.

e. Subsystems of various manufacturers can be intermixed in a variety of combinations with few, if any, problems of fit.

f. Procedures by which an individual owner is assured that a given subsystem is manufactured and installed properly and performs as desired are uncomplicated, inexpensive, and easily comprehensible.

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*As used here, the term "stock subsystem" means any subsystem, either currently available or developed in the future, that is designed and marketed to meet a broad, unspecified demand, in contrast to a custom subsystem designed specifically for a particular project.

g. Building designers can select and specify subsystems with a minimum of analyses of the detailed construction features of the various available subsystems.

h. Subsystems can be installed without encountering undue labor and code problems.

4. Action Needed to Satisfy the Requirements

The actions thought to be essential in satisfying the requirements outlined previously are as follows:

a. Identification of the general types of subsystem to be used in various building types--e.g., structural frame, space dividers, heating/ventilating/air-conditioning, ceiling, flooring

b. Establishment of dimensional, functional, and interface standards (based on a uniform dimensional discipline) for the identified subsystems, by which to ensure a high degree of precoordination and interchangeability of subsystems within and between building types

c. Establishment of a mechanism for evaluating and prequalifying* subsystems developed by different manufacturers and for publishing a list of approved subsystems

d. Promotion of the widespread acceptance of subsystems by owners/users and of the development of subsystems by manufacturers

e. Promotion of appropriate action by code authorities, standards organizations, and labor unions for implementation of the subsystems concept

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*Prequalification as used here implies:

1) Evaluating subsystems developed by different manufacturers for compliance with the standards specified in terms of performance, functions, dimensions, quality, and interface compatibility.

2) Cataloging, publishing, and updating of acceptable subsystems of different manufacturers.

C. A Strategy for Implementation of the Concept

1. Needed: An Organizational Framework through Which Building Owners/Users Can Institute Action

To ensure accomplishment of the specific required actions listed above, the actions must be taken in a coordinated manner in a comprehensive, continuing program conceived and directed by a formal organization having substantial influence on various segments of the building community. The organization that would best serve this purpose would be one comprised of building owners/users.

2. Composition and Financial Needs of an Owners/Users Organization of the Type Required

To successfully carry out the comprehensive program required, an organization of owners/users would have to: a) have an operating budget of at least $500,000 per year for at least the first five years of the program with, possibly, a slightly lower budget in subsequent years; and b) comprise a variety of owners/users, both public and private, whose aggregate construction programs represent a significant demand for a number of different types of buildings, without, however, involving so many owners/users or so many building types as to preclude quick action and efficient operation. Initially, the organization would probably function best with between 40 and 50 owner/user members, each having large annual construction programs, and with effort concentrated on approximately eight different types of buildings.

3. Genesis of the Organization

A building owner/user organization of the type envisaged currently does not exist. The probability of its creation without significant preliminary financing and development of an administrative and functional structure and charter on which it can expand and operate is remote.

The Federal Construction Council is in a unique position to provide the stimulus needed for the early formulation and establishment of an effective organization of building owners/users.

III
PROPOSED PROGRAM FOR PHASE II

Presented below are the general objectives of the program the FCC proposes to undertake in Phase II, the plan of action by which these objectives are to be met, and the schedule for carrying out the plan of action.

A. General Objectives of Phase II

1. Demonstration of the validity of the concept of using precoordinated subsystems as basic building blocks in building construction through development of:

    a. Technical and user requirements for a limited number of subsystems which could serve as the basis for the creation of future subsystem standards within the context of cost- and quality-effective manufacturing and assembly, and the building regulatory system.

    b. A basic framework of institutional relationships required for development and use of precoordinated subsystems.

2. Stimulation of and assistance to building owners/users having significant annual procurement volume, in developing and implementing an appropriate organizational framework through which they can effect, for the benefit of the building community and the public, the development, promulgation and maintenance of the necessary body of user technical standards and the establishment of those institutional relationships necessary for widespread implementation of the subsystems building concept.

B. Plan of Action

Phase II, like Phase I, will be carried out under the direction of a special FCC Subcommittee comprising three agency members and three BRAB members of the Council. The work to be accomplished in Phase II will be divided into three parts, two corresponding to the two general objectives outlined above, and a third involving the preparation of a final report. Details on the work are presented below; a tabular summary of the work is presented in Figure 1. The Subcommittee will be assisted by the BRAB staff, panels of technical and administrative specialists from the various agencies, and private consultants retained by the National Academy of Sciences. The work of the Subcommittee will also be coordinated with appropriate private organizations and state and local government agencies.

PART I

In order to demonstrate the validity of the subsystems concept through development of technical user requirements and the basic framework of institutional relationships required for development and use of precoordinated subsystems, the Subcommittee will:

1. Identify and define the basic subsystems into which up to three categories of facilities--multistory office buildings, hospitals, and low-rise, high-density residential buildings--should be divided, and establish an overall dimensional discipline for the design of such facilities when subsystems are employed.

   This task will be performed for the Subcommittee by a panel of agency building design specialists, working with a private consulting A-E firm selected in accordance with NAS procedures. Work on previous systems projects will be heavily relied upon for guidance. In the course of the effort, meetings will be held with representatives of all major elements of the community, including manufacturing firms with subsystems experience and selected private owners/users, to ensure that the results are compatible with practice in the private sector of the economy.

2. Develop dimensional, functional, and interfacing requirements for a selected number of the subsystems identified in item 1 above. This task will be performed for the Subcommittee by the same people and in essentially the same manner as for item 1 above.

3. Devise a mechanism for evaluating subsystems and publishing a catalog of acceptable subsystems, and develop a recommended method of contracting for and managing construction projects in which subsystems are employed. This task will be performed for the Subcommittee by a panel of agency technical experts with the advice of procurement specialists. The work of this panel will be coordinated with the work of the panel of agency building design specialists (see item 1) and with appropriate private organizations to ensure that the results are compatible with practice in private industry.

4. Establish liaison with standards organizations and building code authorities to facilitate acceptance of prequalified subsystems.

   This task will be carried out by the Subcommittee. The work will be accomplished primarily through meetings with the major standards organizations at which the nature of the FCC project will be explained and the technical requirements developed for the subsystems will be presented to determine their compatibility with current standards. Also, every effort will be made to stimulate action on the part of standards organizations and code authorities to accommodate the subsystems concept of building.

5. Establish liaison with labor unions to identify potential labor problems associated with use of prequalified subsystems and to assist in the resolution of such problems.

   This task will be carried out by the Subcommittee in essentially the same manner as outlined in item 4 above. If major problems are encountered that inhibit implementation of the subsystems concept, the Subcommittee will make every effort to resolve the problems or to suggest how best to address them in the future.

6. Devise a mechanism for dissemination of requirements and lists of prequalified subsystems to manufacturers and private owners/users. This task will be carried out by the Subcommittee.

7. Determine realistic estimates of the market potential for different subsystems. This task will be carried out by the Subcommittee, working with federal agencies and private owners/users, and through questionnaires.

PART II

In order to stimulate and assist building owners/users in developing and implementing an appropriate organizational framework for implementing the subsystems concept, the Subcommittee will:

1. Assist in determining the specific nature and form that the proposed organization should take, and how it should be created.

   This task will be carried out by the Subcommittee. In accomplishing this task, the Subcommittee will arrange a series of meetings of selected building owners/users having large annual construction programs. Among matters to be considered at the meetings will be:

   a. Whether the organization should be independent or affiliated with some existing organization

   b. How direction and control are to be effected

   c. Functions

   d. Staffing

   e. Funding

2. Prepare and distribute to prospective participants a detailed prospectus outlining the suggested purposes, structures, and administration of the proposed organization and a synopsis of the related work outlined in Part I of the program, and requesting support for and participation in creating the organization.

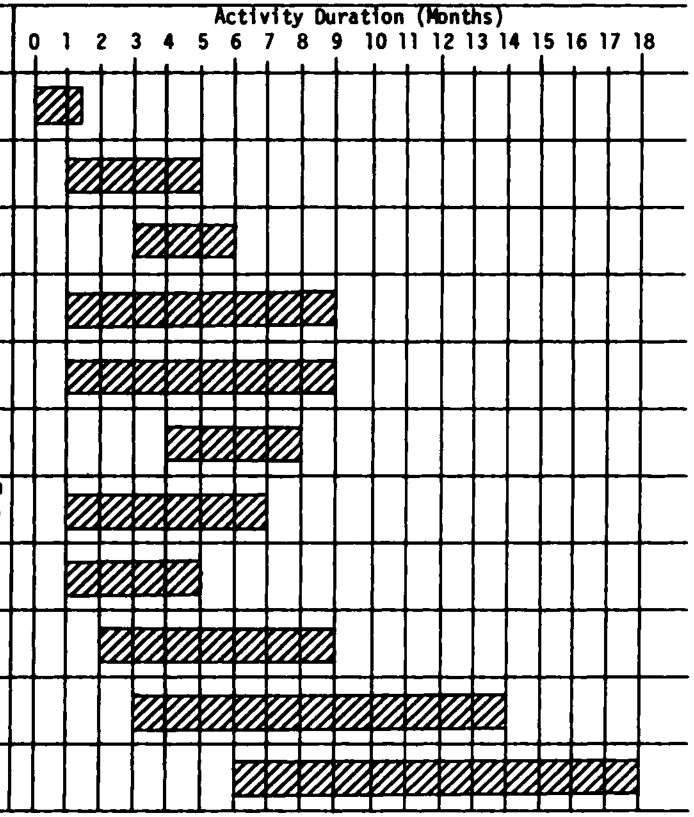
   This task will be accomplished by the Subcommittee.

3. Evolve a means of bringing potential participants together to obtain funds.

   This task will be accomplished by the Subcommittee.

FIGURE 1. SUMMARY CHART OF ACTIVITY SCHEDULE FOR PHASE II

Part	Step	Activities	Activity Carried Out By
I	1	Identify subsystems	Agency building design specialists, Private consulting firm
	2	Develop standards for subsystems	Agency building design specialists, Private consulting firm
	3	Establish Procedures for evaluation and cataloging of acceptable subsystems	Agency technical experts and procurement specialists
	4	Establish liaison with code authorities	Subcommittee
	5	Establish liaison with labor union officials	Subcommittee
	6	Establish mechanism for dissemination of information	Subcommittee
	7	Determine market potential for subsystems	Subcommittee, Agency program specialists, Representatives of owners/users
II	8	Determine nature and form of owners/users organization	Subcommittee, Private owners/users
	9	Prepare prospectus on organization	Subcommittee, Private owners/users
	10	Elicit membership and firm commitment of funds from potential owners/users	Subcommittee, Private owners/users
III	1	Completion of final report	Subcommittee



IV
DISCUSSION

A. Desirability and Feasibility of the General Concept of Employing Subsystems as Basic Building Blocks in Building Construction

1. Need for New Initiatives to Achieve Adequate Productivity and Performance Gains in Building Construction

The traditional building construction process--that process which has been in general vogue for decades in the United States for the construction of most types of buildings, with the notable exception of single family residences--has not produced the needed productivity and performance gains. The traditional process can best be described as one in which the services and products of several different types of independent organizations are combined in a sequential manner to provide a building owner/user with the facility desired. First the professional design team--architect and engineers--prepare plans and specifications, usually in considerable detail, based on the expressed needs and desires of the user. Then, under one or more types of agreement, constructors execute these plans and specifications, bringing together the materials and products made available by manufacturers through a distribution system geared to the process.

As used here, the term "process" refers to the organizational arrangements and divisions of responsibility relating to the creation of physical facilities. It specifically does not refer to the "technology"--the physical elements of buildings and the way they are brought together in a physical sense. Unlike the process, which for the great bulk of construction has not changed substantially, the technology of construction has been changing constantly and, for the most part, such change has been readily accepted and employed within the traditional process--albeit somewhat slowly at times. Hence, although modern buildings are vastly different in design and construction from those created 100 or even 30 years ago, the relationship between owners, designers, contractors, and manufacturers has changed little except at the cutting edge of experimentation. The traditional process has endured partly because it is highly institutionalized. Various corporations, societies, unions, and associations have evolved to deal with construction-related matters through the traditional process, and in the course of evolving have developed and refined complex rules and operating procedures, some of which are even reflected in law. Obviously, basic changes in such deeply rooted practices are not made easily.

The traditional process of construction has also endured because, unquestionably, it has provided consumers with the type of facilities desired at a price most could afford to pay. Unlike most other highly developed industries in the United States, the building industry, organized on the basis of the traditional process, has provided consumers with a custom-designed product as a matter of course. Being able to obtain facilities tailored in significant ways to one's needs and desires has naturally had continuing appeal to consumers, particularly since the cost penalty for such custom design has not been readily obvious.

Within the past few years, however, an increasing number of people in the building community have begun to question whether the traditional construction process is sufficiently effective and efficient. The process has been questioned from at least three basic viewpoints: Costs are now too high and rising far too rapidly; it takes too long to get a facility built; and the quality of buildings, considering the ever-increasing degree of sophistication required, is too low. The validity of such criticism is difficult either to substantiate or refute since too few data are available on possible alternatives to the traditional process to permit comparisons. However, subjectively and on the basis of available evidence, the criticisms seem valid. Specifically:

> It has been well documented that construction costs have risen sharply during the last few years; for example, the Engineering News Record's Building Cost Index in June 1971 was more than 40 percent higher than in June 1967, for an average annual increase of more than 10 percent for the four-year period. This is, of course, considerably in excess of the increase in the cost of living index for the same period. Labor union officials do not believe that construction cost increases have affected construction activity; however, many owners and designers have indicated that those cost increases have caused numerous projects to be either canceled or reduced in scope because of insufficient funds.
>
> All the unusually rapid increases in building costs over the past few years cannot legitimately be blamed on the traditional construction process. However, it seems apparent that the decentralized manner in which business is conducted under the traditional process makes it very difficult for individual

companies in the building industry to resist wage demands and, equally important, for technological changes to be made quickly to compensate for such cost increases. Further, the demands for higher performance and amenities do not abate simply because they add to cost, nor are they readily translatable into increased return on investment. Again, increased efficiencies in the process and in technology are looked to for compensation or at least for a major contribution to maintaining balance.

Owners in general and federal agencies in particular have shown growing awareness of the fact that foreshortening the time to occupancy can be of considerable economic value to the owner. Many owners have therefore tried to speed up the traditional production process. Efforts to reduce time within the traditional process have been generally unsuccessful. Significant reductions in time have been achieved through such devices as "phased construction" (see following section). However, these approaches are not universally applicable and often require compromises in design that are unacceptable to owners. It now appears that time reductions in fabrication and installation under the traditional process cannot be reduced below a certain minimum and that this minimum is rapidly being approached. It is unlikely, therefore, that significant new time reductions under the process will be possible.

Every group with which the subsystems project has been discussed cites poor quality as a major problem in the building industry. Not unexpectedly, poor workmanship by mechanics was cited as a major contributing factor by many, including labor union officials. However, poor work by architects, engineers, and contractors also was cited. Since it is reasonable to assume that most mechanics, architects, engineers, and contractors are conscientious individuals who perform as well as possible, the reason for poor performance must be the circumstances surrounding the traditional construction process. The root cause of poor quality is undoubtedly that, as construction costs have risen, the various organizations in the industry have tried to cut corners wherever possible, resulting in an inevitable but unintentional drop in quality. Therefore, inasmuch as costs under the traditional process are already unacceptably high, even with sacrifices in quality, it is obvious that the level of quality achieved through the traditional process is not likely to improve.

On the basis of its evaluation, therefore, the FCC has concluded that new initiatives are necessary and that these will take the form of seeking alternatives to the traditional construction process.

2. Building with Subsystems: The Most Promising Alternative to the Traditional Process

Various alternatives to the traditional construction process already have been suggested and at least experimentally applied. A number of these concepts appear to offer benefits in one or more respects. Notable examples are:

a. "Turnkey" construction, wherein an owner lets a contract with a single organization to design and erect a facility

b. "Phased" or "fast-track" construction, wherein construction is started on the building before the design of the total building has been completed

c. "Construction Manager" concept, wherein the owner retains, on a professional basis, a construction organization to direct execution of the project from design through construction, either alone or in tandem with a design professional

d. Use of "two-step procurement," which is similar to "turnkey" except that the design-construction team is selected on the basis of elicited proposals

Building with subsystems--i.e., designing and building with subsystems supplied as preengineered packages by various manufacturers appears to hold greatest promise for productivity and performance gains with least undesirable side effects, and it can be usefully integrated with any one of the above alternatives. The key feature of the subsystems concept is that responsibility for design, production, distribution, and perhaps even installation and maintenance of subsystems would rest with the manufacturer. This assignment of more responsibility to manufacturers would have significant ramifications in relation to organization of the building community. Among other things, building designers (professional architects and engineers) would be relieved of much of the immediate responsibility they now have for the detailed design and specification of individual elements of buildings. Implementation of the concept could alter the role of contractors in that they would concern themselves more with management and assembly and less with the purchase and fabrication of a wide variety of materials and products from different suppliers. Most individual parts would become elements in subsystems supplied by manufacturers.

The benefits to be expected from use of the subsystems concept are numerous. For example:

a. The time and cost of building design would be significantly reduced--or design quality significantly increased, or both--because building designers would no longer need to devote such a large portion of their time and fee to routine detailed design of essentially "hardware" elements.

b. The efficiency of onsite construction would be increased and construction time reduced, because the subsystems being installed or assembled would have been more carefully and thoroughly engineered than are most building elements presently used.

c. The time required to train onsite construction workers would be reduced, thereby helping to alleviate the shortage of skilled labor, since the requirements for expertise in the various trades would be less.

d. The quality of the finished product would be less subject to variation because of more careful preengineering and quality control in manufacture.

e. Control and estimating costs would be more accurate since the major element of buildings would be supplied as packages.

That the subsystems concept is feasible, at least for a large segment of building volume, is demonstrated by the fact that the subsystems approach has in essence been successfully employed (under various names) in a number of different projects in the U.S. and Canada (see Appendix C). Although it is doubtful that the manner in which the concept was implemented in these projects would be appropriate to the needs of most owners/users, the fact that the concept has been used with good results is an indication that it offers the productivity and performance gains being sought.

Further evidence of the soundness of the concept is provided by the fact that some subsystems are already being produced and are in general use in building, notable examples being metal curtain walls and elevators. As a matter of fact, it could be argued that the concept is merely a natural and logical extension of the long-term trend toward using bigger and more complex building blocks (or components) in construction and toward transferring responsibility for design and fabrication of building elements from building designers and contractors to manufacturers.

3. The Desirability of Widespread Implementation of the Concept

If, as seems apparent, the subsystems concept offers significant advantages over the traditional construction process, and the concept is feasible, the logical question is: Should not the concept be widely implemented at the earliest possible time?

The answer is not as obvious as it might seem, for widespread implementation of the concept could not be achieved easily. In order to achieve widespread use of the concept, a number of significant changes would have to be made in the basic patterns of business in the building industry--changes, for example, in the types of products produced by manufacturers and in the manner in which products are marketed; in the way architects and engineers design buildings; in the relationships between building designers, contractors, and manufacturers; in the way building codes are written and enforced; and in labor agreements.

Obviously, effecting such fundamental changes would be both difficult and costly, and this undoubtedly is the reason the subsystems concept has not already supplanted the traditional process. Assuming, however, that appropriate machanisms could be found for effecting the required changes, the question becomes: Would the benefits resulting from widespread implementation of the concept justify the costs in dollars and disruptions? The Federal Construction Council believes the answer is yes, provided the plan of implementation is carefully conceived and adroitly executed.

B. Prerequisites to Successful Implementation of the Concept

1. The Key to Successful Implementation: The Owner/User

The key to successful implementation is the owner/user, since it is he who controls the market and thus, if he chooses, can set in motion the chain of events leading to acceptance of the subsystems concept.

The chain starts when an owner/user insists, as he has a right to do, that the building designer base his design on the use of subsystems. Most designers will eventually accede to a client's wishes, provided the results will be safe and reasonably acceptable aesthetically. In the case of subsystems, indications are that most designers would apply the concept willingly, and frequently even voluntarily. Designers have generally shown no reluctance to use the few subsystems already available (e.g., elevators), and have indicated great concern about current problems in the building industry and an open-minded attitude toward acceptance of new ideas aimed at solving those problems.

Working through the designer in this way, users would in effect create a market for subsystems to which manufacturers and contractors would be motivated to respond, and indications are they would respond readily.

Though manufacturers indicated that widespread implementation of the concept would significantly affect their operations and require that they change some of their marketing procedures, most also indicated that, given a market, they would respond. Manufacturers who have already had some experience with subsystems indicated that such problems can be worked out. Like designers, manufacturers generally indicated concern about and willingness to try to improve the building industry.

General contractors indicated that they could easily adapt to the use of subsystems and that, if called for, they would install them. Subcontractors, however, indicated considerable uneasiness about implementation of the concept due to concern that their role in construction would be reduced to merely installing. However, they seemed to recognize that some changes are inevitable and that they would have to adapt. Some indicated that some subcontractors might actually become the developers and suppliers of subsystems, competing with or supplanting manufacturers in this role. In any event, the general impression was that subcontractors would not impede use of subsystems if specified.

Labor unions and code authorities present a different problem since they need not respond rapidly to the marketplace and hence to the owner/user. Both segments indicated that implementation of the concept would necessitate changes in their operation that in some cases might be difficult to effect. However, both also indicated that a concerted effort for implementation on the part of the other segments of the industry would produce some of the needed changes. The nature of the changes required are, of course, different for codes and labor.

Most building codes are written around the use of materials and parts, the specification of which is under the control of a registered professional designer. Codes for the most part do not provide a routine procedure for approving subsystems, the design and installation of which is determined by a manufacturer. Most code officials indicated that in the long run basic changes could be made in codes to permit ready use of subsystems, and that efforts toward this end have already been undertaken. They noted, however, that in the immediate future subsystems would have to be handled as exceptions.

For labor unions, problems relating to the subsystems concept would come mainly from local union opposition to prefabrication and use of laborsaving techniques and equipment, plus jurisdictional disputes between different craft unions. Both union officials and nonunion labor specialists indicated that satisfactory mechanisms* are now available to settle jurisdictional disputes and that such disputes should present no insurmountable problems for subsystems. Union officials also indicated confidence that solutions could be found to local opposition to technological progress through bargaining. Labor specialists not affiliated with unions were much less optimistic on this point. They expressed particular concern about the possibility of secondary boycotts occurring and most felt that some legislation would be needed to resolve these problems.

In any event, the consensus was that the speed with which labor and code problems are resolved would be greatly increased if owners/users expressed active interest in such problems.

2. Convincing the Owner/User of the Desirability of the Concept

The owner/user being the key to obtaining broad acceptance and use of the concept, the primary goal must be to convince the average owner/user that the concept offers him sufficient benefits to justify his exerting influence to promote and implement the concept.

To owners/users, the concept would be worth the effort if, compared with the traditional approach to construction and other approaches, it resulted in significant net benefits in matters that concern them most: cost, time, performance, and quality.

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*In this Context, it will be of interest to note the relief obtainable under the National Labor Relations Board's "right-of-control" doctrine. This is a test used by the NLRB to determine whether an employer is, in fact, a neutral in instances of refusals to install a factory-built component; i.e., a product boycott. "Right-of-control" means that the NLRB will find it unlawful for a union to engage in any such boycott where control of the work to be performed and control of the employees who are performing the work is split between two employers. Where this occurs, union pressure against either employer is unlawful. For example, if an architect or engineer specifies a factory-made product and a contractor both purchases the product and installs it, there is a split in control. The contractor has no control over the work to be performed because he is bound by the specifications. However, if the contractor has a choice as to whether to use a factory-made product or to assemble the product on the job, there is no split in the right of control and many union pressures on the contractor are permitted.

In other words, the cost of construction must be as low or lower; the time to design and erect a building must be equal to or less; the performance and quality of buildings must be equal to or better than with traditional construction or some other proposed approach.

Significant benefits in all four areas would not be required to convince owners/users of the desirability of the concept. However, the concept would not be acceptable if it were at a significant disadvantage in any respect.

3. Requirements for Ensuring Beneficial Results

Cost, time, performance, and quality are affected by many interrelated factors and variables, the net impact of which on any specific project cannot be predicted on the basis of generalizations. However, through discussion with representatives of various segments of the building industry and general analysis of the construction process, a number of requirements have been identified which are believed to be essential to ensure that the majority of owners/users realize benefits from the use of subsystems. These are:

a. That implementation of the concept be predicated on use of stock subsystems (i.e., not specially designed for a particular project) so that the cost of developing subsystems and tooling for their manufacture can be distributed over a large number of projects. Manufacturers were virtually unanimous in reporting that the development and tooling costs for a new subsystem are very high, with amounts in excess of a million dollars not being unheard of. Obviously, costs of such magnitude cannot be absorbed in a single project, unless it is an exceptionally large one, and still permit subsystems to compete successfully with traditional construction. That this is usually the case is demonstrated by the fact that development costs for several new subsystems used in the California "School Construction Systems Development" project* were so high that they were not recovered until the subsystems could be sold on subsequent projects.

b. That there is significant direct competition among subsystem suppliers. The value of competition in holding down prices is widely recognized. Manufacturers have argued, however, against the creation of too much direct competition principally on the grounds that such competition would reduce profits to the extent that risks would have to be minimized and, as a result, innovation would be retarded. It is also

*See Appendix C.

generally agreed, however, that if subsystem suppliers were to seek higher profits on subsystems than is now obtained with traditional construction, the price advantage for subsystems would be lost. It appears essential, therefore, that there be significant direct competition among subsystems suppliers even, if necessary, at the risk of sacrificing some innovation. (That competition would retard innovation is not conceded by everyone in the building industry; some contend that competition spurs innovation.)

c. That contractual arrangements for and administration of projects involving subsystems be relatively uncomplicated. Most of the systems projects undertaken to date have required complex contractual arrangements, frequently involving multi-faceted relationships between several manufacturers, and/or very tight control and administration of the project by the owner or his representative. Although projects usually turned out satisfactorily in the end, the complex arrangements required created numerous problems that the average owner is neither able nor inclined to cope with. There was also a significant increase in the lead time for the projects--time the average owner usually either does not have or would not be willing to give. To be acceptable to a broad spectrum of owners, the subsystems concept must be usable with contractual and administrative procedures no more complex than those used presently with traditional construction.

d. That there is widespread availability of subsystems that meet a broad spectrum of functional and aesthetic requirements. Owners/users have a very wide variety of needs and desires in buildings, as demonstrated by the almost limitless variation in the style, shape, size, and layout of buildings throughout the nation. Although some of this variation is undoubtedly unnecessary, stemming only from the vast array of building products available, most variation results from legitimate differences in needs, judgment, and taste.

   In order to satisfy the needs of a broad spectrum of owners/users, therefore, it is essential that there be a wide variety of subsystems. That such variety is necessary was verified by the panel of agency personnel, which endeavored, on the basis of functional requirements, to classify building subsystems into categories that together would satisfy a significant range of the needs of federal agencies. The panel found considerable variations in essential functional requirements both within individual agencies and among different agencies.

e. That it is possible to mix subsystems of various manufacturers to obtain many different combinations with a minimum of field problems. To satisfy a broad spectrum of users, it is not sufficient merely to have available a wide variety of subsystems. User needs require mixing of subsystems of different types in various combinations. Also, subsystems may have to be mixed with traditional construction. If variety is not to lead to high cost, the necessary mixing will have to be achieved with only minimal field adjustment.

f. That the procedures by which an individual owner is assured that a given subsystem is manufactured and installed properly and performs as desired are uncomplicated, inexpensive, and quick. With traditional construction, an individual owner is reasonably assured of receiving the desired level of quality because the building designer indicates through plans and specifications, normally in fairly explicit terms, what parts and materials are to be used and how they are to be installed. Further, that either the building designer or some other representative of the owner continually or periodically oversees the work of the contractors to ensure that plans and specifications are followed. Although disagreements about levels of quality occur frequently with traditional construction, most often because of conflicting interpretations of plans and specifications, generally the system works satisfactorily and, even more important to the owner, it is uncomplicated, inexpensive, and not unduly time-consuming.

   It appears that the subsystems concept requires quality control at least as effective, as uncomplicated, as inexpensive, and as quick, as with the traditional process.

   Such criteria would appear to rule out, for example, use by most owners of the approach employed in some closed-system projects, which entails submission by the manufacturer of detailed test data to prove compliance with complex performance specifications, and detailed analyses of those data by the designer prior to construction.

g. That building designers can select and specify subsystems without making a lengthy, detailed analysis of the various subsystems available. Under the subsystems concept, design should be simpler, less expensive, and quicker than under the traditional construction process--provided the designer does not have too difficult a task finding what subsystems are available, what their characteristics are, and in what combinations they can be used. If such tasks are difficult, as has been the case in most past projects where subsystems have been used (e.g., Toronto's "Study of Educational Facilities

Project*), then the design process with subsystems would be even more difficult and costly than with traditional construction. Few owners would then be inclined to support the concept.

h. That subsystems can be installed without encountering undue labor and code problems. An important and frequently overriding need of an owner is to have his building finished on or close to the scheduled date of completion. In almost all cases, a delay in occupancy costs the owner money; in some cases any significant delay would massively disrupt the owner's operations. Because of this, few owners are willing to use unproven ideas that might cause delays. Two principal sources of delay are labor problems and problems in obtaining necessary approvals from local building-code authorities. Thus building owners are usually very cautious about employing a new idea if it appears likely to cause problems with labor unions or code authorities. In order to assure owners that use of the subsystems concept will not cause time delays, the concept must be shown to be generally acceptable to labor unions and code authorities.

   Acceptance of the subsystems concept by labor unions and code authorities is also required in order to realize the potential cost benefits. If either manufacturers or contractors anticipate labor or code problems on a project, they automatically and justifiably increase bid prices to provide for resolution of such problems. It is likely that any significant price increase for this reason would make subsystems noncompetitive with traditional construction, which would in turn make the subsystems concept unacceptable to owners.

4. Actions Needed To Satisfy the Requirements

Most of the requirements outlined above for ensuring beneficial results to owners/users from the subsystems concept are unlikely to be satisfied through natural developments in the marketplace--at least not for many years. For the most part, the requirements will be satisfied only if certain specific actions are taken. The actions thought to be essential are itemized below.

a. Identification of the various types of subsystems needed by users. The most basic task is to establish the general types of subsystem to be used in various types of building -- e.g., partitions, structural frames, exterior walls, heating/ventilating/air-conditioning, plumbing, ceilings, roofs. Establishment of this breakdown is of vital importance because

*See Appendix C.

it is the necessary basis for all subsequent work with subsystems in general and for the work to be carried out under item b, below, in particular.

The task will be somewhat difficult and controversial because there are various opinions concerning the optimum way of subdividing different types of buildings into subsystems. Such differences were brought to light in the work of the panel of agency personnel (Appendix A) where, for example, strong disagreement was found as to whether ceilings and partitions should be considered separate subsystems or one subsystem, and whether floor decks should be considered as a separate subsystem or as part of either the structural subsystem or the ceiling subsystem, and whether the ceiling subsystem should include part of the heating/ventilating/air-conditioning subsystem.

Although difficult, the task of getting general agreement on the manner in which buildings are to be subdivided nevertheless must be accomplished if any progress is to be made in promoting the subsystems concept. Based on prior efforts to identify building subsystems, it appears that the task will entail, first, categorizing by type, function, size, shape, and general method of construction those types of building that are constructed in large numbers in the U.S.; second, determining for each type the way in which the building is to be subdivided into subsystems; and third, collating the various identified subsystems for different types of building to permit comparison of subsystems serving the same general purpose.

The process would, moreover, have to be repeated periodically since the user-needs change and building technology advances. The task should be less difficult, however, once it has been done the first time.

b. Establishment of functional, dimensional, and interface standards for identified subsystems. While it is most difficult to develop functional, dimensional, and interface standards, such standards are essential to ensuring that subsystems of different manufacturers can be intermixed, that there is competition, and that design and quality control can be carried out with relative ease and dispatch.

As used here, the term "functional standard" means a standard that defines the specific functions and functional characteristics and related levels of performance and quality required of identified subsystems. Such standards are believed necessary for subsystems so that designers may specify subsystems by some general designation related to a standard, with confidence that the subsystem supplied will satisfy certain functional needs, will possess certain minimum functional characteristics, and will be functionally compatible with other subsystems. Such standards would thereby serve to provide a basis for ensuring and stimulating fair competition among subsystem suppliers and to make relatively easy the job of the designer in selecting and specifying subsystems.

Without such standards, similar subsystems produced by different manufacturers would tend to have differing functional characteristics which would tend to render them functionally incompatible with other manufacturers' subsystems. Such a situation would preclude much mixing of subsystems, would restrict competition among subsystem suppliers, and would require building designers to make a lengthy analysis prior to preparing specifications in order to determine which available subsystems possessed the functional characteristics they need, and of these which could be mixed.

When the idea of functional standards was suggested to manufacturers, few were enthusiastic. However, most conceded that such standards would probably be needed, that there is already precedent for such standards, and that the standards would not unduly hamper manufacturers' initiative, provided the standards are based on performance.

Similarly, owners and designers with whom the idea was discussed were generally convinced of the need for functional standards in the subsystems concept, and indicated that the standards could be successfully employed if they were developed in such a way as to provide for the great variation in user needs.

In order to develop functional standards that satisfy the needs of owners, designers, and manufacturers, it will be necessary to identify and classify user requirements for each of the types of subsystem identified previously. Physical properties and performance characteristics relating to these requirements will then have to be determined and appropriate values assigned.

The term "dimensional standards," as used here, refers to standards in which are set forth the rules governing such matters as: (1) the spacing and dimensioning of and the dimensional tolerances on those subsystem elements (e.g., columns) that intersect with other subsystems (e.g., ceilings); (2) the amount of space to be provided for various subsystems (e.g., the space below the underside of the floor deck to be allocated to the ceiling subsystem); (3) the critical dimensions of a subsystem from a design standpoint (e.g., partition heights and floor spans).

The necessity of such standards is believed to be self-evident: without them most subsystems would have to be custom designed and specially fabricated for each project, or, alternatively, only a limited number of subsystems could be used on any given project with the rest of the building constructed around them by traditional means, which is the present situation.

Considerable work has already been done on dimensional standards, notably by American National Standards Institute Committee A-62 on Precoordination of Building Components and Systems. However, most such work has been concentrated on development of standards for a basic module (4 inches) and its multiples. For the purposes of the subsystems concept, this basic work will have to be expanded--possibly with the assistance of Committee A-62--to provide specific dimensional standards for subsystems. This will involve analysis of general user requirements as well as functional standards for specific subsystems.

The term "interface standards," as used here, refers to standards on the nature of the boundary surfaces of different subsystems where they come together, and on the manner in which one subsystem may be joined to another. Such standards are needed in order to ensure that stock subsystems of various manufacturers can be mixed without need for factory or field modification.

While the need for interface standards is not hotly disputed by any segment of the building industry, several manufacturers have warned that interface standards will be difficult to develop and that, in many cases, subsystems designed to such standards will be less efficient (i.e., overdesigned) than subsystems in which the interfaces have been custom designed.

c. Prequalification* of subsystems. As might be inferred from the preceding discussion, the standards required for implementation of the subsystems concept will be extensive, technically complex, and involve in some cases problems of coordination of standards with the regulatory authorities. Because of this, the average owner/user and designer would neither be competent nor have the time to make a thorough evaluation of each subsystem proposed for use on his project. In addition, it is almost certain that there will be some serious errors and uncertainties in the standards when they are first issued, which will have to be corrected quickly in order to avoid causing confusion in the industry. Reliance on individual

*See page 9.

owners/users and designers for evaluation of subsystems would virtually preclude quick identification of problems and issuance of revised standards.

An organization should be designated to undertake the task of evaluating and prequalifying subsystems for use. Thus (1) individual owners and/or their designers would be spared the difficult job of evaluating subsystems; (2) means of quick identification and solution of errors in the standards would be provided; (3) suppliers would not have to convince individual owners and designers that subsystems did in fact meet the standards; and (4) code problems could be resolved at the same time prequalifications were made.

The task would of course be somewhat difficult and possibly costly, involving the establishment of procedures for detailed evaluation of proposed subsystems, issuance of certificates of acceptability, and spot checking to ensure that the subsystems being installed are the same as those approved. Not only is the effort justified, but without it too few owners/users would, because of unwillingness to do the evaluation required, be willing to use subsystems to ensure widespread application of the concept.

d. Promotion of the widespread use of subsystems by users and of the development of subsystems by manufacturers. Merely having standards and a mechanism for prequalifying subsystems will not of course ensure widespread application of the subsystems concept. It is also of fundamental importance that there be a substantial demand for and an abundant supply of subsystems.

Manufacturers have indicated that they would be unwilling to invest large amounts of money in the development of subsystems until they are assured of a reasonably large continuing market. Users, on the other hand, would be unwilling to insist on use of subsystems until an abundant supply of subsystems is available.

The problem is how to create, almost simultaneously, both a supply of and demand for subsystems. The first step, as discussed previously, is to develop and implement the concept in such a way as to ensure significant benefits to users, and this, of course, is the main thrust of the other actions discussed above. The next step is to convince a significant number of manufacturers that a large market for subsystems exists. The mere existence of standards reflecting the needs of the owners/users would serve in part to accomplish this end; additional indications of the existence of a market would also probably have to be provided. An effective means of doing so would be through a series of conferences in various parts of the U.S. to explain the concept and its potential advantages to owners and to elicit from participants an indication of willingness to use subsystems.

The final step--assuming that at least some manufacturers submit subsystems for approval, which seems likely--would be to publicize the prequalification of subsystems to both manufacturers and users. Such a promotional effort would have to be carried out for only a short period of time. Once a significant number of manufacturers have developed and marketed subsystems, they may be expected to assume responsibility for promotion of their product.

e. Promotion of appropriate action by code authorities, standards organizations, and labor unions necessary for the implementation of the subsystems concept. As noted earlier, labor union and code authority officials have expressed confidence that labor and code problems relating to the subsystems concept could be resolved over a period of time. Other segments of the industry have expressed either skepticism that the problems could in fact be resolved or doubt that the solutions could be developed, through natural evolution, in a short enough period of time to permit orderly implementation of the subsystems concept.

On the good chance that the skeptical estimate of the situation is the accurate one, a coordinated effort would have to be undertaken to obtain acceptance of the subsystems concept, or to stimulate change to accommodate subsystems, by labor unions and code authorities. It is believed that the desired acceptance and change might, in many instances, be obtained merely through a promotional effort aimed at explaining the concept to labor union and code authority officials. Such an effort would of course have to be designed to complement the continuing efforts of manufacturers and contractors to effect desired change in codes and union work rules.

If the promotional effort should fail to obtain voluntary acceptance or change, some other approach would be required. Relief through legislation is one possibility. Such action would, however, probably be taken only as a last resort, if all efforts to obtain the necessary cooperation through discussion and negotiation had failed. Another possibility for solving code problems would be promulgation of subsystems standards as nationally accepted standards by one of the established standards organizations. With such status, subsystem standards and subsystems themselves would probably be more readily accepted by code authorities. Even in the absence of code authority opposition to subsystems, obtaining formal recognition of subsystem standards might be desirable in the interest of promoting general acceptance of the concept.

C. An Appropriate Strategy for Implementation of the Concept

1. Needed: An Organization of Building Owners/Users

As already stated, widespread acceptance and use of building subsystems would appear to be in keeping with the general trend in which the building industry is moving as a whole. Movement in this direction, however, is painstakingly slow because significant changes in established practices are involved. Understandably, such changes are met with reluctance on the part of special or limited interest groups of the building industry due--significantly and perhaps totally--to the fact that their risk and responsibility after the changes are not made clear or are increased. Consequently, it is exceedingly difficult--in the absence of no more motivation than exists today--to expect manufacturers, designers, contractors, labor unions, code authorities, and other segments of the building industry to initiate in the near future, either individually or collectively, the actions required to stimulate widespread acceptance and use of building subsystems.

If the requirements proposed in the preceding section are to be met, some organization is required to implement a well-coordinated and comprehensive program directed at ensuring that requirements are adhered to and that interest and action are stimulated among the various segments of the building industry to be involved or affected. The type of organization most likely to be sufficiently motivated to effect widespread acceptance and use of building subsystems at the earliest possible time would be an independent membership organization of building owners/users--both public and private. First, such a group could marshal a concerted force from that significant segment of the building industry that could have the most to gain from the use of subsystems; second, because of their purchasing power, building owners/users are in a position to encourage other segments of the building industry to accept desirable courses of action; and finally, building owners/users significant financial investment would place them in the position of wanting to assure positive results from the program.

The financial and other benefits to be accrued from the development of such an owners/users organization were explored with some of the nation's leading private corporations and with some local government agencies having large annual construction programs (see Appendix B). Generally, they voiced an interest in dealing more effectively with the growing problems being encountered with traditional construction and described their various efforts to control costs, to speed up the schedule of construction, and to improve quality. They acknowledged that the availability and widespread use of subsystems could resolve many of the current and growing problems and expressed their willingness to join with federal agencies in a suitable program. It was also noted that other owners/users having similar needs might well be involved, resulting in maximum benefits for all.

The idea of an owners/users organization was given further exposure during meetings held with labor, contractors, code authorities, designers, and manufacturers. No evidence from meetings indicated that any sector of the industry was so opposed to the idea that active resistance to such change would cause particular problems in establishment of such an organization.

2. Composition and Financial Needs of an Owners/Users Organization

The effectiveness of the owners/users organization of the type envisaged would appear to depend very much on the composition of its membership and the finances available.

a. Composition

It is recognized that the objectives of the owners/users organization can be best met by having a large and diversified group of owners/users representing a variety of interests. However, enlistment of the vast number of building owners/users in the U.S. in the proposed organization would be difficult. Even if such participation were possible, the organizational and administrative problems involved would be considerable. A more realistic approach would be to develop an organization around those building owners/users having a significant demand for a number of different types of building (e.g., large industrial corporations; large private developers of commercial property; state, county, and municipal governmental bodies responsible for construction; federal agencies). The optimum membership number initially for an expeditious and efficient operation would appear to be between 40 and 50 owners/users, each having multimillion-dollar construction programs and representing about eight categories of building types.

b. Financial Needs

The principal expected costs to the members of the owners/users organization are those related to the expenditure of funds involved in:

1. development of standards
2. establishment of prequalification procedures
3. promotion and liaison activities
4. general administration of the organization

Additional expenditures may be incurred by some or all the members due to the personnel man-hours spent in technical assistance and operations.

To successfully carry out its functions, it is anticipated that the organization would need funding possibly in the order of $500,000 per year for a period of five years; in subsequent years a slightly lower budget might suffice. It is felt that this amount, when shared by all participants, would be a relatively minor annual cost individually and, considering the ensuing benefits, should be a worthwhile investment.

3. Genesis of the Organization

Currently, no owners/users organization exists which has the breadth of membership, technical competence, and the financial resources needed to carry out the kind of coordinated program envisioned. The development of the required organization would invariably involve considerable effort, time, and cost. It is unlikely that such an organization would evolve naturally. Its development could probably be assured only if some existing group were to provide a degree of leadership in the formative period. The Federal Construction Council (FCC) would be a promising candidate for this task.

FCC has already demonstrated its interest in the subsystems concept. It has a better chance than most organizations of obtaining the funding and technical support needed to carry out the various tasks required to ensure development of a vital owners/users organization. Some of these tasks would be:

a. generating a nucleus of technical standards by which to demonstrate the feasibility of the concept

b. evolving an operational framework for the owners/users organization

c. stimulating interest in the organization among owners of the private sector of the economy

Accordingly, concerning Phase II of the subsystems building concept study, the FCC has set as its basic objective the formulation and development of an independent organization of owners/users (see Section III of this report).

APPENDIX A

BUILDING SUBSYSTEMS SUITABLE FOR USE BY FEDERAL AGENCIES--A PRELIMINARY SURVEY

Prepared by

A Panel of Federal Agency
Specialists in Industrialized Construction*

As part of the Phase I study of the subsystems concept of building, a panel of federal agency specialists in industrialized construction was formed to carry out, under the direction of the FCC subcommittee responsible for the overall project, a preliminary survey to determine the extent to which the concept could be successfully employed in federal government construction projects. The specific tasks assigned to the panel were:

1. Identification of the general types of building subsystem which appear to be suitable for use, in standardized form, in government buildings.

2. Classification of such subsystems, on the basis of functional requirements, into categories which together satisfy a significant range of the needs of federal agencies.

3. Quantification of the potential market within the agencies for the various categories of identified subsystems.

4. Identification, in general terms, of mechanisms for specifying, prequalifying, contracting for, and designing with subsystems.

In carrying out its assignment, the panel met approximately once a week for a period of two months. The panel was assisted in its efforts by many agency specialists in the traditional technological disciplines related to the types of subsystems considered for possible use. The National Bureau of Standards also contributed to the panel's effort by conducting a survey to determine the availability of evaluative procedures appropriate for testing identified subsystems.

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*See membership list on page 52.

Presented below, in Section A, are the findings of the panel based on its investigation, and, in Section B, the results of the National Bureau of Standards survey. It should be noted that the time limit of two months set for conduct of the panel's study was not sufficient for a thorough study of all potential subsystems that would be suitable for standardization among federal agencies. Neither was it sufficient for a complete analysis of all the subsystem requirements of the various participating agencies.

A. THE PANEL'S FINDINGS

1. The procedure used for identifying, quantifying, and establishing basic requirements for building subsystems was workable and holds promise as a satisfactory procedure for both federal agencies and other owners.

2. Some basic changes are currently under study by several federal agencies that could affect their future needs, thus contributing some uncertainty. Examples include the systems integration design approach being considered by the Veterans Administration and the consideration being given to special facility requirements in anticipation of a volunteer professional military service.

3. Panel members representing General Services Administration (Public Buildings Service), Army (Office of the Chief of Engineers), Air Force, Navy (Naval Facilities Engineering Command), and Veterans Administration were able to identify a limited number of building subsystems and to quantify their agency's annual requirements. Most of these subsystems are involved in the use of facilities representing the agencies' largest volume, such as bachelor housing, offices, and hospitals. These findings are presented in Tables A-1, A-2, A-3, A-4, A-5, and A-6. The descriptions are brief and include only those characteristics that are necessary to give the reader a quick and adequate understanding of the subsystems. Complete performance specifications would be required before they could be procured.

4. A willingness to resolve differences among agencies in their requirements was demonstrated where such could be supported on a rational engineering basis. In those cases where the current practice by an agency is to write prescription specifications, it was found difficult to convert them into performance specifications and relate these once again to the requirements of all agencies.

5. Dimensional planning can be standardized on the basis of a 4-inch module for all of the agencies' facilities except for nursing towers of the Veterans Administration if they decide to use their systems integration design approach presently under study. The planning module for offices can be increased to 5 feet and for bachelor housing to 2 feet.

6. Facilities constructed by federal agencies vary greatly as shown by Table A-7 and as shown by the supporting data presented in Tables A-8 and A-9. This variation includes height of facilities, which ranges from 1 story to over 20 stories. A variation of this order in height for a single kind of facility such as an office building makes it difficult to standardize on structural frames including columns, beams, and girders. Also, in the case of office buildings, there was an expressed desire to have as much open space as possible within the limit of cost, and since relative costs may vary as new products and construction techniques are developed, there was reluctance to standardize on specific spans for floors and roofs.

   Without standardized structural frames there will be interfacing problems between standardized subsystems and out-of-system components. Due to the limitation in time it was not possible to determine the desirability and the feasibility of standardizing structural framing for facilities such as bachelor housing and other kinds of low-rise facilities which have relatively small space divisions and where long floor spans do not offer any advantages.

7. Electric, heating/ventilating/air-conditioning (HVAC), and plumbing systems are greatly affected by building height, floor space, and the number of building occupants. In addition, the HVAC system is greatly affected by climatic conditions. These variables restricted considerations of these systems. There was not sufficient time to explore the possibility of reducing these variables by other means such as zoning of buildings and zoning by climate.

8. A workable mechanism for specifying, prequalifying, contracting for, and designing with subsystems would include the following:

   a. An organization of owners/users having annual building construction programs that would identify both the types and quantity of subsystems needed by them.

   b. A set of performance criteria and standards for the subsystems which: (1) set forth the detailed requirements of the user; (2) specify the functional, dimensional, and interface requirements; and (3) include basic quality control requirements for the manufacturers.

   c. A mechanism for evaluating the subsystems developed by manufacturers and for publishing a catalog of acceptable subsystems which meet the specified criteria.

   d. Procurement procedures which: (1) allow designers to specify prequalified subsystems by reference; and (2) permit use of both prequalified subsystems and traditionally specified building components on the same project.

B. SUMMARY OF NBS SURVEY OF EVALUATING PROCEDURES FOR SUBSYSTEMS

Presented in Table A-10 is the matrix indicating the available and required performance criteria for the various attributes of the subsystems identified. Table A-11 gives the list of test methods currently available which help in the evaluation of some of the performance requirements of the identified subsystems.

TABLE A-1 GENERAL REQUIREMENTS FOR STRUCTURAL SUBSYSTEMS

Subsystems	Superimposed Loading		Spans	Fire Safety
	Concentrated	Uniform		
S-1 Floor (offices) w/o floor covering w/o ceiling	2000 lbs/2.5' x 2.5'	115 lbs/ft^2	20' minimum 5' increments	2 hr rated with ceiling noncombustible
S-2 Floor (offices)* w/o floor covering w/o ceiling with provisions for electrification located on 5' module	2000 lbs/2.5' x 2.5'	115 lbs/ft^2	20' minimum 5' increments	2 hr rated with ceiling noncombustible
S-3 Floor (bachelor housing) w/o floor covering with ceiling	2000 lbs/2.5' x 2.5'	60 lbs/ft^2 120 lbs/ft^2	24' maximum 14' maximum 2' increments	1 hr rated noncombustible
S-4 Floor (nursing towers) w/o floor covering w/o ceiling	2000 lbs/2.5' x 2.5'	160 lbs/ft^2	40'-6" minimum 58'-6" maximum 4'-6" increments	2 & 3 hr rated noncombustible
S-5 Roof (offices) w/o ceiling & roofing	not applicable	45 lbs/ft^2 minimum (snow loading in excess of 20 lbs/ft^2 to be added)	20' minimum 5' increments	structural support rated noncombustible
S-6 Roof (bachelor housing) w/o roofing with ceiling	not applicable	27 lbs/ft^2 minimum (snow loading in excess of 20 lbs/ft^2 to be added)	24' maximum 2' increments	structural support rated noncombustible

*If economically feasible, these subsystems should be combined with the ceiling/lighting/air subsystems to become a floor-ceiling sandwich subsystem. Where this is accomplished, uniform loading can be reduced by 10 lbs/ft^2.

TABLE A-2 GENERAL REQUIREMENTS FOR SPACE DIVIDER SUBSYSTEMS*

Strength	Dimensions		Maximum Weight	Acoustics†	Fire Safety†	Adaptability
	Height†	Panel Width				
Lateral load = 10 lbs/ft^2 Vertical load = 100 lbs/ft at 6" from face Impact = 60 ft-lbs Door slam test	8'-0" 8'-8" 9'-0" 10'-0"	4" increments; may be restricted to 48" or 40" in some cases	120 lbs in some cases	Nonrated 40 STC 45 STC§ 48 STC	Nonrated and 1 hr rated non-combustible materials	Removable - w/o serious damage to interfaces Reusable - economic factor only Doors - must accommodate standard size Electrification - must be able to accommodate in most cases‡

*Includes surfaces on both sides of the space divider which will be classified to meet at least two different performance requirements.

†Requirements may be in any combination.

§May be required to have 40 STC with doors installed.

‡Not required for VA nursing towers.

TABLE A-3 GENERAL REQUIREMENTS FOR EXTERIOR WALL SUBSYSTEMS*

Strength	Dimensions		Air and Water Infiltration	Heat Transmission	Sound Transmission	Fire Safety	Interface Considerations	Adaptability†
	Height	Width						
Requirements for wind impact and vertical dead loads to be determined	4" increments	4" increments	Limitations to be determined	Limitations to be determined	Limitations to be determined	Either non-rated or non-combustible	Method of attachment, fire safety, sound transmission, tolerances regarding fenestrations and structure	Accommodate fenestration and architectural finishes of interior and exterior Accommodate ceiling heights of 8'-0", 8'-8", 9'-0", and 10'-0" and planning modules of 5'-0", 4'-6", and 4'-0"

*Includes the exterior and interior surfaces to which finish material can be applied. It must accommodate fenestration and doors. Another class may be developed to include prefinished surfaces.

†Exterior aesthetics and the compatibility with interior subsystems will be a consideration.

TABLE A-4 GENERAL REQUIREMENTS FOR CEILING SUBSYSTEMS*

Strength	Dimensions	Sound	Fire Safety	Adaptability	Interface	Illumination
Superimposed vertical load = 5 lbs/ft^2 Upward pressure = 25 lbs/6 ft^2 Lateral load = 5 lbs/ft	Planning module is 5 ft Suitable panel sizes range from 12" x 12" to 24" x 60" based on 4" modules	40 STC (tested AIMA† I-II)	25 flame spread and 50 smoke	Panels removable and interchangeable with lighting fixtures and air terminals	Space dividers Floor Exterior walls Structural frame	75 ft-candles for general lighting

*Includes lighting fixtures — either recessed or surface mounted — and air supply and return terminals — either separate or combined with lighting fixtures.

†Acoustical Insulation Manufacturers Association

TABLE A-5 GENERAL REQUIREMENTS FOR PLUMBING SUBSYSTEMS

Subsystems	Strength	Dimensions*	Surface	Fire Safety
P-1 Plumbing Wall†	Lateral load = 10 lbs/ft^2 and adequate to support fixtures	Ceiling height = 8'-0"	Hardness and cleanability requirements to be determined	Noncombustible
P-2 Toilet Room§	Lateral load - 10 lbs/ft^2 and adequate to support fixtures	Ceiling height = 8'-0"	Hardness and cleanability requirements to be determined	Noncombustible
P-3 Toilet Room‡	Lateral load = 10 lbs/ft^2 and adequate to support fixtures	Ceiling height = 8'-0"	Hardness and cleanability requirements to be determined	Noncombustible

*Dimensional requirements: Spacing of adjacent dissimilar fixtures, 2'-8" on center; spacing of adjacent lavatories, 2'-4" on center; spacing of adjacent urinals and water closets, 2'-8" on center; floor to rim height of lavatories, 2'-7" and 2'-10"; floor to rim height of urinals, 2'-0"; floor to rim height of water closet, 1'-3".

†Includes at least two of the following fixtures: Lavatory, urinal, water closet; plus wall finish (in some cases).

§Includes one shower, one water closet, and one lavatory (wall and ceiling optional).

‡Includes one combination shower-tub, one water closet, and one lavatory (wall and ceiling optional).

TABLE A-6 ESTIMATED ANNUAL AVERAGE USE OF SUBSYSTEMS BY FEDERAL AGENCIES*

Subsystems		Gross Floor Area, Million Square Feet					
		AF	Army	GSA	Navy	VA	Total
Structure							
Floor	S-1	0.03	0.05	0.16	0.07	--	0.31
Floor w/raceway	S-2	--	0.05	2.34	--	--	2.39
Floor w/ceiling	S-3	0.71	1.40	--	1.55	--	3.66
Floor	S-4	--	0.50	--	--	0.60†	1.10
Roof	S-5	0.69	2.00	2.50	0.12	--	5.31
Roof w/ceiling	S-6	1.42	0.50	--	1.00	--	2.92
Space Dividers		2.30	3.50	4.23	2.50	0.70†	13.23
Exterior Walls		3.00	2.00	2.10	3.77	0.60	11.47
Ceiling/Light/Air		0.72	0.80	2.50	0.88	--	4.90
		Number of Units					
		AF	Army	GSA	Navy	VA	Total
Plumbing							
Plumbing Walls	P-1	60	300	300	77	32	769
Toilet Room	P-2	3,380	2,200	--	3,000	--	8,580
Toilet Room	P-3	--	--	--	1,000	--	1,000

*Based on historical data. Indicates how much could possibly be used per year if they are available.

†These figures are valid only if the VA uses their systems integration design approach presently being developed.

TABLE A-7 ANNUAL AVERAGE VOLUME OF CONSTRUCTION OF SEVEN BUILDING TYPES BY FEDERAL AGENCIES* (1966-1970)

Building Type	Agency	Number of Buildings	Dollar Volume (in millions)
Bachelor Housing	AF	56.2	25.1
	Army	54.0	22.9
	Navy	45.0	54.7
		155.2	102.7
Offices High Rise (4 plus stories)	GSA	8	84
		8	84
Offices Low Rise (3 stories or less)	AF	32.6	13.5
	Army	39.0	24.5
	GSA	21.6	9.1
	Navy	40.8	39.3
		134.0	86.4
Hospitals	AF	3.6	10.8
	Army	3.0	14.1
	Navy	2.0	15.0
	VA	1.2	23.8
		9.8	63.7
Laboratories and Medical Clinics	Army	5.0	3.9
	GSA	8.0	9.8
	Navy	4.6	2.0
	VA	1.6	1.4
		19.2	17.1
Maintenance, Production, Supply	AF	25.8	9.1
	Army	32.0	13.9
	Navy	34.8	43.0
		92.6	66.0
Community Facilities and Others	Army	22.0	18.0
	GSA	3.8	20.4
	Navy	21.0	14.0
		46.8	52.4
TOTALS		465.6	472.3

*Includes only types of buildings in which some suitable precoordinated standardized subsystems could have been used.

TABLE A-8 AVERAGE ANNUAL NEW BUILDING CONSTRUCTION BY FEDERAL AGENCIES*

(Fiscal Years 1966-1970 Awards)

	Number of Buildings	Floor Space (million sq ft)	Dollar Volume (in millions)
Air Force	118	2.7	59
Army (OCE)	155	5.7	97
GSA (PBS)	41	4.2	123
Navy (NFEC)	148	5.8	168
Veterans Administration	3	.6	25
Postal Service	Not determined	5.2	118
Other Agencies - Atomic Energy Commission; Bureau of Reclamation; Health, Education, and Welfare; & National Aeronautics and Space Administration	Not determined	Not determined	144
TOTAL	465+	24.2+	734

*Includes only types of buildings in which some suitable precoordinated standardized subsystems could have been used.

TABLE A-9 PROJECTED* AVERAGE ANNUAL NEW BUILDING CONSTRUCTION BY FEDERAL AGENCIES

(Fiscal Years 1971-1975)

	Number of Buildings	Dollar Volume (in millions)
Air Force	116	84
Army (OCE)	96	178
GSA (PBS)	36†	313†
Navy (NFEC)	91	163
Veterans Administration	7	84
Postal Service	Not determined	274
TOTAL	346+	1,096

*Based on need and subject to Congressional authorization. Includes only types of buildings in which some suitable precoordinated standardized subsystems could have been used.

†Currently being reviewed.

TABLE A-10 MATRIX INDICATING THE NEED FOR AND AVAILABILITY OF PERFORMANCE CRITERIA FOR VARIOUS ATTRIBUTES OF THE SUBSYSTEMS IDENTIFIED

		SUBSYSTEMS									
		S-1 Floors-Offices	S-2 Floors-Offices	S-3 Floors-Housing	S-4 Floors-Nursing	S-5 Roofs-Offices	S-6 Roofs-Housing	SD Space-Dividers	EX Exterior Walls	C Ceilings	P-1, P-2, P-3 Plumbing
ATTRIBUTES	a. Dimensional Characteristics	●o	●o	●o	●o	●o	●o	●o	●o	●o	o
	b. Structural Characteristics	●o	●o	●o	●o	●o	●o	●	o	o	o
	c. Fire	●	●	●	●	●	●	o	o	o	X
	d. Acoustics	●	●	●	●	X	X	●o	●o	●o	o
	e. Illumination	X	X	X	X	X	X	o	o	o	X
	f. Surface Characteristics	o	o	o	o	o	o	o	o	o	o
	g. Installability	o	o	o	o	o	o	o	o	o	o
	h. Maintainability	X	X	o	X	X	X	o	o	o	o
	i. Operability	X	X	X	X	X	X	o	o	o	o
	j. Thermal Characteristics	X	X	X	X	o	o	X	o	o	X
	k. Weathertightness	X	X	X	X	o	o	X	o	X	X
	l. Safety	X	X	X	X	X	X	o	o	X	o

● Criteria necessary and available.

o Criteria necessary.

X No criteria required.

TABLE A-11 TEST METHODS CURRENTLY AVAILABLE FOR THE EVALUATIONS OF SOME OF THE PERFORMANCE REQUIREMENTS OF THE IDENTIFIED SUBSYSTEMS

Subsystems	Attributes	Requirements	Tests Available
S-1 Floors-Offices S-2 Floors-Offices (with raceway) S-3 Floors-Housing S-4 Floors-Nursing	b. Structural	1. Provide adequate strength for life safety	Structural analysis of physical simulation (to be specified)
		2. Adequate stiffness with respect to deflection under static loading	Structural analysis of physical simulation (to be specified)
		3. Provide adequate strength to prevent local damage by human impact	Operation BREAKTHROUGH Criterion D.1.4.1(a) modified to require 750 ft-lb impact load any location
S-1 Floors-Offices S-2 Floors-Offices	c. Fire	1. Provide fire safety	ASTM E 119
		2. Control combustibility	Proceedings of ASTM, Vol. 61, 1961, pp. 1336-1347
S-3 Floors-Housing	c. Fire	1. Provide fire safety	ASTM E 119
		2. Control combustibility	Proceedings of ASTM, Vol. 61, 1961, pp. 1336-1347
S-1 Floors-Offices S-2 Floors-Offices S-3 Floors-Housing S-4 Floors-Nursing	d. Acoustics	1. Control airborne transmission	ASTM E 90
S-3 Floors-Housing	F. Surface Characteristics	1. Control surface color stability	Fed. T. M. Std. 501a, Method 5421
S-5 Roofs S-6 Roofs-Housing	b. Structural	1. Provide adequate strength for life safety	Structural analysis of physical simulation (to be specified)
		2. Adequate stiffness with respect to deflection under static loading	Structural analysis or physical simulation (to be specified)

TABLE A-11 (Continued)

Subsystems	Attributes	Requirements	Tests Available
S-5 Roofs	c. Fire	1. Control combustibility	Proceedings of ASTM, Vol. 61, 1961, pp. 1336-1347
S-6 Roofs-Housing	c. Fire	1. Provide fire safety	ASTM E 119
		2. Control combustibility	Proceedings of ASTM, Vol. 61, 1969, pp. 1336-1347
SD Space Dividers	b. Structural	1. Provide adequate strength to prevent local damage under service conditions	Physical simulation or ASTM E-72
	c. Fire	1. Control combustibility	Proceedings of ASTM, Vol. 61, 1961, pp. 1337-1347
		2. Control flame spread	ASTM E 84 or ASTM E 162
		3. Control smoke generation	ASTM STP. No. 422, 1967
	f. Surface Characteristics	1. Resist point impact (This will not necessarily apply equally to all the required space dividers)	Fed. T. M. Std. No. 406, Method 1074
EX Exterior Walls	c. Fire	1. Control combustibility	Proceedings of ASTM, Vol. 61, 1969, pp. 1336-1347
C Ceilings	c. Fire	1. Control flame spread	ASTM E 84 or ASTM E 162
		2. Control smoke generation	ASTM STP. No. 422, 1967
	e. Illumination	1. Control reflectance	Similar to PBS Performance Specifications
	f. Surface Characteristics	1. Control surface color stability	Fed. T. M. Std. 501a, Method 5421

MEMBERS OF THE PANEL OF FEDERAL AGENCY SPECIALISTS IN INDUSTRIALIZED CONSTRUCTION

Panel Members

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Robert W. Blake	Department of Health, Education, and Welfare
John A. Cook	Veterans Administration
Harold H. McCauley	Office of the Chief of Engineers
Edwin B. Mixon	U.S. Air Force
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Douglas D. Schubert	U.S. Postal Service
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Felix Y. Yokel	National Bureau of Standards

Agency Specialists Who Assisted the Panel

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APPENDIX B

REPORT ON MEETINGS WITH REPRESENTATIVES OF VARIOUS SECTORS OF THE BUILDING INDUSTRY

As a part of Phase I of the project to promote the use of subsystems in building, the FCC Subcommittee met on nine separate occasions with various groups of individuals representing one or more segments of the building industry--as follows:

February 25, 1971, The BRAB Building Industry Manufacturers Research Council

March 30, 1971, A group of 214 individuals at a general conference, jointly sponsored by the BRAB-Building Research Institute and the Producers' Council

April 21, 1971, Representatives of nonfederal owners/users of buildings

May 10, 1971, Representatives of industrial and building trades unions

May 11, 1971, Representatives of building contractors and related associations

May 12, 1971, Representatives of building code authorities and related organizations

May 13, 1971, Representatives of architectural and engineering firms

July 7, 1971, Labor specialists not affiliated with labor unions

July 15, 1971, Representatives of manufacturing companies

The basic objectives of all meetings were first, to acquaint the participants with the purpose of the project and its progress to date; second, to elicit from each group a frank expression of views regarding the feasibility and desirability of the subsystems concept; and third, to identify problems that must be solved before the concept can be implemented, and solutions to such problems.

Except for the general conference, all meetings were conducted as informal workshops. In most cases, Mr. Robert M. Dillon, Executive Director of BRAB, opened the meeting with a brief explanation of BRAB and FCC and a request for the help of the participants in carrying out the subsystems project. Next, Mr. George B. Begg, Jr., Chairman of the FCC Subcommittee, explained the purpose and objectives of the project, and Mr. Wallace A. Norum, staff coordinator, discussed the work carried out previously as part of the project by the Subcommittee and its technical panel (see Appendix A). Chairman Begg then posed a series of questions designed to generate frank and free discussion.

The general conference was conducted in a more formal manner, with prepared papers on various aspects of the subsystems concept, a structured panel discussion of the subject, and a general question-and-answer period.

Views expressed during the meetings and conference are summarized in the following separate reports on each session. The summaries are based on the notes of the Subcommittee members and the BRAB staff and should not, therefore, be considered complete transcripts.

As expected, the views of participants differed markedly on many points. There was, however, fairly widespread agreement that three problem areas constituted the major roadblocks to increased use of subsystems:

1. The difficulty in generating a market of sufficient size to permit economical production of subsystems.

2. The resistance of organized labor, especially at the local level, to changes in onsite construction practices.

3. The difficulty in obtaining local building code approval of subsystems.

Meeting with the BRAB Building
Industry Manufacturers Research Council
February 25, 1971

The objective of the meeting with the Building Industry Manufacturers Research Council (BIMRC) of BRAB was to obtain the views of the manufacturers regarding the development, production, and marketing of standardized subsystems.

Highlights of the Meeting

Reaction by the 15 manufacturers' representatives attending this session was one of great interest and favor. The concept was viewed as both an opportunity and a challenge--the challenge stemming from the need to develop: practical performance criteria, with exact methods of evaluation and clearly established minimum requirements (and with means for regular updating of the criteria to keep pace with technology); a means of eliminating labor and code restrictions on the use of subsystems; firm commitments by owners and designers to use subsystems in sufficient quantities to justify the needed investment in research and development (R&D) and plant facilities; and new procurement methods for buying subsystems.

Other critical issues that the manufacturers felt they faced in the development and production of subsystems included the detailed requirements for prequalification and testing and the changes that will take place in marketing methods especially affecting distribution. This may require a new type of sales force and will place more responsibility on the manufacturer in terms of application and service. In addition, new procurement methods will have to be developed to assure volume buying and use. The enthusiasm for subsystems among the manufacturers would be considerably diminished by any program that disallowed or discouraged the marketing of patented and proprietary systems.

Detailed Discussion

Technical details of the problem were dealt with at some length, and the basic considerations of procurement, production, marketing, and distribution outlined above were enlarged upon. Of particular concern to the participants in the technical area were the problems of fitting and connecting floor and roof subsystems to "nonsystem" structure frames; the difficulty of transporting preassembled large roof and floor units; and the small range of acoustical ratings and apparent incompatibility of lightweight partitions and high acoustical requirements. The importance of compatibility of gang toilet subsystems with current hardware and plumbing practices at the present stage of subsystem development was also pointed out, as was the need for a conversion factor between the areas of floor and exterior wall.

With respect to the problems of procurement brought about by a change to subsystems, the participants cited four primary needs: a change in conventional design, plans, specifications, and methods of awarding contracts; assurances that subsystems will be accepted over conventional onsite assembly; identification of the point at which a manufacturer begins the introduction and promotion of a subsystem into the market; and a means of recovering the basic investment in R&D in the face of competition from conventional construction.

Potential procurement changes in turn raised a number of basic questions relative to subsystems use in federal construction: Can a federal agency accept other than the low bid under performance specification? Can a procurement process be developed that will permit a fair portion of R&D investment to be recovered? Can the process be developed on a regional and national scale? Will architects and engineers be instructed by federal agencies to specify subsystems in order to aggregate a market?

The need to refine performance specifications was expressed by some participants, with particular reference to the need for further development of testing methods and performance test requirements.

Resolution of the problems and requirements mentioned above was considered by the manufacturers as prerequisite to the investment of R&D funds for the further development of subsystems. In any event, the participants felt that promotion of the subsystem project should be carried forward.

At this point consideration turned to various problems faced in the actual production, installation, and use of subsystems. A major factor in factory production is the high overhead costs due to plant investment in the industrialized process. To this must be added the cost of transportation. Factors such as plant locations, size and weight of the subsystems, and shipping requirements are critical, especially when large-size floor, roof, partition, and exterior wall systems are involved.

A major concern of the manufacturers was the problem of interfacing and fitting during installations where subsystems of different manufacturers are employed and where subsystems and conventional construction are mixed.

In addition to the technical and economic considerations involved in subsystems construction, legal and jurisdictional problems were raised. Concern over the guarantees and liability was expressed. The participants agreed that although the manufacturer should bear the cost of testing his product, the federal government should share the liability in the development stage of a new subsystem to be used by it. The inability of federal agencies to pay royalties on patented subsystems could raise problems. However, experience indicates that licenses could be granted, permitting a successful bidder to pay a royalty to the patent holder of the subsystem.

Concern was also expressed about labor disputes over installation of subsystems assembled offsite. However, several participants indicated that if a subsystem bore a union seal indicating that it had been manufactured in a union plant, many disputes over installation would be avoided.

Finally, the participants noted again that manufacturers must be assured of a fair profit before they will develop, manufacture, and market subsystems.

General Conference, Jointly
Sponsored by BRAB and the Producers' Council
March 30, 1971

In a sense, the general conference was similar to the February meeting with BIMRC in that the participants were mainly from manufacturing organizations. However, a much larger number of participants were involved, and the group included individuals from the design professions, trade associations, governmental agencies, and contractors. The conference was held under the sponsorship and with the participation of BRAB, BRI, BIMRC, and the Producers' Council.

Highlights of the Meeting

As in the BIMRC meeting, response was very favorable but tempered by some expressions of doubt about the feasibility of putting the concept into practice. Such doubt was implied in the discussion of problems that must be solved before widespread implementation would be possible, particularly problems caused by the following facts: Successful use of performance criteria and specifications requires exact techniques of evaluation, clearly established acceptable minimum standards, and regular updating; detailed requirements for testing and prequalification are critical to the manufacturer; cooperation of labor and building officials is needed to overcome certain restraining practices and requirements; new marketing methods and a new type of sales force will be needed, with more responsibility in application and service placed on the manufacturer; commitments by owners and designers to use subsystems are essential to realizing the market potential, justifying investment in R&D and plant, and reaching the required scale of production. Also, concern was expressed regarding the protection of patented and proprietary subsystems.

Formal Presentations

As already noted, the Producers' Council conference departed substantially from the format of other sessions. Mr. Ross W. Pursifull, AIA, opened the meeting, welcomed the participants, stated the objectives, and presided at the conference. Mr. William L. McGrath, Chairman of the FCC, discussed the objectives, organization, and membership of the Council, and explained the reasons for the interest of a number of agencies in using subsystems in their construction programs.

Mr. Robert B. Darling, President of Producers' Council, expressed, on behalf of the manufacturers, appreciation for the opportunity to discuss subsystems, to get a better understanding of the needs and demands of government construction, and to give the federal agencies a view of what the manufacturing industry can provide. He reported conclusions of two meetings the Producers' Council held recently on the Building System Concept: (1) change is inevitable in the 1970's; (2) there is a need for understanding subsystems and the use of performance specifications in the subsystems concept; (3) there must be an increased role of the manufacturer in developing new technology; and (4) a need exists for a coordinator to resolve the problems of compatibility of products, subsystems, and systems at an early stage in the construction process. He noted that innovations are sometimes discouraged by the "or equal" clause and that attention must be given to such matters as capability, responsibility, and performance specifications. He posed five basic questions to which manufacturers need answers: (1) What is the definition of subsystems and how are they expected to satisfy needs? (2) What contribution is a producer expected to make? (3) Will a viable market for subsystems be created (i.e., to what extent will owners accept them)? (4) What procedures are needed to implement the successful application of subsystems to government building construction? (5) Who should be the coordinator to head up the building team, providing it with needed management leadership?

Mr. David Miller briefly discussed BIMRC, explaining that its primary purpose is to identify the research needs of the manufacturing segment of the building industry and to act as counsel to BRAB on research matters related to the federal government and the building industry.

Mr. Herbert H. Swinburne, FAIA, in a keynote speech, emphasized the "software" socioeconomic side of systems in providing a better environment for the community. He predicted that, as a result of growth and change due to increased population and other demands, the dollar volume of construction will soon increase to $200 billion annually. Industry must change or be forced to change to provide for this increase. Trained manpower is currently not sufficient to continue present methods of building. In Europe, the training period is six weeks on the average for skilled labor. U.S. training requirements must be shortened from years, as is presently the case, to months. He explained that the basic factors to be considered in creating a building environment are time, cost, and quality; and that important forces in the construction industry are the cost of land, materials and products, labor, and money. Industrialized manufacturing processes for subsystems are needed to overcome problems associated with labor, so as to improve the time and quality factors and eventually cost.

Mr. Swinburne defined "systems building" as a "design-construct" process and "building systems" as the "hardware parts, assembled to produce the structure" using components and subsystems, either as an open or a closed system. He cited his experience in systems and traced the school system development projects in California, Florida, Montreal, and Toronto, various military studies, and Operation Breakthrough. The U.S. has the technology, he said, but constraints must be diminished, and each sector of the industry will have to determine the changes that it requires in order to participate in industrialized building. The power of new ideas must be heard.

Mr. George Begg, Chairman of the FCC project Subcommittee, and Mr. Wallace Norum of the BRAB staff, described the FCC project, discussed progress to date in identifying the types and quantities of subsystem applicable to federal construction work, and invited all participants to cooperate in the project.

Mr. N. M. Martin, President of Sheraton Design and Development Corporation, spoke on the private market for subsystems based on his world-wide experience in hotel building and on data from Mr. George Christie, Chief Economist, McGraw-Hill Information Systems Company. He expressed beliefs that the U.S. is ahead of the world in use of the systems concept, that the problem with subsystems in the past has been lack of coordination with the other parts of the building industry and lack of overall integration of subsystems into the building process, and that because of this, subsystems have not reduced costs as expected. He predicted that the coming period of widespread use of industrialized subsystems, produced in factories, would be called the "Manufacturing Construction Era." Before this will occur, he said, the cost of subsystems and the time needed to get plant production established after a subsystem is developed will have to be reduced. Basic user needs that subsystems must satisfy are those related to speed of construction, capital costs, maintenance costs, aesthetics, and performance. Subsystems, he said, are not applicable to special industrial facilities, and standardization cannot always solve manufacturing problems. He also stressed the need for code changes and public acceptance of subsystems in the building process.

Finally, Mr. Martin discussed the potential market for subsystems. He noted that in 1970, a total of $49 billion was spent for nonfederal building facilities in the U.S. and that this is expected to increase to $56 billion in 1971, broken down as shown in the following table.

POTENTIAL MARKET (NONFEDERAL) FOR SUBSYSTEMS

Building Category	Estimated 1971 Construction*	Applicable to Subsystems*
Commercial	$ 9.3	$ 3.0
Industrial & Manufacturing	3.3	1.0
Education	5.5	0.5
Hospital/Medical	3.2	1.5
Religious	0.6	0.2
Miscellaneous	1.1	0.5
Subtotal	23.0	
Recreation	1.2	
Public	1.2	
Residential	30.7	
TOTAL	$ 56.1	$ 6.7

*Figures in billions

In summary Mr. Martin said, "The mass market will develop only when manufacturers take some calculated risks and offer subsystems that can show cost savings. Then the private sector will buy." He pointed out that the Sheraton U.S. building program has been greatly reduced because of high costs.

Mr. Arthur Sampson, Commissioner, Public Buildings Service, General Services Administration, expressed belief in the fact that: profit motive and free enterprise are necessary for the success of the subsystems project; with the cooperation of government and industry, cost reduction can be achieved that would bring projects now on the shelf to the market; the restraints on use of subsystems are solvable; a single government agency program is not enough for the success of subsystems--it will require the efforts of all agencies plus the private sector owners and manufacturers.

Mr. William L. McGrath, Chairman of the Federal Construction Council moderated the afternoon panel discussion and ensuing questions from the audience. The following is a summary of the presentations of the panel and of the discussion.

Mr. J. W. Herron, H. H. Robertson Company: The subsystem already developed by the Robertson Company could be modified to respond to the FCC needs. Points to be considered by FCC and the private sector include:

(1) prequalification and performance testing is critical to success of the project; (2) improper administration by the buyer that results in acceptance of substandard products must be minimized; (3) R&D dollars (investment) must return a profit in the marketplace in order to encourage continuing innovations and any future investment in manufacturing facilities; and (4) building codes are extremely important to the acceptance of subsystems.

Mr. A. J. Faranda, ALCOA Corporation: In 1957, ALCOA held a meeting attended by 30 architects and prefabricator-contractors, on the subject of prefabrication of components and subsystems for high-rise and residential buildings. At that time the potential market was large and subsystems were needed, but it was learned that the following presented roadblocks to the development of a major market for prefabricated units: (1) codes and zoning; (2) labor; (3) the manufacturers' method of distribution in the market; (4) competition for corporate R&D funds; (5) interchangeability of subsystems (dimensions); and (6) acceptability by designers and the need for construction managers in the construction process. ALCOA has developed housing subsystems employing aluminum studs to be used in low cost, turnkey projects in competition with wood framing and concrete box modules. ALCOA is interested in subsystems but it believes considerable hard work and money will be required for successful application and manufacture.

Mr. W. R. Perry, American Standard: Points for consideration in the FCC project:

1. American Standard experimentation with subsystems indicates a long lead time for development of innovations.

2. A new sales force is required by a manufacturer for subsystems and application engineering; there must be technical and engineering training and more costly selling and promotion.

3. Higher inventories are required and distribution through wholesalers presents problems. Direct selling may be necessary. There would be higher accounts receivable and a resulting reduction in cash flow.

4. The national union leaders will agree to the installation of subsystems but the locals in general will not. Also the factory industrialization process may cause conflicts among the craft unions, industrial unions and teamsters since all are involved in the process and the jurisdictional lines between these unions have not been clearly established.

5. The manufacturer may have to take the responsibility for performance of the subsystem and, if so, he must be compensated in order to stimulate the change.

Mr. J. E. Hazeltine, Armstrong Cork: There is a concern that implementation of the open subsystems concept would be a deterrent to innovation because of the standardization required to achieve coordination and interchangeability.

Discussion and Comment

In the ensuing discussion, a number of questions were raised that reflected concern about the open systems concept in general and the acceptability of proprietary systems under that concept in particular. The various FCC Subcommittee members responded with the general view that a final discussion on the specific approach to be taken had not been made but that if a truly open approach is selected, subsystem standards would probably cover only performance, dimensions, and interface restrictions.

Several general comments about the project were offered, including a suggestion that the FCC Subcommittee study the Florida School House Systems project to determine the procedures employed under that project to deal with designers, contractors, and manufacturers of subsystems.

Discussed at some length was the question of how to establish performance criteria for those systems characteristics that cannot be evaluated by test. In the course of the discussion of performance criteria, several participants recommended establishing clear performance minimums rather than specific levels of performance.

It was noted that the National Bureau of Standards is developing performance criteria for Operation Breakthrough, sponsored by the Department of Housing and Urban Development, and has recently developed performance specifications for the Public Buildings Service, General Services Administration. In connection with such work, NBS has determined that sound performance specifications require the following three elements: (1) requirements; (2) criteria; and (3) evaluation--including test methods and certification procedures. It was also pointed out that in the evaluation process several factors besides test results would have to be considered; e.g., past experience, judgment, computations, and aesthetics. Qualification of subsystems will require that manufacturers submit satisfactory evidence that their products satisfy the criteria.

Basic questions posed by many manufacturers were: How can we participate in the FCC project? How can we make the best use of our R&D resources? How can present restraints of labor and codes be lessened?

Illustrations of problems with subsystems were provided by two participants. The first described a partition subsystem that after being developed and field-tested at great expense, was dropped when labor refused to install it because it contained factory-installed electrical wiring. The second described an elevator-shaft subsystem that proved impractical due to transportation limitations.

Among suggestions offered for consideration were: (1) that means be found to ensure that manufacturers are able to recover their R&D investment in subsystems; (2) that an education program be developed to promote both user and trade union acceptance of subsystems; (3) that a step-by-step approach be taken in development and use of subsystems; and (4) that a special effort be made to identify HVAC subsystems that can be developed and used.

Meeting with Representatives of
Nonfederal Owners/Users of Buildings
April 21, 1971

The meeting had the general purpose of acquainting representatives of nonfederal owners/users of buildings with the project and of determinimg the extent of interest among such owners/users in actively participating in the project in the future.

The 13 participants in this session represented diverse firms, agencies, and corporations concerned with a wide range of building types, including office buildings, industrial plants, communications facilities, hospitals, medical and research laboratories, retail stores, apartments, and educational facilities. Each organization represented has a large annual construction program.

Highlights of the Meeting

It was learned that almost every organization represented at the meeting was actively considering major changes in its procurement procedures or was already engaged in programs using the systems approach. Most participants indicated that their organization would readily join in the FCC effort if their individual interests could also be served. Building codes and labor were identified as constraints that might be effectively dealt with through cooperative action by owners. It was also recognized that additional owners with similar interests should be attracted to the FCC program in order to realize more fully the time and cost savings of subsystems.

Seven major findings resulting from the deliberations of the owner group were: (1) that the use of subsystems can solve many problems affecting cost, time, and quality; (2) that joint action by owners (including federal agencies) could help to stimulate other sectors of the building industry to make subsystems available; (3) that top management must be involved in any commitment to be made, and that management must be confident that the company's best interests will be served by such joint action; (4) that additional owners/users with similar needs and requirements will have to be brought into the FCC program in order to create sufficient demand to stimulate producers into making subsystems readily available; (5) that owners will have to become committed to the program in the early stages in order to justify changes in their procurement procedures and related costs; (6) that owners have experienced extreme difficulties in dealing with restraints imposed by labor agreements and building code regulations, and that cooperative effort is essential to improving or correcting any unfair limitations; and, (7) that the owners/users must organize the entire process inhouse by first defining their own needs in terms of subsystems, then committing themselves to this approach, and finally requiring the designers to carry through to construction.

Discussion Details

Chairman Begg opened the discussion by pointing out that the federal agencies cannot unilaterally accomplish the goal they have set but that through FCC they hope to serve as a catalyst. He posed a number of questions for the participants to consider.

The question of organized labor's attitude to subsystems appeared to be a primary concern to the participants. It was felt that if unions require factory-assembled subsystems to be dismantled before installation at the building site, the subsystems concept would fail. Although some satisfactory agreements on the use of factory-assembled units have been reached, union resistance is still widespresd--in some cases, even where an agreement exists. This issue must be resolved at the national, regional, and local levels. Owners should perhaps get involved in labor negotiations to a greater degree than they have to date. It was noted that while wage rates are important, the cost in place is more so. A successful subsystems program will require an educational program aimed at labor unions, not only at the national level but also at the local level where unions number in the thousands.

Participants discussed the use of or interest in subsystems by their organization or steps being taken by them to facilitate the future use of subsystems. In the Florida School House Systems project--under which six buildings have been constructed so far using currently available subsystems--a 10 to 15% cost saving and a one-third time saving over conventional methods of design and construction has been experienced. The Port of New York Authority reported it paid $5,000 to each manufacturer who would develop floor, exterior wall, and partition subsystems for use in the Twin Towers building; those subsystems found to be acceptable were used as a basis for bidding, but manufacturers were permitted to submit alternatives. American Telephone and Telegraph, which has a building program amounting to $800 to $900 million annually, 75% of which is equipment cost, reported it is now standardizing dimensions for equipment; when this job is completed, building dimensions will be standardized. Metropolitan Structures Company reported that it has a 15-year, $1 billion program for the construction of office, residential, and motel facilities, and that it views the systems approach as the only method of combating increased costs. New York State University reported that it has a $4.5 billion program administered by University's Construction Fund, $1 billion of which is already in place, and that many subsystems have been used in the program.

Other corporations are exploring various aspects of the subsystems approach. General Motors is attempting to define its needs more clearly in order to arrive at standard requirements translatable into building subsystems. Proctor and Gamble's principal need is for factory buildings, with some need for laboratory and office facilities. They are currently attempting to define their factory space needs in terms of subsystems and have recently developed a precast foundation system.

It was also noted that the Educational Facilities Laboratories has been serving as an effective clearinghouse for information on subsystems. The participants indicated an interest in obtaining more information on the federal requirements and urged the FCC to establish some form of information exchange on a continuing basis.

When discussing possible development of an owners' organization to promote the use of subsystems, a number of suggestions and comments were made. Owners should standardize their requirements and insist that architects and engineers (A/E's) use standard requirements, thus saving much time that could be devoted to space planning and the design of custom features. Cost specialists should be engaged to demonstrate conclusively the potential benefits of the subsystems concept in order to insure the long range commitment of top management to the concept. Contractors should be asked to bid on whatever requirements are agreed upon by owners. Owners should clearly identify subsystems selected for use in order to permit manufacturers to estimate the size and range of the subsystems market. A logical starting point would be to try to get owners to agree on compromise requirements that closely align with currently available subsystems; i.e., subsystems now "on the manufacturers' shelf." Finally, if the FCC goals are to be realized, owners must commit themselves to "go subsystems," and then organize their planning, design, and construction management team on the basis of the subsystems approach.

In response to several questions posed by the Chairman, the participants agreed: (1) that precoordinated subsystems will help reduce costs and produce better facilities; (2) that manufacturers should be stimulated in every possible way to make subsystems available, thus permitting A&E's to use them without detailing; and (3) that the owners would be interested in participating with other consumers in bringing some order into the market, but not in nonapplicable activities. Finally, the participants suggested several alternative ways of bringing owners together, including use of the U.S. Chamber of Commerce group known as the Construction Action Council. BRAB was requested to send the detailed subsystems requirements developed by the FCC to all participants so that they might study them for compatibility with their own requirements.

Meeting with Representatives of
Industrial and Building Trades Unions
May 10, 1971

While the objectives of the meeting with labor were basically the same as those of earlier meetings, a corollary purpose was to explore further methods of cooperative effort, assuming labor's interest in the long range goals of the FCC project.

The labor meeting was the most poorly attended of all the sessions, with only six of the 23 individuals invited in attendance. This was due in part to a conflicting out-of-town meeting of the AFL-CIO.

Highlights of the Meeting

Although the attitude of those who did attend was constructive and cooperative, there was some indication that the meeting was considered "just another systems presentation." None of the participants seemed overly impressed by either the volume or scope of the federal estimates presented, or by the suggestion that federal and private owners might work cooperatively on the subsystems project. However, there appeared to be an effort on the part of several participants to "point the way" toward constructive cooperation with labor, using the Building Trades Council as the appropriate follow-up route for FCC to pursue in the current program.

Dealing with specifics rather than broad questions of policy, the labor representatives made the following major points:

1. Any program that would help stabilize construction trades employment (countering the "feast or famine" aspect) would gain labor's immediate attention and interest.

2. Labor would view any program that stimulated use of foreign parts, components, or subsystems to be against its interests.

3. Building trades labor groups, individually or collectively, are better equipped to deal with a specific project or a set of specific questions than to commit themselves to the philosophies involved in a continuing project with the scope and ramifications of the FCC program.

4. To be successful, a program of this scope should list specific benefits to labor, utilize union labor at all stages, and be coordinated through the overall Building Trades Council.

5. The labor representatives made it clear that they were not able to make policy commitments for their individual unions, and implied that a firm, long-range policy could never be set that would anticipate all details or local area decisions.

Discussion Details

The participants were evidently primarily concerned with two aspects of subsystems: their effect on employment, and interunion jurisdictional problems. Much of the discussion revolved around the role of subsystems in stabilizing work flow, on improving the economics of building, and in encouraging more building. Considerable concern was expressed regarding foreign imports of systems elements, such as electrical and sheet metal parts, for assembly in the United States. The response to specific "challenge" questions by the Chairman dealt principally with the present spotty but widespread labor oversupply and with unemployment in many areas.

The problem of labor was expressed as a "feast or famine" situation, with the consensus that this was no time to discuss programs that would further displace onsite workers. A "swap" was suggested, with labor accepting the systems building idea in trade for release of federal construction now held "on the shelf." FCC representatives indicated that they knew of very little that was being "held back." The participants did agree that systems building implied a longer lead time and thus a better chance to plan ahead, and that there was usually better cost control in offsite manufacturer.

The thought was advanced that the highest current cost was not labor but the cost of capital, that industry could well afford $15 per hour in labor costs to get a job completed on time, and that there are no cost savings in systems, only time saving. It was also noted that over a 10-year period the cost of land has increased 243% while the cost of onsite labor has increased only 18%.

When asked if labor felt that the private individual was not influenced by the high cost of building, most participants said that they believed that, in nonresidential construction, building demand is related to the state of the economy--not the cost of construction. Other comments in the wage area included the observation that overtime creates problems because of its effect on the "stable use of man"; that if wages were cut in half it would not result in an increase in jobs; and that if demand was stabilized, wage rates would be lower. The Interstate Highway Program was cited as an example of stable demand--a 20-year commitment with "a sense of national purpose." If a parallel program could be developed by the federal government in the building field, with long-term commitments, there would be no trouble talking subsystems building with labor. It was stated that no one wants another "Philadelphia door" case and that labor would support any change in building methods that provides more stable employment. However, one participant expressed concern over the program statement, which pointed toward the probability of "reducing onsite labor," since his union has always done a high percentage of its work on site. He said that even though local unions are concerned, many have already accepted several "package" items. However, they are going to be very watchful of the trend.

Several helpful suggestions were offered regarding the manner in which labor should be approached: inform and obtain support from the Building Trades Department; then go to the individual international unions that are affected; and finally, talk to the local councils of the specific Building Trades Unions involved. This local contact is needed because the internationals cannot dictate to the locals. It was also suggested that FCC review the ten points listed in the publication of the Department of Commerce - "The Housing Industry--a Challenge for the Nation."

In response to the Chairman's request for a summation expressing consensus, the participants appeared to agree on the following:

1. The program should be coordinated through the AFL-CIO Building Trades Department

2. Program must be based on U.S. labor - no foreign components

3. The equity of each of the various trades involved in subsystems must be defined

4. A list should be made of various specific benefits to labor that can be expected by the use of subsystems

5. Recognition should be given to where labor has demonstrated a willingness to accept subsystems

6. A specific program to which labor can respond should be developed--but it should not be initiated in the South

7. Union labor must be used at all stages of subsystems production

8. "Pre-job conferences" should be used to resolve jurisdictional problems

Meeting with Representatives of Building Contractors and Related Associations May 11, 1971

The meeting was attended by ten participants representing building contractors and building trade associations.

Highlights of the Meeting

Participants emphasized the feasible and desirable aspects of subsystems even more than the participants in the meetings with manufacturers and owners. As in previous meetings, organized labor, building codes, performance criteria, and the development of a market large enough to warrant the production of subsystems were identified as matters requiring special attention in connection with subsystems. A matter not discussed in previous sessions, which received considerable attention, was construction management. The increase in the sophistication of buildings, together with the decrease in the amount of design details provided by most architectural and engineering firms, has complicated the construction management function to the point where contractors are no longer able to carry out the function to the satisfaction of many owners. Instead, such owners are turning to construction managers who coordinate financing, budgeting, design, and subcontracting for the owner on a professional basis. Several participants suggested that the construction manager concept might be successfully linked with the subsystems concept.

Discussion Details

Thd conferees spent considerable time in discussing three aspects of subsystems--procurement, installation, and performance. Performance was considered a "gut issue" in the subsystems approach, with responsibility for performance being that of the manufacturer. Responsibility for establishing levels of performance, prequalification procedures, and precoordinated standards should be assumed by the proposed owners' organization. The view was expressed that manufacturers may be faced with the necessity of over-designing their subsystems to be sure of covering guarantees, code variations, state laws, and the like. There was also concern that it may be difficult to get architects to give up custom design and detailing in favor of available subsystems, and to adhere to strict budgeting and cost controls. A number of the participants felt that a major problem in the use of subsystems might originate with the owners themselves and that it may prove difficult to get both the private and public owners to accept the same standards for similar constuction.

The conferees recommended further study of the legal aspects of accountability and liability as they relate to the use and requirements of subsystems in the 37 states having legislation in this area. With greater use of performance codes by the states, variations in requirements for subsystems among states might be decreased, which is in line with the trend toward establishing state codes for building construction, and toward providing for reciprocity between states. Work in this area is being conducted by the National Conference on States Building Codes and Standards. Further development of state codes could be a major factor in promoting the widespread use of standardized subsystems. A number of states now have state codes and a substantial number of other states are showing an interest in the idea.

Testing, standardization, and quality control received substantial attention from conference participants, with the overall view expressed that considerable work needs to be done in these areas. There appeared to be doubt as to the effectiveness of present efforts in these areas and concern that much of the resulting data now used by code and insurance officials is outmoded or inadequate or both. Cited as an example was the fact that although modern low cost sprinkler systems can greatly reduce the probable fire-loss in high-rise buildings, codes and insurance regulations allow only for expensive extinguishing systems.

Several participants suggested that the use of subsystems might accelerate the trend toward greater manufacturer involvement in construction, since manufacturers might find that their competitive position is enhanced if they install their own systems. It was also noted that owners are exercising more control over construction out of a desire for stricter cost control and adherence to a budget, and that the "turnkey" approach to building is causing contractors to act in the multiple capacities of designer-contractor-builder-owner-manager.

At the conclusion of their deliberations, the participants were in agreement on the feasibility and desirability of subsystems, provided the three major influences of labor, codes, and market can be satisfactorily resolved. From the contractor's point of view, the more parts that are put together in the factory, the better the quality, uniformity and cost control, and the less the dependence on traditional onsite skills. Young men entering the building field are being trained in and understand the systems concept. While some architects may for a time resist the subsystems concept in institutional and commercial construction, such resistance will eventually disappear.

Meeting with Representatives of Building Code Authorities and Related Organizations
May 12, 1971

The meeting was attended by 20 participants representing state and local code officials and trade associations.

Highlights of the Meeting

The participants reinforced in a number of respects the position of the manufacturers, owners, and contractors regarding subsystems. They indicated that the widespread use of building subsystems can be achieved through the FCC program providing enough is done to remove certain roadblocks created by organized labor and "local code officials." They found a need for a national certification program involving "third parties" to inspect and certify preassembled subsystems and to ensure installation at the jobsite that is acceptable at the local code level. The participants looked upon subsystems as desirable only if their use resulted in a safer building facility. Thus, like the labor groups, code officials viewed the subject somewhat more narrowly than either the contractors, the owners, or even the manufacturers. At the same time they recognized that a trend toward the increased use of subsystems is irreversible.

Discussion Details

Testing, approval, and certification received a substantial amount of attention. Most participants agreed that local jurisdictions would be reluctant to forego detailed onsite inspection of preassembled items until some equally effective mechanism of assuring code officials of the quality and acceptability of such items has been developed. Cited as steps in the right direction were the efforts to achieve greater uniformity in codes and to develop national certification programs being undertaken by model code groups and the National Conference of States on Building Codes and Standards, aided by the NBS Liability and Product Accreditation program.

The conferees felt that the professional registration laws might be a restrictive factor in those states where the law requires that a subsystem be approved by a state-registered architect or engineer before it can be approved by a local building official. However, a number of precedents for certification of the preassembled units through professional societies already are in operation and are widely accepted for such items as pressure vessels, elevators, and laminated wood members.

There was agreement on the need to explore further various possible procedures for evaluating combinations of preapproved subsystems intended for use in specific buildings. Mention was made of France where insurance companies are used as the final arbiter. This was viewed with disfavor as it tends to inhibit innovation even though this procedure assures safe buildings. The use of such independent organizations as Underwriters Laboratories in the electrical field and accredited laboratories for testing and approval of a subsystem was considered essential. Employment of a third party consisting of an elite group of people or a university or state laboratory to evaluate the use of combinations of subsystems was believed desirable, otherwise regulatory agencies will experience extreme difficulties. The third-party approach is needed at two levels; (1) to inspect individual subsystems, and (2) to provide overall coordination of subsystem assembly.

The conferees identified three basic areas that will affect the use of subsystems within each code jurisdiction: (1) the codes themselves; (2) the submission procedure to obtain approval, and (3) inspection procedures. Enactment and enforcement of building code will vary by jurisdiction, and there are thousands of separate code jurisdictions in the United States. However, intrastate code differences are expected to be reduced through establishment of statewide building code regulations (with enforcement at the local level) and interstate differences are expected to be minimized through more widespread acceptance of the model building codes published by the four model code organizations: Building Officials Conference of America, International Conference of Building Officials, American Insurance Association, and Southern Building Code Congress. Code differences are expected to be reduced still further as a result of greater cooperation among the model code organizations themselves, who are not only attempting to establish uniform requirements but also common interpretations. In connection with this effort, consideration is being given to the creation of a "Model Code Research Institute." Also encouraging are the efforts of the National Conference of States on Building Codes and Standards to promote state codes and reciprocity among states in areas of certification of preassembled building units.

Several participants warned against relying solely on performance to judge the acceptability of a subsystem. Adequate tests for measuring all aspects of performance are not available and until they are, it will be necessary to continue to rely at least in part on competent human judgment.

There was general agreement that while development of a uniform national code covering subsystems was not possible, reciprocal arrangements between states were both possible and feasible. The conferees noted, however, that major problems lay ahead where conflicting code requirements exist and where no provision currently exists for the use of subsystems.

The question of the feasibility of subsystems themselves developed a mixed response, the problem being one of "conversion over time." There was no unanimity regarding the inhibiting effects of labor; views ranged from it being a minor factor to constituting the bulk of the problem.

Several participants suggested that the best overall approach to obtaining the acceptance of subsystems might be for the federal agencies to develop the required performance criteria, standards, and specifications. It was noted that the climate appears to be favorable for obtaining the acceptance of appropriate standards by state code organizations, and that once accepted at the state level the job of getting local acceptance of building subsystems would be greatly simplified.

Among the various other suggestions offered for facilitating the acceptance of subsystems were:

1. Study and adopt successful subsystem approval techniques already in existence; e.g., manufacturers' accreditation

2. Develop national standards

3. Obtain research approval from the model code groups

4. Assign overall coordination responsibility to the architect-engineer-owner

5. Provide for review and evaluation of specific installations by an acceptable third party

6. Make use of such existing quality control institutions as Underwriters Laboratory, American Gas Association, and Factory Mutual

7. Develop a team approach to the approval of subsystems for which a complete set of evaluation tests do not exist

8. Establish an "elite" review body to respond to item 7

Meeting with Representatives
of Architectural and Engineering Firms
May 13, 1971

The meeting of the architects and engineers was the best attended session other than, of course, the general conference. Twenty-two invitees attended, most of whom represented private architectural and engineering firms.

Highlights of the Meeting

The meeting seemed to develop more questions than it answered, with major attention being given to leadership, management, and "human problems and living qualities" as contrasted with purely technical considerations. Consensus emerged in four areas: the need for a larger market; need for federal leadership; utilization of the architect as manager and coordinator (in contrast with the contractors); and the need for flexibility and avoidance of the "catalog" approach.

Discussion Details

The marketing and use of subsystems received initial attention, with the view expressed that the indicated federal market was not too impressive and that there was presently no precise way of evaluating subsystems now on the market or their value in building. The conferees expressed some doubt regarding subsystems being able to compete with conventional construction, at least initially, because of lack of variety in a limited market. It was suggested that promotional efforts concentrate on systems presently in use rather than on development of new ones.

The architects and engineers apparently did not view either labor or building codes as a real restraint or impediment to subsystems. They felt that systems and subsystems are being designed around labor and that the architect is writing specifications around both labor and code restraints after determining what will be accepted in each case. Unlike participants at previous meetings, the conferees felt that it is subcontractors rather than unions who resist and limit the use of subsystems.

Although it was agreed that the contractor is liable for satisfactory construction, the view was voiced that the A/E's are responsible for keeping any project within a budget. Others felt that problems involving coordination, labor, and assembly required a systems contractor.

One of the few points on which there was almost a consensus was the need for leadership from the federal agencies in advancing the subsystem concept. The firm commitment of a single public agency to the task of overcoming existing restraints was thought to be a necessity. While emphasizing the importance of the federal role, some A/E's appeared to discount the importance of an owners' organization. The comment was made that instead emphasis should be put on the "builder and construction producer."

There appeared to be no question in the minds of the architects that they should assume the management functions in building construction. It was noted that subsystems would tend to reduce the A/E's "design time" while increasing the time that could be devoted to management functions. Management time must increase because of the desire to telescope the project schedule, requiring close coordination and prompt resolution of code and labor problems. In the A/E's view, a partnership between the A/E and a system consultant is required.

The following considerations were felt important to any program or individual construction project for ensuring the successful use of subsystems:

1. Identify and establish a "software" program (standard requirements)

2. Use the lowest possible level of management for decision making

3. Define the problem; e.g., comfort levels

4. Commit owner or owners to the use of subsystems

5. Develop an evaluation technique (need basic model)

6. Develop performance specifications

7. Establish a management plan for projects (explore the market and constraints, reach agreement, then follow through)

8. Establish set of goals; e.g., time or cost savings

9. Develop liaison with the manufacturer for credibility of the program or project

10. Resolve legal and other constraints

11. Foster understandings, agreement and follow-through by all parties involved, including assembly of the right combination of parties (team) at the outset

Other discussion included the suggestion that the FCC become a clearinghouse on subsystems, including issuance of studies and monographs in the field, stressing that the product to be "sold" in this case is a "process." The real essential, however, is the firm commitment of a big aggregated market, requiring a commitment by many owners to use subsystems now and over the long term.

In developing the program outlined in these 11 points, the participants recommended against a "catalog" approach to subsystems, which would restrict the options of a designer. They cautioned that success or failure relies on the application of subsystems to the project, which requires good management throughout and a real commitment by the owner.

Finally, the A/E's devoted a considerable amount of time to discussing a "software" program to be developed concurrently with a subsystems hardware program--with emphasis in the software program on the "living qualities" of buildings in which subsystems are used. As an example, the comfort of a room is a human problem that cuts across considerations of size and shape, color and light, and temperature and humidity. According to the architects, while there is no question as to the technical feasibility of subsystems, their desirability rests principally on the less understood and less easily determined qualities of environment and human use and enjoyment.

Meeting with Labor Specialists
Not Affiliated with Labor Unions
July 7, 1971

This meeting, supplementing the one held with organized labor on May 10, 1971, was held to obtain views on the labor question from industrial and legal specialists in labor matters who are not affiliated with labor unions. In attendance were two representatives of the air-conditioning industry and two attorneys who have handled labor cases for manufacturers. They were briefed on the FCC program and asked to identify the types of problems they would anticipate for subsystems and to recommend methods of dealing with such problems.

Highlights of the Meeting

The participants generally felt that manufacturers would hesitate to develop subsystems involving a substantial amount of factory assembly until labor union opposition to factory-assembled items had been largely overcome. They were also of the opinion that it would be impossible to overcome such opposition through negotiations at the national level, and that it would be difficult to negotiate satisfactory agreements at the local level as long as unions may boycott factory-assembled items. The boycott problem can, the conferees indicated, be satisfactorily overcome only through legislation.

Discussion Details

The participants indicated that the major problem would be the resistance of local construction unions to the use of factory-assembled subsystems. Resistance might not take the form of a direct refusal to install such subsystems; instead, a local might try to resist subsystems by ensuring that properly qualified workers are unavailable. It was noted, however, that resistance would not necessarily be universal; for example, little resistance was encountered in either the SCSD project or the Florida school project--probably because both were treated as special cases.

When more labor is used in a factory and less on the jobsite, local construction unions feel threatened even though they may be affiliated with the industrial union through the AFL-CIO. When labor feels threatened, it will resist change and its ability to shut down a project is an effective weapon. It will be nearly impossible to get a national agreement covering the program being considered by FCC since 17 different building and construction trade unions and some 11 industrial unions, each having many locals, would have to be involved.

Almost any program that appears to provide for a greater amount of factory preassembly will be difficult to sell to construction trade unions. At present, many of these unions are in fact attempting to get more onsite construction required in contracts. This effort has been going on since the "Philadelphia door case," which established that where preassembly of building parts is specified, even though traditionally these parts had been assembled on the jobsite, the project is not subject to boycott.

Favorable negotiations with the various construction trade locals throughout the United States is probably impractical. The local trade unions' right to boycott strongly precludes satisfactory agreement.

The participants indicated doubt that a satisfactory solution would be found in the tri-trade agreements between the electrical, plumbing, and carpentry trades and a few manufacturers--wherein the manufacturers agreed to employ construction workers for factory assembly of housing modules in return for authorization to affix a tri-trade union seal of approval to modules. The agreement does not guarantee the acceptance of modules at the jobsite, and moreover the arrangement might be considered a secondary boycott, which is illegal.

To ensure installation without undue delay of subsystems that are at least partially assembled in a factory, the participants stated that some legislative action is needed to eliminate boycotts at the jobsite. The legislation should provide for relief in the form of injunctions and damages. It was felt that Congress is now more receptive to proposals for legislation that will help hold down building costs and thereby help ensure fulfillment of the country's future building facilities' needs. They also were of the opinion that the total labor force in the building industry would not be reduced to any substantial degree by the widespread use of preassembled subsystems; the primary result would be to shift jobs from the jobsite to the factory.

The labor specialists suggested introducing legislation that prohibits unions from preventing installation of preassembled components and subsystems. It could be in the form of either broad legislation or specific legislation relating to federal construction projects or Federal Procurement Regulations. Although broad legislation would be preferred, they noted that such legislation might be difficult to obtain.

Meeting with Representatives
of Manufacturing Companies
July 15, 1971

The last of the scheduled series of meetings was attended by 12 representatives of manufacturers of a broad range of building porducts. Several of the manufacturers represented had substantial previous experience with systems and subsystems projects.

Highlights of the Meeting

Three broad topic areas were discussed: (1) marketing and R&D; (2) assignment of responsibility in and management and coordination of the building process when subsystems are employed; and (3) the reaction of labor to prefabrication. At the close of the meeting the participants indicated general approval of the project and a willingness to participate in it in the future.

Discussion Details

Among the important points made during the discussion of marketing and research and development were: (1) in order to stimulate real interest in subsystems among manufacturers, specific funded projects, committed to the use of subsystems, must be developed; (2) where new subsystems are desired or required, sufficient time must be provided for development of such subsystems; (3) to be economically successful, a subsystem developed for a specific project must also be marketable in the general construction market; (4) the volume of sales required to justify production of a subsystem is different for different manufacturers and subsystems; (5) in many cases basic products and components that go into subsystems are marketable as separate items; (6) subsystems that decrease the life cycle cost and improve the overall performance of a building will have distinct market advantages; and (7) subsystems will in most instances have to be marketed separately from traditional building products, at least in the immediate future.

In the discussion on marketing, the participants indicated that subsystems will be developed once specific funded projects are announced. They also warned, however, that projects must be presented clearly to avoid having manufacturers misdirect their R&D efforts. In the absence of a guaranteed market, manufacturers must have a realistic estimate of the market potential for a subsystem, on a relatively near-term basis, if they are to invest in a development program. It was pointed out that different products, components, and the resulting subsystems would have to have different minimum market demands to justify the research and development of subsystems. Manufacturers' costs will vary depending upon whether the subsystem involves merely the assembly of existing products or the development of a sophisticated, unique, highly specialized prefabricated subsystem. In addition, the minimum market demand would vary with the degree of complexity and automation of the production line. The decision to undertake R&D is based on market study; with broad demand, the investment risk is minimized and manufacturers are usually more willing to approve an R&D program. This fact, the participants advised, should be taken into account in the FCC project.

Additional factors and suggestions that participants thought should be considered in the FCC program were: (1) subsystems should be purchased on the basis of performance specification which allow for multiple solutions rather than detailed specifications; (2) manufacturers have to recover development costs on a new product quickly, before competition has a chance to copy the idea; (3) it costs much less to modify an available subsystem or to put together a new subsystem using existing products than to develop a highly innovative subsystem; (4) the risks to manufacturers associated with subsystems development would be reduced if performance testing techniques were improved; and (5) the manufacturing segment of industry should be allowed to participate in the development of performance criteria.

There was lengthy discussion of the extent of manufacturer involvement in the building process under the subsystems concept. The participants generally agreed that they would have to assume responsibility for the ultimate performance of the installed subsystems. This is already being demanded of them by some designers and, as a result, they are trying to produce more complete and reliable subsystems and to exercise greater control over installation. Responsible project managers would be needed to coordinate and organize projects in which subsystems are employed. A project manager should, it was suggested, have authority to order modification of products and subsystems so that they interface properly and perform adequately. The participants also discussed the relative merits of open and closed systems. Most agreed that with open systems manufacturers would have a larger market for their subsystems, but that with closed systems they could furnish more efficient subsystems.

It was suggested that the functions of the architect and engineer may change under the systems concept, with designers continuing to perform the planning and programming functions associated with building design but relinquishing some responsibility for technical design to manufacturers.

Participants generally agreed that development of the subsystems approach would be impeded unless the concerns of owners/users, labor unions, and code authorities were dealt with. The need for agreements with organized labor was considered particularly important. Participants expressed much concern over labor's reaction to preassembled subsystems. Although labor unions have in some cases agreed to permit factory assembled subsystems to be installed, some participants felt that when use of subsystems becomes more widespread, unions will be less inclined to permit prefabrication.

To the final question, "What do you think of this FCC subsystems project?" all workshop members responded with enthusiastic approval of the objectives of the project and optimistic comments on its probabilities of success. They added, however, words of caution and advice on the successful introduction of subsystems. All expressed the desire to be involved as soon as practical in specific projects.

APPENDIX C

RECENT AND CURRENT ACTIVITIES RELATED TO THE INDUSTRIALIZED BUILDING*

Both the structure of the building industry and building technology are undergoing change at an accelerating rate. Furthermore, projections of future demand upon the industry and the total economic system suggest that pressures for further change in how and what we build will continue to grow.

These pressures for change in large measure result from rising costs of land, money, labor, materials and products, and from increased demand for greater quality, diversity and flexibility in the facilities and the ultimate environment produced. As a result, all segments of the industry have been seeking ways to better organize the total building process and in so doing, to provide for more effective development and use of building technology. The implication is that this "industrialization" of the total building process will provide the much needed productivity gains, and that, if properly directed, these efforts will provide the means for achieving the desired improved performance as well.

Industry has made substantial progress in industrialized building technology. Thus far, however, this has been true principally in the area of materials and products--i.e., components for building which do not necessarily bear a direct relationship to systems building. Such progress has been accomplished by achieving a degree of dimensional and functional standardization and coordination within and between segments of the building industry where high volume production is possible and large markets have existed or could be created. To some extent, this now has been extended into and blended with various of the emerging building systems concepts. However, neither a truly high degree of dimensional and functional coordination nor truly high-volume production of systems, subsystems, and systems-oriented components has been achieved. Further, no one form of industrialized building process organization or building technology has yet emerged as predominant or has shown a clear and significant cost- and performance-effective gain. However several experimental and developmental

*Information contained in this part of the report consists basically of excerpts from a February 1971 report prepared by BRAB entitled "Industrialized Building and Building Technology," a statement on the current industrialized movement in the United States, but adapted and updated for this presentation.

programs have been initiated in the past decade. Among the more significant of these programs are those which follow.

1. School Systems Development Projects

Widely publicized have been the several school systems development projects, many of which were initiated under the sponsorship of the Education Facilities Laboratories, Inc.

a. The Cupertino Project--Begun in 1960, this was a small-scale first effort designed to test the value of using a range of coordinated building subsystems. Two school projects in California's Cupertino School District were used. Though generally recognized as unsuccessful, this project led to a number of decisions related to establishing a systematic approach to school design and construction, and to formulation of the concept for the well known California School Construction System Development (SCSD) project. The more important of these decisions can be summarized from the literature as follows:

(1) In order to interest manufacturers in providing components designed specifically to new performance and dimensional criteria, the volume of work that such manufacturers could reasonably expect to obtain would need to be large enough to enable them to "write down" a substantial portion of their development cost.

(2) Effective coordination of system components and their respective producers would require a single authority which controlled a sufficient volume of potential work to make cooperation advantageous to the manufacturers.

(3) Any development work on the part of industry would require the participation of larger companies than those which had been involved in the Cupertino Project.

(4) The volume of work necessary to accomplishment of (1) and (2) above would need to be established through further investigation.

b. School Construction Systems Development (SCSD)--Capitalizing on the results learned from the Cupertino effort, the SCSD program was begun in 1961 with a feasibility study. Sufficient market was to be provided by binding 13 school districts into a legal mechanism having an immediate need for $20 to 40 million in buildings. In examining education needs, flexibility, space layout, air conditioning, height increments, and similar needs were isolated for special study. Both horizontal and vertical planning and design modules were established.

The following subsystems were identified for development: (1) structural, (2) lighting/ceiling, (3) air conditioning, and (4) interior partitions. Performance specifications were prepared indicating the dimensional and functional requirements--i.e., how each subsystem should perform in response to loads, fire, etc.; what environmental conditions must result; what specific horizontal and vertical planning modules must be adhered to; and, what would constitute compatibility between subsystems. The final choice of subsystems followed a complex bidding process involving prebidding, prebid conferences and a two-stage review process, to assure compatibility between subsystems offered by different manufacturers. The importance of compatibility and, in particular, compatibility in relation to cost was demonstrated by the reported fact that one successful bidder gave a price for air conditioning that was twice as much for use with one structural system as for another. Further development of the program involved testing of components in a 3,600-square-foot mockup structure. The school district bore the responsibility for hiring architects, monitoring design and bidding individual projects. The general contractor was not asked to include the cost of components in his bid, but to concern himself only with nonsystems construction and management of the construction/assembly process.

The inherent flexibility built into the component subsystems is reported to be one of the most important achievements. A number of other objectives were realized as well. The systems building concept was appreciably advanced and it was learned that manufacturers would respond to an adequate, organized market. Further, it was learned that quality buildings could be procured within a reasonable length of time and at reasonable cost using developed subsystems.

The SCSD project was considered by the California school districts participating to be successful. With continued help from the Educational Facilities Laboratories, Inc., this general approach to school facilities procurement spread to other parts of the country, and inadvertently to facilities other than schools as subsystem manufacturers, both winners and nonwinners of the competition, sought markets for their new products and services. For example, even before the construction phase of the SCSD program was underway, bidders were successfully marketing their components in other school districts in Nevada and Illinois. In 1965, Inland Steel Company and Lennox Industries were engaged by Lockheed Aircraft Corporation to produce their subsystems for a 300,000-square-foot office facility to house 3,500 engineers working on the development of the C5A transport plane. Space was needed quickly and the subsystems developed for SCSD were available. Lockheed was able to state its needs in the same language the manufacturers were using, and to accept performance criteria developed for a similar though quite different application--i.e., for schools. As a result, the facility was built in nine months at a reported cost of $15.10 per square foot. By applying the systems approach to the project, the facility was produced in an orderly, cohesive fashion to meet the owners needs. Application of CPM became simple and effective, but only because the owner recognized the potential and organized an appropriate procurement management system to plan and coordinate the entire project.

c. Schoolhouse System Project (SSP)--In 1966 in Florida, the basic SCSD approach again was applied, initially using the same four subsystems. However, the State Department of Education, in organizing and coordinating the program, spared the local school districts the task of legally organizing themselves. As each group of school districts became participants, specifications were modified and bids sought. The project staff has expressed the view that this approach provides for a continuing and evolving manufacturer, technical, cost and performance response. Recent reports based on six schools constructed under this program indicate savings of 10-15 percent on cost and one-third savings in time over conventional design and construction methods.

d. University Residential Building System (URBS)--In this project an effort was made to apply the SCSD approach to student housing for the University of California. Subsystems were redefined to include (1) structure, (2) partitions, (3) bathrooms, (4) furnishings, and (5) HVAC. Despite a carefully developed program only three of the five subsystems came in under cost, only one bid came in under the fourth category, and the fifth category had to be reconsidered altogether. At the same time, the University experienced a period of reduced funding which in turn necessitated a reduction in the original commitment of 4,500 units to 2,000 units. However, these problems were finally surmounted, and the project now is continuing.

Several significant lessons were learned, among which were the following:

(1) While providing many inherent benefits, systems building of itself can do little to overcome economic and political problems

(2) The market provided was neither sufficiently large nor stable to meet the needs of manufacturers

Nevertheless, the URBS project, by applying systems building concepts to student housing, demonstrated the potential for application to other building types--e.g., to housing, hotels, motels, nursing homes--each of which, although imposing special requirements, could be characterized by repetitive elements.

e. <u>The Montreal Catholic School Commission (RAS)</u>--The RAS project approach differed from that of SCSD, SSP and URBS which relied upon resolving most detailed problems after bidding in mock-ups and pilot structures. Already having an organized market and having many performance specifications already written, a set of specifications for five compatible subsystems was produced. Manufacturers were invited to form together into industrial consortia to develop and submit bids for a precoordinated package of compatible subsystems. Of the 11 totally integrated bids, three qualified for the complex cost criteria relating to initial cost and ownership and operating cost. By using this approach, it was believed that post bid delays could be reduced by moving immediately to implementation. It was also believed that true innovation would not result from the use of compatible subsystems alone, but that the entire system needed to be considered at one time.

f. <u>Study of Educational Facilities (SEF)</u>--This project, undertaken by the Toronto Metropolitan School Board, was approached from yet another viewpoint. The school systems development projects to this point, while offering flexibility and compatibility between subsystems, could be classified more nearly as "closed systems," in that they were developed with a particular overall building system in mind and were designed and had to be used within the specific dimensions of that particular system.

The SEF group, although having a short-term goal of producing school buildings with the usual objectives of quality, flexibility, and cost and time savings, also had a long-range goal of developing many components and combinations of components which could form the basis for a great catalog of subsystems which could be used universally and interchangeably. To do this, a more "open-system" approach was adopted. Ten subsystems were identified (structure, atmosphere, lighting/ceiling, interior space, vertical skin, plumbing, electric/electronic, casework, roofing, and interior finishing) and performance specifications were developed embodying a concept of "mandatory interface," in which any given subsystem would have to be compatible with at least two other subsystems in each category. The resultant combinations of variables required extensive machine processing of data: a million possible subsystem combinations were bid; 13,000 "full" systems met SEF performance criteria; 4,000 full systems met SEF performance and cost criteria; and the lowest 30 in cost were analyzed in detail before final subsystem contractors were identified. Post development work still was required. A full-scale mock-up was built as an addition to an existing school and a separate pilot school was built and studied before the components were finally cleared for use in the SEF schools.

2. Housing Systems Development Programs

In post-World War II Europe, both East and West, governments placed a high priority on the production of housing. To meet this essentially government-created demand, predominantly site cast and precast concrete industrialized systems emerged--i.e., concrete panel, module, and lift-slab systems. By means of standardization on basically closed systems, a large volume of housing was produced. Its cost- and performance-effectiveness in terms of what might have been the experience in the United States at the same point in time is not known. However, on the basis of experience gained and development achieved, many Western European systems are being marketed by franchise or licensing agreement in countries throughout the world. As the backlog of need has been reduced and the influence of free-market economies has become the dominant factor, a better balance has been achieved in the materials mix, and greater attention has been given to more open systems that offer the potential for greater variety and flexibility.

In post-World War II United States, housing needs did not reach the crisis proportions experienced in the war-damaged countries of Europe and elsewhere in the world. The American economy, including the housing industry, recovered more quickly. As a consequence the pressures for quick movement toward industrialized housing faded quickly, as is evidenced by the fate of many prefabricated housing producers. The resurgence of interest in industrialization in the 1960's, coupled with the pressures discussed at the outset of this paper, have now resulted in two significant, yet quite different development programs which stress industrialization--HUD's Operation Breakthrough, and the New York State Urban Development Corporation.

a. Operation Breakthrough--Drawing upon the authority and impetus given by Section 108 of the 1968 Housing Act, the Department of Housing and Urban Development (HUD) initiated the Operation Breakthrough program in 1969. The primary goal of this program was "...to provide housing systems and construction concepts which can supply...aggregated markets with quality housing produced in volume." Operation Breakthrough is unique as a development program in that it encompasses all phases of the building process--from land planning and site development, through housing systems development, to final occupancy, operation and maintenance--and is directed at a potential material market, as yet undefined and unaggregated. A request for proposals (RFP) was issued asking existing and potential housing systems producers to submit their proposals under two broad categories: systems ready or nearly ready for production, and systems and concepts requiring further development. The response to the RFP for housing systems greatly exceeded HUD's expectations. Of 632 proposals received, 244 proposals dealt with the first category--i.e., with design, testing, and evaluation of complete housing systems; 388 dealt with the second category, or hardware and software concepts relating to housing that required further development before they could be implemented. Embodied in these proposals was a fair representation of the state-of-the-art in the United States, as well as a very considerable representation of European systems, (e.g., Balency, Tracoba, Skarne, Sectra, Shelley, Relbec, Wates, Cebus, Coignet, Bison, Jespersen, Sepp Firnkas).

Of the complete housing systems proposed, the number of acceptable systems was progressively reduced to 22 that were selected for contract award. The RFP furnished the proposers with material on the broad theoretical basis for the program and addressed more than technical objectives to be accomplished. In selection of the systems for initial contract award, the evaluation factors included in addition to system design, the quality and diversity of management and professional talent of the proposer, his organizational structure, evidence of experience necessary to implement the overall production requirements, and financial soundness and capability. Evaluation also included understanding of the overall program and proposed means of recognizing user needs at all design scales, as well as testing, evaluation, and other aspects of prototype construction, and of large-scale production considerations, including plant location, transport, and financial planning. In selecting the 22 systems, HUD further attempted to achieve a mix of housing types, materials, and techniques.

The Breakthrough program is divided into three phases: Phase I, systems design; Phase II, prototype construction; and Phase III, volume production. To form a basis for evaluation of systems design and prototype construction, the National Bureau of Standards, at HUD's request, has assembled "Guide Criteria" which embody: (1) performance requirements, (2) performance criteria, (3) evaluative techniques, and (4) commentary (providing reasoning for performance requirements, criteria, and/or evaluation methods). This set of criteria is viewed as a guide and is subject to continuing refinement as the development program progresses. The guide criteria do not specifically treat either site development or foundations.

In addition to housing systems development, the Breakthrough program included separate RFP's for site planners, site developers, and quality control, resulting in the award of contracts for nine site developers and nine site planners to plan and develop nine prototype sites for approximately 3,000 units. One contract has been awarded for development of a quality-control program to be applied in the industrialized production of the housing systems. Other aspects of the program include a projected HUD certification program for the housing systems, market aggregation for volume production, and coordination of HUD programs (including planning, financing, and assistance in community development) with the Operation Breakthrough effort. The program is now in Phase I, Systems Design. Development has begun on three sites with all site development scheduled to have been started by spring of 1971, and Phase II, Prototype Construction, to be initiated for several systems by the summer of 1971.

As has been the case with other systems development programs, a number of both successful and unsuccessful proposers are developing and marketing systems outside the established program. The Breakthrough program has not progressed sufficiently to permit an evaluation as to potential impact; however, it has been credited by numerous sources as already having produced a major stimulus to industrialization activities.

b. New York State Urban Development Corporation--In 1968, New York State was faced with the same problems of providing housing and shared the same concerns on a state level as the Congress did on a national level. As a consequence, the Governor asked the State Legislature to authorize establishment of the Urban Development Corporation (UDC) with extraordinary powers to float loans, to condemn land, and to override local codes and ordinances. The primary mission has been stated to be one of helping localities in providing urgently needed housing for low and middle income families. The program as now planned encompasses 43,000 dwelling units in 54 projects located in 26 communities across the state, with two "new towns" being planned.

The stated aim of UDC's technology program is to check spiraling costs wherever possible in the construction process by concentrating on finding and implementing cost-saving innovations throughout the building process. It is concerned not only with complete housing packages, but is giving encouragement, as well to cost-saving subsystems components, and to techniques which can be introduced where appropriate, in housing being produced by more or less conventional methods. The latter concept is embodied in a quotation from the report of the Housing Commission on Urban Problems: "Housing costs can be reduced if none of the many avenues for savings is dismissed as inconsequential. Add them all up and they promise to be substantial."

By using its own large-volume market, UDC believes it can provide innovators in the building industry with the needed incentive. It is recognized that innovators frequently avoid those innovations which would entail changes in entrenched building practices or local code provisions, simply because they cannot afford the time and risk involved. UDC, therefore, seeks to encourage those who normally bear the high risks for research and development to undertake the necessary investment for volume production tooling. As a basic premise, UDC first must satisfy itself that a prospective innovation has already been employed and essentially proven either in the United States or elsewhere, without jeopardizing health or safety.

Even though design and quality evaluation constitute a heavy burden, the program, oriented to cost-saving technology, adds a practical dimension to the industrialized housing movement. Those promoting new technology need large orders to justify large investments for plant and equipment, and those placing orders need tangible evidence of benefits to be derived from innovations. UDC's approach to solving this problem is three-fold: (1) only systems with demonstrated capability are considered; (2) original costs of prototypes are not weighed in final cost judgments, it being recognized that prototype costs will in all likelihood be high and that the reason for the program is to demonstrate or test new concepts; and (3) the Cost Analog System, developed for the purpose, will be used to determine whether a proposed innovation in fact has cost-saving potential. Although it is fully recognized that the high cost of housing results from many other factors, the Analog System is specifically directed toward cost savings from construction technology. It purports to equate industrialized and conventional procedures and practices, and provide UDC with a yardstick for cost assessment.

The UDC program and approach is unique in the sense that it faces the question of cost effectiveness directly and accepts less than a complete building system package, thus taking advantage of all manner of recent innovations which have as yet to achieve acceptance in New York State or in any other significant market.

3. <u>Federal Construction Agency Building Systems Programs</u>

Further evidence of the focus on industrialization is the attention being given systems building within the federal construction agencies. The Veterans Administration is applying the systems approach to design of subsystems for hospitals; the U.S. Postal Service is employing modular systems in its construction program; the General Services Administration and the Department of Health, Education, and Welfare have ongoing programs to establish the feasibility of using standardized systems and subsystems throughout their programs. The military construction agencies have been utilizing industrialized and systems building in limited applications for a number of years.

a. <u>Veterans Administration</u>--They have just recently received (October 1971) the final report from the Joint-Venture consulting firm which they engaged to develop a Buildding System for the design and construction of VA hospitals using the systems integration approach. The system developed is one of disciplined planning and rules of assembly rather than a system of hardware components or "kit of parts." It is a completely open system which utilizes products and materials presently available on the market. However, through the application of this systems approach, the VA expects to produce working drawings which will incorporate many of the design details which are now left to shop drawings and to on-the-job decisions and to be so organized that contractors and manufacturers will be stimulated to developing and producing larger pieces or components of construction than are now available. One of the major features of the Building System is the coordinated, organized layout of mechanical services within the interstitial space "service zone." The system shows great promise and potential in responding favorably to the ever present problems of increasing construction costs and constantly changing requirements in medical treatment and technology.

b. General Services Administration (PBS)--In January 1971 the Public Buildings Service published The PBS Performance Specification for Office Buildings. This document provides a comprehensive approach and the specific details required for the use of building systems in the construction of federal office buildings. It is the result of an intensive effort carried out over several years by the National Bureau of Standards and PBS.

The specification which establishes the performance requirements for a building system and the legal and managerial framework for its development, is currently being applied to the construction of three large office buildings for the Social Security Administration. The buildings will be located in San Francisco, California; Chicago, Illinois; and Philadelphia, Pennsylvania and will constitute approximately 1.9 million square feet of office space at a cost of approximately $97 million as of October 1973.

The building industry has been invited to submit proposals for the system. Each proposal will represent an integrated building system consisting of seven subsystems: Structural Frame, HVAC, Electrical Distribution, Luminaires, Finished Floor, Finished Ceiling and Space Dividers. The government will enter into a contract for the procurement and installation of the system in all three buildings with the consortium of firms which proposed the system with the lowest life cycle costs for the buildings. GSA hopes this project will be the springboard for the application of building systems in the construction of both federal and privately owned office buildings.

c. Air Force--With its special need for family housing that often must be provided in small quantities and at remote sites, and with the need to cope with rapid buildup of personnel at one base while another is shut down or curtailed, the Air Force has looked toward the development of adequate, easily erected and readily movable housing. It has also sought to provide the necessary incentives to stimulate private involvement in this field. The market that could be provided by this Service alone could exceed $60 million annually over the next several years.

The current Air Force interest in relocatable housing dates from the early 1960's. Congress approved the development of a concept for such housing and authorized construction of 2,200 units in Fiscal Years 1962 and 1964. First units developed were factory fabricated and erected at selected bases. The initial plans for these units were developed for the Air Force by a private architect-engineer firm which produced designs for two types: one a complete unit that folded for transport, and the other a unit built in two sections that had to be bolted together to form the complete house. Contractors bidding on the initial and later projects reportedly favored the fold-up type by a large majority. The same type of housing also has been constructed overseas (in the Philippines and Viet Nam).

In one successful operation, an entire group of some 200 one-story, three-bedroom, one-and-a-half-bath homes were moved from Glasgow AFB in Montana, across the Rocky Mountains about 800 miles, and were re-erected at Mountain Home AFB in Idaho at a cost reported to be well under half that of new construction at Mountain Home. More recently, the Air Force formally opened a 200-unit housing development at George AFB (near Victorville, California) where the units (up to four bedrooms and two baths in single-story and townhouse configurations) were produced in a movable factory. Savings on these units over conventional construction were estimated to be 15 to 16 percent in the first year (under normal business amortization). It is reported that an estimated additional savings averaging about 4 percent per year on a cumulative basis, could be achieved.

To date, Air Force development seems to have settled on two basic types of housing systems. One is the foldable type (used at Glasgow and Mountain Home), which allows for an entire home of 1,170 gross square feet to be folded upon itself to produce a shipping package 10 feet wide, 11 feet 6 inches high, and 47 feet 4 inches long, weighing some 25 tons. This package can be shipped easily by trailer truck and can be easily re-erected at another site. The second system (used at George AFB) consists of panels with steel channels replacing conventional wood studding. The panels are produced in a movable factory located 18 miles from the construction site. The prefabricated panels include all necessary wiring, plumbing, and other fixtures; "wet walls" for kitchen and bathroom areas are also produced as complete sections.

In conjunction with its housing program, the Air Force also has increasingly used a two-step procurement procedure under which prospective bidders are asked to first submit a general plan and specifications for a given number of units, one proposed system is selected, and then bids or proposals for actual manufacture and erection of the units are solicited. In general, the Air Force reports that interest in this type of proposal has been "gratifyingly high." In fact, more bids were received in every case to date than were received on projects in which in-house designs and specifications were prepared for bidders. The Air Force reports that manufacturers are becoming increasingly interested in the field, some preferring to make alliances with construction firms for erection, and others preferring to handle the whole process from manufacture through erection as a package operation, thus establishing clear responsibility for the entire project.

A recent contract with the General Electric Corporation for 250 homes of an improved version of the George Air Force Base type has further demonstrated the practicality of industrialized relocatible family housing.

At this writing the Air Force has gone on the market for an aggregated two-step buy of its entire fiscal year 1972 family housing program. This will call for industrialized relocatable family housing involving 2,910 units at a cost of about $70 million. Bids will be received on both a regional and national basis. To date responses have been gratifying.

Recent retrenchment of missions, changes in strategy, and reductions in construction budget levels, have caused the Air Force to seek new approaches to construction requirements and procurement. It is reported that such developments have been responsible for the closing of some 27 major and 75 minor installations. These closures have resulted in a facilities and real estate inventory reduction valued at several billion dollars. In family housing alone, over 18,600 units (valued in excess of $230 million) have been removed from the inventory because they were no longer required at their location and the use of conventional construction techniques precluded their relocation economically. During the same time period, the Congress approved construction of 14,300 units, resulting in a net reduction of 4,300 units. It is reasoned that neither the Air Force nor any of the three military construction agencies, which all share the same problem, can afford to continue construction of fixed facilities which may eventually become a virtual total loss when there may be alternatives.

The Air Force thus is attempting to develop new approaches to procurement of facilities other than family housing, as well, so as to provide high-quality, large relocatable structures. It is exploring the feasibility of using building systems and industrialized building techniques for specific building types which are part of the annual Military Construction Program. Specifically, these types include enlisted bachelor housing, composite enlisted bachelor housing, bachelor officer housing, warehouses, and administration and training facilities. The study is intended to reflect the best available talents of industry, the design professions, and the Air Force itself. An architectural firm has been engaged to assist in the definition, evaluation, and development of the program. In the prospectus inviting industry proposals, performance requirements are spelled out for each type of facility and include such considerations as: concept, space allocation, cost limitations, site preparation, structural considerations, roofs, interior and exterior finishes, plumbing, electrical, HVAC, fire protection, geographic location, and dollar volumes. General requirements address warranties and guarantees, manufacturing capability and financial stability, as well as conformance with recognized national standards, codes, and practices. The Air Force contemplates the use of the two-step procurement technique for the program. The objective of this approach is to permit the development of a sufficiently descriptive and not unduly restrictive statement of Air Force requirements in "step one" in order that more definitive procurement action may be taken in "step two."

At this point in the program, numerous responses have been received from industry and are being evaluated. Future plans include the calling of a prerequest-for-proposal symposium, and, predicated on Congressional authorization, issuance of a Request for Proposals, and, predicated on Congressional appropriations, evaluation and award of contracts.

d. <u>Naval Facilities Engineering Command</u>--Sharing similar problems, NAVFAC has utilized available technologies and has looked seriously, though not on as large a scale as the Air Force, at the potential of industrialized building and new approaches to the building process. The Northwest Division of NAVFAC has carried out a program in which concrete modules were completely fabricated with all finishes in Seattle, Washington, and then barged to Alaska for erection as barracks facilities. And in a recent action, family housing units were purchased from the Air Force for removal and re-erection at a permanent Navy base.

More significantly, however, is a longer range approach undertaken within the past few years. NAVFAC, believing that the basic approach taken in the school systems development programs cited earlier held promise, engaged the services of the designers of the SCSD and URBS systems programs to assess the applicability of existing building systems to Navy facilities needs.

In a first phase, existing systems, subsystems, and components which might be used to provide enlisted men's barracks, bachelor officers quarters, and administrative buildings of up to 50,000 square feet each were identified. Among subsystems investigated for potential use were: structural, HVAC, lighting/ceiling, and partitions. It was estimated that together these subsystems represent 40 to 60 percent of total building cost, the remaining costs being those for subsystems that vary from site to site, such as special foundations and exterior cladding for which nonsystems solutions are most economical. In phase two, a second contract was awarded to the same firm to develop a design for naval barracks facilities and to select possible subsystems which would be applicable. A design was developed and a full-scale mock-up built. Instead of continuing with the approach of using selected subsystems incorporated within a building, the remainder of which is conventionally designed (as in the case of the SCSD program), it was determined that total building systems offered a more viable solution; eight systems have been selected as suitable and bids are now being sought. The system provided by the successful bidder will be utilized in construction of a $4.3 million Navy barracks in Memphis, Tennessee, which will house 1,680 enlisted men. This facility will serve as a basis for evaluation of this approach to future design and construction. If this initial effort proves fruitful, it is intended that the approach will be developed further. In the case of the Navy, the market is reasonably predictable and user requirements for military barracks appear to be relatively simple since they are based on a functional program and administrative unit with a good many preset conditions. However, the situation is changing and many past concepts of military life may not be adequate for the future. Therefore, the need to provide for future change also is being recognized.

Although this systems program is different from the SCSD program, it is viewed as a direct descendant. Approaches have been modified and it is believed that experience gained will add significantly to knowledge as to the effectiveness of systems building.

e. U.S. Army Corps of Engineers--Not only in its own construction program for the Army, but as construction agent for other federal agencies, the Corps of Engineers has been closely following developments in industrialized building technology. Its experience parallels that of the Air Force in the use of building systems and components, particularly in the area of housing.

However, to answer the need for support facilities for the SAFEGUARD program, a systems building approach was begun early in 1970. An architect-engineering firm was engaged to ascertain which, if any, types or combinations of preengineered/prefabricated buildings and conventional construction could be used for the nontechnical support facilities for the Perimeter Acquisition Radar and Missile Site Radar sites for the SAFEGUARD program. As a result, a catalog of possible systems and subsystems was developed along with outline performance specifications for use in the two-step procurement, which is scheduled for award in the next few weeks.

This program formed the basis for a much larger program directed toward a comprehensive study on the feasibility of applying preengineered/prefabricated and systems building to the Army military facilities program. The study was conducted by the Corps of Engineers Construction Engineering Research Laboratory in Champaign, Illinois, and included:

1. Identification of related studies which have been completed or are underway.

2. Complete documentation of the state-of-the-art and the present offerings of industry.

3. Analysis of the complete range of facility needs for Army bases to determine the types of building structure which would be amenable to use of preengineered/prefabricated and/or systems building; and a selection of representative building facilities for use in detailed analysis.

4. Establishment of a complete evaluation procedure to include all parameters of worth to the owner/user, such as initial costs, life-cycle costs, economic life, relocatability, and performance effectiveness.

5. Determination of potential markets for these representative facilities within the Army military facilities program, including a fiscal year program and for a projected five-year period.

6. Determination of the general extent of markets provided by other military facilities programs.

7. Detailed analysis of selected centers to determine volume in the projected military facilities programs, and to establish the feasibility of using preengineered/prefabricated and/or systems building for construction of these representative building facilities. (It is intended that this analysis indicate feasibility and cost advantages and/or cost disadvantages.)

8. Alternative methods for procurement and construction of Army facilities, using the types of building and technology identified. (The study also includes

development of a procedure for in-place evaluation of the performance, and maintenance and operating costs of these types of building after procurement, and an evaluation format.)

The study is now complete and the report will be available from the Clearinghouse for Federal Scientific and Technical Information, U.S. Department of Commerce, Springfield, Virginia 22151.

The extensive data bank generated by the study will be expanded and updated on a continuing basis. The results are being implemented in upcoming Army construction programs in which projects are planned for construction using industrialized procedures and are to be tested on site for performance, maintenance and operating costs, and user response.

Independent of this CERL study, OCE has been investigating procurement methods in various programs. Finding that one- and two-step procurement has certain benefits in specific applications such as housing, OCE is now developing outline specifications for use by its field offices. A manual giving guidance for two-step procurement has been prepared. Other manuals are planned to assist the Corps of Engineers Field Offices in one-step procurement and programming of industrialized building.