AA Bates

NATIONAL BUREAU OF STANDARDS REPORT

8983

The Opportunity for Building Systems Innovation in the Military Construction Program of the Department of Defense

Prepared for
Assistant Secretary of Defense
for Installations & Logistics

NBS

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

THE NATIONAL BUREAU OF STANDARDS

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NBS PROJECT 4002410

October 1965

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IMPORTANT NOTICE

NBS

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"Our experience in conducting concept formulation and contract definition has verified its value in defining large, complex projects before major commitments are made. I believe that the procedure provides firmer and more realistic estimates of performance, cost and schedule than are otherwise realized, that it minimizes change in the course of a development, and that it substantially reduces total costs and significantly improves a system's operational effectiveness."

Harold Brown
Director of Defense Research & Engineering

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I Forward

The two decades since World War II have been characterized by a rate of growth in the availability of new knowledge that is unprecedented in history. The major increases in this new knowledge are most apparent in scientific ana technological areas. Change is the key-word associated with this increase. Change in the nature of the weapons systems used by the Department of Defense; change in the emphasis which the nation places on the importance of differing ways to use our new plenum of science and technology, and change in the way we manage our collective efforts to realize the benefits.

There are two events which fall into the category of management changes which are important to recognize in order to understand the nature and intent of this report. In the last five years national leaders have been increasingly concerned that ways be found to apply the results of our new plenum of science and technology to "civilian" interests. The Institute for Applied Technology was formed by a reorganization of certain programs in the Department of Commerce in order to provide management direction to this opportunity. During this same period of time the Defense Department, through its Office of the Director of Defense Research and Engineering, has developed successful systems management techniques for conducting large scale engineering development projects.

It was in the belief that these systems management techniques might be used to create an opportunity for new building systems development that this project was initiated in the spring of 1964. The Institute for Applied Technology had as its objectives:

- a desire to extend its services as advisor to other government agencies.

- a desire to provide an occasion for advancing the state of the art in writing performance standards for building systems.

- a desire to advance its mission of creating opportunities for the application of technology by industry.

Defense Department personnel with whom the potential project was discussed evidenced an interest in making available some portion of the military construction program as a market opportunity for this purpose because:

- the changes which have occured in weapons systems have generated the need for buildings which are capable of themselves changing over time in response to user needs.

- it was believed desireable to explore the possibility of providing measurably better buildings at costs equal to or less than current costs by utilizing a systems engineering approach.

This report is therefore being submitted to point out a feasible approach and to outline the scope and structure of a pilot project.

II Acknowledgements

The Institute for Applied Technology wishes to acknowledge the cooperation and assistance of many organization and individuals in the preparation of this report.

The Defense Department has been most cooperative in providing, in addition to the necessary financial support, staff assistance and advice in many areas. We can not acknowledge all who have helped, but we would like particularly to single out the cooperation of those members of the NBS-DOD Joint Committee who have given valuable advice drawn from their long experience in military construction. (See Section X). Max Barth, Chief of Technical Division, Directorate for Construction, Office of the Assistant Secretary of Defense (Installations & Logistics), must be specifically acknowledged because of his early personal encouragement and his continued willingness to take time from his busy schedule to suggest appropriate contacts within DOD and to provide constructive criticism at critical points in the development of this report.

We also want to recognize the contribution made by the Building Systems Development, Inc. staff. Their experience gained from the management of the School Construction Systems Development project (see pp 7 to 10) has been most valuable in helping to shape the direction of the proposed pilot project.

Organizations like the Associated General Contractors, the American Institute of Architects, the Building and Construction Trades Department of the AFL-CIO, and a number of industrial firms in the building field have been willing listeners and advisors.

The Institute for Applied Technology, however, takes full responsibility for the statements and recommendations in this report to the extent that they are merely opinions and does not wish to implicate any of the above in errors or omissions which may exist in the report.

III Summary

This report resulted from a feasibility study contract sponsored by the Assistant Secretary of Defense for Installations and Logistics to the Institute for Applied Technology of the National Bureau of Standards. The feasibility study team, supplemented by outside consultants and liaison support from DOD staff, investigated the possibility of utilizing a systems engineering approach for a pilot project for new designs for facilities within the military construction program. The successful use of systems engineering management in the design and procurement of weapons systems suggested a parallel approach in the application to military facilities (buildings). The success of a project in California which had utilized the systems approach in generating new and more economical building sub-systems for schools provided a precedent.

The project objective of providing DOD with measurably better buildings (as judged by their suitability in responding to user requirements) at costs equal to, or less than, current costs is presented as a feasible and practical goal.

In order to build on the experience of DOD project systems management, and to overcome certain obstacles within the current military construction procedures and appropriations structure, the recommended pilot project should be granted exceptional project systems technical management authority. It is recommended that, with certain minor modifications, the provisions of DOD Directive 5010.14, "Systems/Project Management" and DOD Directive 3200.0, "Initiation of Engineering and Operational Systems Development", be applied.

It is further recommended that this pilot project utilize a 30 million dollar portion of the FY69 and FY70 Milcon program in order to create the organized purchasing power needed to provide a market of sufficient attraction to industry to develop, at their own expense, advanced building systems and subsystems responsive to performance standards. These performance standards will be developed after a thorough analysis of the user requirements (including systems maintenance and operating costs). Preliminary cost-benefit analysis indicates that the project objectives can be achieved within the projected cost framework.

An analysis of the facilities forecasts (generated by the five year force structure) indicates the following potential targets:

- A General Purpose Two-Story Building envelope with flexible interior spaces and other environmental systems responsive to "desk-type" work. This could be utilized in a large number of projects classified as Administration Buildings, Training (classroom) Buildings, and R&D Office Buildings.

- Bachelor Officers Quarters if all three services provide a share of the market.
- Enlisted Men's Barracks if DOD decides that major improvements in the quality of these facilities is more important than cost reduction.

Implementation of the proposed project is planned in a phased manner with the first phase (Formulation of Concept Pre-requisites) to cost $75,000 in contract funds and two man-years of DOD staff time. The complete project which will result in a test and evaluation of the systems approach, will cost approximately 2 million dollars.

To the best of our knowledge no statute law revision is necessary for implementation of this project.

IV Introduction

This feasibility study was conducted in essentially three stages. The first stage involved a preliminary exploration of market opportunities within the military program and potential industrial interest, and an examination of the management procedures used in facilities procurement. The second stage covered a more detailed analysis of the market and a search for ways to overcome certain obstacles encountered in the first stage. The final stage involved the design of a pilot project and the framing of specific recommendations for proceeding. These three stages are discussed in detail on the pages which follow.

V Stage One - A Preliminary Exploration

The early efforts of this study proceeded with the assumption that it would be possible to build on the experience which had been gained in systems engineering as applied to weapons systems within the Department of Defense, and to reinforce, where necessary, this know-how with experience gained by the one major building systems project which had been undertaken in this country. This project which is known as the School Construction Systems Development (SCSD) project had been designed by its project manager, Ezra Ehrenkrantz, as a result of two years he had spent in England studying their use of the systems approach to building. Ehrenkrantz, under a grant from the Education Facilities Laboratories of the Ford Foundation, had managed to get thirteen school districts in California to pool their needs for new high schools into a joint effort. This meant that it would be possible to approach manufacturers and contractors with a potential market of 25 million dollars worth of new school construction. Briefly described the SCSD experiment consisted of the following steps:

a) Acting under joint venture provisions of California law, 13 school districts who planned to build 25 million dollars worth of schools agreed to adopt a systems approach to develop technical innovation for school construction.

Procurement of approximately 12 million dollars of building sub-systems was centered in the joint venture.

b) A team of educators and architects drew up an educational specification which laid out the users requirements essentially in educator's terminology.

c) Architects and engineers then converted the educational specification to a performance specification which expressed in technical terms what performance was to be required of four subsystems, namely,

1. structural subsystem
2. ceiling-lighting subsystem
3. heating-ventilating-air conditioning subsystem
4. interior partition subsystem in three variations
    a. demountable
    b. operable
    c. accordion

These subsystems had their interface points precisely defined and controlled during the design and development phase. Other features of the building, e.g., exterior walls and plumbing subsystems were excluded from the development phase.

d) Manufacturers went through a two-stage process.

The first stage consisted of design preparation, and design evaluation as compared to the performance requirements. The second stage called for group bids (a consortium) on the in-place costs of compatible subsystems. The contract was awarded to the lowest cost combination of the four subsystems.

e) Successful manufacturers were then required to submit prototype subsystems to be incorporated in a demonstration building for final evaluation and debugging.

Results of the bids and specific job proposals to date indicate that project goals are being met (even exceeded). Overall costs for component subsystems in the project are lower while performance is significantly higher. For example, air conditioning is provided where none is provided in the conventional solutions. The following table shows bid results for subsystems, expressed in dollars per square foot, compared to conventional costs.

Subsystems	Conventional Construction	SCSD Project Bid
Structure	3.24	1.81
Heat-Vent	1.90	
Heat-Vent-Air Cond. 1/		2.24
Light/Ceiling	1.58	1.31
Partitions	1.62	1.57
	8.34	6.93 2/

1/ Includes 5 year maintenance contract

2/ This represents a cost saving of 16.8% on approximately half of the cost of the building, hence 8.4% saving on overall costs.

Key features of the SCSD operation are:

(1) The constraints on existing and proposed systems were carefully analyzed and recognized as specific problems to be dealt with.

(2) The bridge from the educational spec to the finished working drawings was built on these successive actions:

Educational Specification

Performance Specification

Design Proposals
Prototype Testing

Material Specifications and Shop Drawings

(3) A technical systems manager had overall control of the operation

With this project as a precedent our study team began a detailed look at facilities projections by DOD based on the five year force structure. At the same time preliminary conversations were held with DOD personnel to explore the transferability of the SCSD approach. Still other team members held exploratory conversations with industry executives in order to see what reservations, if any, industry might have regarding the nature of this project and how far they might be willing to go in responding to requests for proposals from DOD.

Detailed information which was gathered on facilities projections began to eliminate certain building types from consideration on the basis of inadequate dollar volume of construction programmed. (The SCSD experience had shown that it would probably take between 25 and 30 million dollars of construction volume to generate a market of sufficient size to interest industry in tooling and development investments for new systems.) Still other categories were eliminated on the basis of being too specialized to provide any transferability of the new systems to civilian applications, since large repetitive markets beyond the military will have to exist to interest industry in the investment opportunity. One early favorite, hospitals, was rejected since steps were already underway within the Army Surgeon General's Office to explore hospitals as a systems opportunity for Defense oriented industries. It was felt desirable to avoid any semblance of duplication.

The exploration which was made regarding the transferability of the SCSD concept to military procurement procedures soon indicated that there were several places in the existing practice which were going to prove to be obstacles:

- Statute limitations associated with appropriations for the military construction program would not permit any advanced commitment by an Agency, actual or implied, of the military building dollars. This meant that the assurances of a market which SCSD had been able to provide to industry prior to actual construction would not be possible. Industry would not be willing to risk specific development costs without some form of assured reward or predictable volume market.
- The existing procedures of the military construction groups, the Corps of Engineers and the Bureau of Yards and Docks, did not appear to offer a favorable climate for success in a venture of the kind proposed, even though they may be well-suited to conventional industry practice. Responsibility for various phases of a project's life (from the statement of users needs to the supervision of actual construction) was delegated to different offices and linked only by a series of information forms. Projects are also managed (as is common in the industry) one at a time with the transfer of the knowledge gained on one project to the next essentially dependent on personal experience.

- There appeared to be no way within current practice to group geographically distributed projects for joint bidding.

VI Stage Two - Detailed Market Analysis

As a result of the obstacles encountered a regrouping of effort was called for. A more thorough exploration of the structure of the military market - one which went beyond the conventional categories like "training buildings" or "administration buildings" - was begun using the computer facilities of NBS to make a computer aided analysis as described in Technical Annex C. At the same time management methods were explored in greater detail in order to see if a way might be found to structure a project that avoided as many of the obstacles as possible.

It was clear to the project team that the project approach had to address itself to the total process of building. Figure 1 illustrates the various stages of this total process. Unless our analysis began with the user needs (recognizing that there are various levels of "users", from the actual occupants of the building, to the military service who uses the facility as one of the requirements in performing its mission) we would not be likely to identify the "systems" requirements of the buildings we considered, but rather be limited to some form of "product improvement" based on traditional views of the building's design requirements. Also, since the project intended to go beyond the procurement of "off-the-shelf" products this meant that it would be necessary to introduce competition not just at the construction site, but also in terms of concept formulation, the design approach, process management and similar factors.

This stage, therefore, proceeded along the two paths shown in Figure 2. One was the analysis of the market to find potential building "targets" and the other was one of looking for ideas on procedures.

The market analysis during this stage involved three parallel efforts. These efforts are covered in greater detail in Technical Annexes A, B, and C, but the nature of the effort should be summarized here for the purpose of understanding the intended technical approach of the proposed pilot project.

Technical Annex A provides a descriptive display of the spectrum of technical systems. The chart* and accompanying material describe a hierarchy of possible systems running from conventional building products like bricks and boards (which are essentially building parts which cannot be any further subdivided) to complex whole units like house trailers or mobile offices. The spectrum, therefore, shows a range of available choices of systems with varying amounts of factory labor (industrialization) and site labor. Since conventional practice does not vary

* Chart located in rear pocket.

THE BUILDING PROCESS

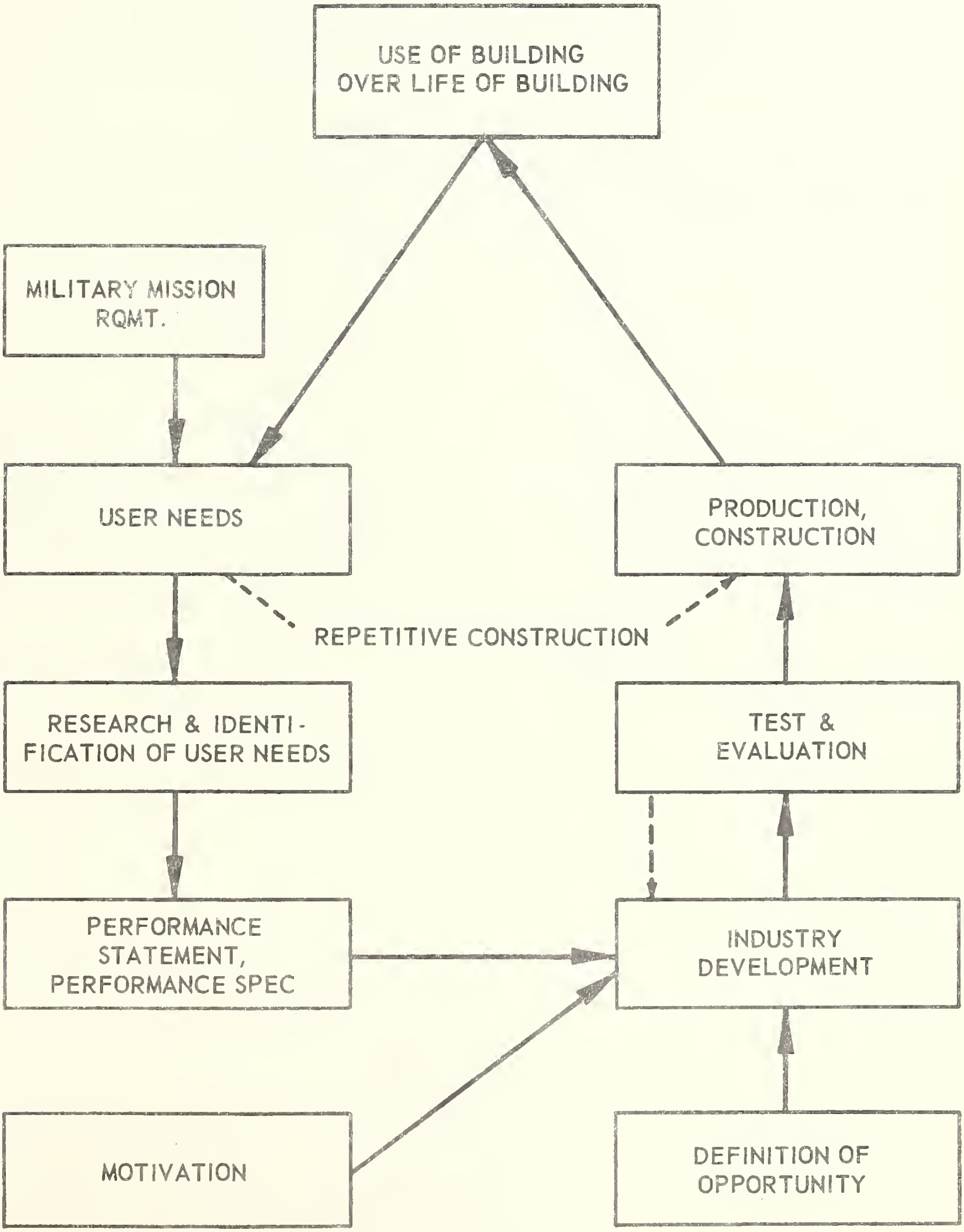

FIGURE 1

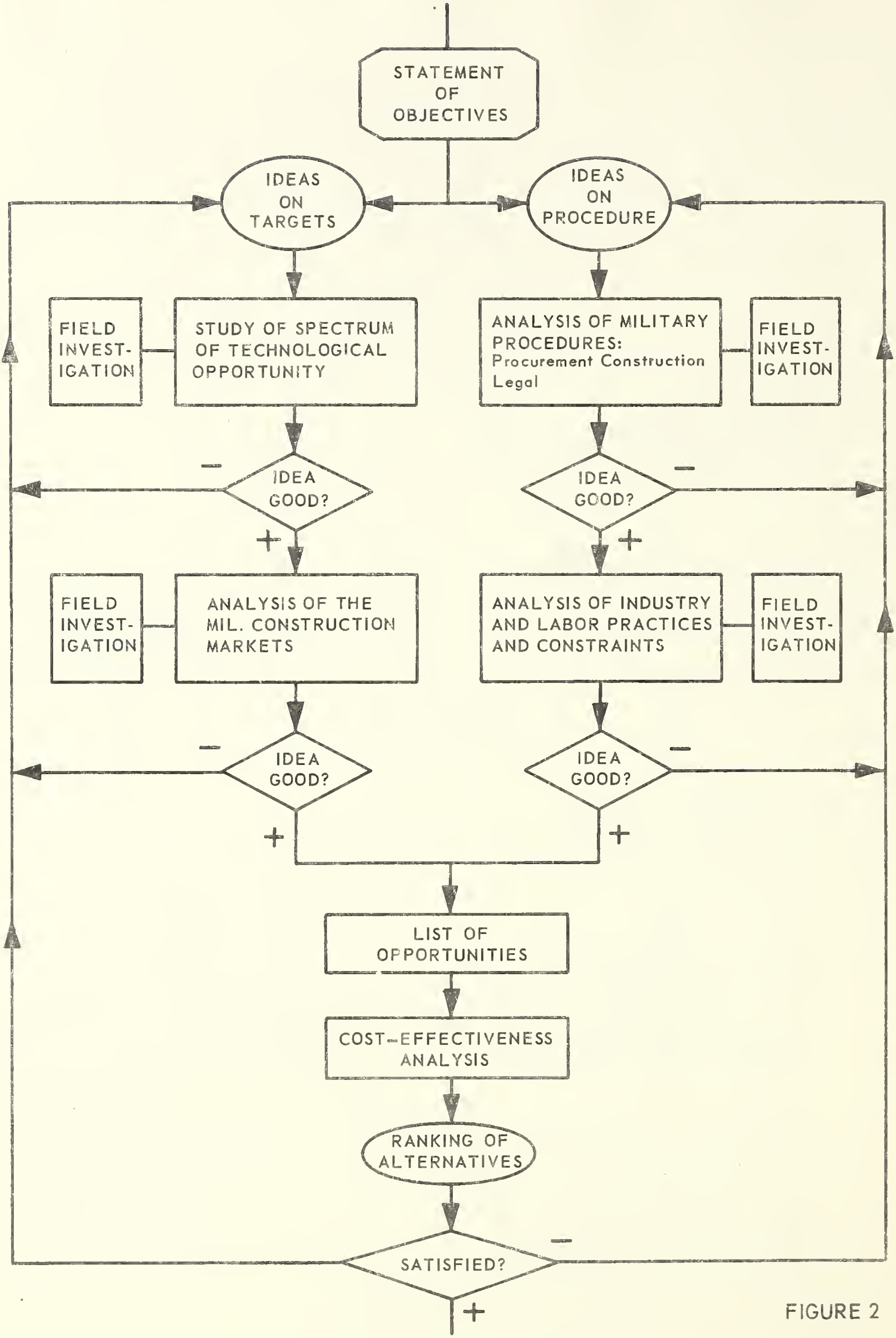
STATEMENT OF OBJECTIVES
IDEAS ON TARGETS
IDEAS ON PROCEDURE
FIELD INVESTIGATION
STUDY OF SPECTRUM OF TECHNOLOGICAL OPPORTUNITY
ANALYSIS OF MILITARY PROCEDURES: Procurement Construction Legal
FIELD INVESTIGATION
IDEA GOOD?
IDEA GOOD?
FIELD INVESTIGATION
ANALYSIS OF THE MIL. CONSTRUCTION MARKETS
ANALYSIS OF INDUSTRY AND LABOR PRACTICES AND CONSTRAINTS
FIELD INVESTIGATION
IDEA GOOD?
IDEA GOOD?
LIST OF OPPORTUNITIES
COST–EFFECTIVENESS ANALYSIS
RANKING OF ALTERNATIVES
SATISFIED?

FIGURE 2

far from that end of the spectrum that deals with parts, any project which moves towards greater industrialization will encounter groups within the building industry whose interests are threatened. The extent of this threat is estimated on the diagram for each stage of industrialization. The spectrum thus provides a useful tool in evaluating alternative courses of action.

Technical Annex B identifies a key problem in conventional construction practice for which the systems engineering approach can help to provide solutions. This is the problem which develops each time a subsystem - like heating ducts - interfaces with another system - like a structural system. If these subsystems (as is common practice in the building industry) are designed and produced independently of one another they obviously work well together only by chance, or a large amount of reengineering. The study which backs up this annex has shown that maintenance and remodeling costs are effected in a major way by the fact that these subsystems are not integrated into a total system. Since the total building process includes the requirement to maintain and remodel buildings over time, this should obviously be considered as a part of the cost-effectiveness of any system considered. This annex further suggests that it might be well to consider individually "articulated" systems (systems which are kept separate from one another) in order to be able to modify one - like electrical wiring - without having to partially destroy another - like the partition system.

Annex C, as has already been suggested, used a computer based matrix to explore the functional requirements for military buildings. This exploration took two directions:

1. To explore the functional and geographical requirements for a class of buildings identified by a construction category code - like barracks and BOQ's to see how much of the projected volume shared similar requirements which might be grouped into a systems market. For example, BOQ's that were low-rise structures would provide a systems market different from those using high-rise structures, and new construction had to be separated from remodeling.

2. To explore a potential group of buildings whose functional needs would be similar even though they fell into different construction categories. For example, find how many buildings needed lighting systems which provided the same illumination levels, and also required air-conditioning.

Further refinements made it possible to analyze geographical distribution within these categories, and distribution of volume between the military departments.

Comparison of the desired building volume of 30 million dollars for a pilot project over one or two fiscal years in FY69 and FY70 (from Tables C24 to C27 in Annex C) indicates the following favorable possibilities:

	Army	Navy	Air Force
Admin/1 Training/1 R&D/1	good	good	poor
Barracks	good/2	good	poor
BOQ	fair/3	fair/3	poor

Notes: 1/ This category consists of a general purpose building "envelope" two stories in height, with similar requirements for lighting, heating, and air-conditioning and with a need for flexible interiors. It could be used in all three of the categories indicated for that portion of the total volume identified by our analysis.

2/ Substantial portion of volume is in barracks complexes (See Table C10).

3/ Adequate volume programmed but Congressional reduction of program, if it materialized would reduce the market necessary for a successful project.

If it were decided that a tri-service project is to be instituted, then any of the building target areas constitutes an adequate market.

In the Spring of 1965 our exploration of possible ways of putting together a procedure which would avoid the obstacles mentioned in stage one, was dramatically rewarded when DOD Directive 5010.14, "System/Project Management" was issued. This directive, together with the subsequent directive 3200.9, "Iniation of Engineering and Operational Systems Development,"* provides a methodology for conducting a pilot project of the sort we would like to recommend. Even though minor modifications will be desirable in order to adapt this procedure to the building industry and to accommodate current procedures of the Military Construction Program (to the extent that is feasible), these directives have the advantage of being well-suited to the general practice of the Defense Department in its own research and development activities. Surely if they are considered effective enough to be required for major weapons systems development, they should be given a fair trial in the building area. It is possible that the differences between manufacturers in the building industry and manufacturers in the "defense" industry are too great to effectively

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* It should be recognized that the methodology and approach represented by these directives differs very markedly from traditional practice in military construction. On the other hand, DOD development approaches, readily appreciated by the weapons industry will not be understandable to the civilian oriented U.S. building construction industry without careful briefings.

transpose these directives, but it is our professional judgment that major segments of the building industry are ready and willing to participate in a systems approach of this sophistication.

VII Stage Three - The Criteria for a Pilot Project

Having identified several building targets that appeared to offer good possibilities for a pilot project, and having found a procedural methodology that would lend itself to such a project, we proceeded in this last stage to design a pilot project which we considered feasible. We first set out for ourselves what we considered to be the important criteria for establishing a building systems pilot project. They are:

1. The pilot project should have a clean cut objective which upon attainment is susceptible to quantified measurements as to its degree of success. Such success may then be used as a practical working model for extension of the system principle. A DOD building systems project that introduces technical innovation and provides measurably better buildings at costs equal to or less than present costs thus qualifies.
2. The pilot project should provide an opportunity for genuine innovation, not just minor product improvements, and should be in an area in which industry can make major systems improvement through new technology.
3. The pilot project should be directed towards the customers military performance requirements rather

than a product concept. A critically important feature of the proposed DOD building systems project is the matter of designing to the users needs realizing that in a large military complex, this means the needs of the whole hierarchy of users from the local users of the building, the commanders of the local users, all the way up to the Military Department owner-user.

4. The pilot project objective should be attainable within the DOD's predictable need for the building systems. The proposed project deals with hardware systems ready for new construction (ground breaking) in late 1969.

5. The pilot project manager should be granted exceptional project-start to project-finish centralized technical systems management authority. In addition, the pilot project development phase should follow such institutionalized procedures as are appropriate to minimize the generation of internal problems. The proposed project and recommendations contained in this report include application of DOD Directive 5010.14, May 4, 1965, subject "System/ Project Management", and DOD Directive 3200.9, July 1, 1965, "Initiation of Engineering and Operational Systems Development."

Other factors influencing the structure of the pilot project are Manpower and Project Costs Estimates (See Table 1) and Description of Major Work Activity and Key Milestone Approvals (See Table 2). Figure 3 ties these elements together in a time phased manner.

TABLE 1. MANPOWER & PROJECT COST ESTIMATES

Phase	Time Required	Manpower Required NBS	Manpower Required DOD	Contract Costs
Feasibility Study	10 mos.	3 my		$ 100,000 *1/
I Concept Formulation Phase				
A. Establishing planning office, etc.	4 mos.	1 my	2 my	75,000
B. Expand planning office, etc.	6 mos.	2 my	3 my	145,000
II Development Phase	9 mos.	5 my	6 my	160,000
III Test & Qualification Phase	9 mos.	6 my	5 my	150,000
Testing Program *2/				1,000,000
IV Construction Evaluation Phase	24 mos.	4 my	4 my	140,000
				1,770,000
	Estimated DOD manpower costs			500,000
	Total project costs			2,270,000

*1/ NBS staff time is supplemented by consultant computer time in varying degrees so that dollars and man years do not have a direct correspondence.

*2/ These testing costs are based on the assumption that industry will be willing to bear the risk in development costs, if DOD will fund the testing costs which will be required to determine the proposed systems compliance with performance standards to be developed.

TABLE 2. DESCRIPTION OF MAJOR WORK ACTIVITY AND KEY MILESTONE APPROVALS (See also Figure 3)

1. (Key Milestone) OSD approve initiation of Concept Formulation Phase and tasks a Military Department for execution of this phase. OSD programs $220,000 for Concept Formulation and releases $75,000 with the balance held in abeyance until approval of Concept Formulation.

2. <u>MilDepts establishes a Systems Project Planning Office</u> including an Acting Systems Project Manager and 5 other professionals plus administrative support, and with NBS staff technical support at a level of 3 professionals.

I. CONCEPT FORMULATION PHASE

A. Establish Planning Office

A1. <u>Concept Formulation Pre-requisites</u>: Determine that:

a. Primarily engineering rather than experimental effort is required, and the technology needed is sufficiently in hand.

b. The mission and performance envelopes are defined.

c. The best technical approaches have been selected.

d. A thorough trade-off analysis has been made.

e. The cost effectiveness of the porposed item has been determined to be favorable in relationship to the cost effectiveness of competing items on DOD-wide basis.

f. Cost and schedule estimates are credible and acceptable.

A2. Survey building targets in the military construction program for FY69 and FY70, which buildings are appropriate for application of the process of systems engineering for development of technical improved systems/subsystems. Corrolate with A1c above.

A3. & A4. Prepare a Draft Outline of the Functional User Requirements & Performance Specifications for buildings identified in A2 above.

A5. Prepare a Draft Outline of Technical Development Plan (TDP) for execution of the total project.

3. (Key Milestone) OSD/Mil Department approves the Concept Formulation Pre-requisites, directs completion of the concept formulation, and releases $145,000 for technical support.

4. MilDept expands Systems Project Planning Office to a total of 6 professionals plus administrative support with NBS staff technical support at a level of 4 professionals.

B. Expand Planning Office

B1. Complete statement of functional user requirements for building targets.

B2. Complete a Performance Specification responsive to user requirements

B3. Complete TDP including information for the request to manufacturers to develop and procedures for pre-qualification to bid on building systems/subsystems.

B4. Prepare a draft of a System/Project Manager Charter.

B5. Initiate contacts with representatives of industry professional and labor groups to advise them of the scope and intent of the project and receive their advice and reactions.

B6. Publish a project Synopsis in the Commerce Business Daily.

B7. Secure manufacturers letters of intent to develop.

5. (Key Milestone) OSD/MIL Dept approves the Concept Formulation, directs initiation of the Development Phase, releases $160,000 for development work, and issues a Systems/Project Management Charter.

6. Mil Dept appoints Systems Project Manager and expands office to 8 Mil/Civilian professionals, plus administrative support, and with NBS staff technical support of 6 professionals.

II DEVELOPMENT PHASE

C. Manager completes the following items of work:

C1. Update TDP including improved cost estimates and project payout estimates.

C2. Issues request for development to industry with terms of pre-qualification for bidding systems/ sub-systems equipment.

Cs. Carries on continuous coordination of industry draft design proposals to ensure responsiveness to performance specifications.

C4. Approves design proposals for test & qualification phase.

7. (Key Milestone) OSD/Mil Dept approves development phase and directs initiation of test and qualification phase, and releases $1,150,000 for conduct of this work.

III TEST AND QUALIFICATION PHASE

D. Prototypes developed

D1. Conduct prototype test for performance and inter-subsystem compatibility.

D2. Review and approve material specs shop drawings of manuals.

D3. Qualifies manufacturers to bid on building systems. Industry participants prepare material spec shop drawings and manuals and submit for approval. Industry participants submit costs not-to-exceed unit prices.

8. (Key Milestone) OSD/MilDept approves Test & Qualification phase and directs completion of project.

IV CONSTRUCTION EVALUATION PHASE

E. Contract Drawings and Specifications Prepared

E1. Industry completes advance production planning and submits data for Architect-Engineers

E2. Architect-Engineers complete job design.

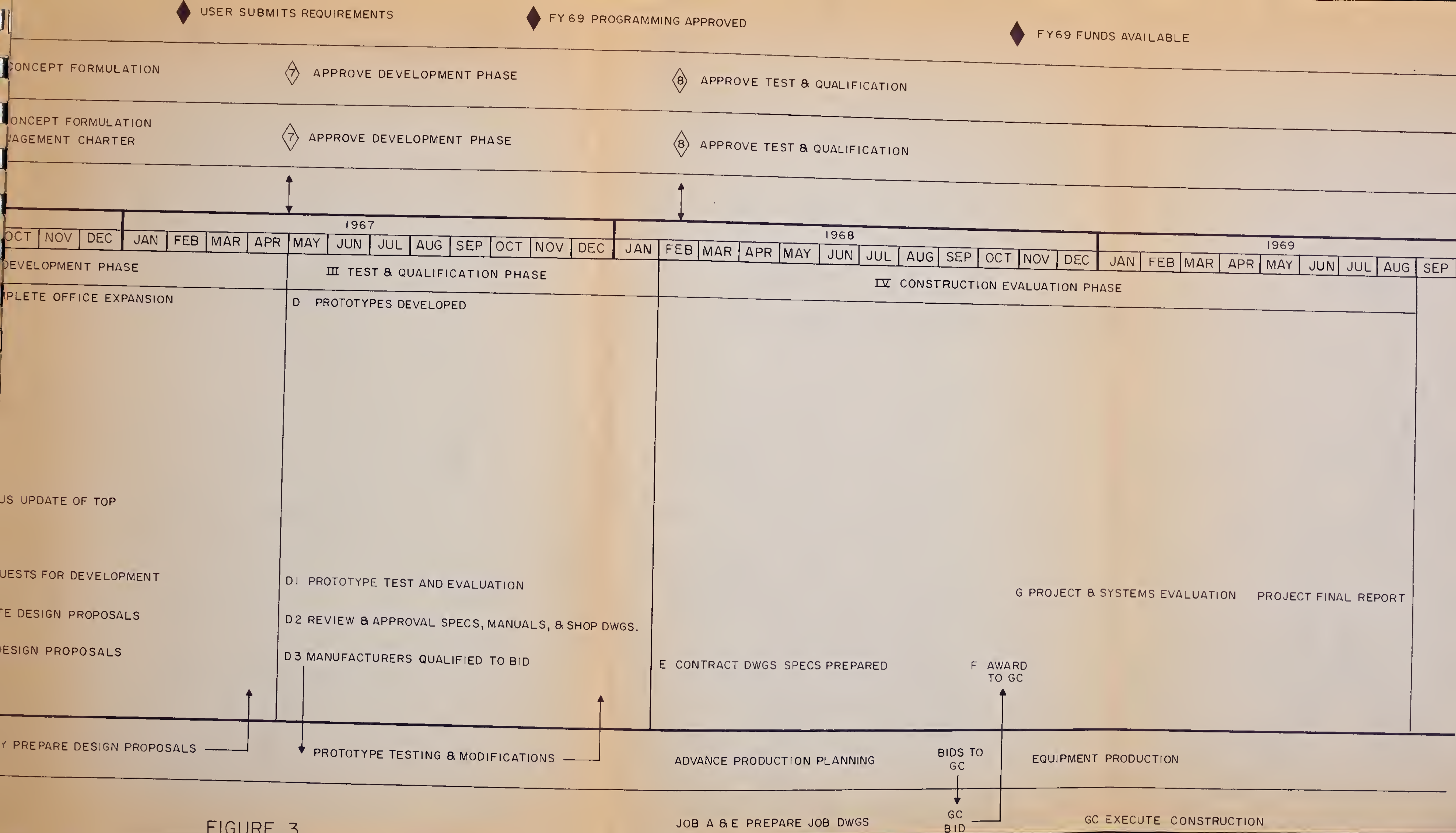
F. Award to General Contractor

F1. Industry submits advance production plans to General Constractor

G. Project and Systems Evaluation and Final Report

G1. General Contractor completes construction

G2. Project Management Office completes systems evaluation and submits final report.


USER SUBMITS REQUIREMENTS
FY 69 PROGRAMMING APPROVED
FY69 FUNDS AVAILABLE
CONCEPT FORMULATION
7 APPROVE DEVELOPMENT PHASE
8 APPROVE TEST & QUALIFICATION
ONCEPT FORMULATION
AGEMENT CHARTER
7 APPROVE DEVELOPMENT PHASE
8 APPROVE TEST & QUALIFICATION
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III TEST & QUALIFICATION PHASE
IV CONSTRUCTION EVALUATION PHASE
PLETE OFFICE EXPANSION
D PROTOTYPES DEVELOPED
US UPDATE OF TOP
UESTS FOR DEVELOPMENT
D1 PROTOTYPE TEST AND EVALUATION
G PROJECT & SYSTEMS EVALUATION
PROJECT FINAL REPORT
TE DESIGN PROPOSALS
D2 REVIEW & APPROVAL SPECS, MANUALS, & SHOP DWGS.
ESIGN PROPOSALS
D3 MANUFACTURERS QUALIFIED TO BID
E CONTRACT DWGS SPECS PREPARED
F AWARD TO GC
Y PREPARE DESIGN PROPOSALS
PROTOTYPE TESTING & MODIFICATIONS
ADVANCE PRODUCTION PLANNING
BIDS TO GC
EQUIPMENT PRODUCTION
JOB A & E PREPARE JOB DWGS
GC BID
GC EXECUTE CONSTRUCTION

FIGURE 3

VIII Action Recommendations

It is recommended that the Department of Defense establish a Military Construction Building Systems Development Project, which recommendation contains the following actions for implementation:

- Apply provisions of DOD Directives 3200.9 and 5010.12, titled, "Iniation of Engineering and Operational Systems Development" and "Systems/Project Management" respectively, for the establishment and guidance of a Project Planning Office in a Military Department
- Authorize 2 man year of DOD manpower and administrative support for initiation of the project, and name an Acting Systems/Project Manager.
- Task the project planning office to:
    1. Complete the pre-requisites to Concept Formulation
    2. Survey and identify the specific building targets.
    3. Draft functional user requirements.
    4. Draft performance specifications.
    5. Draft a Technical Development Plan (TDP) for entire project.
- Fund the project initiation, including the work outlined above, in the amount of $75,000 for technical support to be furnished by the Institute for Applied Technology of the National Bureau of Standards.

Technical Annex A

Spectrum of Technical Systems

NBS/DOD Project

Preface to Chart Showing Hierarchy of Product Organization Within the Building Industry

The table indicates the spectrum of alternatives available to build at different levels of industrial sophistication, from the use of materials unformed when delivered to the site to units which are complete in themselves and ready for occupancy at the time of delivery. If one accepts the premise that the method of providing enclosure for human requirements should be met in the best possible way within the limits of available resources, then the various alternatives must be carefully weighed.

Each approach has relevance for specific sets of conditions with various factors both pro and con that must be evaluated. Upon defining a general human use requirement the appropriate alternatives must be evaluated in terms of potential to:

1) satisfy use requirements

2) meet economic considerations

3) meet time requirements

4) provide for feasible working procedures within the building industry.

An approach which subverts the principles of public bidding or calls for procedures that can be blocked by a sufficiently powerful group within the building industry is probably not acceptable no matter what its potential may be for accomplishing the first three objectives.

This Annex will deal primarily with item number 4 above. Any approach to organizing the forces within the building industry must take into account the interests of Architects and other Professionals, Contractors and Subcontractors, Labor, Industry, Code and Regulatory agencies.

Each approach has certain problems which must be resolved in the course of providing building facilities to meet specific use requirements. The procedures which are finally used should not be chosen because they avoid the largest number of problems but because they promise the greatest opportunity of fulfilling points 1, 2 and 3 while at the same time allowing for a visable method of working with respect to point 4.

The actual method of working should be determined with the full knowledge of the areas of difficulty which must be overcome and the procedures developed to meet the basic problems. It is in this context that this annex includes a discussion of problem areas of which one must be aware when charting a course of action in the next phase of this project.

The table is developed from left to right showing the spectrum of construction alternatives from highly industrialized and coordinated products and procedures to those representing the status quo. The table indicates a decrease in factory labor content as it moves from left to right with respect to site labor. A similar table may be drawn up whereby the spectrum of alternatives might be represented in terms of site rather than factory industrialization at one side and status quo site procedures at the other. The lift slab technique offers one example of site industrialization. The drawings at the lower left hand portion of the table reference this area of work. A similar range of alternatives related to effective site procedures may be developed at most points on the table. At the lower left hand corner of each diagram on the table are a number of letters indicating specific groups within the building industry which would be particularly affected by the alternatives suggested on the table. If a capital letter is used the concern is major, if a lower case letter is used the concern is minor.

Legend

A Architect

E Engineers

C Code

GC General Contractor

SC Sub-Contractor

I Industry

L Labor

The explanation of the table which follows goes from parts on the right of the table to units on the left. As the products increase in complexity the problem areas stated in prior categories will still apply. Thus the problems related in connection with the various subsystems will still apply when a number of subsystems are joined together to form a building system.

Part

Definition	A portion of a component. A single factory fabricated item such as a hinge or brick. As defined here it may be made up of smaller bits and pieces which do not have a unique identity until put together to make a part.
General Comments	The parts which are used in turn to make up components, assemblies, subsystems, etc. are given their initial size and configuration through a factory process. Once this size and shape is fixed it determines the nature of all products no matter what their location on the table might be. When working with any industrialized part the coordination of the two is predetermined when they are each made. Modification is possible to make them fit or work together but this is a most wasteful process as with proper coordination they can be designed to do initially. This problem of coordination of products holds true for all levels of organization within the building industry, and when things go wrong one must always go back to the individual parts from which the more complex products are made in order to correct the difficulties.

When we work at a lower level in our hierarchy than parts we are generally working with building materials not completely formed for construction so that their use requires some alteration at the site by way of adding to the material, subtracting from it or forming before it is finally introduced into the building. This table begins with the part as it is essentially a chart of the different ways in which factory made products may be organized for construction.

Component

Definition	A coordinated group of parts which form a complete building product, or a product which is used with others as a portion of an assembly.
Precedents	Windows
Areas of Use	Any traditional building.
Advantages	The component and its use is within the realm of traditional building design and construction. Its use has a long history and the results are predictable on the basis of that history.
Disadvantages	New forms of organization are required for progress in the building industry in order to keep up with the evolution of current technology and user requirements.
Problem Areas & Solutions	Represents the status quo.
Findings	Where the status quo can be questioned other alternates should be considered which change the basis of design production of building products, and the construction of the buildings themselves. It is also necessary at times to try pilot programs to see if other alternatives are now possible and if they represent a better way of doing the job.

Assemblies

Definition	A coordinated group of components put together to perform one or more functions within a subsystem, or within a conventionally designed building.
Precedents	Traditional curtain walling panels which may include doors, glazing and opaque spandrel panels. The truss-deck assembly performs some of the functions within SCSD structural subsystems. A truss and deck assembly may appear in a conventional building.
Area of Use	Well-coordinated traditional building programs, taking advantage of the best of traditional technology, use assemblies in normal practice today.
Advantages	Ample precedents for well-coordinated work done by the architect and his consultants at the time individual buildings are designed. Many manufacturers are contractors and able to bid directly and no procedural developments are required for normal construction situations.
Disadvantages	The problem of coordinating pre-designed assemblies to work with one another. The lack of opportunity to fit user requirements into

the initial statement of the problem when the products are first developed by manufacturers.

Problem Areas & Solutions

The major problem area is the inability of this approach to meet the ever-changing requirements of the client rapidly enough.

Findings

The use of well designed assemblies represents the best of traditional construction. Architects and engineers design buildings so that all the products will fit together to do a complete job even though the boundary conditions between assemblies were never considered when the products were designed by the manufacturers. The inevitable site fitting and tolerance problems indicate that there should be a better way. The coordination of components represents a degree of sophistication on the part of industry when producing assemblies which is most desirable. On the other hand it reduces the possibilities for inter-fitting with other products as a higher degree of industrialization is involved without coordination with other products. Unless assemblies are designed as specials coordination to do a total job is sometimes difficult. Therefore it is difficult to develop a sufficient market to justify the production of mass produced assemblies. Mass production seems to require being either more or less sophisticated than that of working with assemblies, since assemblies tend to produce closed systems..

<u>Subsystems</u>

Definition — A coordinated group of assemblies for the purpose of performing a building function.

Classification — In this study, classified as six:

<u>Utility subsystems</u> - concerned with circulation of utilities, sometimes their generation, and their termination at point of use. Includes water, gas, electricity, waste disposal, etc.

<u>Lighting/Ceiling subsystems</u> - concerned with ceiling surface and lighting functions, and may involve terminal components of air distribution subsystem.

<u>Structure subsystems</u> - concerned with support of roof, floors.

<u>Interior Partitions subsystems</u> - concerned with vertical, and sometimes horizontal subdivision of space.

Thermal subsystems - concerned with heating, ventilating and/or cooling the building environment.

Exterior/wall subsystems - concerned with weather protection and vertical treatment of building perimeter.

Advantages	Coordination makes for faster and better installation or erection. Research and development on a subsystem basis makes for more performance predictability. Coordination within the subsystem makes it possible for effective development work to be done by a single manufacturer without necessary involvement of many companies. It provides for an efficient way of solving the inherent problems related to a specific component area, and due to the fact that the products may be used in an independent manner it makes it possible to obtain very wide distribution for the completed components.
Disadvantages	Not effective for single or small project. Difficulty of coordinating individual subsystems with other building components as they are not designed initially to work together.

Problem Areas and Solutions

There may be considerable difficulty with justifying the use of independent subsystems along with other components not designed on the same basis, as the greatest economies are obtained when all the components are coordinated with another. Extent of predesign raises problems with relevant design professions, estent of prefabrication raises problems with subcontractors and labor, acute in utilities, less acute in electrical and lighting, minor or negligible in enclosure, structure, thermal, and exterior wall.

Large scale production involves very careful code studies during Research and Development period.

Exterior wall subsystem may have major problems in architect acceptance, and its use as a load bearing wall may cause the same problem with structural engineers as the structural subsystem.

Structure - The problems here are in meeting the various demands of structural engineering and satisfaction of codes. They may best be handled by developing a subsystem which gives a range of alternatives with respect to loading and fire protection. If the design features of the subsystem are appropriate to the function architectural adaptation should be simple to obtain.

Thermal & Ventilation - Problems will develop with limitation on mechanical engineering design and mechanical subcontractors practice shopping around for components. Mechanical subcontractors like to be able to shop components which comprise a subsystem from many different manufacturers. In using a subsystem all they can do is install the components and assemblies without the opportunity to substitute equals. If it is possible to bid subsystems against one another, however, there should be no great problems as they will still be able to shop manufacturers for the whole subsystem. Mechanical engineers will be concerned with obtaining sufficient flexibility within a system to accommodate the entire range of user's requirements. This can be handled with unitary packages for simple repetitive situations or with sophisticated system for buildings of complex function. Labor will be concerned with the way the distribution system is handled but the appropriate use of site labor would solve this problem. The general contractor will be satisfied if prime contracts are not let. The architect will desire good appearance of the equipment and compactness of design to save area. Specialty manufacturers who normally sell portions of this subsystem to subcontractors might not like to approach but do not have sufficient force to upset the work. As in the case of structure, the subsystem should provide for a sufficient range of alternatives so that various requirements can be met.

Utilities Adjustments in labor practices will be involved here. Experience has shown to the introduction of factory fabrication techniques or any approach which markedly reduces site labor. Ventures in this area should try to develop site techniques perhaps working with mobile site factories, if possible. There is also strong subcontractor pressure against units which might be factory fabricated and used as complete utility core and also pressures from traditional manufacturers in this area against the introduction of new materials. The current codes tend to respect the wishes of the above listed groups and act as a barrier to the use of new techniques. Progress here may be slow but site fabrication techniques for large programs appear to offer the best chance of progress in this area.

Ceiling - Major problems will be found with just about everybody in this case. The architect will be very concerned with the appearance of all the components and assemblies. The electrical and acoustical engineers with their ability to solve all the problems, labor with the coordination of what was traditionally the products of many different specialty manufacturers into one subsystem, and electrical subcontractors who see their work going to integrated ceiling subcontractors. Sufficient precedents, however, have been established in this area and the integrated ceiling subcontractors are making sufficient headway so that this portion of the industry is now in a period of rapid evolution. This evolution will make it possible to do what is desired even though everyone will not be happy. The subsystem should be designed to provide a range of alternatives appearance, illumination, acoustical properties, etc., if it is desired to have this subsystem meet normal design requirements. The user requirements for this subsystem are extremely varied.

Interior Partitions - The architects will be most concerned with this subsystem. The problems will relate primarily to the appearance of the building. The best way of handling this is to develop a sufficient range of alternatives. Other problems will occur with subcontractors, codes, labor, industry and engineers if one tries to build in the various services as an integral part of the partitions system. At the present time it appears more desirable to install these services at the site rather than in the factory.

Exterior Wall The architects and codes are to be considered here. If the wall is expected to contribute to the system structurally then the problems of a structural subsystem will apply. The architect's problem will be one of variety of expression and the code will apply primarily to fire protection and separation problems.

Incomplete Building Systems

Definition	A coordinated, or related, group of subsystems which perform some of the functions of the complete building.
Precedents	SCSD is an incomplete, coordinated system, Western Sky Envirogrid is an incomplete, related, system, embracing as it does a group of environmental subsystems (lighting, acoustics, air distribution).
Area of Use	Any facility of clearly defined functions and a large building program to underwrite the considerable necessary research and development.
Advantages	Almost any requirements can be built in (including economic) tends to reduce amount of site labor relative to traditional building, and to substitute more efficient shop labor. Conversely local labor is still required and quantity can be géared to the political situation. At present, most effective in more sophisticated buildings, but not intrinsically so. Choice can concentrate on more sophisticated subsystems. A good balance between production efficiency and design choice can be built in.

Potential cost and time savings with these techniques tends to increase relative to traditional building as building type gets more sophisticated. Choice of subsystem categories can ease specific contractor, professional, or labor problems.

Disadvantages	Not effective for single or small project. Economics not likely, if large geographic spread of projects or remote area projects unless systems can be bid locally and be installed by local labor systems.
Problem Areas & Solutions	Contracting problems are involved in any system where certain subsystems must be used with others and subcontractors are not free to put any combination of components together in order to perform a specific job. The selection of the components relating to specific categories and extent of predesign raises problems with design professions, extent of factory fabrication raises problems with localized contractors, subcontractors and labor.
Findings	The judicious choice of subsystem categories can go a long way to alleviate these problems: e.g., non-system plumbing helps with

labor and subcontractors. Large scale production involves very careful code studies during Research and Development period. Time taken to develop system may make it out to date after too short a production time. Contracting problems can be reduced very considerably if a number of different subsystems are developed each category of the building system that is part of the program thus allowing the subcontractors to take bids from the various acceptable manufacturers participating in the program.

A clear statement of objectives and a rationale the systems approach combined with judicious allocation of the degree of procedural change required by all parties in the building industry can ease design, contracting, and labor problems. Allocation of as much work as possible to the site can prevent contracting problems from becoming critical. Coordination and repetition in the work can keep costs down. Incomplete system does not have potential for technical innovations to same degree as complete system, but political advantages at this time far outweight this.

Building Systems

Definition	A coordinated group of subsystems which perform all the functions of the complete building. A high level of industrial production is implied although not intrinsic.
Precedents	Acorn house (Koch)
Area of Use	Any facility of clearly defined functions and a large building program to underwrite the considerable necessary research and development work.
Advantages	Can be designed to meet almost any functional requirements. Tends to much more efficient construction procedures than traditional building forms. Should result in more sophisticated building, but not intrinsically so. A good balance between production efficiency and design choice can be built in. Potential cost and time savings, with these tending to increase relative to traditional building as building type gets more sophisticated.
Disadvantages	Not effective for the single or small projekt. Economies not likely if large geographic spread of projects, or remote area projects. In trying to work with the entire building

it is possible to subsidize less efficient portions of the system with those that are more efficient. By incorporating all aspects of a building to a system it is possible to build up resistance on the part of various building groups.

Problem Areas & Solutions

This approach using a total building system which is to be constructed at the site requires the cooperation of all groups within the building industry and at the same time changes the role of each of the basic groups. The fact that a single system is used in its entirety makes it difficult for traditional bidding procedures to be employed.

Extent of predesign raises problems with design professions, extent of factory fabrication raises problems with localized contractors, subcontractors, labor and codes. Large scale production os a complete building system involves very careful code studies during Research and Development period. Time and money taken to develop system with the participation of different companies each working with their own specialty requires a very complex organization. It is very difficult to get such a group of manufacturers to work together for any period of time.

Findings

A clear statement of objectives and a rationale for the system's approach, combined with careful review of the changes which may be required on the part of all parties in the building industry can ease design, contracting, and labor problems. To do this the system should provide a design keyboard for the architect and his consultants to meet program requirements using their own design approaches. It should provide for viable bidding techniques for the contracting industry. Careful allocation of as much work as possible to the site, and systemization and repetition in the work, can prevent contracting and labor problems becoming critical. Code problems can be overcome, if in the provision of alternatives within the system for design freedom, choices are made which will provide for a variety of code requirements.

<u>Incomplete Units</u>

Definition

A space enclosure which is not self-sufficient in use, but requires other units, subsystesm, or components to make it so.

Precedents	Modulux prefabricated classroom unit.
Area of Use	Facilities which require limited mobility. Less repetitive function and more complex user requirements than units.
Advantages	Not dependent on very much site labor. Very fast erection. Possible relocation and reuse of facility. Efficiency of production and distribution. Appropriate for urgently required fixed facilities as well as mobile facilities.
<u>Disadvantages</u>	Spatial limitations, size and story height. Limitations on accommodating complex functions.
Problem Areas	If factory made units are produced this approach may limit the use of the design professions for individual buildings to that of layout draftsmen. This approach represents a serious threat to all involved in the design and construction of traditional buildings, since it begins to trespass on that area to a much greater extent than the mobile unit. In the civilian sector special units for larger and more complex buildings will result in problems with regard to each group within the building industry as indicated above.

	Decreased repetition of individual units is likely to make factory production inefficient and site production impracticable except for large grams of work.
Findings	As in the case of units this approach would gain acceptance within the building industry if the units were mobile and were used accordingly. If, however, this approach is used as a new way to obtain traditional fixed facilities there would probably be very strong objections by contractor, labor, and professional groups.
	<u>Units</u>
Definition	A complete space enclosure usually relocatable. Relatively small in size limited by transport possibilities.
Precedents	Trailer, portable classroom.
Area of Use	Facilities which generally require mobility. Have simple function which can be housed in simple repetitive units.
Advantages	Not necessarily dependent on local labor. Very fast erection. Possible relocation and reuse of facility. Efficiency of production and distribution.

Disadvantages	Spatial limitations of size and story height. Difficult to accommodate complex or unusual functions.
Problem Areas	If factory made units are produced this approach eliminates the use of the design and contracting professions for individual buildings. They will object strenously if the facilities are not required to be mobile. The traditional building industry similarly would object. To place units anywhere in the civilian sector could result in code problems. These would be accentuated as one moves from complete units to special units having different functions which can result in larger and more complex buildings. If units are produced on site difficulty of controlling tolerances will reduce the potential for mobility and interchangeability of units.
Findings	Site units individual designed can handle design profession, contractor profession, code problems. However, one loses (efficiency and the major aspects of interchangeability). Site units built locally (stock plan) solves contractor and labor problems only. As long

as units are really used in mobile manner there should not be major trouble with factory units.

Summary of Findings

A review of the table in detail will indicate that any approach to reorganizing building procedures will require careful review and great political skill if factory fabrication techniques are to be relied on. Much could also be done through programs of site industrialization which would be most desirable in dealing with labor, but it is difficult to build sufficient programs of construction around the use of site factories. Also general contractors are not set up to make major investments in plant for production purposes. Therefore, factory industrialization is the major route to explore with a number of side studies in specific areas such as utilities for site industrialization.

It seems obvious that a program of factory industrialization should be instituted at the level of an Incomplete Building System if sifficient gains are to be made to warrant the effort that must go into any program. It also seems that the problems involved in a complete building system are too great to be overcome in a single program so that the Incomplete Building System working with and coordinating a number of subsystem appears to offer the greatest possibility of success for all but mobile buildings. If mobility is desired so that buildings can be relocated than the traditional restraints within the building industry must give way as the industry is not able to cope with the requirement.

If mobility of space is desirable then one can look toward a unit system.

TECHNICAL ANNEX B

Subsystem Interfaces

SUMMARY

The construction and use of buildings is changing from a constant to a dynamic system. Construction tends more and more to be assemblies of industrial components and use patterns change with greater frequency.

Any dynamic system has critical subsystem interfaces. The development of the new systems must permit subsystem articulation either at interfaces or in variable planning arrangements.

There are many kinds of obsolescence applicable to components of building systems. Any future applications of systems development must include obsolescence criteria as this factor becomes increasingly critical to efficient construction and functioning of buildings.

Mechanical distribution systems are the most sensitive area in current building to rehab, remodeling and maintenance expense. This fact should be more recognized in current building design to minimize the cost of performing these changes.

1. STATEMENT OF THE OPPORTUNITY FOR SYSTEMS APPLICATION TO FUTURE MIL-CON PROGRAMS

The conventional view of the construction and use of buildings is that the parts of which buildings are made, and the ways in which they are to be used always bear the same fixed relationship to one another. In other words, the system of the building is constant in both construction and use, with its component subsystems in static inter-relationship. For example, in site construction the installation of each subsystem invariably falls into a fixed sequence-foundation, then frame, enclosure, interior subdivision, service subsystems, then finishing surfaces. The constancy of this sequence has encouraged the integration of compatible subsystems such that in some cases their interfaces are no longer physically discernible (such as load-bearing interior partitions which are both frame and structure as well as interior subdivisions) and it would not be possible to modify one without major readjustment of the other. In this circumstance, time is regarded as a constant - the construction sequence is most logically planned as an integrated operation such that in most cases, as soon as the building carcase is placed, the nature and performance of service and other subsystems are immutably fixed.

A parallel attitude exists in regard to the building use. In nearly every case a building is designed to meet a program of spaces and function that, it is assumed, will exist substantially unchanged throughout the life of the building, and therefore the performance requirements of the subsystems comprising the total building system will remain constant.

In these circumstances of 'static systems' of construction and building use, the interfaces between component subsystems are not a critical area and the current strategy of exploiting the symbiotic interchange through these interfaces is the logical consequence of the initial premise of a constant relationship.

But how valid is this premise, especially for the future? Is the construction process a technologically static phenomena and likely to stay so, and are our current buildings being used exactly as they were planned? There is increasing adoption of prefabrication of components, and pre-site assembly of pieces such as pre-hung doors or windown wall sections, so that the site operation becomes more an assemblage of subsystem units rather than any fabrication. In terms of building use, the increased mobility and quickening pace of technological and social innovation now make user requirements a dynamic pattern that is impossible to accurately project over the life span of the current building.

With these changing circumstances the overall system can no longer be regarded as static (except for the case when its life is drastically shortened). With a system of dynamic capacity, i.e., capable of adjustment, time must be regarded as an integral criterion of the system. If time is a system variable in the construction and use of buildings then the interfaces between component subsystems would become a most critical area.

With these fundamental changes in basic system criteria, it is essential to re-examine the organization currently in usage, not so much to make immediate reforms, but to better discern the best long range systems objectives and to iniate methodologies by which the transitions can be efficiently implemented. The objective of this portion of the feasibility study has been to document critical areas and suggest criteria that can be used to develop building systems whose better adjustment to future trends will produce buildings of significantly higher efficiency or cheaper overall operation.

2. FACTS BEARING

One source of information has been the plans and bid estimates for an Army Barracks Complex built in 1965 at Fort Dix. The complex includes 27 major buildings and several small maintenance structures. Brief descriptions of these buildings are found in Table B-1. The construction cost of each building was broken down into major systems and subsystems using the bid estimate. A typical breakdown is seen in Table B-2 for the barracks building. A summary of these cost breakdowns is seen in Table B-3, as well as a comparison with typical non-military buildings. 'Labor' costs in the estimates were taken to be on-site costs, 'materials' costs were taken to be off-site costs. This data for the barracks complex, specifically the on-site costs as a % of the total cost of the system named, is presented in Table B-4. Also shown is the typical range, representing different systems in different buildings doing essentially the same job. For example, the proportion of the total cost of ceilings that is spent on site typically ranges from 30% (in a building like the Battalion Headquarters) ro 54% (in a building like the Regimental Headquarters). We have tried to make an evaluation of the interractions of various building systems both in the design phase and physically in the building. The barracks building was taken as a guide, and the resulting list appears as Table B-5. Table B-6 shows the trend of increasing cost of mechanical systems in buildings over the last 40 years taken from general industry statistics.

In summary, we have found the barracks complex buildings to be similar in construction, cost, and cost breakdown to the industry in general. However, they do show a variation in spaces, structure, organization, mechanical systems, and to some extent, in interior and exterior finishes. They also vary in the proportion of total cost spent on site. The variation in major systems, such as enclosure, over the eight building types, was typically around 10%, with the variation in subsystems more typically 15-20%. A great deal of interraction among subsystems was found along with the corresponding lack of articulation. One interesting exception to this is the provision for air-conditioning equipment in the Administration & Storage building. The separate structure adjacent to the building reflects the different climatic zones in which the building will be built. This is especially significant since mechanical systems in general have been taking an increasing portion of the building dollar.

Another source of information was a list of Navy construction projects for 1967 - 1970. Job titles indicated which line items were for 'rehabilitation,' 'modification,' and 'modernizing.' A summary of this data is seen in Table B-7. In these four years the Navy will spend 9% of its construction funds in rehabilitation of existing buildings, and 18% of the projects undertaken will be rehabilitation. In the area of troop housing this is substantially greater, with 32% of the projects being rehabilitation. Examining the figures for a typical barracks, modification involved an expenditure of $650/man, about 1/3 the new per man cost.

Information about the costs of maintenance is difficult to obtain consistent with construction, estimating, or interface data. Table B-8 shows the change in Army building area over the last ten years. Also plotted are the building maintenance and repair statistics of the Army Repair & Utilities budget and the Army Construction budget for the same years. It should be noted that these figures are not necessarily consistent with each other, that different definitions of 'building' and 'construction' seem to be used, and the geographical areas included may not be the same. Nevertheless, the observation can be made that about $5000 million is being spent in building construction and maintenance each year by the Army while the total area of buildings is decreasing. An attempt to define these costs more accurately using current statistics is shown in Table B-9. Of the total budgets relating to building, about $519 million is devoted directly to building: 44% new construction 12% rehabilitation, and 44% maintenance. In addition, $109 million is devoted to construction and maintenance of building related facilities, principally utility plants and distribution systems. Extrapolating these Army figures to the total DoD program gives a total building budget of $2 billion/yr: $1.2 billion for building construction, $0.7 billion for building maintenance, and $0.1 billion for building rehabilitation. Also, the 'Backlog of Essential Maintenance' may be as much as $0.4 billion. Table B-10 compares the maintenance budget breakdown with a typical building construction budget breakdown.

3. THE NATURE OF INTERFACES IN BUILDING SYSTEMS

In the construction of buildings, the majority of site labor is applied at subsystem interfaces, as for example, in the installation of distribution systems and the application of final finishes (Table B-4). Site labor costs are the major inflationary pressure and demand maximum efficiency of site operations, hence the application of PERT/CPM to scheduling the building process.

We can say that the on-site cost (primarily wages) of any subsystem is the measure of its non-industrialization. In the overall building process, on-site costs vary widely but average about 40%. In mechanical subsystems, for example, the energy conversion function involves 25% of total cost in on-site costs, the distribution function runs to 50%. Within different buildings performing parallel functions which were examined, there is considerable variation in these subsystem percentages, implying that existing design does not achieve an overall high standard of efficiency. Note that the service distribution subsystems (piping and ducting) have large diffuse interfaces with other subsystems (Table B-5), whilst the energy conversion subsystems (heaters, ventilating fans, etc.) have small, highly articulated interfaces. The size of interface is a measure of site labor needed in the process, so any system minimizing them should ease scheduling problems as well as reducing the overall time for site operations.

4. <u>SUBSYSTEM CLASSIFICATION</u>

The construction industry is not a closely integrated system. Its wide spectrum of aims and methods provide many sets of criteria which can each generate different subsystem groupings, with their concomitant advantages of insight and disadvantages of specialist interpretation. The commonest subsystem categorization currently in use in the industry is by trade grouping. As the dominant system criteria this permits easier estimation of costs and contract administration through sub-bidding correlation, but has little potential in appreciating production conflicts of performance characteristics. (Note: Most of our tables are in the format of trade groupings, not from any decision by us that this was the most appropriate form, but solely because this is the only form in which the data was available.)

Of the many other possible criteria we have selected the following as having the most pertinence to the pattern of future construction operations and building usage.

a) The rate of technological innovation and change of use of existing buildings is rapidly accelerating. Therefore, criteria based upon task and performance specificatios will become more important. Performance and task subsystems are what might be described as functional subsystems. Each subsystem has a particular job to accomplish. Performance subsystems are distinguished from task subsystems in intent or generality. Performance subsystems generally involve the regulation of environment to generate the conditions for human occupation, in physiological, social and psychological terms. These include temperature, humidity, air, light, and the less defined qualities of view, security, variety and safety.

Task subsystems involve getting a job done. Task criteria are becoming increasingly specific, reflecting the more specialized nature of the tasks to be performed. Task criteria will involve spatial dimension, and localized service requirements and corrections. Thus mechanical environmental regulation equipment is usually part of a performance subsystem, while interior space definers are usually part of task subsystems.

b) One special case of subsystem definition recently proposed in architectural circules in the fit/misfit criteria of Christopher Alexander*. Alexander's criteria are essentially performance criteria, but with the requirement that all criteria be of similar 'importance' and that they be readily verifiable. He states that systems derived from these definitions will differ substantially from conventional system breakdowns. His focus on the design process stresses the importance of the simi-lattice as distinguished from the hierarchical tree-like structure which typifies

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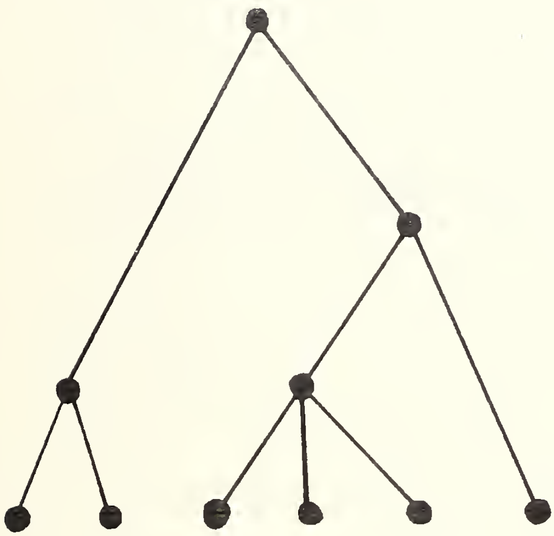
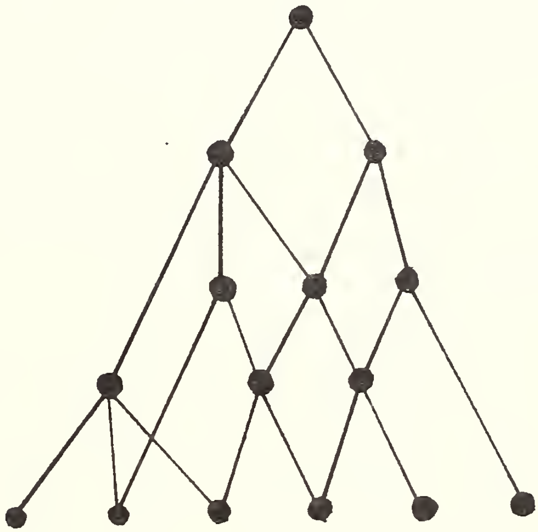
*Notes on the Synthesis of Form, Christopher Alexander, Harvard University Press 1964.

most analytical breakdowns. In the case of the construction process, the strategy of symbiotic exploitation could be diagramatically expressed by the semi-lattice where through-interface relationships were numerous and component integration the goal.



Tree



Semi-Lattice

However, if we are seeking a more flexible relationship where any one subsystem or portion can be adjusted in size or character with minimum readjustment of the whole (in fact, anywhere where the interface relationship is dynamic rather than static), then the tree with its restricted interrelationship would represent the ideal diagramatic form, typifying a strategy of articulation of subsystems rather than integration. Of course, neither extreme provides the optimum configuration for a comprehensive construction program, but each can be fruitfully applied to different facets of it.

c) Probably the most important set of criteria usually absent from current building system proposals is that of component obsolescence. Subsystems obsolese at differing rates and for a variety of reasons, requiring replacement long before the life term of the building.

Obsolescence can be caused by five different factors, every subsystem being sensitive to each factor in differing degrees. The five are

1. physical
2. performance
3. task
4. aesthetic
5. interface

Physical obsolescence is the wearing out of components, their failure to continue performance according to specifications. This factor causes the bulk of building maintenance, in renewal of worn out parts. Some of these, such as fluorescent tubes reflect this through their highly articulated interfaces. Subsystems representing about one quarter the initial cost of the building will physically obsolese within the normal 25-year lifetime of the system (Table B-11).

Performance obsolescence occurs when the standards and usage are upgraded so that the initial system cannot perform to the upgraded specification. This could be simply higher user demands, as have occurred in lighting intensity levels for office buildings, or else where new components have been evolved which perform the role much more economically such as when fluorescent light replaced incandescent for general illumination. Subsystems more susceptible to this pressure amount to as much as 60% of the building costs (Table B-1).

Task obsolescence occurs when the role of the building or portions of it change - when the original function is surplanted, or else performed in a different manner requiring new conditions. One such example is the recent growth of automatic data processing and the man/machine systems where electrical equipment has replaced routine human tasks. This category is closely related to performance obsolescence as in man/machine system introduction. Usually both man and machine require a higher service level than before. Although most subsystems are liable to task obsolescence, probably those most vulnerable are identical with the list already compiled for performance obsolescence.

Aesthetic obsolescence is the result of changes in user attitudes in societal dynamics or sytlistic cycles. This obsolescence is most readily discernible at its broadest manifestation in commercial buildings, where store fronts, for example, are continually being 'updated'. However, this factor will become increasingly important to the DoD where an affluent society will create competition between all sectors of the economy to attract staff or prestige through emphasis on the 'image' or qualitative aspects of the environment. In narrower and less subjective terms, aesthetic obsolescence dictates the frequency of surface refurbishing, the change of plumbing fixtures and other furnishings, floors, etc., usually much prior to their need for replacement by physical obsolescence. An aesthetic obsolescence is always manifest through the subsystem/user interface, it is usually those portions of subsystems which are exposed to view which are most sensitive to this pressure.

Although it can be said that the subsystems which have their user interface aggregate 70% of the total cost of the building, it is only about one quarter of each subsystem which is affected. Therefore, it is safe to say that 20% of the initial building investment is susceptible to localized aesthetic obsolescence.

Finally, interface obsolescence occurs when one system becomes obsolete and through interface integration cannot be divorced from an adjacent subsystem which is still operative. Hence, both subsystems are scrapped - the second for interface obsolescence. Usually, other economic factors influence the degree to which this interface obsolescence will operate. For example, the performance life for a building structure is 100 years plus. When most of the other subsystems are obsolete, it is the usual course to scrap the whole building system, the structure disappearing as a result of interface obsolescence. However, in two recent mid-Manhattan instances in the highest ground rent areas, significant time and hence money saving has been achieved by stripping the whole building down to the exposed structural steel and preserving this one (non-obsolete) subsystem for incorporation into a new building system.

5. RECOMMENDATIONS FOR DEVELOPMENT IN FUTURE BUILDING SYSTEMS

1. We recommend that any future systems should include criteria relative to the usages of buildings in addition to those relative to initial construction. The cost of a construction program does not cease with the construction of the buildings, neither should system criteria. There is need for further data into the usage pattern of DoD buildings especially relative to their initial purposes and hence primary investment. Our figures show that rehab and other building maintenance costs are significant. They should be reflected more in the criteria for building design and procurement.

2. The wide diversity of the mil-con program in both building types and conditions of construction make it not suitable for comprehensive application of one-system orientation overall. For example, the development of a task or performance oriented system for the procurement and use of operational buildings is justifiable. It has much less potential when applied to warehouses. We recommend therefore that new systems developments be initially restricted to those building types which show greatest potential gain from their application - and not applied as a generalized procedure. Whatever basic orientation the system is given - performance, task, craft, etc. - criteria ensuring flexibility should always be included. The method of achieving flexibility should not be implicit in the setup of the criteria which should permit for a variety of solutions.

At least three possible methods can be cited.

a) A low initial cost and rapid obsolescence of the total system, and its replacement by the next generation of improved and/or modified versions.

b) A relatively fixed character of overall system which has the capacity for in-system variation through differential subsystem manipulation. This would imply strong interface articulation.

c) A variable major system made up of ad hoc combinations of autonomous units of integrated subsystems. The integrated subsystems could then exploit symbiotic inter faces.

Strategy (a) implies buildings fabricated as industrial products with high autonomy and hence minimum environmental interface, probably a program of relatively rapid turnover of temporary buildings. Strategy (b) is more easily integrated with current practice, as it permits the building system to appear to remain unchanged whilst the subsystems accomplish their smaller scale transformations. This strategy also can be accomplished within the current trade oriented system of the industry. Strategy (c) implies more fundamental changes in the procurement pattern, as the final buildings will result from the assembly of smaller units or three dimensional modules, possibly procured industrially in quantity and probably unrelated to site or building type.

3. We recommend the development of system criteria based upon performance requirements currently located in one and two story structures of the mil-con program. From this should develop light construction subsystems with interchangeable components to satisfy the spectrum of performance demand of all one and two story building types. These subsystems should have strongly articulated interfaces.

4. We recommend long term research and theoretical development of system criteria based on task requirements, and the development of a system based upon autonomous task modules. These modules will be autonomous structures with self contained subsystems requiring only generalized and

universally available material and energy inputs. Each type could be regarded as a large scale appliance or machine for working, being designed to house a specific individual or group task activity. The modules should ideally be fabricated such that all subsystems would obsolesce at the same rate. Thus symbiosis could be optimally exploited. The modules could either be combined into building systems of a fixed or static relationship for cheaper assembly costs or else have probably more expensive, well articulated functions to permit the variable building system strategy described in 2(b) above.

5. We recommend that obsolescence criteria be incorporated in all systems development work both short and long term. At this stage of the study reliable detailed data is not available, so incorporation of any obsolescence orientation is likely to be confined to general awareness at the design stage. For long term we recommend a program of comprehensive data gathering on costs of remodeling, rehabilitation, building maintenance and building usage - and the development therefrom of related criteria for systems development. A preliminary analysis of a barracks building design and the commencement of a subsystem commentary in terms of obsolescence potentials is enclosed as illustration on one possible approach (Table B-13).

6. Nearly all preceding recommendations are long term

proposals. However, our studies have generated conclusions of immediate implication which we recommend be considered for incorporation into current or next phase building systems activity.

a) The cost of installation of mechanical systems of the building now exceed that of structure (Table B-6). The maintenance and rehab costs of mechanical systems far exceed the parallel costs for structure, and in both cases this margin is increasing. However, the dominant subsystem used to determine the general building system form and modular dimension remains the structure. The trade-off advantages of the manipulation of the structural system to promote greater mechanical economy have not been sufficiently investigated and developed.

b) Mechanical subsystems are the fastest obsolescing categories within the building system. They account for approximately 35-45% of the initial cost; and over 40% of the rehabilitation and maintenance costs. This is a strong case for articulation of the interfaces of the mechanical subsystems from other subsystems: to facilitate cheaper remodelling and maintenance and also prevent costly interface obsolescence. However, of the designs studied these subsystems (and especially their distribution systems, which are their fastest obsolescing components - see Table B-12) have not been designed to minimize the interface area. The strategy of complete articulation is costly even if physically possible - (the service systems could be made self structured and relate directly to the areas to be serviced) - so the most logical strategy is to relate distribution of services to one other building subsystem and restrict it to that. This strategy has been most successfully employed in the SCSD school components in California, * where the air conditioning and lighting subsystems interfaces are entirely confined to the horizontal roofing/ceiling subsystem, and consequently do not apply constraint to other subsystems. In this particular case they have also achieved remarkable flexibility of distribution arrangement to match variable spaces below - primarily by developing the full potentials of this one interface and not seeking general solutions to relate to other components of the building system.

* "SCSD, An Interim Report", Educational Facilities Laboratories 1964.

TABLE B-1

Brief Descriptions of Barracks Complex Buildings

All buildings have brick/block exterior walls, block interior walls. Practically all floors are asphalt tile over concrete. Heating is basically hot water systems.

Barracks: 3 story concrete frame, partial basement. Mechanical ventilation system. Built-in wardrobes.
42,200 sf, 438,300 cf. $14.01/sf, $1.34/cf. (11 in complex).

Regimental Headquarters: 3 story steel frame. Air-conditioned.
9,800 sf, 98,500 cf. $19.66/sf, $1.96/cf. (1 in complex).

Batallion Headquarters: 1 story, partially steel frame, partially brick/block bearing wall with steel joists. Air-conditioned.
6,100 sf, 91,500 cf. $24.83/sf, $1.66/cf. (4 in complex).

Administration & Storage Buildings: 1 story, steel joist bearing wall construction. 40% Air-conditioned.
12,200 sf, 187,800 cf. $18.66/sf, $1.48/cf. (4 in complex).

Mess: 1 story steel frame. Air-conditioned. Kitchen equipment not included in cost data.
11,900 sf, 205,200 cf. $25.78/sf, $1.49/cf. (4 in complex).

Branch PX: 1 story steel joist bearing wall construction. Mechanical ventilation.
4,800 sf, 76,800 cf. $23.75/sf, $1.48 cf. (1 in complex).

Group Dispensary: 1 story steel joist bearing wall construction. Air-conditioned.
3,500 sf, 42,300 cf, $26.51/sf, $2.21/cf. (1 in complex).

Chapel: Laminated wood arches and bearing wall construction. Steeple and office wing attached. Air-conditioned.
7,500 sf, 241,600 cf. $32.36/sf, $1.59/cf. (1 in complex).

TABLE B-2

Barracks Construction Cost Breakdown (Brks.Bldg.only)

	% Total Cost	% System Cost	Cost	% On Site/ % Off Site Cost
Site Preparation	1.5%	2%	$ 7,600	100/0
Structure	32.1%	32%	$157,400	41/59
Foundations	4.4	14	21,560	36/64
Basement Walls	1.6	5	7,990	49/51
Slabs	19.2	60	94,460	40/60
Columns & Beams	6.4	20	31,930	46/54
Stairs	.3	1	1,440	47/53
Exterior	9.6%	10%	47,000	46/54
Brick	3.7	39	18,330	66/34
Windows	3.4	35	16,580	24/76
Roofing & Insulation	1.1	11	5,340	45/55
Exterior Finishing	1.4	14	6,720	43/57
Interior	26.3%	26%	129,000	47/53
CMU Walls	9.1	35	44,590	56/44
Doors	1.9	7	9,560	24/76
Flooring	2.5	10	12,490	44/56
Ceiling	.5	2	2,490	59/41
Interior Finishing	12.2	46	59,670	44/56
Mechanical Systems	30.5%	31%	150,000	43/57
Heating	8.5	28	41,800	38/62
Preparation	3.1	36	15,160	31/69
Distribution	3.1	36	15,200	60/40
Local Processing	2.3	27	11,480	17/83
Ventilation	5.3	17	25,900	31/69
Equipment	3.0	57	14,750	13/87
Ducting	1.8	35	9,030	56/44
Local Processing	.4	8	2,140	43/57
Plumbing	9.0	29	44,000	54/46
Supply Piping	3.3	37	16,180	73/27
Waste Piping	2.8	31	13,680	49/51
Fixtures	2.9	32	14,220	38/62
Electrical	6.6	22	32,400	45/55
Preparation	.2	6	1,010	24/76
Distribution	4.4	66	21,460	58/42
Fixtures	1.9	28	9,200	19/81
Communications	1.0	3	4,800	28/72
Construction Cost	100.0%	100%	$491,000	44/56
Overhead, Profit, Insurance			101,400	
TOTAL COST			$592,400	

TABLE B-3

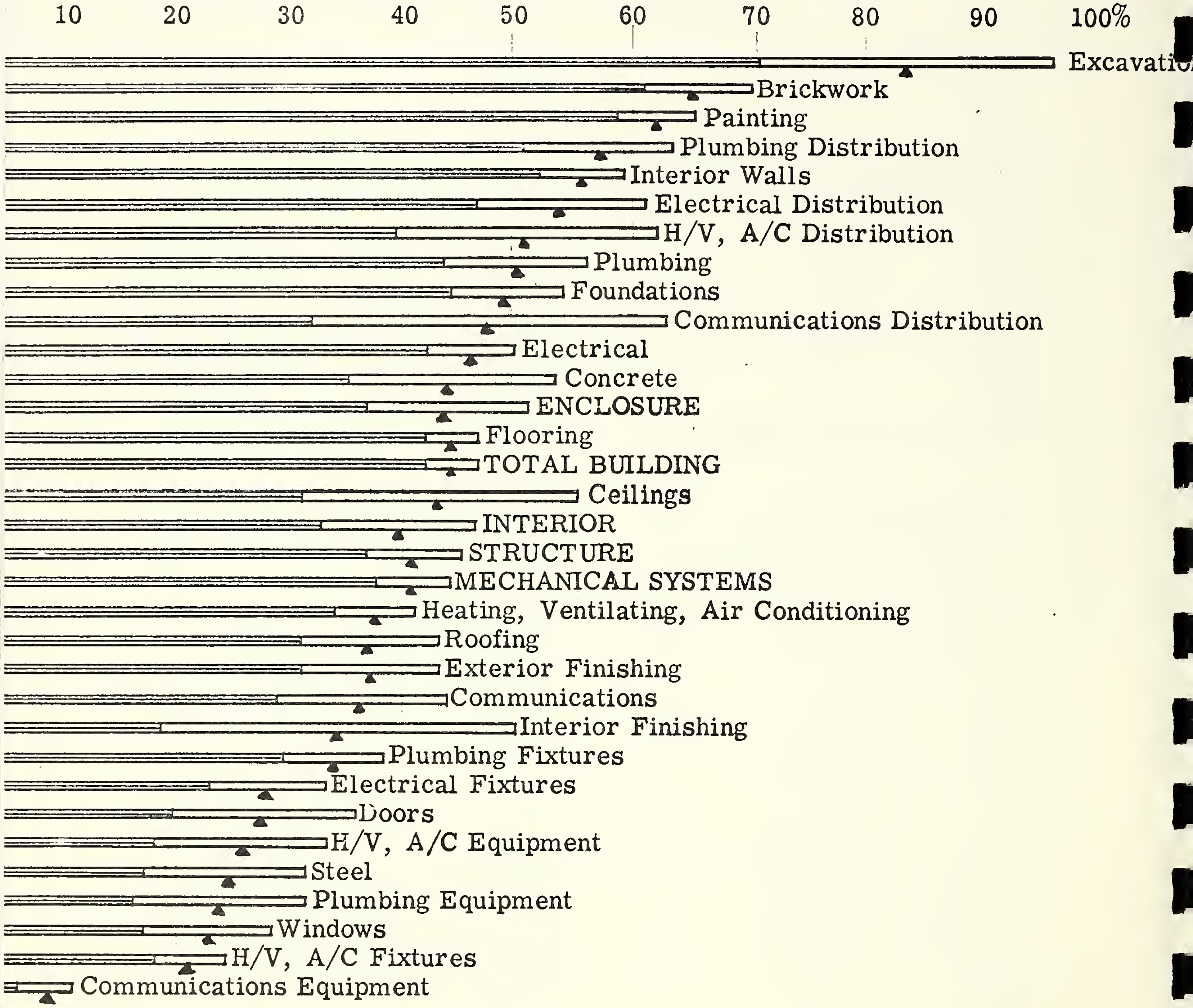
Building Cost Breakdowns (Percent of initial cost)

	% Structure	% Exterior	% Interior	% Mechanical	SF Cost
Typical Barracks Complex					
Barracks	34	10	26	31	14.01
Regimental Headquarters	21	13	24	41	19.66
Batallion Headquarters	23	17	19	41	24.83
Administration & Storage	22	16	28	33	18.66
Group Dispensary	23	14	29	34	26.51
Batallion Mess	30	11	16	42	25.78
Branch PX	20	19	23	35	23.75
Chapel	28	15	28	28	32.36
Typical Buildings					
Office Buildings	28	13	30	28	
Office Building	28	10	18	42	13.15
Schools & Apartments	29	14	30	27	
Small Hospital	25	5	20	50	23.22
Shopping Center	24	18	23	35	18.52
Dormatories	18	17	32	32	15.77

Data from 11EM Barracks Complex, Fort Dix, estimate, and Means "Building Construction Cost Data" and *Engineering News Record* "Where the Building Dollar Goes", March 18, 1965.

TABLE B-4

Ranges of On-Site Costs in Various Construction Systems and Sub-systems Expressed as a Percentage of the Total Cost of that System or Sub-system



Source: Cost breakdowns of eight Fort Dix Barracks complex buildings from bid estimate.

Example: The proportion of the total cost of ceilings that is spent on site typically ranges from 30% (in a building like the Battalion Headquarters) to 54% (in a building like the Regimental Headquarters).

TABLE B-5

List of Interreactions

The most direct example of interreaction is interfacing. Systems not actually adjacent may interreact by being designed together, using the same materials, or by jointly satisfying the same performance criteria. The list does not differentiate among these modes of interreaction. Note that in some cases the interface can in itself be a minor subsystem. For example, a flashing between a wall and a roof could be construed as belonging to either subsystem or constituting one on its own. Such interface subsystems are the commonest strategy of articulation, both acting as a link and as a separator. Note, all gaskets and caulking are in essence interface subsystems acting as the link between components of different dimensional tolerances, but at the same time separating them so that the tighter tolerance subsystem does not act as constraint on the looser subsystem.

Building/Ground

utility input/output
building load transmission
form for structure
mechanical at bottom of building
internal interdependence: soil, building design, machine efficiency

Structure/Structure

continuous/discontinuous structure
connections
strength
differential movements
internal subdivision
flexibility
material characteristics and interfaces

Structure/Preparation

cost tradeoff
interface = foundations

Structure/Exterior

proximity important - designed to coincide
dual role elements
structure supports exterior - interface
interface requires special materials
most exterior materials have some structural properties

(continued)

Structure/Interior

where is interface ?
interior subdivisions coincide with skeleton members
interfaces: conc. slab/tile, conc. slab/paint, conc. slab/cmu, conc. slab/hangers, base walls/paint, column/paint, columns/flooring, columns/ceiling, columns/cmu, beams/cmu, beams/ceilings, beams/paint.

Structure/Mechanical

mechanical designed around structure
structure pierced by mechanical
mechanical hangs from structure
most mechanical is structural to some extent
some dual function systems possible (distribution)
communications protects structure: fire

Exterior/Exterior

design aesthetics and evocative function of building
purchasing
interfaces complex: flashing, caulking
differentiation of service functions: thermal, particle, light, sound

Exterior/Site

dual role: site
'slab at grade'

Exterior/Structure

structure and exterior coincident
dual role elements: floor slabs, brick wall, window, door, roof deck
support of exterior
clear interfaces: roof deck/roofing (except for thermal, sound, light)

Exterior/Interior

dual role elements: windows, doors, brick/block cavity wall
exterior/interior special case of A/ not A interface
design interreaction: exterior = Σinterior
exterior is thermal & particle modulator, interior is light and sound modulation

Exterior Mechanical

environmental change = exterior change + mechanical change: tradeoff heating/insulation, ventilation/windows, heating/windows
interfaces: ventilator/roof

(continued)

Interior/Interior

services: enclosure, separation: sound, light, atmosphere, psyche; quality suggestion, interior subdivision.
interfaces: cmu/paint, walls/floor, walls/ceiling
multi-service materials common. Obsolescence controls
design interreactions: economy, repetition
maintenance

Interior/Site

view

Interior/Structure

dual role elements: slabs, columns, beams
design: strong, "structure" concept

Interior/Exterior

dual elements
"environmental modulation zone"
design: aesthetics, organization

Interior/Mechanical

interface: penetration of services, local use, special finishes
design: aesthetics (hide mech) zoning
distribution systems have large interface - high labor cost
human vs. service organization (man vs. machine)

Mechanical/Mechanical

heating needs all services
electrical serves all
communications controls

Heating/Building

requires mechanical room
hangs on and penetrates structure
design: exterior, interior
needs ventilation, plumbing, electrical, communications

Plumbing/Building

design: interior layout, finishes, heating, exterior materials, ventilation
plumbing has some structural capability
tree-like organization
aesthetic obsolescence

(continued)

TABLE B-5

Ventilation/Building

design dependent on most other system organizations
tree-like organization
interface: structure, interior walls, ceilings, roof

Electrical/Building

tree-like organization
design: interior layout, structure, mechanical

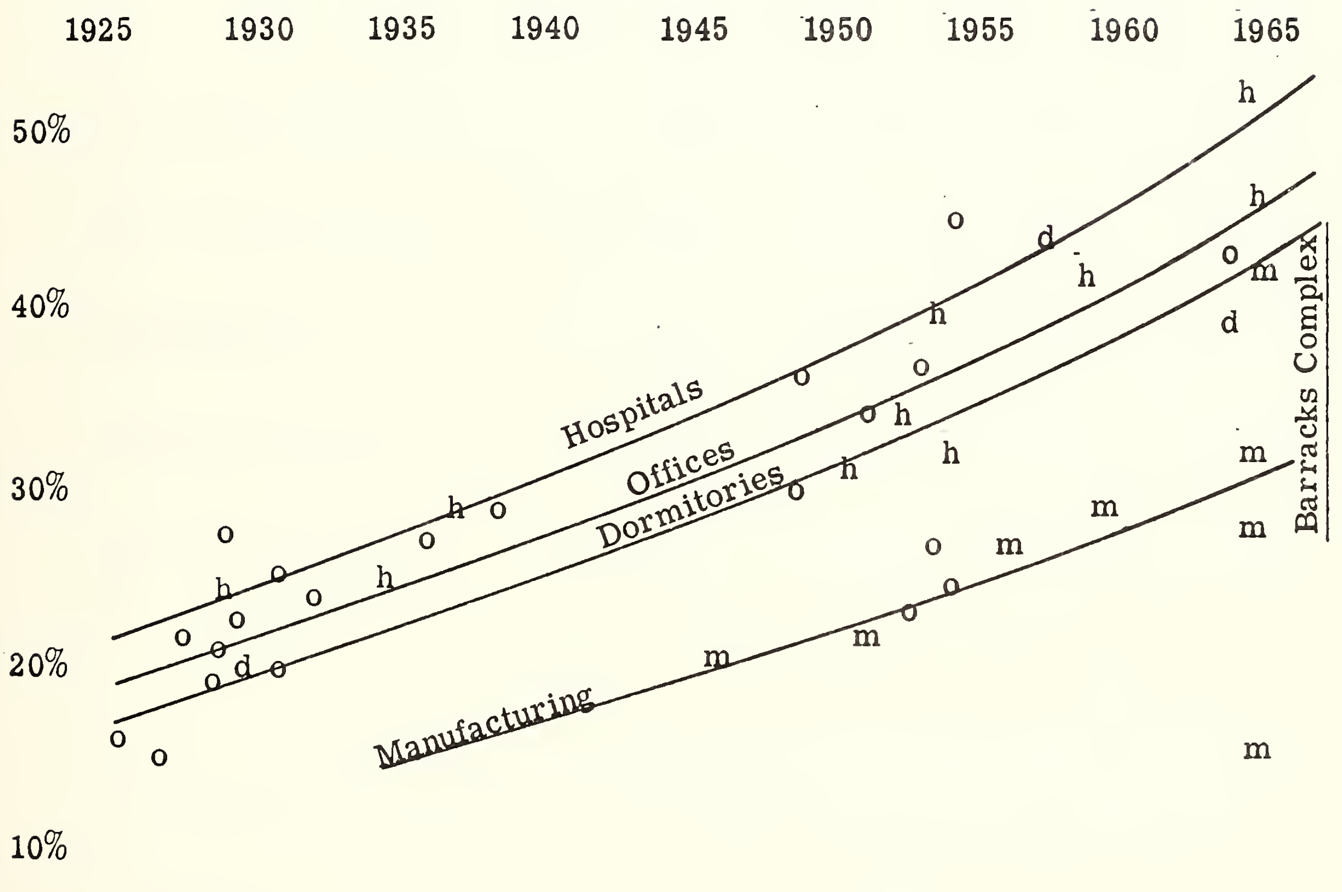
Communications/Building

telephone, fire alarm, intercommunications, antenna, thermostat
design: fire/building

Note: The list was prepared using the Army barracks (Figures 1 & 2) as a guide.

TABLE B-6

Proportion of Total Building Cost Spent for Mechanical Systems



DATA: Each letter represents a typical building or average. Sources: Means, "Building Construction Cost Data", Engineering News Record, "Where the Building Cost Dollar Goes", Turner Construction Company.

TABLE B-7

Navy Rehabilitation Program

	Total Personnel Buildings	Barracks & BOQ	Working	Special
1967-1970 Construction	$652,895	$231,173	$149,763	$272,922
% Rehabilitation	9%	11%	16%	4%
1967 Construction	153,087	48,807	47,424	56,856
% Rehabilitation	9%	15%	10%	3%
1968 Construction	168,842	67,630	32,812	63,400
% Rehabilitation	12%	10%	27%	7%
1969 Construction	174,191	57,059	32,659	85,473
% Rehabilitation	5%	5%	9%	4%
1970 Construction	161,774	57,677	36,863	67,193
% Rehabilitation	10%	14%	18%	2%

Data: List of Navy building projects scheduled for 1967-1970. Costs are for all construction in thousands. Percentages are the proportion of 'rehabilitation', 'remod', 'mod', 'rehab', 'modification', and 'A/C' in list.

Categories:

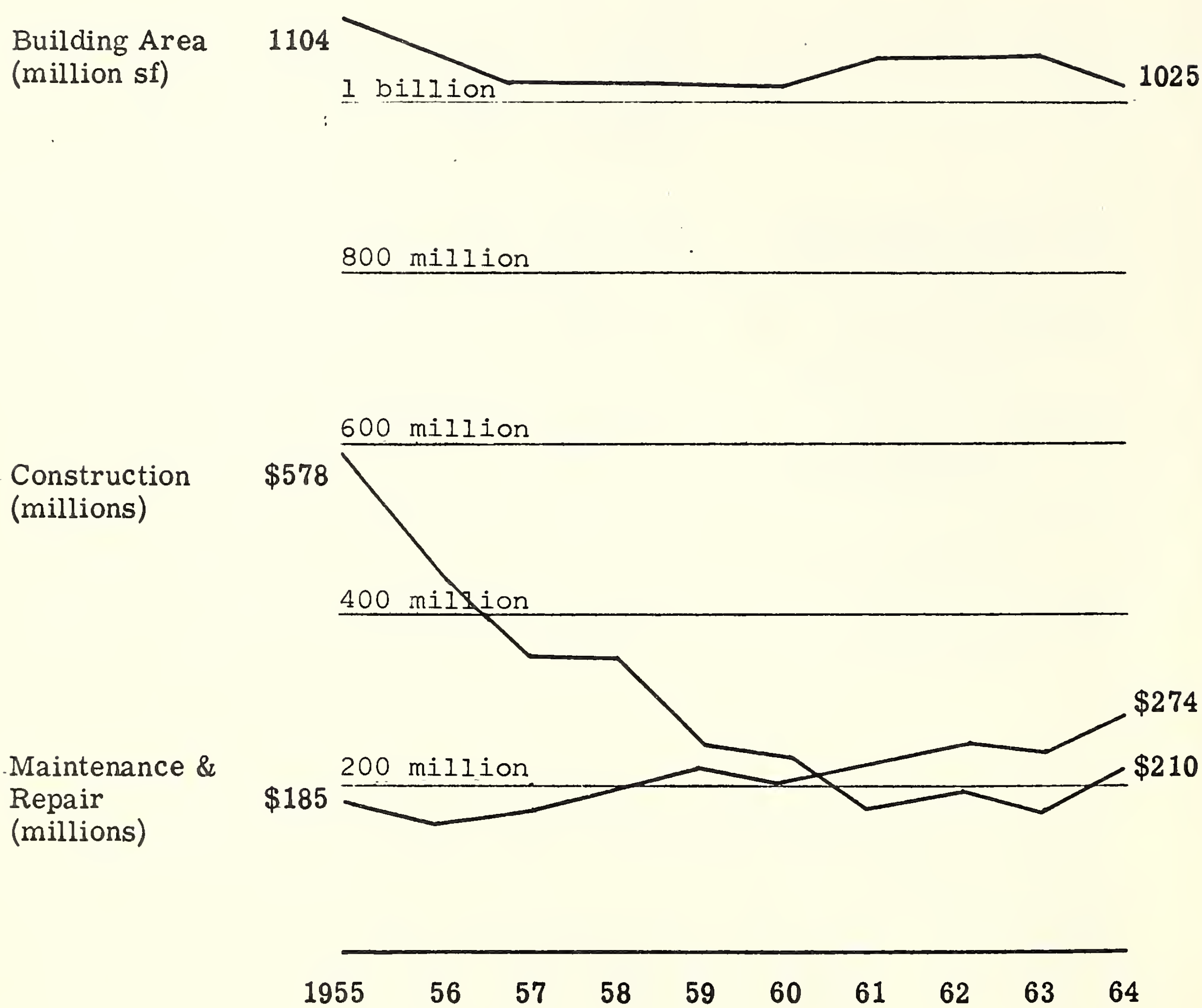
Barracks & BOQ:
- 721--Barracks with mess
- 722--Barracks w/out mess
- 724--BOQ

Working:
- 171--Training Facilities
- 171--Reserve Training Facilities
- 610--Administration

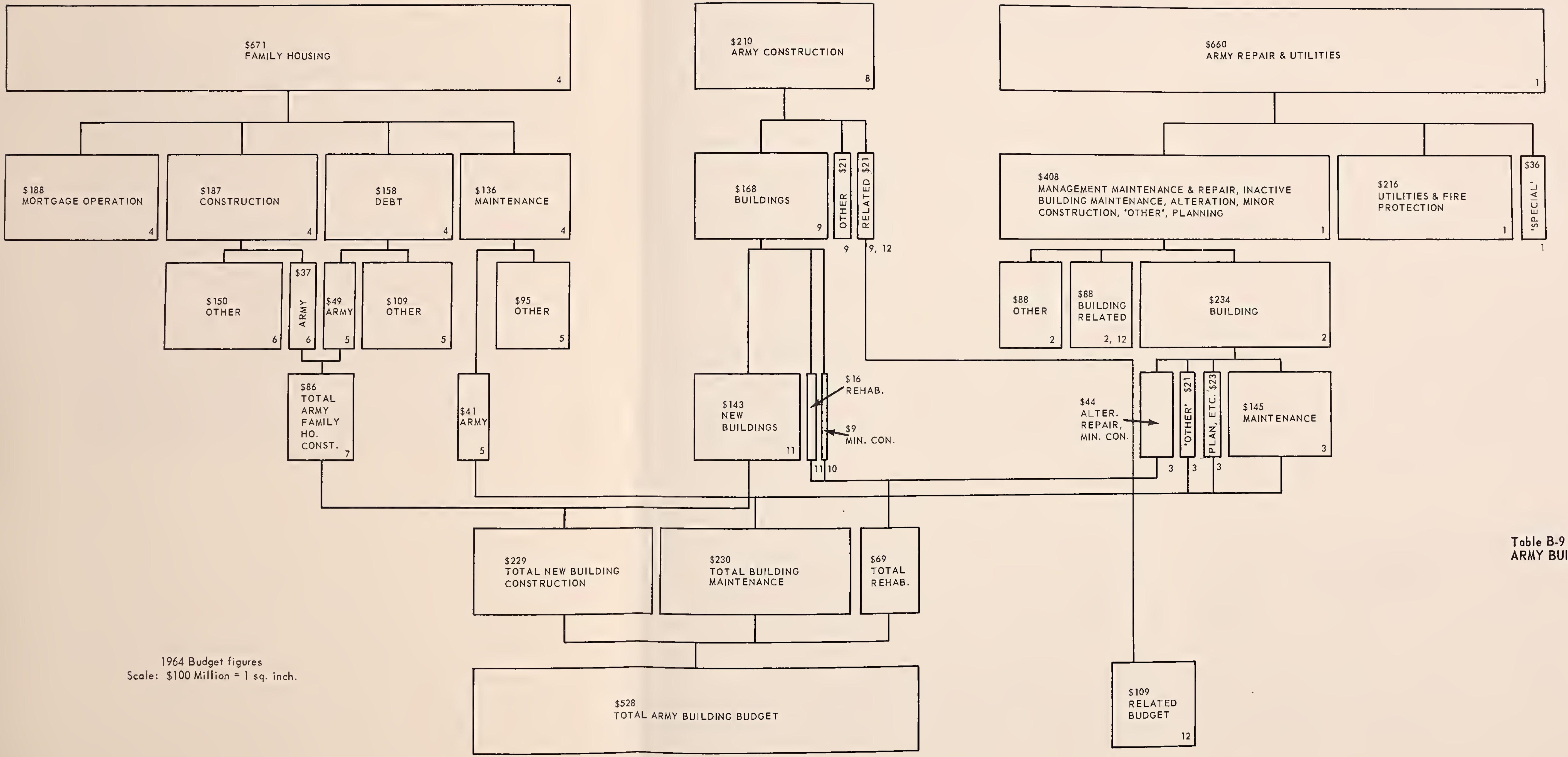
Special:
- 141--Operations Buildings
- 310--Research, Development and Test
- 530--to 550--Hospital labs, clinics, dispensaries
- 730--Community Facilities: Support and Service
- 740--Community Facilities: Morale, Welfare

TABLE B-8

Trends in Army Building



Source: Army's "Repairs and Utilities Annual Summary of Operations" for various years. Construction date from Direct Obligations (actual) shown in various President's Budgets.



1964 Budget figures
Scale: $100 Million = 1 sq. inch.

Table B-9
ARMY BUILDING COST (millions)

TABLE B-9

Notes

1. Army Repair and Utilities budget, 1964.
2. Army Repair and Utilities budget, 1964, Maintenance and Repair. 57% of budget is for buildings. 1965 Navy Construction budget summary indicates that ½ on non-building budget is for related items, ½ is for other items.
3. Army Repair and Utilities budget, 1964, primary breakdown.
4. 1966 Military Budget, Family Housing, 1964 data.
5. Army's "Repairs and Utilities Annual Summary of Operations" for FY1964 shows the Army has 36% of total housing square feet in CONUS.
6. 1966 Military Budget, Family Housing, 20% of new units are for Army.
7. 1966 Military Budget, Family Housing, 1964 data. The debt figure results from purchase of housing units from other programs, a net increase in housing units equivalent to new construction.
8. 1966 Military Budget, Total Army construction.
9. 1965 Summary of Navy Construction. 80% of budget for buildings, 10% for building related facilities, 10% for other categories. This breakdown is assumed to be similar in Army.
10. Army Repair and Utilities budget. Total rehabilitation includes this item as being from the Milcon program.
11. 1965 list of Navy projects planned for 1966-1970. 10% of dollars for construction are for rehabilitation. Assume that this is typical of total Milcon program.
12. Building related construction consists primarily of utilities generation and distribution systems outside the 5' line.

TABLE B-10

Building Maintenance Breakdown

	Building Maintenance[1]	Barracks Construction Cost[2]
Building Shell	30.2%	52.3%
Exterior Finish	5.4	1.4
Roofing	8.5	1.1
Interior Finish	12.0	12.2
Plumbing	11.1	9.0
Heat/Vent	15.6	13.8
Electrical	13.1	6.6
Flooring	4.1	1.1
All Mechanical	39.8	30.5

[1] 1958-1960 Average for Building Maintenance shown in the Army's "Repairs and Utilities Annual Summary of Operations."

[2] Breakdown of construction cost of Army Barracks, a statistically typical element of the building construction program. (See Fig. 2)

TABLE B-11

Scope of High Obsolescence Grouped by Type (see Table B-12)

Note: Task and Interface Obsolescence are too general and dependent on user requirements.

Physical Obsolescence		Cost %
	Exterior Finishing	1.4%
	Flooring	2.5
	Interior Finishing	12.2
	Heating Preparation	3.1
	Ventilating Preparation	3.0
	Electrical Fixtures	1.9
	Communications	1.0
	Roofing	1.1
	TOTAL	26.2%
Performance Obsolescence		
	Windows	3.4%
	Roofing	1.1
	Exterior Finishing	1.4
	Interior Walls	9.1
	Doors	1.9
	Flooring	2.5
	Ceilings	0.5
	Interior Finishing	12.2
	Heating	8.5
	Ventilation	5.3
	Plumbing	9.0
	Electrical Systems	6.6
	Communications	1.0
	TOTAL	62.5%
Aesthetic Obsolescence		
	Concrete Slabs	19.2%
	Columns and Beams	6.4
	Stairs	0.3
	Brickwork	3.7
	Windows	3.4
	Exterior Finishing	1.4
	Interior Walls	9.1
	Doors	1.9
	Flooring	2.5
	Ceilings	0.5
	Interior Finishing	12.2
	Radiators	2.3
	Diffusers	0.4
	Plumbing Fixtures	2.9
	Electrical Fixtures	1.9
	TOTAL	68.1%

TABLE B-12

Typical Periods of Obsolescence

	%Cost of construction	Physical Obsolescence	Performance Obsolescence	Task Obsolescence	Interface Obsolescence	Aesthetic Obsolescence
Site Preparation	1.5%				30/100	
Structure	32.1%	100	100	30	100	30
Foundations	4.4	100	100	30	100	
Basement Walls	1.6	100	100	30	30/100	
Concrete Slabs	19.2	100	100	30	10/30/100	30
Columns & Beams	6.4	100	100	30	10/30/100	30
Stairs	0.3	.1/30/100	100	30	100	30
Exterior	9.6%	30/100	100	30	30/100	30
Brick	3.7	30/100	100	30	30/100	30
Windows	3.4	1/3/100	30	30	3/30/100	1/3/30
Roofing & Insulation	1.1	10	30	30	10/30/100	
Exterior Finishing	1.4	3/30	10	30	3/10/30/100	10
Interior	26.3%	.1/3/10	30	30	10/30/100	30
Interior Walls	9.1	100	10	10	3/10/30/100	30
Doors	1.9	3/30	30	10	10/30/100	10
Flooring	2.5	.1/1/10	10	30	10/30/100	10
Ceiling	0.5	3/10	10	10	3/10/30/100	10
Interior Finishing	12.2	1/3/10	10	10	3/10/30/100	3
Mechanical Systems	30.5%	100	100	10	10/30/100	
Heating	8.5	30	10	100	10/30/100	
Preparation	3.1	1/30	10	100	30/100	
Distribution	3.1	30	30	100	3/10/30/100	
Local Processing	2.3	1/3/30	10	100	3/10/30/100	30
Ventilation	5.3	30	10	10	10/30/100	
Equipment	3.0	1/10	10	10	10/30/100	
Ducting	1.8	30	10	10	10/30/100	
Local Processing	0.4	3/10	30	10	3/10/30/100	30
Plumbing	9.0	30	30	30	10/30/100	
Supply Piping	3.3	30	30	30	10/30/100	
Waste Piping	2.8	30	30	30	10/30/100	
Fixtures	2.9	.1/1/30	30	30	10/30/100	10
Electrical System	6.6	30	10	10	10/30/100	
Preparation	0.2	30	30	30	30/100	
Wiring	4.4	10/30	30	30	10/30/100	
Fixtures	1.9	1/10	10	3	10/30/100	10
Communications	1.0	10	10	3	10/30/100	10

(continued)

TABLE B-12

Note: Numbers in table are typical periods of obsolescence in years and relate to obsolescence breakpoints in the following way:

	Janitorial Maintenance						Remodeling		Rehabilitation		Building Life
Typical Period of Obsolescence	.1 yr		1 yr		3 yr		10 yr		30 yr		100 yr
Obsolescence Breakpoints		3 mo		2 yr		6 yr		20 yr		60 yr	

Table was prepared with the barracks building (Figure 1) as a reference, and % Cost data refers to this building.

TABLE B-13

Commentary on Barracks Subsystem Obsolescence

Excavation 1.5% Being almost totally process, there is nothing to obsolesce and therefore there is no physical obsolescence. The site can move out from under a building in certain instances, but this is generally no obsolescence. The only obsolescence would arise when it became necessary to replace the parts of the building in contact with the site. We might call this interface obsolescence.

Structure 32.1% Physical obsolescence is slow and is a result of variable conditions: freezing damage depends on protection from water, differential settlement depends on soils and design, material deterioration in concrete is most highly dependant upon construction and materials used, out of designer's control for a large extent. Span of physical obsolescence is expected to be on the order of 20-100 years. Performance Obsolescence is not usually seen. A semantic issue might be raised as to when a given building function requires heavier and heavier machinery this was a case of task or performance obsolescence. To the extent that structure is reasonably independent of task, task obsolescence is also not a factor. In general the independence also has to do with the density of structure. Generally the combination of structure and internal subdivision is needed before task obsolescence can be considered meaningful. Aesthetic Obsolescence works more slowly with exposed structural elements, those with a user interface. Correction of the obsolescence generally is a matter of a covering, either adding or replacing the covering.

Exterior 9.6% The enclosure or exterior of a building functions as an environmental modulation surface, and in conjunction with the interior mechanical services, determines the environment within the building. Performance obsolescence occurs through the raising of the standards of environmental control. Usually, however, mechanical services take up this burden. At present there seems to be a trend of lowering the standards of the enclosure to best utilize the mechanical. Changing codes and variations in codes tend to obsolete enclosure, e.g. the reduction of fireproofing standards. (Actually performing better than standard could hardly be called obsolescence, since in normal performance the design potential of systems are rarely approached.) . . .

Physical Obsolescence is generally a result of movement due to thermal differentials, although related effects due to freezing can also be important. Roofing guarantees are for a term of 15-20 years, although occasional repairs are needed earlier, and the ultimate life may be greater. Brick walls need repointing every 30 years - often the surface is cleaned more frequently. Windows should be washed at least twice a year; frames must be painted every five years. Railings and exterior stairs need attention to surfaces every three to five years. Cleaning should be done on a daily basis, depending on use and surroundings. Flashing, an interface subsystem, usually is not replaced. However, leakage is not uncommon and a sub-subsystem is applied for patching. Task Obsolescence is usually not a factor, although occasional openings are opened and closed in enclosure. It is difficult to determine just how much fixity of enclosure is a factor in the discarding of task obsolete buildings. (Note: The Army construction budget can be considered to be totally a replacement program for obsolete buildings, task obsolescence being one of the chief factors.) Aesthetic Obsolescence: 'Good' design obsolesces very slowly in this area (the Brooklyn Bridge, for instance, is almost 100 years old, and in little danger of replacement for aesthetic reasons). However, it is to be doubted that many Army buildings, or this building in particular, are free from the effects of aesthetic obsolescence.

(Note: This is included as a sample of the kind of thinking involved in considering the effects of obsolescence. In a later phase of research this would be extended further.)

ANNEX C

Analysis of the Military Market

1. INTRODUCTION

This study has been undertaken as a part of the larger feasibility study on the applications of advanced building systems technology to the Military Construction Program. Its purpose is to identify markets within the Military Construction Program which are both large enough to support major development programs and large enough to accrue substantial benefits from them. At the outset of the program, it was intended that a major part of this analysis would include some cost-benefit studies of the potential value of subsystems and systems innovation in particular areas. As the study progressed, it was discovered that there was not an adequate data base of current subsystems costs to allow such studies at this time. Therefore, this section of the total report will concentrate on the examination of market areas for opportunities for innovation, and will identify certain characteristics of these markets in terms of technological content, geographic location, size of market, and distributions of sizes of projects. In the event that factors relating to any of these characteristics should be major constraining considerations in the selection of a recommended area for development work, this information will be useful in supporting such decisions.

2. THE IMPORTANCE OF MARKETS IN BUILDING SYSTEMS DEVELOPMENT

Experience in the SCSD schools program cited elsewhere in this report indicated that manufacturers are extremely concerned about the size of market for which they are developing components. The major reason for such concern is that the manufacturer must ultimately be able to sell on a cost-value competitive basis with traditional materials. The manufacturer expects that, through the use of advanced technology in production and through mass production, he will induce some economy. But he also realizes that development costs and the cost of new plant and equipment must be written off by charging a fraction of this cost to each unit he produces. The more he produces, the less this unit amortization cost is. At the point that the allowable unit amortization cost is equal to his cost savings through advanced technology, his unit price will be competitive.

To illustrate this, let us presume that conventional construction is producing one-story structural systems at $1 per square foot of building. A manufacturer perceives the opportunity to develop an advanced system for such one story buildings. He also knows that he must sell at a cost-value level competitive with the conventional systems. Assessing his new design for production, he decides that he can produce such a system for $.90, including all profit, but not including amortization of plant and equipment. He can charge up to $.10 per sq. ft. of product for amortization, and he can still be competitive.

On the other hand, he sees that it will cost him $100,000 to develop this system, build the plant and install the machines to make it. If he recovers 10 cents on each square foot of product he sells, this means he must sell 1,000,000 square feet to break even on his new investment, i.e. he must have a market of $1,000,000. It remains to be seen, through his own analysis of the market, whether this kind of market can be generated, and correspondingly whether the development is a good risk.

No manufacturer insists that the market be there in its entirety at the outset, and most are willing to take some risks on the future markets that may grow as a result of his introducing the new product. But there is a certain acceptable risk level, and the new product developer must be assured that at least an acceptable "starting" market exists now. Coupled with the fact that his product will appeal only to a specific sector, it is important for him to have reasonable measures of markets prior to his embarking on costly development programs. The larger his capital risk, the more assurance concerning the markets he will insist upon.

One of the underlying theses of this proposed development program is that by virtue of its size, the Defense construction program can exhibit programs of size which make larger development investments worthwhile. These larger concentrations of development funds will presumably result in larger innovations in building technology, which are of use both to the military and the nation.

If this is to work, however, there must be ample evidence that such markets do in fact exist in the Military, and that they are available to the products of development.

3. THE IMPORTANCE OF PERFORMANCE REQUIREMENTS

Another important characteristic of markets for building systems must be observed. Because of the nature of materials and technology, any given product will have limitations on performance. Rather than making products with such a broad range of possible performance as to bracket all conceivable needs, we find that production economics makes it prudent to produce a variety of products geared to specific ranges of performance, the sum total of varieties covering the total range of need. It is not generally economical to produce one size of steel beam for all spans, but rather a series of sizes is produced. For the purposes of marketing, each size, or configuration of product must be considered as a separate production item, and the decision to make or to continue to make a specific size is based upon the need and demand for that particular size, i. e. that particular range of performance.

Thus from the producers point of view, his "market" is all those persons who can potentially use the performance which he is building into his product, independently of why they wish to use it, i.e. in a school or a barracks or an administration building. Therefore, if a major factor in the success of attracting manufacturers to development programs in the size of the market to which he will sell, the market should be identified to him in terms of the kinds and quantities of performance needed.

It follows that if we wish to sponsor the development of a particular subsystem, it will be necessary to create a market of consistent performance requirements which is large enough to attract the producer. It is extremely difficult to estimate how large the market should be since the required volume is dependent upon the subsystem developed, the desired level of development activity and other variables. The only experience available, that of the SCSD school program, indicates that if a producer can develop a subsystem for a market representing a total building volume of from 20 to 30 million dollars, this would be sufficient attraction. This figure is assumed to be correct for the purpose of this study.

4. THE DETERMINATION OF PERFORMANCE RANGES COMMON TO MILITARY CONSTRUCTION

The number of factors which can enter into determining the required performance in a building is large indeed, and ranges from the eminently rational constraints imposed by existing technology to the non-rational areas of personal preference, tradition, and aesthetic choice. The major variables which seem to operate on military buildings, however, become evident upon reading and studying the DOD Instructions and Directives for building:[1] They are:

cost constraints
use of the building(function)
climate/geography
human physiology

The performance of the building is typically constructed using these factors as a base. TABLE C-1 lists these factors as they interact to control the performances specified as they interact to control the performances specified for particular major subsystems in the buildings. There are many indirect effects not indicated on this chart.

Cost constraints act largely on the total building configuration, limiting its size and scope for particular building types. For instance, the total scope of any barracks is determined on cost-per-man basis. Within this broad control, specific cost trade-offs between subsystems are not controlled.

1. Department of Defense Instructions, in this instance issued by ASD(I & L)

Function, or the use of the building, e.g. training or housing, again operates in control of overall building configuration and virtually all specific subsystems. For instance, the function of housing officers determines the permissibility of multi-story construction, the fact that the building will be largely repetitive small space units, etc. In some cases, function will also dictate the presence or absence of some subsystems i.g. air conditioning and/or heating, and may, by virtue of function "permanence," control the quality of envelope and structure by specifying that buildings shall be permanent, semi-permanent, and so forth.

Function will also be the principal determinants of structure and equipment and furnishings, for fairly obvious reasons.

Human physiological (and psychophysical) requirements operate largely to determine the quality of light, heat, and human support needed, given the tasks at hand. Thus these factors interact with the function to be performed in the control of requirements for mechanical subsystems. For instance, if the function of training calls for desk work, the requirements for lighting are determined by the amount of light a human requires to perform that task efficently.

Climate as a function of geographic regions acts principaly as an influence on the building envelope and upon the requirements for heat, power and air conditioning. It is assumed that climate and geography do not affect the tasks required to execute specific functions.

Many of these factors are made explicit by the Directives & Instructions from DOD, indicating required lighting levels, methods of calculating heat loads and systems capacities, and so forth, all as functions of these major variables. Others are implied but not explicit. These directives allow some prediction of the technological content of buildings which are not yet designed if some assumptions about the tasks performed in those buildings can be made. For instance, if it were possible to determine the task-uses of the space in an administration building, we could project the required temperature, lighting level, and so forth, by use of these DOD Directives. Further, if the geographic location were known for a projected building, it would be possible to make some predictions about the existence of air conditioning, the heat system requirements, and the quality of exterior envelope.

Through a series of such procedures, it would be possible to predict the general performance level required for each major subsystem for all projected buildings, and then to examine this total group of buildings for consistency of performance requirements. From this information, it would be possible to do two things:

1. If no particular markets have preference for other than technological reasons, it would be possible to assemble a market for development on the basis of uniform user requirements.

2. If some particular building type has a preferential value for political oroperational reasons, it will be possible to anticipate in what areas changes in performance requirements or practices of construction might be required (if any) in order to produce a market of suitable size for development work.

In either event, the main function of such an analysis would be to determine what markets existed for a product with particular performance capabilities.

The principal limitation in execution of this market analysis was the size of the task. From fiscal 67-70, it is estimated that in excess of two thousand separate building construction projects will be executed. Many of these will be remodeling and rehabilitation projects. While each of these projects is projected in some detail on DOD forms DD1391, it was not possible to consider separate analysis of these forms as a means of market analysis due to the time required to do this.

Each of the Services (Army, Navy and Air Force) does have listings of all projects planned on punched cards, however, and it was considered possible to combine the existence of this data with sampling techniques to predict the "technological content" of the military construction program.[2]

2/ Such projections are of course subject to changes by Congressional action, and the projection is therefore not too reliable for future years.

The services supplied duplicate decks of their listings, modified to exclude classified information, but giving the construction category code, the size and cost of the project, and regional location information. These cards were divided into the seven major construction categories. For each category, Definitive Drawings supplied by the Navy and Air Force, plus selected real projects from the Army, were sampled to determine the following factors:

1. distribution of sizes of rooms
2. percent of space devoted to the activities of:
   - sedentary work
   - active work
   - circulation
   - sanitation
   - living, sleeping and social recreation
   - eating and food preparation
   - physical recreation
   - building services
   - general storage
3. consumption of power, heat, light & water
4. story height and typical bay size

These samples were selected to be indicative of highly repetitive non-specialized types, and were spread across the entire range of construction types with some concentration in areas of special initial interest. The Definitive Drawings were used on the assumption that they represent an idealized military building for specific task, even though actual buildings may vary from the definitive designs. The secondary assumption is that the actual buildings will not vary greatly.

With the completed sample, data from the samples was projected into the listings of milcon programs, FY 67-70, using computerized search techniques to match planned buildings with sample buildings. Where precise matches were not possible, averages of samples at different levels of aggregation were used. Thus each major sector of the building types was given some projection of content with regard to space usage, distribution of room sizes, and other factors collected from the sample buildings. With these completed data listings, general correlations between data values and generalized performance ranges for each of the major building subsystems were constructed. Table C-2 summarizes the bases for these assumed correlations, and Table C-3 lists specific correlations used in this study. It should be observed that these correlations are very rough, and are not intended to be explicit and universal in implication. They are used only to help the judgment process perceive the generalized kinds of building configurations which might be encountered.

6. Data Quality and Accuracy

While the computerized search-and-match programs have been successfully developed, nonetheless several conceptual and operational difficulties have been encountered in this program which do affect the quality and quantity of data handled in the output stages of the analysis.

First, the data decks provided by the Army, Navy and Air Force contained keypunch errors, which caused a number of rejects and/or complete data losses during our process of manipulation.

Second, absence of critical data on some cards, or mispunches of it, caused a number of losses.

Third, the generalized level of the program was such that proper distinctions of the building data were not made in some highly specialized areas where the sample size was very small.

The sum of these errors or malfunction caused a total data loss of between 5 and 7% of all data cards supplied.

Finally, while the computer itself is reliable, the card sorter which was used to generate final listings of buildings and building programs is not as reliable. Time did not permit verification of the final sorts made, and therefore all listings do not show the same number of projects in a given area. This error can be estimated accurately and was found to average about ±3% of the actual program figures. Therefore, any figures quoted in this analysis can be estimated to be accurate only within a tolerance range of ±10%. Since most of the errors were data losses, the figures will always tend to be on the conservative side.

In view of the high degree of change in projections of military construction, and the fact that projections are continuously modified by DOD, this accuracy is probably acceptable for the immediate purposes of this study.

7. SELECTION OF AREAS FOR ANALYSIS

Obviously, the number of searches which could be initiated with this data bank is quite large. Thus a complete analysis of all military construction was not attempted and probably should not be attempted without more accurate data and more reliable techniques. Many areas of military construction can be eliminated as areas of interest on other than technological grounds; on the same grounds, other areas emerge as areas of special interest. For the reasons that these areas of special interest are chosen largely for political and/or operational reasons, the analysis was designed principally to answer specific questions about buildings types of interest rather than suggest that certain areas should be of interest.

Of the major alternatives which emerged early in the feasibility study, the two foremost areas of special interest were:

(1) low rise buildings used for administrative and training functions, and

(2) barracks and BOQ's

Essentially, these two alternatives represented the alternative of developing an "open" system, i.e., a general system of building technology covering specific performance ranges, which could be applied when and where needed, regardless of function,and the alternative of the "closed" system, which is oriented to a specific building function and designed only for that.

DATA PRESENTED FOR THE ANALYSIS

In order to accomplish this analysis, the following data was collated using the procedures described:

1. Total Projected Volume: Tables C-4 to C-7 provide listings of the projected volume for each service, FY67-70, for CCC 170, Training Buildings, CCC 600, Administration and Headquarters Buildings, CCC 721-2, Barracks with and without Mess, and CCC 724, BOQ's.

2. Distribution of Projects by $ Size: This data is provided in Tables C-8 to C-12 for all items listed above for the total volume projected FY67-70. This data will help identify typical sizes and variations in the sizes of projects.

3. Distribution of Projects by Naval Operations District (Tables C-13 to C-16): the total volume of all three services grouped by Navops District, the lowest common denominator of geography available. This data provides insight into densities of groupings, climatic demands on buildings and variations thereof. In addition, if special operational problems may be anticipated in certain districts, such information assesses the markets available outside of those regions.

4. Listings of sample data: Tables C-17 to C-20 provide listings of sample data, giving the high and low values of all factors measured for each of the four building categories.

The implications of this data will be discussed in the following:

ANALYSIS OF ADMINISTRATIVE AND TRAINING FACILITIES

Size of the Market: (from tables C-4 & C-5). Over the next four years, 300 million dollars worth of such buildings are programmed. However, no single service in a single year generates enough volume in either administration or training buildings to satisfy the requirement for twenty to thirty million dollars worth of construction. Thus work in this area would require a program that either combined the two types for a single service for a single year, or else used multi-service or multi-year programs. In FY69-70, the presumed target years, either the Army or the Navy could yield enough volume to satisfy this requirement, but the projected Air Force volume is not adequate.

Technological characteristics: (from tables C-17 to C-18). Major variations are encountered in the structural configurations in these buildings, but all are limited to low-rise structures with very few specialized exceptions. There are also wide excursions in measured utilities factors; however, the mode of space usage is a reasonably consistent in pattern between the two types, both giving high preferences to sedentary work spaces. The kind of sedentary work in administration building will be quite different than "sedentary" work in an engine repair training shop, however, and no data are available to suggest the range of requirements imposed by these variations. The excursions of measured power and light consumption factors indicates that there are in fact greatly differing user requirements in the mix of these building types. This suggests further study through the detailed use of DD1391 forms. The simple breakdown of active vs. sedentary work is not adequate in this case.

Size of Projects: Both types of buildings show high consistencies in the distribution of sizes of the projects undertaken. By far the largest number of projects falls below three quarter million dollars; the dollars expended on projects of this size or smaller is estimated to be:

Training Buildings:	$ 44 million (FY67-70)
Administration Buildings:	38 million

Adjusting these estimates for FY69-70 only, the figures are:

Training Buildings:	$ 21 million
Administration Buildings:	18 million

From these figures, several things may be concluded:

1. Combinations of both types of buildings would create a market of about 40 million dollars, which would mean than options could be exercised to eliminate about one-quarter of the market on grounds of geography and other factors making certain projects undesirable.

2. A decision to work in only one building type, or a decision that more latitude was needed to select projects in desirable locations, etc., would require that this market be expanded to include more of the larger projects, which may tend to be more highly specialized.

Nonetheless, it would be possible to decide to work with a large number of "smaller" projects and still have a desirable market. Likewise, there is enough volume in the 3/4 to 1 1/2 million dollar size range to generate the required market, if both types of buildings for all services are included, FY69 & 70. Such a decision, however, would eliminate nearly all options to select specific buildings or specific locations, and the market would have to include whatever came along.

Location of Projects: The highest concentrations of number of projects and dollar volume is in the southern states (including D.C., Maryland and environs; for complete listings of states in Naval Operations Districts, see Table C-21) and in the northern midsection of the nation. Tables C-13 and C-14 indicate that projects in these high concentration areas tend to run somewhat larger than the average project size, and larger still than the median size. It has not been determined whether this is due to the inclusion of a very few large projects in these areas or due to a smooth but higher-than-average distribution of project sizes.

General Notes: Field investigation of these building types has indicated a demand for flexibility in their allocation and use. Due to the general nature of their usages, high incidence of sophisticated mechanical systems is indicated, and variations in the kinds of mechanical subsystem performance demanded are expected to be great.

Conclusions: This study has uncovered no specific obstacles to the combination of these two building types into a single market for the development of components. It is observed that they appear more amenable to the development of non-mechanical subsystems than to mechanically-oriented subsystems, due to the potential wide variations in requirements on the latter. It may also be possible to achieve greater standardization of mechanical subsystems than now appears to exist without undue penalty to the user.

The size of the market is not great enough, however, to allow unlimited exercise of options in the selection of a specific development market. It appears that the assembly of a market of buildings of uniform size, compact geographic location, and common function requirements will be difficult, and some reasonably wide variations must be accepted in all of these factors. As observed above, exercise of any of the options precludes the operation of the program within a single service, FY69-70.

ANALYSIS OF BARRACKS AND BACHELOR OFFICER QUARTERS

This area is immediately confused by the existence of Army Barracks Complexes in the projections. While these complexes are simply assemblages of buildings resembling the "individual" projects built elsewhere, their size and scope suggest substantially different planning and logistics problems. On the other hand, since they tend to be repetitive, they may offer a good opportunity for systems development work. Thus in this analysis they are singled out in all the data, not only for these reasons, but because their size (approximately $13 million each) distorts the aggregation of data.

Size of the Market: Barracks will account for over 425 million dollars worth of construction from FY67-70; BOQ's will account for $ approximately $115 million. In the target years of FY69-70, the figures are 203 million and 51 million respectively. About 70 million dollars or more of the 203 million figure will be Barracks Complexes built for the Army. The figures (Tables C-6 & C-7) suggest that the Army alone can generate adquate volume in either barracks or BOQ's in a single year; the Navy could do the same in Barracks over two years, but the Air Force will not have enough volume by itself unless current projects change drastically.

The size of the Barracks Complex market is quite large. In the next four years, 20 complexes are projected at an average cost of about $13 million, giving a total market of $260 million. In FY69-70, 9 are projected.

Technological Characteristics: The patterns of space use are, as might be expected, very consistent, with minor variations attributable to the size and configuration of the building itself. Mechanical subsystem indicators also vary only in proportion to expected variation due to building shape (i.e. story height and gross area). This is as might be expected due to (a) uniform and specialized usage of the building type, (b) the tri-service administration of standards and congressional control of space allocation and funds. Some wider variation is encountered in structural configuration, due to the fact the high-rise construction up to 6 or more stories is used, and due to the fact that units vary from housing only a few men to several hundred. Distributions of space sizes are very consistent, however, indication that the internal contents of the building, no matter what total size, are quite uniform. The repetitive nature of the interior spaces as well as the specialized and uniform kind of use of these buildings suggests that mechanical system requirements would be nearly uniform, varying principally with the size and geographic location of the building.

The bulk of the buildings are built using medium span, low rise structures or short span low-rise structures.

Size of the Projects: Of the 192 BOQ projects listed in the output, 139 are less than $1 million in size, representing an estimated dollar volume of $65 million. For FY69-70, this figure is approximately $30 million. Projects in this size range would probably exclude large high-rise construction projects, indicating that the formation of an adequate market can be accomplished without the inclusion of high rise buildings.

In Barracks, Table C-10 shows the concentration of Army effort in the field of barracks complexes, while Table C-11 indicates that the Navy and Air Force a concentrating on smaller individual units. There is more evidence of multi-million dollar projects, however than in Administration and Training buildings. The total value of project under 1 million dollars in size is estimated at $45 million (Navy and Air Force only), which is less than one half the total dollar volume in Navy and Air Force Barracks. All of these factors indicate the general requirement for larger project sizes, and indicates a good opportunity to assemble the required market with fewer projects than in Administration and Training Buildings. This is especially true of the Barracks Complexes are considered. The average sizes of Barracks and BOQ projects, discounting the complexes, appears to be well over $1 million dollars, as contrasted to between

$600 and $800 thousand for administration and training buildings.

Location of Projects (Tables C-15 and C-16): In view of the above comments, geographic location and distribution is somewhat less important to this market, since the number and size of the projects will allow considerable latitude in the exercise of options as to the specific market locations selected for development. Distributions run about the same as for administration and training buildings, with the notable exception of substantially more activity on the West Coast of the United States. Otherwise, the main areas of concentration are the southern and northern midsection states. Barracks complexes are concentrated in the southern states and the northeastern states (4 and 6 respectively) with 4 additional in the northern midsection.

Conclusions: Expected variation in building configuration and subsystem requirements is extremely difficult to assess. On one hand, the functional and user requirements are likely to be uniform; on the other hand, size and location variation, with especial attention to the large number of projects on the West Coast and in the South, may induce wide variations in structure and envelop requirements. In contrast to the administration and training buildings, this market appears more amenable to the development of mechanical subsystems than to the development of a single uniform structure/envelope package which would eventually satisfy the entire market. The unique variation in structural requirement, however, is the height and area of the buildings which may be susceptible to standardization. The precise quantity and impact of high-rise construction cannot be estimated from the data on hand.

The very large size of this market indicates that the options for developing a prototype market are large in number, but that extension of the development products to use in the general market may involve added requirements for standardization of designs or multiple-system solutions in the development work.

GENERAL CONCLUSIONS

None of the markets examined are homogeneous to the point that they suggest a single system solution can be applied uniformly to the entire spectrum of buildings within that category. It does appear on the basis of this limited examination, however, that many markets do exist of substantial size with homogeneous requirements, such that the development of subsystems with moderate requirements for flexibility can yield positive results in either area. Generally speaking, most markets appear to suggest that multi-service programs are a likelihood, with the exception of Barracks, which can be developed within the context of the Army.

Further, there are very large areas of common subsystem performance requirements extending across the category lines. The market for 1-3 story medium span structural systems is estimated at nearly 150 million dollars for four years, for instance. Some indication of the total subsystems markets has been developed in Tables C-24 to C-27. (These figures were derived by multiplying total construction values by Indices for subsystem costs supplied by the Engineering News-Record, 12-17-64, and confirmed by other sources; see Table C-23).

Assessment of these subsystems expenditure estimates must of course be modified, as they do not represent the total market for a single subsystem product; rather they represent the total market for the aggregate of all subsystems needed to satisfy the entire spectrum of performances required.

Particular attention is called to the total investments to be made in structural and mechanical systems. There is ample evidence that the development of multiple solution subsystems in these areas which are interchangeable with one another, would yield the largest potential benefits by reducing the inventory of parts needed to build a wide variety of military buildings. Analysis of the general range of performance requirements indicates that not more than four types of structure (light and medium span low rise, permanent and semi-permanent) are in fact required to solve the large majority of structural problems encountered.

In conclusion, this study does not uncover any major constraints to the formation of markets for prototype development in either area. This statement is made with extreme caution in observation of the lack of detailed knowledge about performance needs. It is judged possible however, observing the minor constraints emphasized in this report, to select the area of development on the basis of other preference factors with the assurance that a market of reasonable size and content should exist, barring major changes in mission and appropriations. Future decisions, however, should be reconfirmed by more detailed analysis of the configurations of projected buildings. It is recommended that special areas of interest be further isolated by preferential choice supported by this information, and that these areas be scrutinized in detail prior to commitment. This can be done with satisfactory accuracy by detailed analysis of DD1391 for project areas of interest, combined with continued investigation of the DOD Instructions and Directives and continued liaison with the technical staff of OSD and the three services.

INFLUENCING FACTOR	SUBSYSTEM PERFORMANCE AFFECTE									
	STRUCTURE	ENVELOPE	INTERNAL SUBDIVISION	TEMPERATURE CONTROL	ILLUMINATION	SANITARY & WATER SUPPLY	SOUND CONTROL	POWER DISTRIBUTION	EQUIPMENT & FURNISHINGS	TOTAL BUILDING CONFIGURATION
COST CONSTRAINTS			*							●
FUNCTION	●		●	●				●	●	
HUMAN FACTORS				●	●	●	●		●	
CLIMATE/GEOGRAPHY		●		●						

*There is indirect influence on this system by virtue of space allocation control.

Table C-1
INTERACTIONS OF MAJOR VARIABLES USED AS CRITERIA AND BUILDING SUBSYSTEMS

Table C-2: Basis for Correlation of Sample Data & Performance Requirements

Data Gathered	Implications drawn from data
Size of Rooms	1. Required Span: building of small rooms can usually employ shorter spans, and vice versa. 2. Planning Module:higher incidence of small rooms areas usually implies that smaller modules are required for flexibility of plan. 3. Density of Heat Distribution Equipment: higher incidence of smaller rooms will increase the incidence of distribution devices the quantity of ductwork and piping.
Usuage of Rooms: % of space devoted to activities of: Active Work Sedentary Work Circulation Sanitation Living & Social Rec Physical Rec Eating & Food Prep Facility Support Storage	1. Quality of Lighting: and requirements for lighting vary directly with the use requirements of the space, and standards for lighting are well related to activity such as work, etc. 2. Heating/AC Control Tolerances: not only desired temperature levels, but tolerable variations, are related to use of space. High tolerances will probably have greater impact on sedentary work than upon physical rec. activities, for instance. 3. Homogeneity of Building Use: from studying the mix of activity in a building, some important inferences about the variation in technology and the potential changes of requirements through the life of the building can be drawn. This is by and large a qualitative judgment, and somewhat speculative of necessity.

4. Acoustic Tolerances: assuming noise generation levels for each kind of activity, it is possible to predict the need for suppressive devices. Further, by examining the mix of activity in a given building, it is possible to assess whether acoustic transmission reduction will be an important consideration.

5. General Building Finish Quality: standards of usage will indicate what percentage of the building requires high, medium or low quality surface finishes.

Spans & Height of Building

Critical Span Ranges:
- 0-20 (short span)
- 20-50 (medium span)
- 50- (long span)

Critical heights:
- 1-3 stys (lo-rise)
- 3+ (hi-rise)

1. Sophistication of structure: increasing length of span typically requires more sophisticated products solutions, e.g. simple steel beams vs. welded plate girders; open webs joists vs. trusses vs. space frames. Increasing story height requires more sophistication in the construction process, e.g. manual vs. machine handling of components, hand vs. machine fastening, etc. Thus the simplest kinds of technology and process, e.g. hand assembly of timber fraes, is possible with a low-rise, short span building, and the most comples technologies and processes would normally be found in the high-rise, long-span structure.

2. Structural materials: Traditional materials are competitive in particular performance ranges. For instance, common reinforced concrete structures are usually applicable to the medium span range; prestressed concrete is usually economical only in long-span configurations.

Consuption of Heat, Power and Water:	These figures when divided by the area served provide a quantity defined as the UTILITIES DENSITY FACTORS. This factor is an indicator of the density of consumption per square foot, and thus indirectly indicates the number of devices required in the building. For instance, a high power density factor would indicate that the particular building has more receptacles or power using devices per square foot, hence a "more sophisticated" or more complex electrical system.

Table C-3: Correlations of Data Gathered and Specific Subsystem Performance Ranges*

SUBSYSTEM	PERFORMANCE RANGE CONSIDERED	CONDITIONS FOR REQUIREMENT OF PERFORMANCE RANGE BASED ON AVAILABLE DATA
STRUCTURE	Low Rise	Typical buildings in category less than 3 stories in height
	High Rise	Typical building in category or function over 3 stories in height
	Short Span, 0-20'	Permissible if typical room sizes or majority of room sizes in 0-400 wquare foot range AND if no special function requirement dictates greater requirement.
	Medium Span, 20-50'	Permissible and/or mandatory if majority of functions require rooms of 400-900 square feet AND no functional requirement observed indicates need for greater clear span.
	Long Span, over 50'	Mandatory based on special functional requirements.
	Special Note: These statements regarding span are highly generalized based upon present practices, and do not necessarily indicate best planning practice or optimum planning requirements.	
ENVELOPE	Low Thermal Resist. (U= .56 or more)	*Facilities other than family housing and located in Navops Districts 6,11,or 12 and Western portion of 13 (4270.9; 4270.11; others)
	Moderate Thermal Resis. (U= approx. .27)	*Family housing in Dist. 6, 11,12, western 13; All other facilities located in districts 1,3,4,8,5,9, and east 13 (4270.9; 4270.11;others)

	High Thermal Resis. (U= approx .10)	*Family housing in 1,3,4,5,8 9, eastern 13.
	Permanent) Semi-Permanent)	Indeterminate on basis of data used in this study.
INTERNAL SUBDIVISION	Moderate Quality Finish	Space devoted to sedentary work, living and social recreation, sanitation, eating & food preparation (4270.11; others).
	Low Quality Finish	Spaces devoted to all other activities.
	Note: the density of use of internal subdivision is directly related to percentages of space in a given area devoted to room size ranges of 0-400, 400-900 and over 900 square feet.	
LIGHTING	High Quality, over 30 foot-candles	Space devoted to sedentary work (4270.29 & other Military Design Manuals)
	Moderate Quality 15-30 foot candles	All spaces devoted to activities other than sedentary work, storage or building maintenance.
	Low quality 0-15 foot candles	Storage, building maintenance and some circulation areas.
	General lighting system	All areas other than living and social recreation
	Local lighting or special purpose	Living and social recreational areas

HEATING COOLING SYSTEMS	General Systems	Building gross area less than 2000 square feet.
	Zoned Systems	Building gross area in excess of 2000 square feet.
	Note: The sizes of systems required, I.E. low, medium, high capacity can be correlated on the basis of building volume, climatic zone, and gross heat loss figures. This work is underway for inclusion in future analyses.	
	Note 2: Existence of air conditioning is based on complex priority and climatic conditions (4270.7). The following general rules can be extrapolated without great loss of accuracy; Operational, Hospital, Training, Administrative and Personnel Facilities in Districts 5,6,8 & 11 will be air conditioned; Similar facilities in Districts 3,4,9 & 12 are likely to be air conditioned; Facilities in Districts 11, 12 & parts of 8 may use evaporative cooling and must use it if cheaper than AC. See Instruction for precise information.	
	Note 3: Size-capacities of air-conditioning systems are being correlated based on building volume, use, climatic zone, and other factors for future projections.	
SANITARY & WATER SUPPLY	High Consumption and Density	Barracks, BOQ, Family Housing, Food Preparation Facilities, Messes. (Based on correlations of water consumption density factors).
	Moderate Consumption	Administrative Facilities, classroom buildings, repair and maintenance shops.
	Low Consumption	Storage, Warehouses, Operations buildings.
	Indeterminate	Training buildings, R&D-testing, ordinance, power plants, other special purpose buildings.

ELECTRICAL POWER DISTRIBUTION		Indeterminate on basis of data used in this study.
ACOUSTIC CONTROL	Transmission Reduction Required	Indeterminate on basis of data used in this study.
	Suppression Reduction Required	Generally, active work areas, sedentary work areas, eating and social recreation areas. specifically indeterminate without detailed consideration of function.

TRAINING BUILDINGS

FY	ARMY	NAVY	AIR FORCE	TOTAL
67	(16) 18938	(39) 36858	(11) 4374	(66) 60170
68	(18) 23689	(21) 10282	(6) 3301	(45) 37272
69	(11) 18778	(28) 20555	(4) 1831	(43) 73164
70	(33) 29922	(23) 15951	(1) 4768	(57) 50641
SERV. TOTAL	(78) 91327	(111) 83646	(22) 14274	(211)171247

TABLE C-4. Programmed: Number of Projects and Dollar Volume (in thousands) of Construction, FY67-70

ADMINISTRATION BUILDINGS

FY	ARMY	NAVY	AIR FORCE	TOTAL
67	(19) 19926	(14) 9153	(5) 7675	(38) 36754
68	(35) 21084	(11) 5712	(12) 3445	(58) 30241
69	(10) 6681	(18) 7840	(6) 3299	(34) 17820
70	(24) 16887	(17) 10352	(4) 1888	(45) 29127
SERV. TOTAL	(88) 65298	(60) 33057	(27) 16307	(175)113942

TABLE C-5. Progammed: Number of Projects and Dollar Volume (in thousands) of Construction, FY67-70

BARRACKS

FY	ARMY	NAVY	AIR FORCE	TOTAL
67	(13) 85941	(23) 19670	(13) 6794	(49) 112408
68	(15) 98327	(18) 21069	(5) 1875	(38) 121271
69	(9) 93186	(19) 22466	(1) 100	(29) 115752
70	(6) 67756	(20) 17631	(1) 3053	(27) 88450
TOTAL	(43)345210	(80) 80836	(20) 11825	(143) 437871

TABLE C-6. Programmed: Number of Projects and Dollar Volume (in thousands) in Construction, FY67-70

BACHELOR OFFICER QUARTERS

FY	ARMY	NAVY	AIR FORCE	TOTAL
67	(24) 22571	(13) 9647	(15) 9109	(51) 41327
68	(6) 10353	(6) 6130	(8) 5197	(20) 21680
69	(14) 16072	(7) 6787	(14) 9590	(35) 32449
70	(10) 14370	(5) 2528	(5) 3015	(20) 19913
TOTAL	(54) 63313	(31) 25092	(42) 26911	(106)115369

TABLE C-7. Programmed: Number of Projects and Dollar Volume (in thousands) in Construction, FY67-70

Table C-8
DISTRIBUTION OF PROJECTS BY SIZE OF PROJECT IN DOLLARS:

Army, Navy and Air Force TRAINING BUILDINGS, FY 67-70

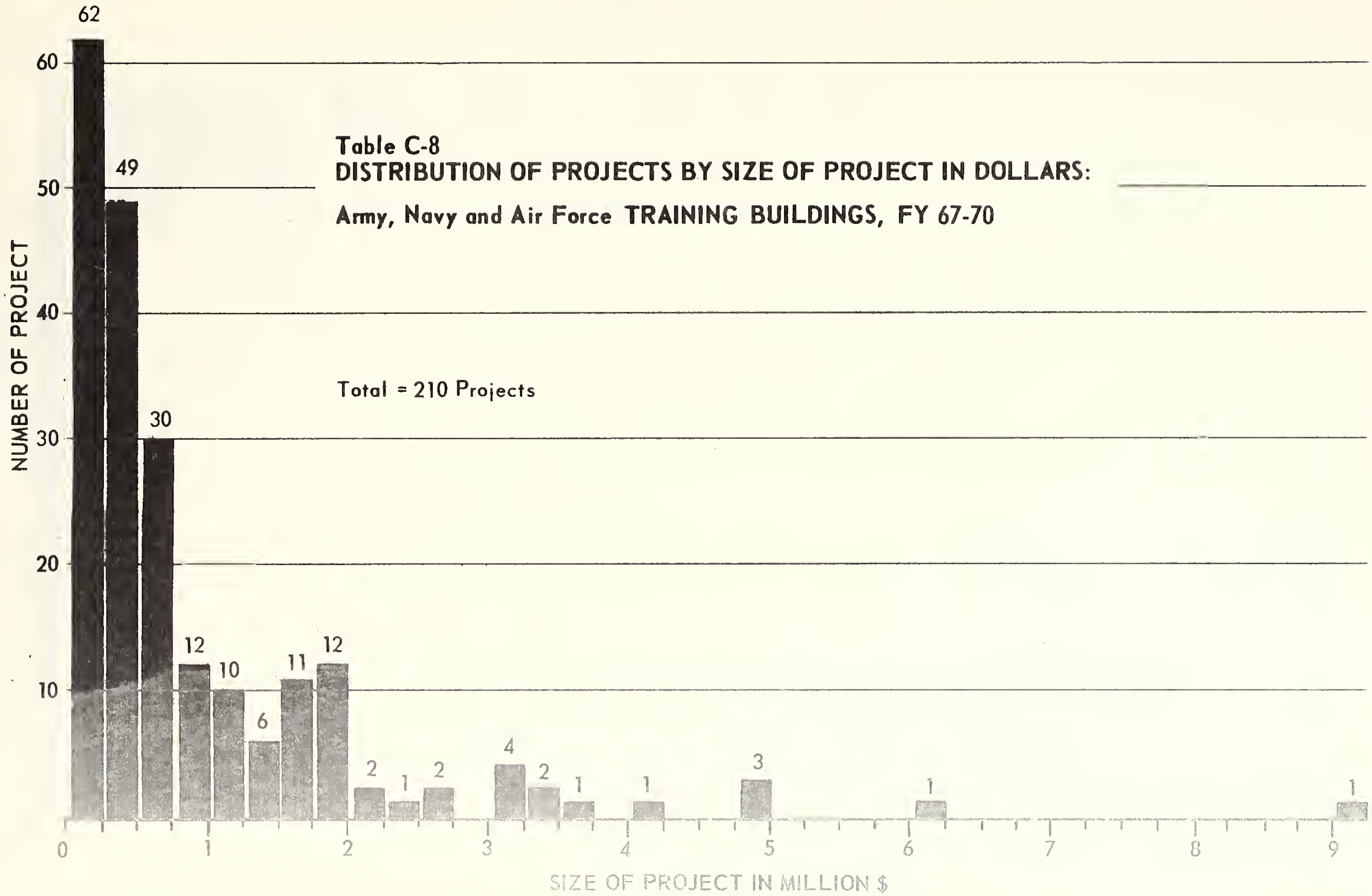


Table C-9
DISTRIBUTION OF PROJECTS BY SIZE OF PROJECT IN DOLLARS:

Army, Navy and Air Force ADMINISTRATION BUILDINGS, CCC 600-, FY 67-70

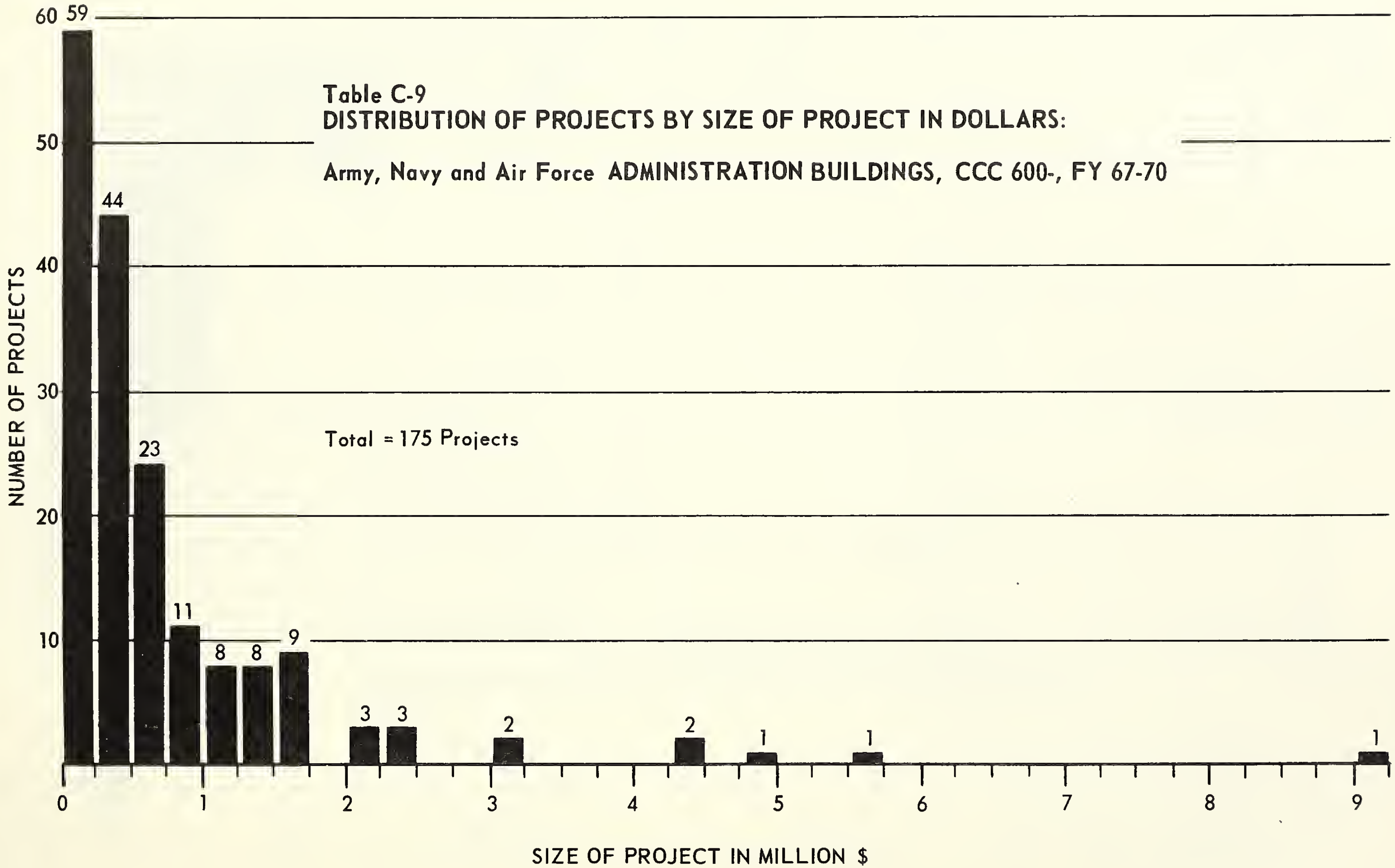


Table C-10
DISTRIBUTION OF PROJECTS BY SIZE OF PROJECTS IN DOLLARS,

ARMY BARRACKS, CCC722, FY 67-70

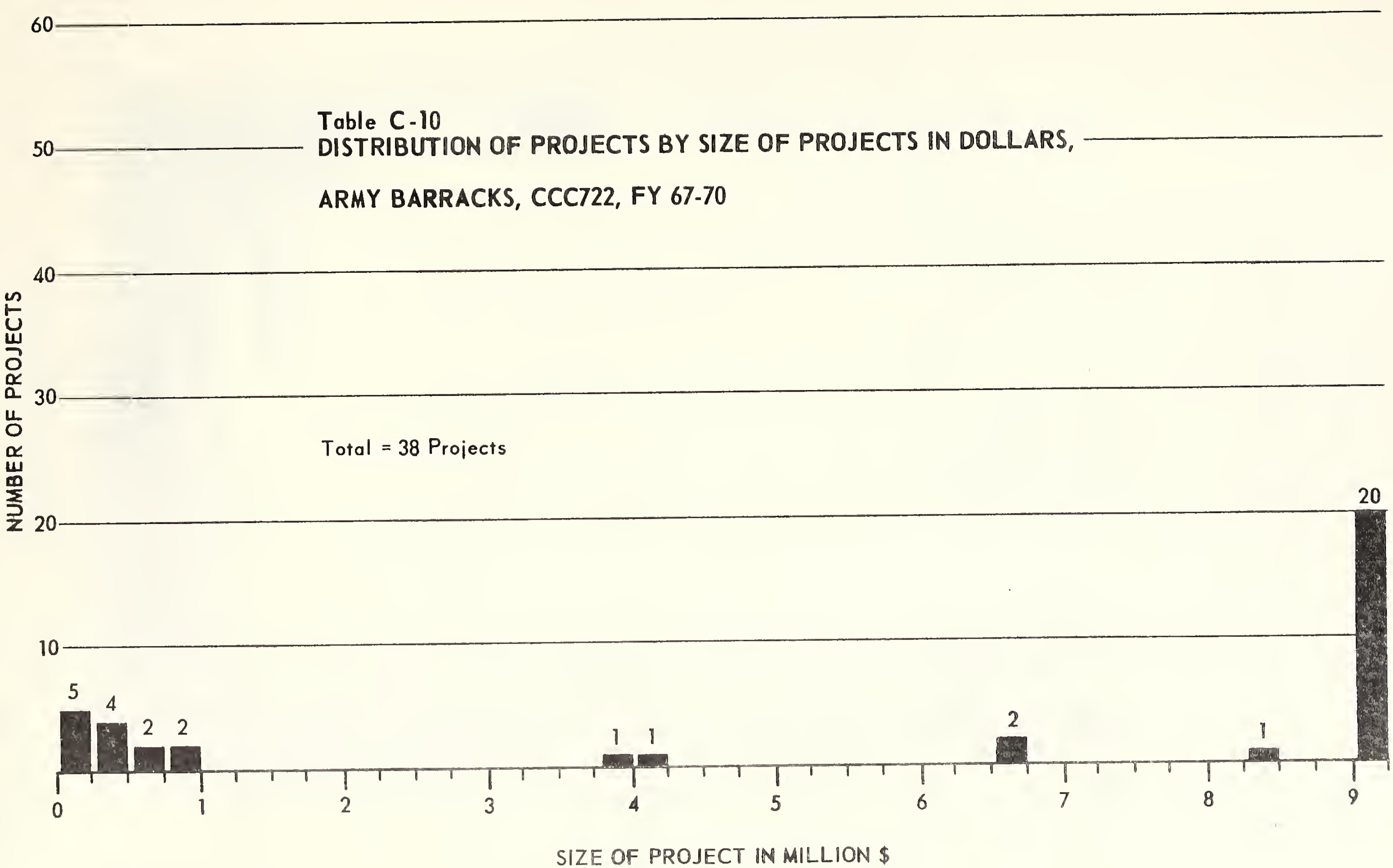


Table C-11
DISTRIBUTION OF PROJECTS BY SIZE OF PROJECT IN DOLLARS:

NAVY and AIR FORCE BARRACKS, CCC 722-, FY 67-70

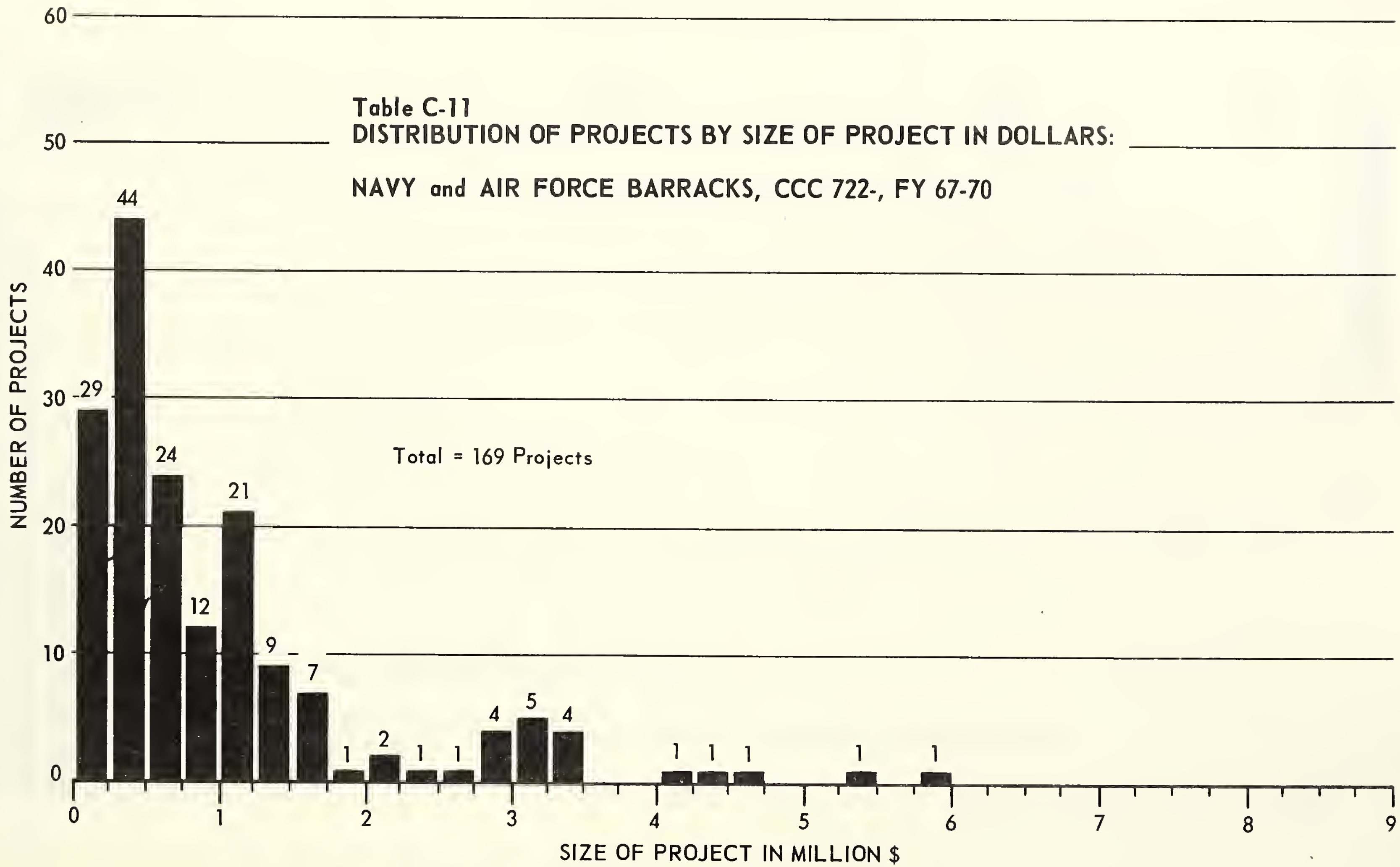
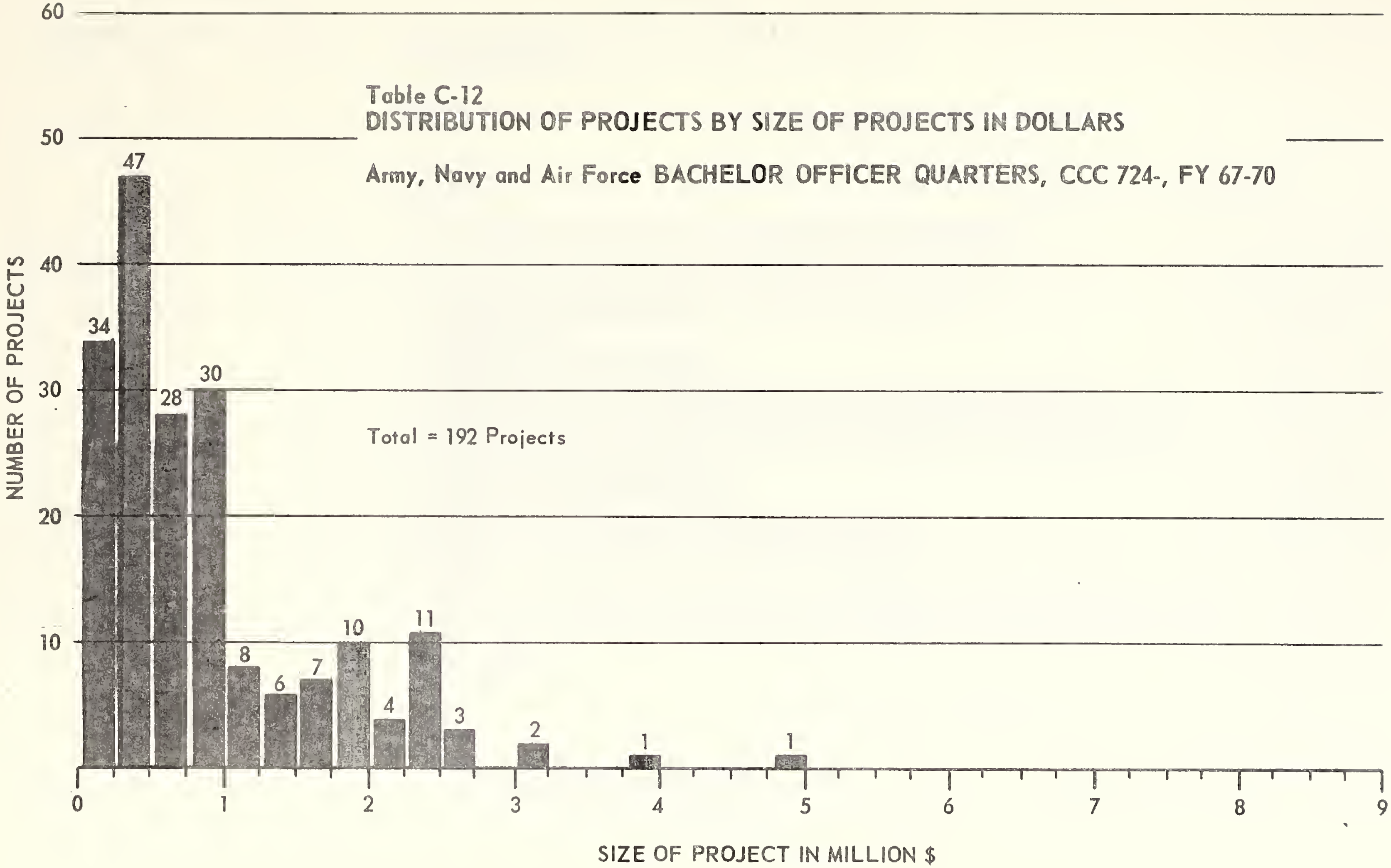


Table C-12
DISTRIBUTION OF PROJECTS BY SIZE OF PROJECTS IN DOLLARS

Army, Navy and Air Force BACHELOR OFFICER QUARTERS, CCC 724-, FY 67-70



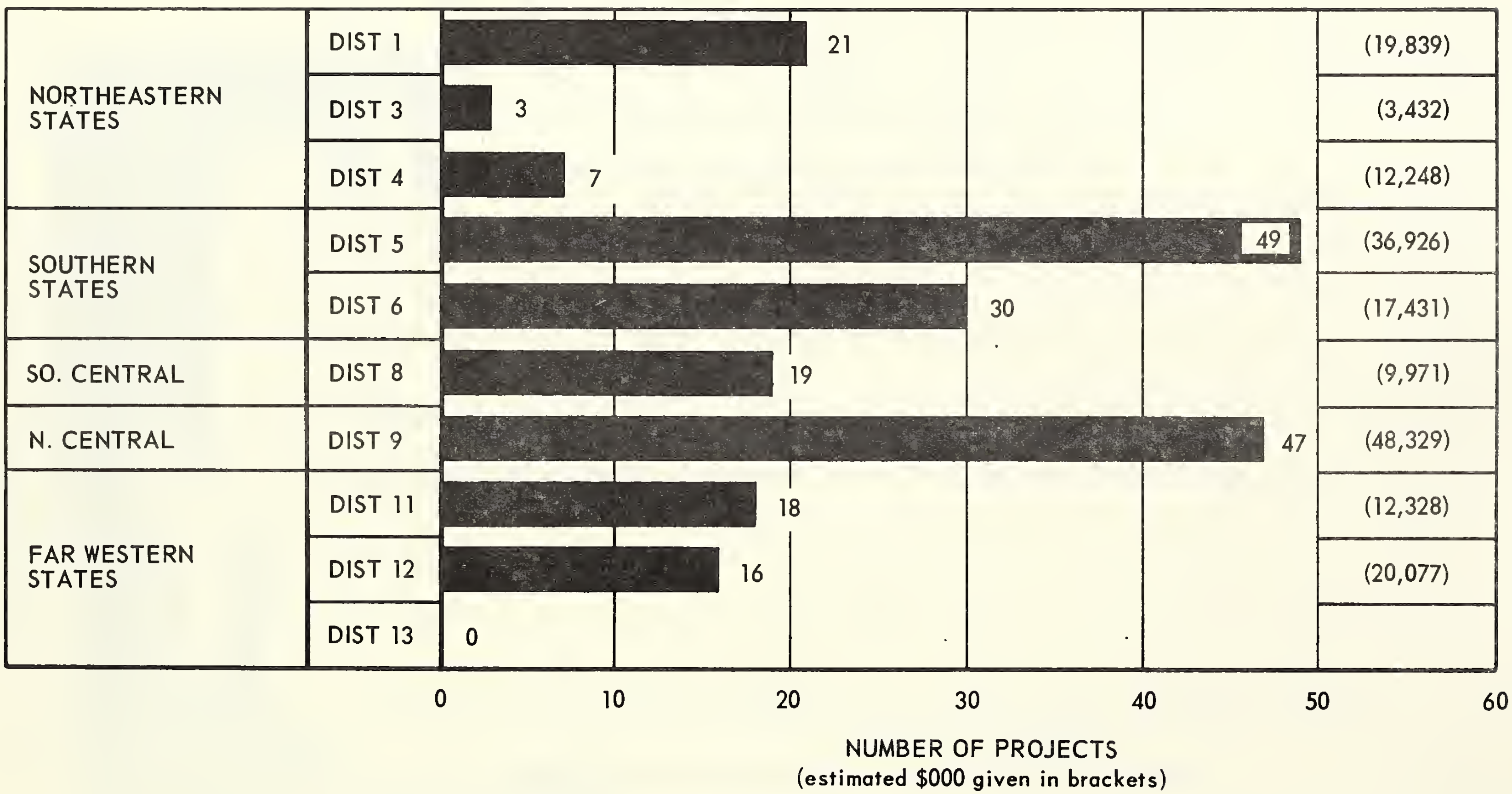


Table C-13
DISTRIBUTION OF PROJECTS BY NAVAL OPERATIONS DISTRICTS, FY 67-70

TRAINING BUILDINGS for Army, Navy, and Air Force, CCC 170

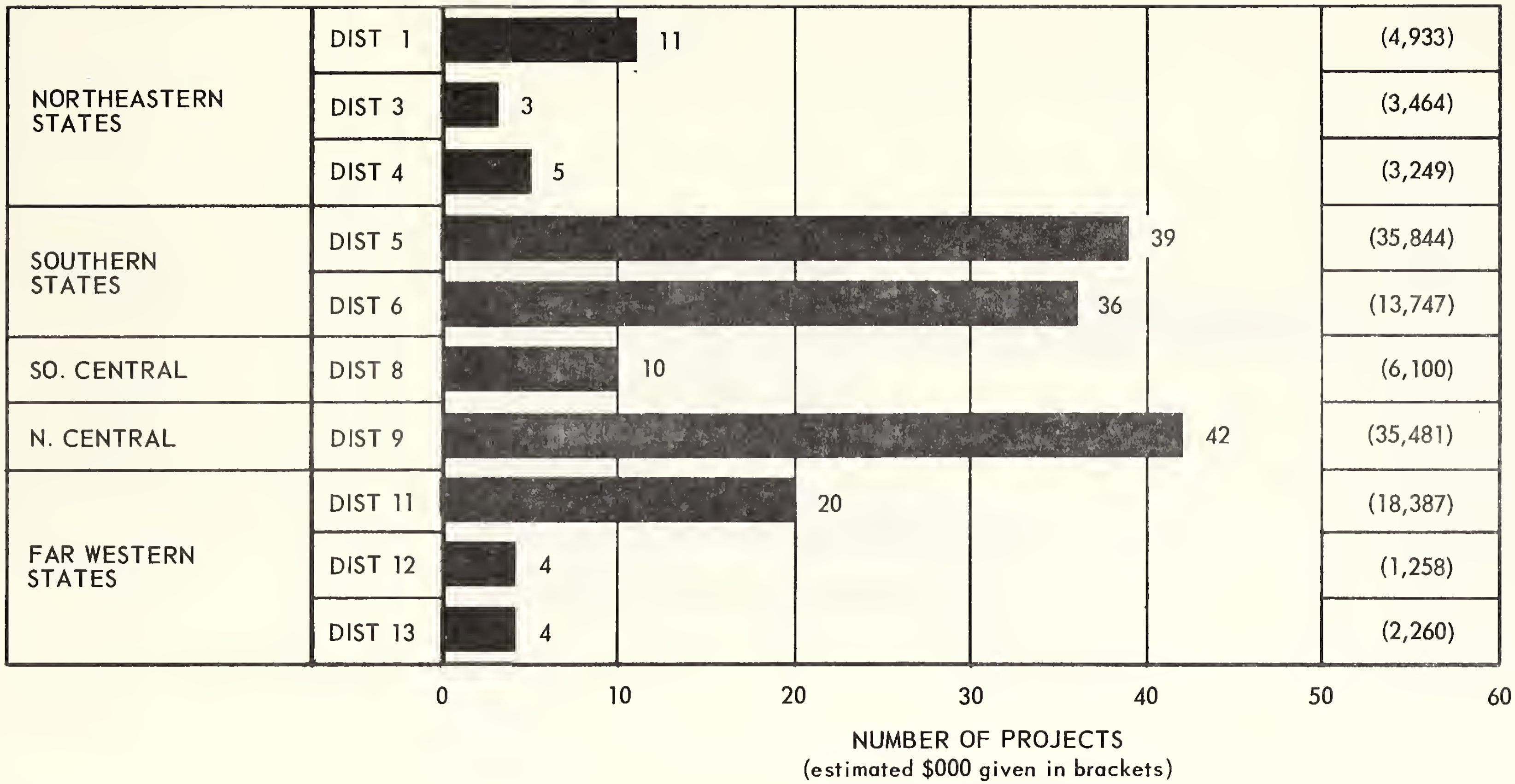


Table C-14
DISTRIBUTION OF PROJECTS BY NAVAL OPERATIONS DISTRICTS, FY 67-70

ADMINISTRATION BUILDINGS for Army, Navy and Air Force, CCC 600-

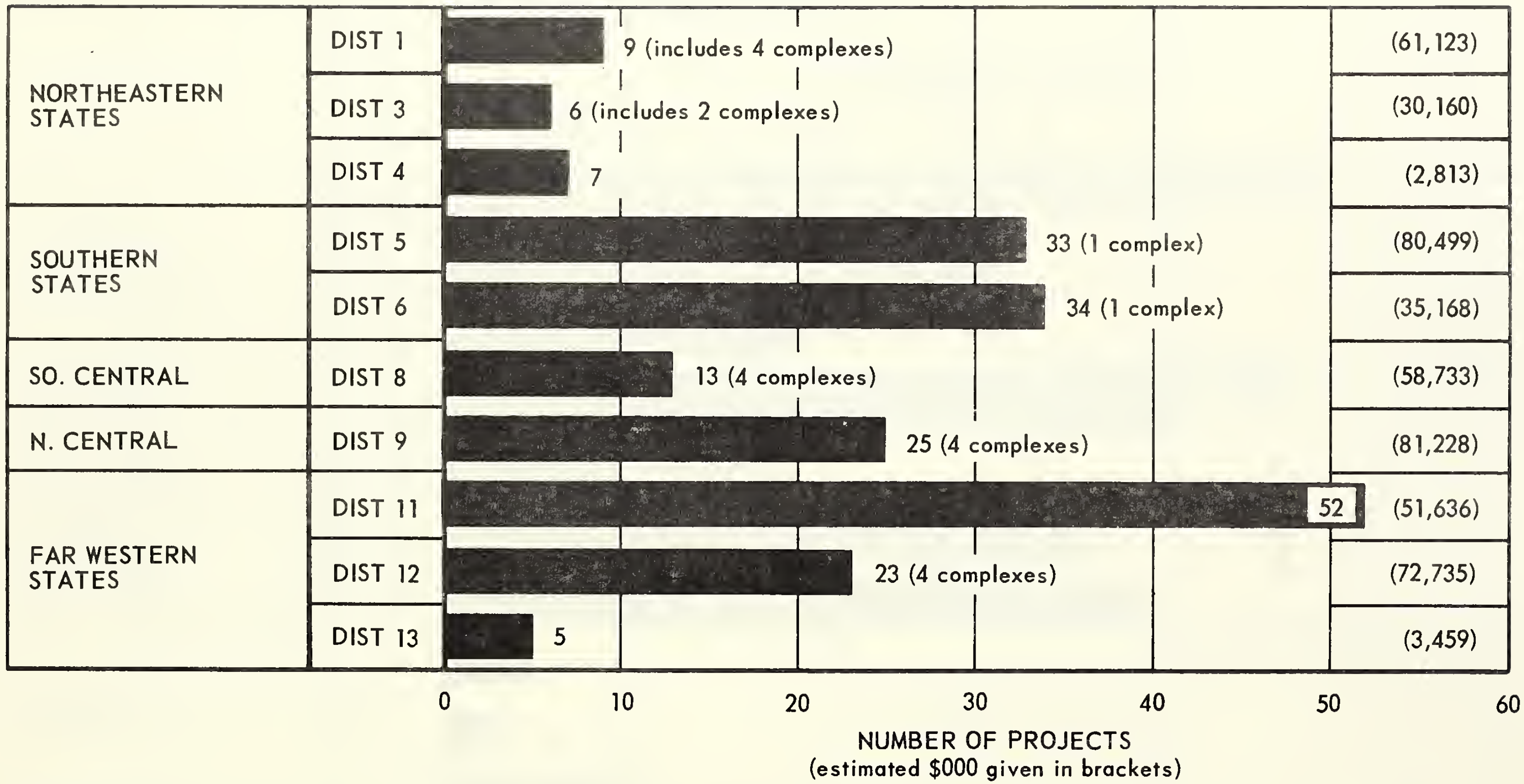


Table C-15
DISTRIBUTION OF PROJECTS BY NAVAL OPERATIONS DISTRICTS, FY 67-70

BARRACKS for Army, Navy and Air Force, CCC 722-

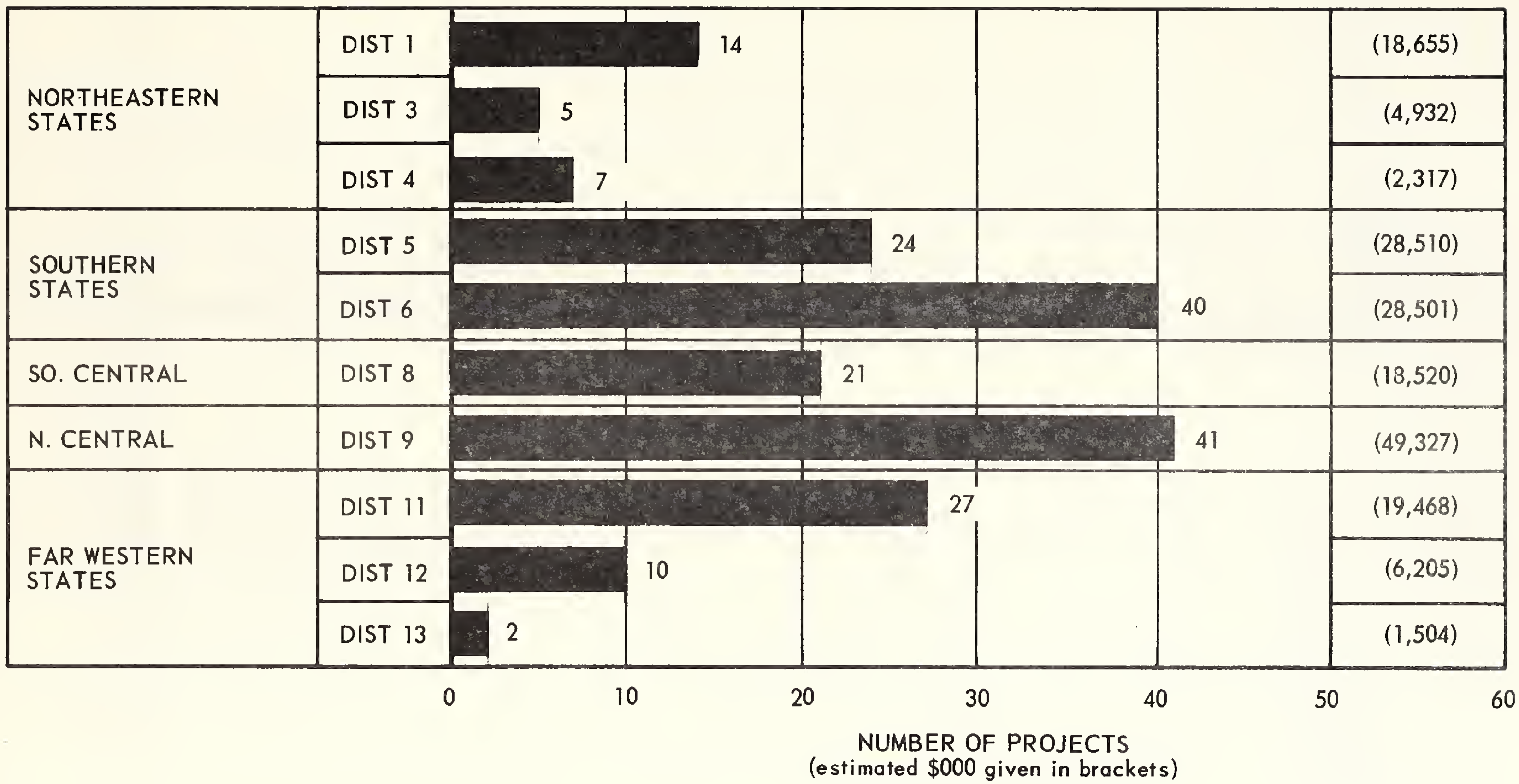


Table C-16
DISTRIBUTION OF PROJECTS BY NAVAL OPERATIONS DISTRICTS, FY 67-70

BACHELOR OFFICER QUARTERS for Army, Navy and Air Force, CCC 724-

TABLE C-17: Sampled Data for Training Buildings

FACTOR OBSERVED	SAMPLE DATA	
	high	low
% of space devoted to activities of:		
sedentary work	67	17
active work	47	0
circulation	18	15
sanitation	4	2
eating & food pr	0	0
living/soc recr	0	0
build mainten	14	6
phys recreation	0	0
storage	3	0
span implied	65'	25'
story height	2	1
power density fact	141	24
heat serv.dens.fa.	1672	411
water cons.dens.f.	3052	381
light cons.dens.gf	39	26
% space, 0-400 s.f.	37	10
% space, 400-900 s.f.	15	0
% space, 900 + s.f.	54	17

TABLE C-18: Sample Data, Administration Buildings

FACTOR OBSERVED	SAMPLE DATA	
	high	low
% of space devoted to activities of:		
sedentary work	75	14
active work	29	0
circulation (%)	35	7
sanitation	5	1
eating & food pr	4	0
living/soc recr	2	0
build mainten	4	2
phys recreation	0	0
storage	62	0
span implied	80'	20'
story height	3	1
power density fact	121	3
heat serv.dens.fa.	866	346
water cons.dens.f.	20	7621
light cons.dens.gf.	65	26
% space, 0-400 s.f.	52	0
% space, 400-900 s.f.	71	0
% space, 900 + s.f.	55	0

TABLE C-19: Sample Data, Barracks

FACTOR OBSERVED	SAMPLE DATA	
	high	low
% of space devoted to activities of:		
sendentary work	5	1
active work	4	1
circulation	17	10
sanitation	11	7
eating & food pr	14	0
living/soc recr	63	38
build manten	4	2
phys recreation	0	0
storage*	7	2
span implied	30	20
story height	3	3
power density fact	20	3
heat serv.dens.fa.	23	13
water cons.dens.f.	547	104
light cons.dens.gf.	335	272
% space, 0-400 s.f.	75	25
% space, 400-900 s.f.	45	2
% space, 900 + s.f.	12	3
*does not include individual storage space in rooms for men.		

TABLE C-20: Sample data, Bachelor Officer Quarters

FACTOR OBSERVED	SAMPLE DATA	
	high	low
% of space devoted to activities of:		
sedentary work	1	0
active work	0	0
circulation (est.)	17	10
sanitation	10	6
eating & food pr	9	5
living/soc recr	60	56
build mainten	2	1
phys recreation	0	0
storage	3	1
span implied	48'	22'
story height	6	1
power density fact	92	18
heat serv.dens.fa.	375	728
water cons.dens.f.	2425	263
light cons.dens.gf.	33	18
% space, 0-200 s.f.	80	67
% space, 200-900 s.g.	1	0
% space, 900 + s.f.	2	0

TABLE C-21: States, Naval Districts and Army Districts

Maine, New Hampshire, Vermont, Massachusetts, Rhode Island	1 ND	1 ARMY
New Jersey, Connecticut, New York	3 ND	1 ARMY
Delaware, Pennsylvania, Ohio	4 ND	2 ARMY
Maryland, Kentucky, Virginia, West Virginia	5 ND	2 ARMY
PRNC	MDW	
North Carolina, South Carolina, Georgia, Florida, Tennessee, Alabama, Mississippi		3 ARMY
Arkansas, Oklahoma, Louisiana New Mexico, Texas	8 ND	4 ARMY
North Dakota, South Dakota, Minnesota, Wisconsin, Kansas, Michigan, Indiana, Illinois, Missouri, Colorado, Wyoming, Nebraska, Iowa	9 ND	5 ARMY
Arizona, Lower California	11 ND	6 ARMY
Utah, Nevada, Upper California	12 ND	6 ARMY
Montana, Oregon, Washington, Idaho	13 ND	6 ARMY

District	170	600	722*	724
1	944	448		1332
3	1144	1154		986
4	1749	685		331
5	753	919		1187
6	581	381		712
8	524	610		881
9	1028	884		1200
11	684	919		721
12	1254	315		620
13	X	565		752
Nat'l Avg.	811	651		1088

*not computed due to distortions introduced by Barracks complexes.

TABLE C-22. Average Project Size ($ thous) by Navops Districts for Construction Category 170, 600, 722, 724

	PERCENTAGES High	Low	Median	
I STRUCTURE & ENVELOPE				
a. Structure	54	22	30	
b. Envelope	20	11	16	59
c. Internal Subdiv.	24	7	13	
II ENVIRONMENTAL CONTROL				
a. Temperature Control	23	3	13	
b. Lighting Control	19	5	10	24
c. Acoustical Control	2.4	0.2	1	
III SERVICES				
a. Power Supply	X	X	X	
b. Sanitation & water Supply	9	4.5	5	6.6
c. Equipment & Furnishings	3.3	0.3	1.6	
IV ALL OTHER EQUIPMENT	11	0.6	1.6	5
				94.6

TABLE C-23. Costs of Major Subsystems as % of Total Cost

Source: ENR 12/17/64
8 Low Rise Bldgs.

PROJECTED EXPENDITURE
BY SUBSYSTEMS

THOUSANDS OF DOLLARS

TABLE C-24

BARRACKS
CCC 721-722

SUBSYSTEM		ARMY				NAVY				AIR FORCE				TOTAL			
		67	68	69	70	67	68	69	70	67	68	69	70	67	68	69	70
Ia Structure	30%	25700	29500	28000	20300	5900	6300	6700	5200	2040	560	-	920	33720	36380	34730	26540
Ib Envelope	16%	13750	15700	14900	10800	3100	3400	3600	2800	1090	300	-	490	17990	19400	18520	14150
Ic Int.Subdiv.	13%	11200	12800	12100	8800	2600	2700	2900	2300	880	240	-	400	14610	15770	15050	11500
IIa Temp Control	13%	11200	12800	12100	3800	2600	2700	2900	2300	880	240	-	400	14610	15770		11500
IIb Light Control	8%	6900	1000	7500	5400	1600	1700	1800	1400	540	150	-	240	8990	9700	9260	7080
IIc Acoustic Control	1%	859	983	900	700	200	200	220	170	67	20		30	1120	1210	1160	880
IIIa Power Supply	7%	6000	6900	6500	3800	1400	1500	1600	1220	480	130	-	210	9870	8490	8100	6190
IIIb Sanitary & Water	5%	4300	4900	4700	3400	1000	1100	1100	870	340	90	-	150	5620	6060	5790	4420
IIIc Equip & Furnish	2%	2800	2000	1900	1400	400	400	450	350	140	40	-	60	2250	2430	2310	1770
IV All Other	5%	4300	4900	4700	3400	1000	1100	1100	870	240	90	-	150	5620	6060	5790	4420
TOTAL*	100%	85941	98327	93186	67756	19670	21069	22466	17631	6797	1875	-	3053	112408	121271	115752	88540

* Due to rounding, figures may not add to total. Totals are as shown in other tables.

TABLE C-25

BACHELOR
OFFICER QUARTERS
CCC 724

SUBSYSTEM		ARMY				NAVY				AIR FORCE				TOTAL			
		67	68	69	70	67	68	69	70	67	68	69	70	67	68	69	70
Ia Structure	30%	6770	3110	4820	4310	2894	1840	2040	760	2730	1560	2880	900	12400	6500	9740	5970
Ib Envelope	16%	3610	1660	2571	2300	1540	980	1090	400	1460	830	1530	480	6610	3470	5190	3180
Ic Int.Subdiv.	13%	2930	1350	2090	1870	1250	800	880	300	1180	680	1250	390	5370	2820	4218	2590
IIa Temp Control	13%	2930	1350	2090	1870	1250	800	880	300	1180	680	1250	390	5370	2820	4218	2590
IIb Light Control	8%	1810	830	1290	1150	770	490	540	200	730	420	770	240	3310	1730	2600	1590
IIc Acoustic Control	1%	230	100	160	140	90	60	70	30	90	50	100	30	410	220	320	200
IIIa Power Supply	7%	1580	720	1130	1010	670	430	475	180	640	360	670	210	2890	1520	2270	1390
IIIb Sanitary & Water	5%	1130	520	800	720	482	310	340	130	460	260	480	150	2070	1080	1620	1000
IIIc Equip & Furnish.	2%	450	207	320	287	190	120	140	50	180	100	190	60	830	430	650	400
IV All Other	5%	1130	520	800	720	480	310	340	130	460	260	480	150	2070	1080	1620	1000
TOTAL	100%	22571	10353	16072	14370	9647	6130	6787	2528	9109	5197	9590	3015	41327	21680	32450	19910

TABLE C-26

ADMINISTRATION
BUILDINGS
CCC 600

SUBSYSTEM		ARMY				NAVY				AIR FORCE				TOTAL			
Ia Structure	30%	5980	6330	2000	5070	2750	1710	2352	3110	2330	1030	990	570	11030	9070	5350	8740
Ib Envelope	16%	3190	3370	1070	2700	1470	910	1250	1660	1240	550	530	300	5880	4840	2850	4660
Ic Int.Subdiv.	13%	2590	2740	868	2200	1190	740	1020	1350	1010	450	430	250	4780	3930	2320	3790
IIa Temp Control	13%	2590	2740	368	2200	1190	740	1020	1350	1010	450	430	250	4780	3930	2320	3790
IIb Light Control	8%	1590	1690	530	1350	730	460	630	830	620	280	2640	150	2940	2420	1430	2330
IIc Acoustic Control	1%	200	210	70	170	90	60	80	100	80	30	30	20	370	300	180	290
IIIa Power Supply	7%	1390	1480	470	1180	640	400	550	720	540	240	230	130	2570	2120	1250	2040
IIIb Sanitary & Water	5%	1000	1050	330	840	460	290	390	520	390	170	160	90	1840	1510	890	1460
IIIc Equip & Furnish.	2%	400	420	130	340	180	110	160	210	160	70	70	40	740	600	360	580
IV All Other	5%	1000	1050	330	840	460	290	390	520	390	170	160	90	1840	1510	890	1460
TOTAL	100%	19926	21084	6681	16887	9157	5712	7840	10352	7765	3445	3299	1888	36754	30241	17820	29127

TABLE C-27

TRAINING
BUILDINGS
CCC 170

SUBSYSTEM		ARMY				NAVY				AIR FORCE				TOTAL			
		67	68	69	70	67	68	69	70	67	68	69	70	67	68	69	70
Ia Structure	30%	5680	7110	5630	8980	11060	3080	6170	4790	1310	990	550	1430	18050	11180	6950	15192
Ib Envelope	16%	3030	6820	3000	4780	5900	1650	3290	2550	700	530	290	760	9630	5960	3710	8100
Ic Int. Subdiv.	13%	2460	3080	2440	3890	4790	1340	2670	2070	570	430	240	620	7820	4850	3010	6580
IIa Temp Control	13%	2460	3080	2440	3890	4790	1340	2670	2070	570	430	240	620	7820	4850	3010	6580
IIb Light Control	8%	1520	1900	1550	2390	2950	820	1640	1280	350	260	150	380	4810	2980	1850	4050
IIc Acoustic Control	1%	190	240	190	300	370	110	210	160	40	30	20	50	600	370	230	510
IIIa Power Supply	7%	1330	1660	1310	2090	2580	720	1440	1120	310	230	130	330	4210	2610	1620	3540
IIIb Sanitary & Water	%%	950	1180	940	1500	1840	510	1030	800	220	170	90	240	3010	1860	1160	2532
IIIc Equip & Furnish.	2%	380	470	380	600	740	210	410	320	90	70	40	100	1200	750	460	1010
IV All Other	5%	950	1180	940	1500	1840	510	1030	800	220	170	90	240	3010	1860	1160	2530
TOTAL		18938	23689	18778	29922	36858	10282	20555	15951	4374	3301	1831	4768	60170	37272	23164	50641

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XI GLOSSARY

Articulation	-	Interrelation and interchangeability between sub-systems so that several different combinations of sub-systems are possible without modification.
Assembly	-	A coordinated group of components put together to perform one or more functions within a sub-system, or within a conventionally designed building.
Component	-	A coordinated group of parts which form a complete building product, or a product which is used with others as a portion of an assembly.
Interfaces	-	Interreaction of systems and sub-systems whether actually adjacent to one another or not. Interfacing may be obtained by systems being designed together, using the same materials, or by jointly satisfying the same performance criteria.
Material	-	Unformed when it is delivered to the site.

Part	-	A portion of a component. A single factory fabricated item, that may be made up of smaller bits and pieces which do not have a unique identity until put together to make a part.
SCSD	-	"School Construction Systems Development," a joint venture of 13 school districts in the State of California to commit approximately $25 million of school construction to a systems development.
Sub-system	-	A coordinated group of assemblies for the purpose of performing a building function.
Symbiosis	-	The intimate coexistence of two dissimilar organisms in a mutually beneficial relationship. In systems terms: the utilization by one sub-system of attributes of an adjacent sub-system in order to perform its role more economically or more efficiently.
System	-	A coordinated group of sub-systems which perform all the functions of the complete building. An incomplete system performs only some of

the functions of the complete building.

Unit - A complete space enclosure, usually relocatable.

Chart

for

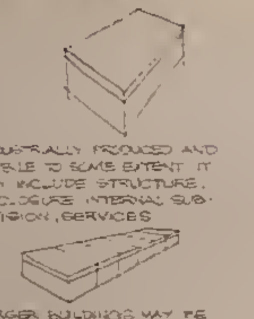
Annex A

Spectrum of Technical Systems

UNIT

A COMPLETE SPACE ENCLOSURE USUALLY RELOCATABLE E.G. A PORTABLE CLASSROOM

THE UNIT BUILDING 1

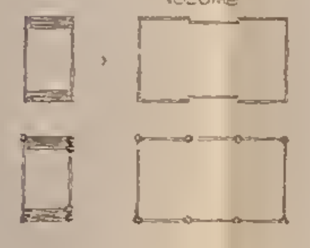


INDUSTRIALLY PRODUCED AND MOBILE TO SOME EXTENT. IT MAY INCLUDE STRUCTURE, ENCLOSURE, INTERNAL SUB-DIVISION, SERVICES

LARGER BUILDINGS MAY BE ASSEMBLED FROM SUCH UNITS

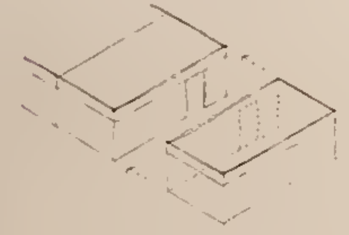
THE EXPANDABLE UNIT 2

EXPANDABLE ENCLOSURES ARE A TYPE OF UNIT WHICH ALLOW FOR INCREASES IN BUILDING VOLUME



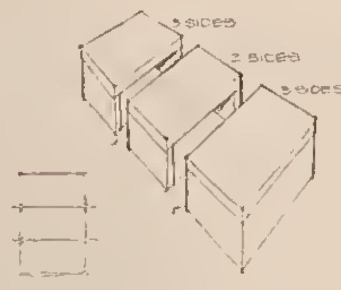
SPECIAL UNITS 3

IF THE UNITS ARE DESIGNED WITH PROVISION FOR CIRCULATION BETWEEN THEM THEY DON'T ALL HAVE TO PROVIDE THE SAME SERVICES. LAVATORY FACILITIES MIGHT BE THE FIRST TO BE SEPARATED IN A SPECIAL UNIT



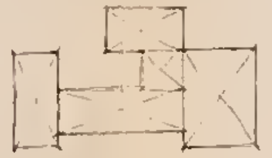
INTERDEPENDENT UNITS 4

UNITS MAY SHARE SOME PART OF ENCLOSURE



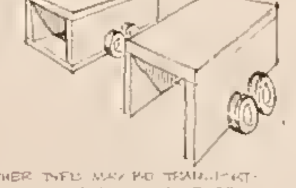
UNITS OF RELATED SIZES 5

UNITS MAY BE DESIGNED IN A RANGE OF RELATED SIZES WHICH CAN BE COMBINED IN DIFFERENT WAYS TO SUIT DIFFERENT FUNCTIONS



UNIT FLOORS 6

A MAJOR DISTINCTION MUST BE MADE BETWEEN UNITS WITH THEIR OWN FLOORS AND UNITS WHICH REQUIRE A PREPARED SLAB OR PLATFORM



EITHER TYPE MAY BE TRANSPORTED WITH INTEGRAL WHEELS, REMOVABLE WHEELS, OR ON A SEPARATE CARRIER.

UNIT SERVICES BY SEPARATE SUB-SYSTEM 7

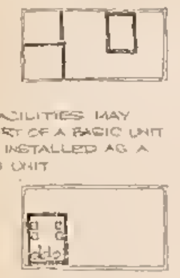
SOME SERVICES MAY BE SEPARATED FROM INDIVIDUAL UNITS AND TREATED AS A SUB-SYSTEM SERVING SEVERAL UNITS

FOR EXAMPLE AIR CONDITIONING AND ELECTRICAL EQUIPMENT

SUBDIVISION WITHIN UNIT 8

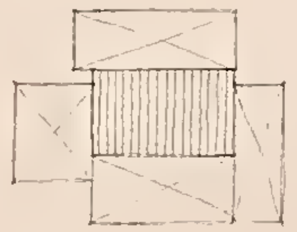
WITHIN UNITS SPACE MAY BE SUBDIVIDED BY PARTITIONS OR COMPLETE ENCLOSURE UNITS MAY BE INSERTED

LAVATORY FACILITIES MAY COME AS PART OF A BASIC UNIT OR MAY BE INSTALLED AS A SUBDIVIDING UNIT



INFILL BETWEEN UNITS 9

UNITS MAY BE DESIGNED TO MAKE USE OF COMPONENTS TO FILL IN SPACES BETWEEN COMPLETE UNITS



STRUCTURAL FRAME UNIT 10

THE BASIC UNIT MAY BE A STRUCTURAL FRAME ONLY, PROVIDING A MATRIX FOR OTHER SUB SYSTEMS

THE SIGNIFICANT CHARACTERISTIC OF THE SYSTEM IS THE NUMBER OF DIFFERENT SUB SYSTEMS WHICH ARE COORDINATED WITH EACH OTHER

BEYOND THIS CONSIDERATION IS DIRECTED TO RELATED SUB-SYSTEMS

COMPLETE SYSTEM 11

THE COMPLETE BUILDING SYSTEM ACCOMODATES ALL THE FUNCTIONAL REQUIREMENTS OF THE BUILDING. IT IS A COORDINATED GROUP OF FUNCTIONAL SUB-SYSTEMS OR SYSTEMS

THERE ARE FEW EXAMPLES OF COMPLETE BUILDING SYSTEMS

NOTES

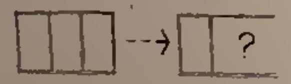
TERMINOLOGY

UNIT	COMPLETE ENTITY OF SPACE ENCLOSURE	HOUSE TRAILER
SYSTEM	COORDINATED GROUP OF SUB-SYSTEMS	[illegible]
SUB-SYSTEM	[illegible]	STRUCTURE
ASSEMBLY	COMPLETE SECTION OF A SUB-SYSTEM	[illegible]
COMPONENT	SECTION OF AN ASSEMBLY	[illegible]
PART	ONE PIECE	[illegible]
MATERIAL	UNFORMED WHEN IT IS DELIVERED TO SITE	CONCRETE

FLEXIBILITY

FIXED BUILDING SYSTEMS SUPPORT ONE USE PATTERN EFFICIENTLY DURING THEIR LIFE SPAN - ACCEPTABLE WHERE USE PATTERN CAN BE PREDICTED TO CONTINUE FOR LIFE SPAN OF SYSTEM

FLEXIBLE BUILDING SYSTEMS ARE REQUIRED WHERE USE PATTERNS CAN BE PREDICTED TO CHANGE DURING SYSTEMS' LIFE SPAN OR WHERE ACCURATE PREDICTION IS NOT FEASIBLE



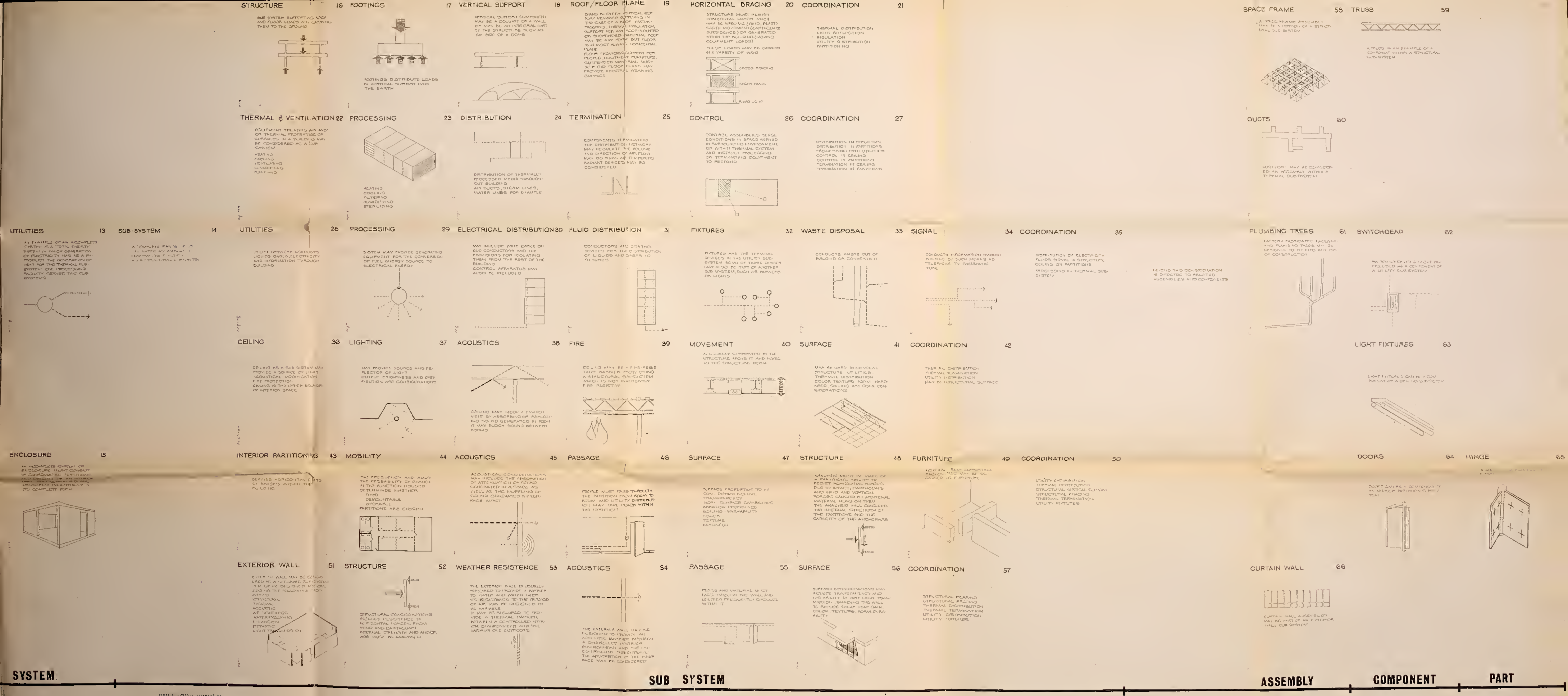
MOBILITY

WHETHER THE INTERIOR IS FIXED OR FLEXIBILITY IS BUILT IN IT MAY BE DESIRABLE TO BE ABLE TO MOVE UNITS TO MEET CHANGING PATTERNS OF NEEDS FOR SHELTER IN DIFFERENT LOCATIONS

ORGANIZATION

THIS CHART ILLUSTRATES A SPECTRUM OF ALTERNATIVE WAYS OF ORGANIZING FACTORY MADE BUILDING PRODUCTS.
A SIMILAR HIERARCHY EXISTS FOR SITE PRODUCTION OF BUILDING PRODUCTS OR THE DIRECT FABRICATION OF BUILDINGS. FOR EXAMPLE, LIFT SLAB TECHNIQUES MAY BE COMPARED WITH CAST IN PLACE OR PRE CAST METHODS OF CONSTRUCTION

UNIT — SYSTEM



STRUCTURE 16
SUB SYSTEM SUPPORTING ROOF AND FLOOR LOADS AND CARRYING THEM TO THE GROUND
FOOTINGS 17
FOOTINGS DISTRIBUTE LOADS IN VERTICAL SUPPORT INTO THE EARTH
VERTICAL SUPPORT 18
VERTICAL SUPPORT COMPONENT MAY BE A COLUMN OR A WALL OR MAY BE AN INTEGRAL PART OF THE STRUCTURE SUCH AS THE SIDE OF A DOME
ROOF/FLOOR PLANE 19
HORIZONTAL BRACING 20
STRUCTURE MUST RESIST HORIZONTAL LOADS WHICH MAY BE ARBITRARY (WIND, BLAST) EARTH MOVEMENT (EARTHQUAKE SUBSIDENCE) OR GENERATED WITHIN THE BUILDING (MOVING EQUIPMENT LOADS)
THESE LOADS MAY BE CARRIED IN A VARIETY OF WAYS
CROSS BRACING
SHEAR PANEL
RIGID JOINT
COORDINATION 21
THERMAL DISTRIBUTION
LIGHT REFLECTION
INSULATION
UTILITY DISTRIBUTION
PARTITIONING
THERMAL & VENTILATION 22
EQUIPMENT TREATING AIR AND OR THERMAL PROPERTIES OF SURFACES IN A BUILDING MAY BE CONSIDERED AS A SUB SYSTEM
HEATING
COOLING
VENTILATING
HUMIDIFYING
PURIFYING
PROCESSING 23
HEATING
COOLING
FILTERING
HUMIDIFYING
STERILIZING
DISTRIBUTION 24
DISTRIBUTION OF THERMALLY PROCESSED MEDIA THROUGHOUT BUILDING
AIR DUCTS, STEAM LINES, WATER LINES FOR EXAMPLE
TERMINATION 25
COMPONENTS TERMINATING THE DISTRIBUTION NETWORK MAY REGULATE THE VOLUME AND DIRECTION OF AIR FLOW MAY DO FINAL AIR TEMPERING RADIANT DEVICES MAY BE CONSIDERED
CONTROL 26
CONTROL ASSEMBLIES SENSE CONDITIONS IN SPACE SERVED IN SURROUNDING ENVIRONMENT, OR WITHIN THERMAL SYSTEM AND INSTRUCT PROCESSING OR TERMINATING EQUIPMENT TO RESPOND
COORDINATION 27
DISTRIBUTION IN STRUCTURE
DISTRIBUTION IN PARTITIONS
PROCESSING WITH UTILITIES
CONTROL IN CEILING
CONTROL IN PARTITIONS
TERMINATION IN CEILING
TERMINATION IN PARTITIONS
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FLUID DISTRIBUTION 31
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FIXTURES ARE THE TERMINAL DEVICES IN THE UTILITY SUB-SYSTEM SOME OF THESE DEVICES MAY ALSO BE PART OF ANOTHER SUB SYSTEM, SUCH AS BURNERS OR LIGHTS
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CONDUCTS WASTE OUT OF BUILDING OR CONVERTS IT
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CONDUCTS INFORMATION THROUGH BUILDING BY SUCH MEANS AS TELEPHONE TV PNEUMATIC TUBE
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DISTRIBUTION OF ELECTRICITY FLUIDS, SIGNAL IN STRUCTURE CEILING OR PARTITIONS
PROCESSING IN THERMAL SUB-SYSTEM
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LIGHTING 37
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FIRE 39
MOVEMENT 40
IS USUALLY SUPPORTED BY THE STRUCTURE ABOVE IT AND MOVES AS THE STRUCTURE DOES
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MAY BE USED TO CONCEAL STRUCTURE UTILITIES, THERMAL DISTRIBUTION COLOR TEXTURE FORM HARDNESS, SOILING ARE SOME CONSIDERATIONS
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THERMAL TERMINATION
UTILITY DISTRIBUTION
MAY BE STRUCTURAL SURFACE
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SURFACE PROPERTIES TO BE CONSIDERED INCLUDE
TRANSPARENCY
WORK SURFACE CAPABILITIES
ABRASION RESISTENCE
SOILING - WASHABILITY
COLOR
TEXTURE
HARDNESS
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ANALYSIS MUST BE MADE OF A PARTITIONS ABILITY TO RESIST HORIZONTAL FORCES DUE TO IMPACT, EARTHQUAKE AND WIND AND VERTICAL FORCES CAUSED BY ADDITIONAL MATERIAL HUNG ON THEM THE ANALYSIS WILL CONSIDER THE INTERNAL STRENGTH OF THE PARTITIONS AND THE CAPACITY OF THE ANCHORAGE
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PEOPLE AND MATERIAL MUST PASS THROUGH THE WALL AND UTILITIES FREQUENTLY CIRCULATE WITHIN IT
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SURFACE CONSIDERATIONS MAY INCLUDE TRANSPARENCY AND THE ABILITY TO VARY LIGHT TRANSMISSION, SHADING THE WALL TO REDUCE SOLAR HEAT GAIN, COLOR, TEXTURE, FORM, DURABILITY
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A TRUSS IS AN EXAMPLE OF A COMPONENT WITHIN A STRUCTURAL SUB-SYSTEM
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DUCTWORK MAY BE CONSIDERED AN ASSEMBLY WITHIN A THERMAL SUB-SYSTEM
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FACTORY FABRICATED LAVATORY AND PLUMBING TREES MAY BE DESIGNED TO FIT INTO ANY TYPE OF CONSTRUCTION
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LIGHT FIXTURES CAN BE A COMPONENT OF A CEILING SUBSYSTEM
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CURTAIN WALL ASSEMBLIES MAY BE PART OF AN EXTERIOR WALL SUB SYSTEM
SYSTEM
SUB SYSTEM
ASSEMBLY
COMPONENT
PART

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