# Systems Analysis
# For a "New Generation" of Military Hospitals

## Volume 9. Appendix: Building Systems in Military Hospitals

## Final Report





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SYSTEMS ANALYSIS

FOR A "NEW GENERATION" OF MILITARY HOSPITALS

VOLUME 9

APPENDICES: BUILDING SYSTEMS IN MILITARY HOSPITALS

FINAL REPORT
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# SYSTEMS ANALYSIS
# FOR A "NEW GENERATION" OF MILITARY HOSPITALS

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## PREFACE TO VOLUME 9

This study of building systems for military hospitals was undertaken independently of the work on acquisition of health care facilities reported in Volume 3. Out of a recognition that concepts and methods for providing health care and constructing buildings are changing rapidly, and that conclusions reached today about the best ways to build, equip, and operate health care facilities are likely to be superseded tomorrow, that portion of the study emphasizes improvements to the process by which buildings are planned, designed, and built.

The work presented in this volume addresses the question, do the concepts and developments collected under the rubric of building systems offer any improvements worthwhile to the Department of Defense for the "new generation" of base-level military hospitals? To answer this question, this study defines building systems, discusses the advantages presumably to be derived from using them, and explores the relevance of these advantages to military hospitals. It then examines and evaluates a number of current hospital building systems, including components, modules, and complete systems.

SRS Consultants, Inc., Boston, in collaboration with Campbell, Aldrich and Nulty, Architects, Boston, have carried out the work for Arthur D. Little. William Smock, President of SRS Consultants, was Project Director. Dr. Joshua Shuchatowitz, Vice President of SRS was in charge of liaison. Nelson W. Aldrich was Managing Partner for Campbell, Aldrich and Nulty, Glenn R. Merithew, Partner in Charge of Research, was Associate Project Director.

The Principal Investigator and author was John M. Ellis of Campbell, Aldrich and Nulty.

For the study of all individual systems except Greenwich Hospital, research included discussing the system with the developers or authors of the system. Plans of recent military hospitals and of some hospitals still under design were analyzed. Visits were made to civilian and military hospitals, both finished and under construction. A partial bibliography of sources is included at the end. The valuable editorial assistance of Miss Loretta Thometz is gratefully acknowledged.

# SECTION I INTRODUCTION

## A) PURPOSE AND SCOPE

The purpose of this volume is to identify a significant way to build more cost effective hospital buildings. That way is the adoption of an integrated building system program.

The study identifies hospital problems, explains building systems, shows how they can meet these problems, distinguishes the requirements of hospital systems from those of other building systems, reviews systems developed to date, and makes recommendations for a program to be followed by the Department of Defense.

## B) DEFINITIONS

The subject of building systems is riddled with semantic problems. The words "systems", "flexibility", "modules", and others are subject to widely differing meanings, depending on who uses them and in what context.

Our choice of terminology is based on using those terms which are least ambiguous and most immediately understood. Jargon is avoided.

Uses of the word "systems" are distinguished below. Other terms are defined as they occur in the text.

Systems - Webster's definition of a system is "an assemblage of objects united by some form of regular interaction or interdependence." We distinguish between two of these:

Subsystems - Hospitals consist of a large number of different systems: heating systems, plumbing systems, structural systems, and partition systems, for example. Each performs limited functions and is subordinate in scope to the overall building. These, therefore, are subsystems.

Integrated Building Systems - An integrated building system is a set of rules governing the selection of subsystems and the way the subsystems may be used together. The set of rules is based on the coordination of components into a "kit of parts" in such a way that each subsystem can be installed and used efficiently without interfering with the other subsystems. This characteristic is known as compatibility.

In general usage, a building system is a kit of parts.

C) SYNOPSIS OF FINDINGS

1) Current military hospitals represent an inefficient utilization of resources -- they are expensive to build, inflexible to change, unresponsive to user needs, and out of date before they open.

2) Much of the problem stems from the relatively complex needs of hospital buildings, and the difficulty of coordinating a large number of different subsystems. The design of individual hospitals represents great duplication of effort in the separate attempts to resolve essentially the same problems again and again; the limits of time and money on any one project are such that each project is at best a compromise.

3) The development and adoption of an integrated building system will overcome much of the problem. Major benefits include:

a) Simplification of change by recognizing what parts of a building will need to change and making provision for it.

b) Lower lifetime costs by reduction of the cost of change, allowance for changes which will reduce operating cost, extension of the life of the building, and in some cases, reduction of initial cost.

c) Better performance of buildings resulting from more thorough analysis of needs and the capacity of different subsystems to meet those needs.

d) Faster production of buildings resulting from coordination of components and from coordination of programming, design and construction schedules.

4) Flexibility is the key need of hospitals and therefore of hospital building systems. The rate of change of techniques and requirements is greater than usually recognized. Hospitals are demolished not because they are deteriorating but because they are unable to adapt to changing needs.

5) The scope of a building system should include the more repetitive and/or expensive elements. This would ordinarily include the structure, HVC, ceilings, partitions, and electrical and plumbing distribution.

(6) Hospital systems are unique. Their requirements are too special to be filled by trying to adapt a building system from another field. Office, school and housing systems are simply not relevant to hospitals.

(7) Any hospital system which is to be used for a number of different buildings should be an open system, so that changes and alterations may be incorporated in the system as better methods and subsystems are developed and recognized over a period of time.

(8) Although improved building products can be developed, this is expensive and time consuming, so any system which is to be used soon should not require new product development.

(9) The development procedure for a new system would take two to three years, depending on how comprehensive it is to be.

(10) The starting point of any system is the analysis of user needs. This would be worth initiating whether there are plans for a systems program or not.

(11) There will be resistance to the introduction of building systems, just as there is to any change. However, the resistance will be dealt with by anticipating the problems and dealing with them in advance.

(12) Interstitial space provides a significant improvement in flexibility and can be used to speed the design and construction process. These benefits justify some extra cost.

(13) Many of the benefits of systems are long range rather than short range, so it is useful to try to project trends for the future. Major changes may include a greater intensity of mechanical and medical services, a faster rate of change, fewer in-patient beds, more use of building systems, and perhaps a different form of owner-

ship (e.g., hospitals leased from large organizations which design and built them).

(14) A current trend which may soon affect military hospitals is the integration of the nursing "tower" into the main body of the hospital, forming a more horizontal, possibly more compact plan. Any hospital system adopted should be capable of meeting the constructional needs of such a form.

(15) Current approaches to hospital building systems fall into three categories:

a) The development of components or groups of components which are not part of a program for total integration of subsystems.

b) The development of factory made rooms or modules, which are presently suitable mainly for temporary or emergency buildings. Attempts to consider these for complete buildings have not yet been well worked out.

c) The development of systems which focus on the whole building and try to integrate all the main elements of hospital construction.

(16) The most significant criterion in evaluating current hospital systems for use in the military hospital program is applicability, i.e., the ability to fit the needs of a wide range of different situations.

(17) Building systems are clearly feasible for military hospitals. The Department of Defense, as the agency in charge of a large, repetitive hospital program, is in a unique position to implement and benefit from building systems.

(18) The New Generation Prototype Hospital of 1973 should employ a building system.

(19) Because of progress in current systems, development of a new system without first taking advantage of existing work would be wasteful of time and money. The Department of Defense may still develop a new system later, but will have had the benefit of experience with one at this time.

(20) The system currently being developed for VA hospitals would have immediate and natural application to military hospital construction, because it is geared to general application, it is sound and pragmatic, it can be ready in time for the Prototype, and it offers opportunities for interagency cooperation. Other current systems are too limited in scope, too specialized, or unrelated to current technology.

(21) For these reasons, the VA Hospital System should be used to expedite the construction of the New Generation Prototype hospital. Because the system can be adapted to a variety of situations, its use is not contingent on the acceptance of other recommendations in this Report.

(22) Implementation of a building systems program should start with a closer study to demonstrate the VA system will fit military hospital needs, and to identify any changes which may be needed.

## SECTION 2 PROBLEMS AND GOALS

### A) CURRENT PROBLEMS

Relative to what they could and should be, most current military hospitals are inflexible to change, uneven in quality, expensive to build and re-model, and out of date when they open. Much of the problem stems from inadequate use of procedures and techniques which can streamline the design/construction process without inhibiting design freedom.

#### 1. Flexibility, the Key Problem

The customary design approach results in a building "tailor-made" to fit a particular set of needs. Conventional construction techniques convert this tight tailoring into a concrete overcoat. As needs change it is difficult, disruptive, and costly to change the building. If the building is not adapted to suit new needs, effectiveness goes down, operating cost goes up, or both.

Buildings change more over their period of existence than is generally acknowledged, and hospitals change more than other buildings. Staff patterns change, new techniques are developed, individual medical problems increase or decrease in significance, and standards of environment are modified. A hospital is out of date on the day it opens because the design is fixed so long before the building is put in use. A building either adapts to these changes or becomes progressively more obsolete.

There are boundless ways in which buildings may inhibit change. Close spacing of columns can make it difficult to rearrange partitions; pipes and other service chases may be in the way of a desired plan arrangement, or in other cases, may be inaccessible when they may be needed; likewise, services may be near enough, but have inadequate capacity for their new requirements; when larger services are planned, the available ceiling space may be inadequate; a special shaped building may work excellently for one staffing pattern, but may be impossible to adapt to factors that require different staffing; floor loads may be inadequate to new equipment requirements; different ceiling heights and support grids for different rooms may be impossible to reconcile when the separation between the rooms is removed; uncoordinated dimensions may require extra time for cutting and fitting; special fittings may be impossible to re-supply because they are out of production; equipment may be difficult to replace because it is so solidly built into the building; excessive demolition may be required to gain access to parts which might have just as easily been left accessible; in general, changes cause more noise, mess and disruption of operation than should be necessary. The result is that direct and indirect costs of change are greater than they need be.

The usual building is tailored to meet special needs, and this becomes a special building. Yet the more a building is shaped for particular uses, the less it is suited to general uses; i.e., the more specialized, the less flexible.

An immeasurable factor is the cost of not making changes. When inflexibility in a building prevents change, the cost of the loss of efficiency is impossible to measure, so it remains one of the hidden costs.

Growth creates problems, especially in circulation and interdepartmental relationships. Many plans which are efficient and comprehensible initially, become labyrinthian when the building is expanded, simply because expansion was not planned for, or because it did not occur in a way that was expected. It may not be possible to know in advance what form growth will take, but it is possible to organize so as to let it occur painlessly.

2. Design and Construction Time

It takes at best five years from identifying a need for a hospital to completion of the project. During that time, personnel change, medical practice changes, the hospital mission can change, and building products change. The design may be fixed several years before the hospital opens. Therefore the facility is certain to be out of date in many respects the day it opens.

The need for change is evident in many projects in the large number of change orders issued during construction. Some changes are due to clients' requests, some are due to construction details that do not work, and others are due to changes in availability of materials. If aspects of the detail design could be deferred until a point closer to the actual construction time, many changes could be avoided and the design would reflect more nearly current hospital thinking.

3. Building Costs

Hospitals are among the most expensive of all buildings to construct, are even more expensive to remodel, and end up with a relatively short life span.

The cost of change over the lifetime of a hospital may be as much again as the initial project cost. Hospitals which are unable to change may incur even more expense in the hidden costs of inefficient, out of date operations.

The initial cost of hospitals is now out of hand due to wage increases that are far out of line with cost of living increases, lack of standardization, inefficient use of manpower, and inadequate use of cost control techniques.

Five percent increase in building costs per year was once a workable rule-of-thumb, but last year brought increases of 1% per month in many areas. Controlling building costs (rather than merely predicting them) seems even less possible. The architect/engineer's estimate is only an attempt to predict what building contractors will gamble regarding the construction of a one-of-a-kind object -- a particular hospital on a particular site. When project costs exceed allowable limits, the project is either deferred (to become less timely and even more expensive) or "cut". Since the need to cut costs becomes known only at a late stage, it is not feasible to build a smaller facility which responds in a balanced way to a reduced mission. Rather, the cuts tend to consist of either skinning the project (putting on one coat of paint where three are needed) or crippling it (leaving off entire wings of buildings). Such cuts inevitably produce a less effective and more expensive health care operation.

4. Quality and Performance

For a highly industrialized society, buildinga are among the worst bargains available because so many of their parts are individually designed and hand-constructed. In spite of the highly organized military specification and supevision systems, how product specifications relate to user needs is not clearly spelled out, with resultant uneven performance.

Some examples of deficiencies in quality are air conditioning systems which are noisy or drafty, rooms with inadequate sound insulation, and bedrooms which produce glare to the extent that patients are uncomfortable.

People are very tolerant of inadequate environment, often because they are not aware of how it could or should be improved. It becomes a matter of concern only when a "threshold of intolerance" is reached. Even then, people are too often willing to adapt to deficiencies. In a hospital, this is not good enough. The environment and performance of a hospital is critical, whether it is a question of bacteria in operating rooms, or comfort in patient rooms, or walking distances to supply rooms.

5. Incompatibility of Subsystems

One source of difficulty is the large number of different subsystems used in hospitals. Although the subsystems may individually be of high quality, the problem of coordinating these is such that some advantage of this quality may be lost.

The subsystems are engineered by different specialists, produced by different manufacturers, and installed by different contractors; not surprisingly, they have problems of compatibility.

With new products being developed every day, it is difficult enough to evaluate the products for their primary qualities, without having to evaluate them also for how they relate to a host of others.

Architects and engineers so far have had to work in a partial vacuum on this matter, relying on imagination, limited experience, incomplete reports of new buildings, and a patchwork of product information to sort out the best or optimum organization of subsystems for each job. The same questions are solved repeatedly for different projects with great duplication of effort. Yet the limited time and money available for any one project makes it impossible to achieve a systematic analysis of alternatives, with the result that each project is at best a compromise.

If at least one thoroughly workable and relevant method of putting together a hospital was known and could be pre-selected, improvements could be made in the four major problem areas:

a) flexibility could be built-in,

b) time could be saved on design and construction,

c) costs could be saved where they mattered most, and

d) quality could be assured.

How building systems can bring improvement to these four problem areas is analyzed below.

B) HOW BUILDING SYSTEMS IMPROVE FLEXIBILITY

An integrated building system is the result of a study of how building elements are put together. To provide for flexibility, the study will include how to add to and subtract from the building. A great deal of preplanning and coordination is required to do this, but the resulting system will make it quicker, simpler, cheaper, and quieter to make changes.

Materials and details will be chosen or designed to go together in a variety of ways. Standardization will be employed to ensure that the same products can be used everywhere. Access will be provided at the places where it is needed. Costs of products will be correlated with their frequency of change, so that resources will not be wasted on elements which need to be replaced frequently, and also that quality is not shortchanged on elements that need it. Prefabrication will be employed to achieve the necessary level of quality control to insure that interchange of standard parts is possible.

The system will also be correlated with plans to locate structure and services in ways that do not inhibit change and growth.

A variety of techniques have been developed for providing flexibility. Some of these techniques are simply different ways of accomplishing the same end. In order to distinguish between these, Principles of Flexibility are analyzed at the end of this Section.

C) <u>HOW BUILDING SYSTEMS CAN REDUCE DESIGN AND CONSTRUCTION TIME</u>

There are three ways in which building systems can be used to save time:

Time is saved on design and working drawings. The primary gain is in the working out of subsystems relationships. Since a rationale for this will already exist, planning can be carried out, knowing that as long as the set of constraints imposed by the system are observed, the parts will fit together. This removes from the architect/engineers the burden of one of the least efficient, most time consuming, and least rewarding aspects of the job. It also means that many decisions as to type of structure, dimensions, etc. are already made. Time on working drawings is saved because standard details can be used. Standardization insures that there will be fewer special conditions, that details will have been well worked out, and that time required for working out and drawing details will be greatly reduced (Non-system elements and details will of course still exist, and will be treated conventionally).

Time is also saved on construction. The major gain will be through the use of prefabrication of parts. All buildings are to some extent prefabricated (elements such as windows, doors, mechanical equipment, etc.), but a great deal more will be included. Prefabrication saves time by carrying out in the factory operations which would otherwise be carried out on site by time consuming hand labor. Because components can be designed on a modular basis, the necessity for trimming to size can also be eliminated. Because procedures can be more clearly predetermined, scheduling can also be tightened, eliminating some slack from the program.

In addition to savings on the design and construction operations themselves, the two phases can be telescoped (overlapped), saving more time. Ordinarily, construction begins only when drawings and other contract documents are complete. However, construction can begin much earlier if a layout exists which is based on planning principles related to a building system.

One way in particular to do this is to divide the construction contract into two parts -- the first for the fixed elements, the second for the movable and disposable ones. Since the fixed elements are designed as a standard matrix to receive any internal layout, first phase construction can carry on and even be completed before the interior plan is finalized.

Accurate programming and preliminary planning assures that the final plan will fit the confines of the structural frame and building envelope, and the use of standard dimensions assures that regardless of how arranged, all parts will fit.

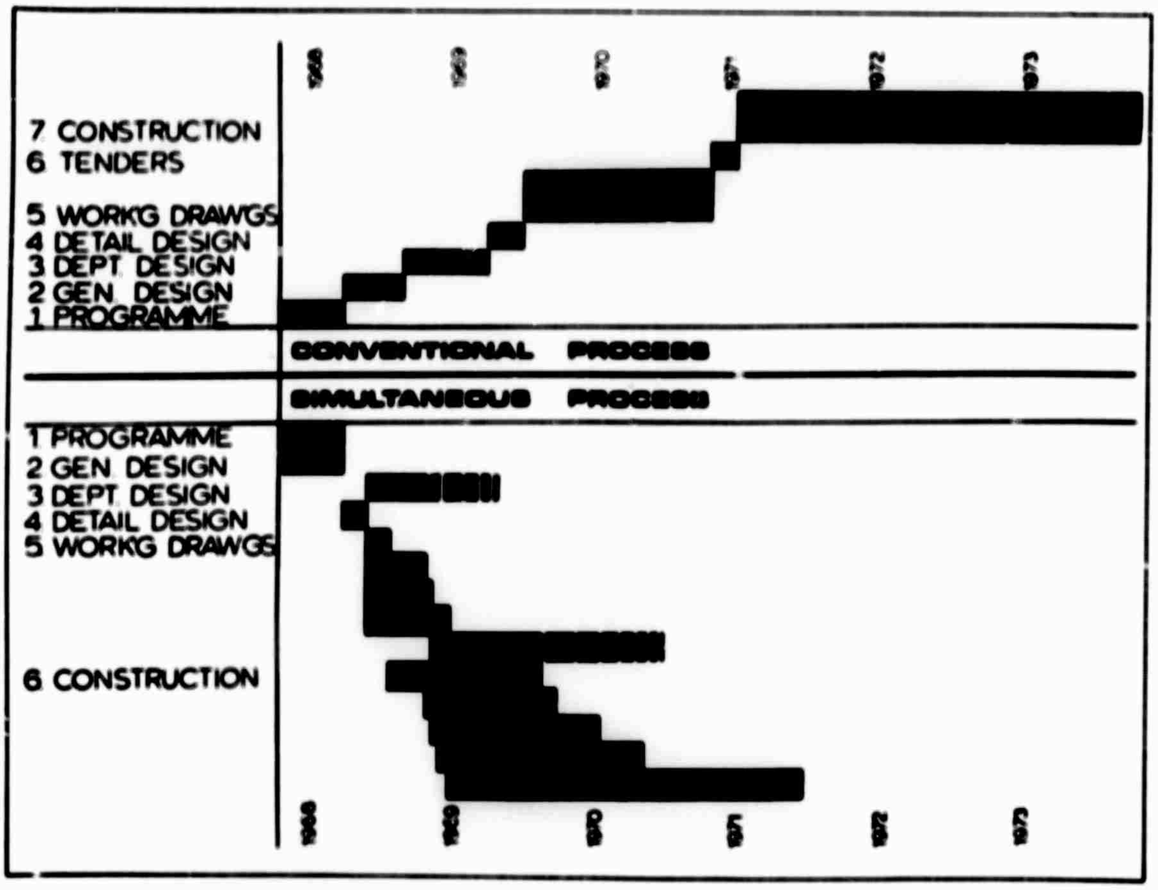


ILLUSTRATION OF HOW TIME SCHEDULES MAY BE TELESCOPED WITH BUILDING SYSTEMS - This chart was prepared for McMasters University Health Sciences Center, and illustrates how overlapping of design and construction phases is expected to save two and a half years on the overall program.

Besides reducing the total time, the postponement of the internal planning until closer to completion gives less time for the plan to become obsolete, and reduces the number of change orders.

On housing projects, systems have saved from six months to a year on the construction phase alone. On hospitals, it is reasonable to hope for the same. Another six months each may be saved on design and through telescoping of phases. Systems for VA hospitals are expected to save up to two years on the overall process.*

D) HOW BUILDING SYSTEMS REDUCE TOTAL OWNERSHIP COST

Building systems improve cost effectiveness on initial construction by increasing prefabrication, reducing site labor, cutting construction time, starting earlier, facilitating cost control techniques, and allowing more contractors to compete. The major savings may come nevertheless from long range savings resulting from improved flexibility.

1. Total Ownership Costs

Total ownership cost is the lifetime capital cost plus those operating costs which can be attributed to the building. Lifetime cost is the initial project cost plus the cost of changes over the life of the building. The most meaningful measure of building cost is ownership cost spread over the life span of the building.

A system built hospital can cost more initially than a conventional

* Conversation with John Villett, of Building Systems Development Inc. June 10, 1970

hospital, but only because of higher performance, especially in the realm of flexibility. Since the provision of flexibility can reduce the cost of changes, the long range cost of the system hospital may be less than the conventional.

One factor in this is the longer useful life span of the flexible hospital. Hospitals are demolished when they can no longer adapt and have become uneconomical to operate. This point will be reached far earlier in a conventional hospital, thereby requiring replacement years before it would be needed if a fraction more had been spent for flexibility.

Another factor is the unmeasurable cost of changes not made. A study which shows no changes in the life of a hospital indicates not that change was unneeded but that the building was not capable of change. The resultant extra operating cost needs to be added to capital costs in order to make a meaningful comparison.

2. Prefabrication and the Reduction of Site Labor

The increased use of factory made components decreases the use of site labor, one of the most expensive and at the same time inefficient parts of the job. Wages in the building trades are presently skyrocketing, with some recent union contracts being signed for increases totalling 90% over the next three years.* Factory wages, by contrast, are rising only at the rate of the cost of living. Time, therefore, strongly favors a switch to more prefabrication.

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* Engineering News Record. June 4, 1970. p. 45.

3. The Cost of Time

Time is money. A saving in construction time saves interest on capital for that period -- a significant savings. In civilian work, this is interim finance. Government jobs do not have interim financing, but this does not change the fact that the money spent is essentially borrowed money and interest is being paid on it.

In this period of runaway inflation, another saving from quicker processing and construction is the lower contract price resulting from advancing the construction date one or two years.

4. Cost Controls

Building costs are notoriously difficult to predict. The chronic practice of underestimating hospital costs (with resultant later cheese-paring) has been criticised,* but continues nevertheless.

Building systems will facilitate the creation of a data bank on costs. The use of the standard details and components will provide feedback on future jobs, and will permit a process of continuing evaluation of materials and techniques to select those to retain and those to change. The result will be more cost effective buildings and more realistic future cost estimates.

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* Architectural Record. October 1968. p. 169.

5. More Bidders on Large Jobs

One further way that systems can control costs is by permitting more contractors to participate, creating a more competitive situation. A complete hospital is too large a job for many builders, and a near monopoly situation among a few builders can develop in some areas. The job may be split into two or more separate contracts for separate phases (e.g., for fixed and unfixed elements, as discussed above), which makes individual parts of the job small enough for other builders.

E) HOW BUILDING SYSTEMS CAN IMPROVE QUALITY AND PERFORMANCE

Building systems can improve quality and performance in three ways:

User needs can be systematically identified and translated into performance criteria. Until it is clear what are the user needs, it is impossible to be sure they are being satisfied. This is function-oriented and goes beyond simple building specifications. For instance, there is no point in specifying high sound reduction for partition systems if a lightweight door negates the benefits of the partitions. And more fundamentally, exactly why and where sound reduction is really needed must be understood. On a normal project, limitations of time and money prevent questions such as these from being investigated thoroughly. A system study can identify the needs and evaluate all the alternatives, and establish how these products may be used together effectively. The results of this analysis then can benefit all future projects. Quality will be assured in the places where it matters.

Replacing hand work with factory produced articles reduces human error, and insures a uniform level of quality. A machine can produce higher quality finishes, and bulk buying may permit better materials to be used.

Thirdly, by adequate pre-planning of costs, the all too frequent last minute cutting or cheese-paring can be avoided, so that the intended quality level can be maintained. If any cuts need to be made, it will be known in advance, and the program adjusted accordingly.

## F) PRINCIPLES OF FLEXIBILITY

As the need for flexibility has been increasingly recognized in recent years, various techniques for achieving this have been developed. The use of building systems is one; others such as interstitial space and horizontal planning are discussed and evaluated in Section 4. Since some techniques are merely different ways of trying to do the same thing, it is useful first to understand the underlying principles of flexibility in order to clarify what the techniques are trying to accomplish.

These principles can be described as:

a) Separation of permanent and impermanent elements
b) Indeterminacy
c) Interchangeability of parts
d) Accessibility

a) <u>Separation of Permanent and Impermanent Elements</u>

A fundamental principle of flexibility is to separate elements which are likely to be changed at different times.

In terms of life-span, building elements may be classified as permanent and impermanent. The impermanent elements can be sub-classified into movable (re-usable) and disposable (non-re-usable) elements. Ordinarily, permanent elements are those things which cannot move (structure, main services) or which do not need to move (e.g., floors). Movable elements are usually prefabricated items (equipment, doors, and movable partitions) which can be taken down and re-used.

Disposable elements are those which are built-in (e.g., plumbing, built-in cabinets, and conventional partitions) or are for other reasons incapable of re-use after being dismantled.

In conventional buildings elements of different life span are often so interlocked that elements which might have no functional reason to change are removed simply because they are in the way or because they are connected to something which does have to change.

To facilitate change, the permanent elements should be separated as much as possible from the movable and disposable elements. Zones of change can be created for those elements which need to be replaced or rearranged.

Although it is desirable to minimize the cost of disposable items, extra cost on permanent elements can be justified if it is necessary to improve its separation from the impermanent elements.

The implication of this is that columns and structural walls should be as widely spaced as possible. Fixed walls in particular are a limitation, since they cannot be "by-passed" as easily as columns. In theory, since hospitals consist of a large number of very small rooms, it is possible to manipulate the plan so that these rooms can be fitted between closely spaced obstructions (short span structure), but in view of the unpredictable nature of change, the only certainty is that wide spacing (long span) is preferable. Any plan that can fit short spans can also fit long spans; the reverse is not true.

Since buildings often expand, solid walls on the perimeter of the building should also be minimized.

Since service mains are expensive to move, they also need to be permanent, and therefore should be planned to cause minimum obstruction. The horizontal runs can be located within the ceiling, where they are out of the way, and the vertical risers may be concentrated into a few strategic locations.

b) Indeterminacy

Indeterminacy is the principle of leaving the organization of spaces loose enough so that a change in one department does not need to produce a chain reaction of adjustments to every other department. The idea is to let expansion to occur in one department without affecting others.

There is a quite rational tendency to plan hospitals in a very compact way, with adjacencies as close as possible. The tendency also involves the creation of very specialized forms (circles, triangles, and snowflakes, to name a few) geared toward the solution of very special problems in a very particular way. The trouble is that the requirements which generate these tight relationships do not remain fixed, but the forms do. Alteration becomes very difficult. Yet the more specialized the plan, the more it can relate only to the particular set of requirements which obtained at the time of the design. As John Weeks points out, "The more carefully the building is tailored to its program, the more certain it is to need alterations and additions very quickly."*

Such plans assume a static world. Yet, as Buckminister Fuller frequently points out, not only is the world and technology changing, but the rate of change is increasing.

When very fixed or pristine forms eventually are obliged to expand, the form is so inviolable that the growth resembles a tumor.

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* Weeks, John: World Hospitals, Vol. 5. Pergamon Press, 1969. Gt. Britain

Indeterminacy may be reflected in open-ended plan concepts -- those which by virtue of structure and layout will permit all departments a space to grow -- ordinarily to the outside, although it could mean into internal open spaces or court yards. In terms of form, it implies an informal massing which appears natural at any stage of growth. "The more compact and centrallized the hospital, the more difficult it is to alter and add to it without destroying its basic cohesiveness."* Open-ended growth by contrast is the natural extension of a healthy organism.

Low horizontal structures are inherently more open-ended than vertical ones, since more of the area is close enough to the ground to be able to extend. Because it is almost absolutely constricted by its sides, a tower is highly determinate. Vertical expansion is prohibitively uneconomical when all the factors such as disruption are included.

The particular implication of indeterminacy to building systems is that the pattern of structures and service distribution must be capable of repeating or extending itself with no loss of effectiveness.

c) Interchangeability

Interchangeability is a basic principle of flexibility. It is part of any building system, and is employed to varying degrees in conventional construction.

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* Weeks: Ibid.

By means of standardization of dimensions and details, the same building elements may be used in a variety of places or a variety of different elements may be used in the same place. For instance, the same wall panel may be used anywhere throughout a building if the ceiling height and connection details are standardized. Or a wall panel may be exchanged for a door panel, or even for another kind of wall panel. The principle affects the relationships of all the different subsystems and relates particularly to modular coordination (which is discussed in the following Section). When change is desired, elements may be removed and re-used elsewhere without any problem of special cutting or other waste. Likewise, worn out or obsolete components may be replaced by newer ones as long as the same dimensions and/or joint details are used.

The popular "plug-in" principle is one version of interchangeablity. The most arguable aspect is how much to plug in -- a piece of equipment, or an entire room.*

d) <u>Accesslbility</u>

Accesslbility is provision of sufficient space to work in and a reasonably convenient way of getting there. It is an obvious principle of flexibility although one which is universally ignored. It relates primarily to the lower scale of change -- replacement of services, etc. without any significant plan change. Yet this

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* See Section 5-C on Disposable Modules.

is the most frequent kind of change and, because it can be done by maintenance personnel, one that may never show up on cost records. Therefore the importance of accessibility may tend to be overlooked.

Provision of access may involve simply including removable service panels, or special ceilings, or it may mean a special service floor (interstitial space). In making small changes, a disproportionate amount of the work may be in gaining access, and this is avoidable. The important principle is to make the accessibility of any component proportionate to the scale of work and the frequency of repair or change.

## SECTION 3 CHARACTERISTICS OF BUILDING SYSTEMS IN HOSPITALS

### A) SCOPE OF SYSTEMS

There is an understandable but not entirely logical tendency of many people to think of a building system as a structural system; i.e., a system of beams, columns, panels and trusses which holds up the rest of the building. Perhaps this thinking is an extension of our childhood concept of buildings as consisting of nothing more than the enclosure of space by blocks. In any case, it is a misleading tendency, especially for hospitals, because the structure is only about 15% of the total budget, so if time and money are to be saved, many other elements must be considered besides structure. What is true is that many systems start with the structure, that it influences all the other subsystems.

In order to maximize benefits, the development of a building system should focus on the more expensive, time consuming and/or repetitive aspects of construction. For hospitals, these would include the structure, mechanical distribution, ceilings, partitions, plumbing, electrical, and patient services, and perhaps the exterior wall.

The hospital as a whole should be considered, rather than particular parts or departments.

The level of detail is an open question. A lot of detail means that very little still has to be worked out when working drawings are needed, but it may also mean that choices and opportunities for introducing better products are restricted. The alternate approach is to set up a system by which locations are fixed for subsystems and characteristics of subsystems are predetermined, but that these decisions be taken only to the point at which it is certain that the systems will all be compatible. Choices of individual materials or products may vary from project to project. The resulting system may be more nearly a set of rules than a kit of parts.

## B) GENERAL CHARACTERISTICS OF SYSTEMS

### Open vs. Closed Systems

An open system is one which has integrated a variety of different subsystems, while a closed system is one which is limited to individual products for each subsystem. An open system, therefore, allows a choice of products to be used for any particular subsystem, based on cost, availability, details of the particular application, and other factors, all of which may vary from place to place and time to time. A closed system can sometimes cost less, but may be controlled by a single producer. The automobile is a classic example of use of a closed system. Since, unlike cars, hospitals still are individually designed, design flexibility is important, and this favors open systems. Open systems are also better suited to current construction contract procedures (bidding) and to the uncertainties of future product development.

### Modular Coordination

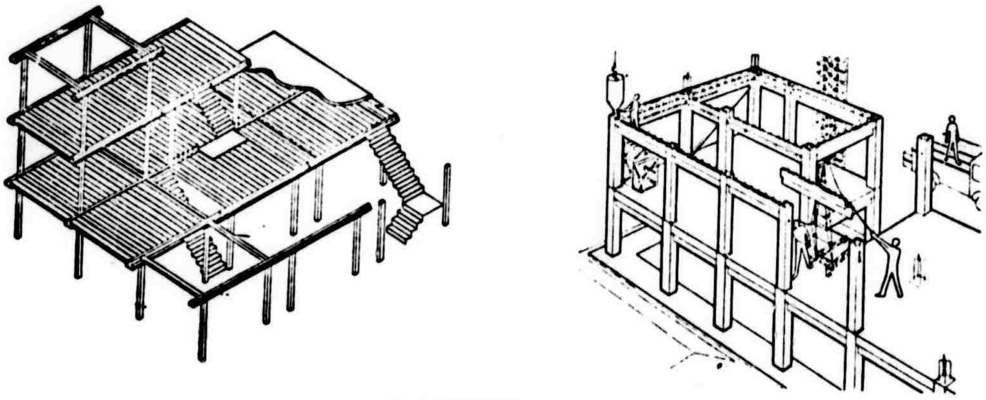
Modular coordination is the use of a pattern or grid of standard dimensions, called modules, to coordinate the way walls, ceilings, equipment and other subsystems fit together. By making components always in dimensions which are multiples of the module, it can be assured that all components will meet on the same grid. To distinguish it from other kinds of modules, we refer to this as a construction module.

Modules can simplify design and construction, but the size must be carefully selected with a view to the functions it must fit. The general range of sizes is related to what is a convenient size for the manufacture, delivery, and installation of building components. The specific dimension selected will typically depend on door and window sizes, corridor widths, and minimum room sizes. Modular coordination has been used extensively for schools and offices. However, because it is harder to fit small rooms onto a grid than large rooms, it is possible that for hospitals the production advantages are not worth the loss of flexibility, in which case no module would be used.

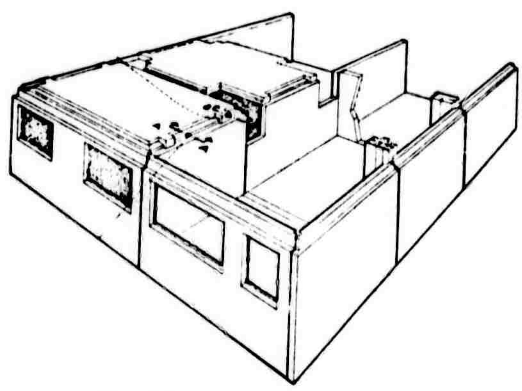
Planning Modules are large scale versions of construction modules. They are standard sized units of space, usually a related group of rooms, which for convenience can be considered single blocks. If a construction module is being used, it makes sense for the planning module dimensions to be multiples of the construction module. Planning modules are not a necessary part of building systems, but a building system can be related to a planning module.

## Generic Types of Building Systems

The structure employed for any system is related to the use of the space. The degree of flexibility needed is particularly important. There are three basically different generic types. (See illustration next page.)



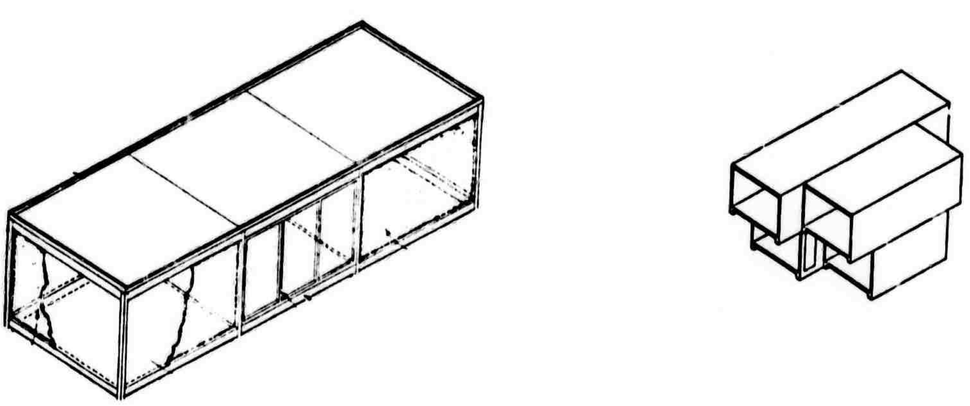
FRAME SYSTEMS



Room Size Panels

Long Span Panels

PANEL SYSTEMS



VOLUMETRIC MODULES

Frame structures use elements which are essentially one dimensional, such as columns and beams. These enclose spaces which are interupted only by columns, and therefore are the most flexible.

Panel structures use two dimensional elements such as panels and slabs. Since space is enclosed by the wall panels, these are much less flexible, although from a production standpoint these have the advantage of making a building out of fewer parts.

Volumetric modules are three dimensional elements -- boxes. These are usually just as inflexible as panels, but some modules exist which are open on the ends or sides or both, which increase their flexibility.

C) USERS VS. PRODUCERS OF SYSTEMS

The users of any building or system are those who have an interest in the performance of a building in operation. The users may be direct or indirect. The direct users are those who actually occupy the building -- the doctors, nurses, patients, administrators, etc. They care about the building being pleasant, efficient and durable because they are directly affected by it. The indirect users are the "clients" -- the Department of Defense organization, who are the users in the sense that they have the prime responsibility for making the long range decisions that ultimately affect the occupants' use of the hospital, and who therefore must be more knowledgable about the hospital needs than the occupants themselves.

The producers are those who are paid to get the building built -- the product manufacturers, suppliers, contractors, etc. Their interest is in seeing the production operation flow as smoothly as possible so they may maximize their profits and/or satisfy clients.

From the users' standpoint, the perfect system is one which can be shaped or varied to meet all possible requirements of use. From the producers' standpoint, the best system is the most industrialized -- low labor content, inexpensive, easily available materials, freedom from complexity, and avoidance of stoppages.

The ideal system would be one which has both of these characteristics. Unfortunately, the tendency so far is for user-oriented systems to be expensive and complex to produce, and for producer-oriented systems not to meet enough user needs. The ideal is so far unattainable. Instead we accept a degree of trade-off between the twin goals. In evaluating different systems, we must relate the degree to which each system achieves these goals.

The point to remember is that the only purpose of the building is to meet user needs; no amount of enclosure of space is worth doing unless it is meeting functional requirements. Therefore, where user needs and production effectiveness are in conflict, the user requirements must take precedence.

## D) DEVELOPMENT PROCEDURE FOR BUILDING SYSTEMS

The development of an integrated building system requires time and money, but it is a long term investment which pays dividends in the use of the system for a number of hospitals over a period of years.

Development of a system involving new products will mean developing individual products or subsystems to be compatible with others. However, designing the product is only part of the job, because manufacturers are reluctant to invest in the production of new products unless they are assured of sufficient volume to guarantee a profit, and an apparent demand for new products has been known to evaporate as reality was approached. A commitment by the sponsors of a system to buy in large volume is therefore sometimes required to persuade manufacturers to participate. Other methods of involving industry can be used, but all involve heavy commitment by the sponsor.

The integration of existing subsystems requires less time, cost and commitment than the development of new subsystems. Work currently underway indicates that this course is feasible. It does nonetheless involve an element of compromise: by restricting oneself to existing products, certain options are closed. It is reasonable to assume that a better system could be developed if those options were left open.

Either way, the development of an integrated building system must start with an analysis of User Needs: what activities will be carried out, what space will be required, and what is the optimum environment for these activities.

The user needs must then be translated into Performance Requirements. These state what the system must do, as opposed to conventional building specifications, which state what the building must be in terms of materials, dimensions, etc. The idea is to identify only what is necessary in order to allow leeway in the system design. The system must then be conceived from the performance requirements. As much as possible will be left open to allow for a range of choices.

If existing products are to be used, these will then be identified. If new products are to be developed, then performance specifications should be written for these. The degree of product design by the system developers may vary, but ultimately prospective manufacturers must be involved in the product development. Selection of the products to be used will involve a bidding process, which can be very complex if the compatibilities of a large number of different new subsystems are to be involved,* since the permutations of these may be enormous.

This will complete the main development of the system, but the overall development is a continuing process, depending on the design, construction, and evaluation of buildings to provide feedback for modifying and continuously improving the system.

E) ARTIFICIAL CONSTRAINTS ON BUILDING SYSTEMS

Any change meets resistance. Building systems traditionally meet resistance from labor unions, because jobs are threatened and jurisdictions must be

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* Research Staff, Office of Construction, VA. "Integration of Mechanical, Electrical, Structural and Architectural Systems in VA Hospital Facilities" (Phase I). Vol. 1. pp. 30-33.

redefined. Building regulations are also a problem, since many regulations are too narrow in scope and were not able to anticipate methods which are superior but which nevertheless do not meet the terms of reference of the regulations. Contract procedures may also be a constraint, since different sequences, jobs, and bid procedures may be involved. Other resistance may be met from contractors, architects, and engineers.

These are all problems which can be dealt with. Sometimes aspects of the system must be altered, but if the system is sound in every other respect, it will be hard for these artificial constraints to be exercised. Naturally however, all other things being equal, it is desirable to choose the course which involves the least likelihood of this kind of resistance.

Resistance to the introduction of building systems can be dealt with far more effectively in advance than after a building is in production. Part of the development of any system is to anticipate and deal with these problems.

## F) WHY HOSPITALS CANNOT BE BUILT WITH SYSTEMS FROM OTHER BUILDING TYPES

A wide variety of building systems for schools, offices, and housing are in production and have had much opportunity to be tested in use. Since no hospital system has yet been developed in as much detail, it is superficially attractive to consider trying to build hospitals from a system developed for other uses.

Such an idea represents a misunderstanding of what systems are and why they are used. The virtues of any particular system are related to how it meets the user needs of that particular building type only.

In their present form, no housing, office, or school system would be suitable for use in hospitals. Some systems might be altered to fill hospital needs, but the changes would be so great that the systems would have lost their original virtues, and in any case, the work required to make such changes would be no less than that required to develop a new system.

We shall explain why hospital systems are so different from others.

<u>Housing Systems</u>

Housing systems have had much publicity. "Operation Breakthrough" in particular has brought systems to public notice.

Housing problems however are not hospital problems. A major need in housing is cheap mass produced cells. The need in hospitals is flexibility. Housing systems have short spans, while hospitals want large open spaces. Panel systems in particular would chop hospital space into rigid bits. Housing has relatively simple service requirements, and therefore low floor to floor dimensions (like 9'-0"); hospitals, with large numbers of internal rooms and many requirements for special environmental conditions has heavy heating, ventilating, and cooling loads, as well as other special services, which lead to high floor-to-floor dimensions (like 14' to 16').

In housing the ceiling is usually just the underside of the floor above, while in hospitals these are two separate surfaces. Housing involves a repetition of standard elements, while hospitals have a large number of varied, often specialized, spaces. Because of repetition and because of the volume involved, industrialized housing usually is produced from a factory which operates only within a certain radius, like 100 miles. Hospitals however are usually one shot propositions, and the locations are scattered all over the country.

In housing systems, the structure and the enclosure of the buildings are important; for hospitals, the relationship of the different subsystems is more important. The list could go on much longer. The point is that the whole character of housing systems is different from that of hospitals.

Office and School Systems

Office and school systems are much closer to the needs of hospitals, but they still are not close enough. Offices and schools have in common with hospitals a need for flexibility, and this leads to long span structures, movable partitions and some access to services, all of which are suitable for hospitals. Nevertheless, hospital service requirements are usually greater than offices' and schools', requiring more service space. Lighting which is usually a key feature in office and school systems, is different from hospital needs (the all-over down lighting is undesirable for patients lying on their backs). Hospitals require much more in the way of plumbing services, and the locations of the plumbing cannot be centrallized as it is for schools and offices. Hospitals also require more individualized control of HVC systems. The kind of flexibility required for hospitals is also different. For schools and offices, it is usually a matter of rearranging partitions, whereas in hospitals change more often means leaving partitions in place but installing new services. All of these differences are reflected in the kind of system used. Hospitals may need to be high rise, whereas many school systems are limited to low rise.

In order to meet the different requirements, changes would be needed in the systems as they stand. And after you change the partition system, the lighting system, the structure, the floor height, the floor loads, the HVC system, the plumbing distribution, and the accessibility of services, you no longer have the system you started with, and you no longer have the benefits it was intended to provide, because the selections of components and dimensions made for that system were based on a different pattern of requirements.

If the needs of a hospital are not met by the system itself, they will still have to be worked out. Finding out what are the user requirements for any building and finding ways in three dimensions to meet these requirements is what systems development is all about.

The changes, therefore, that would be needed to adapt school, office or housing systems for hospitals would require at least as much work as the development of a new system. Yet to start from an existing system would inevitably involve compromises, so the resulting system would be less suitable than one which started without any constraints.

Adapting a system intended for different purposes would simply be a patch-work job.

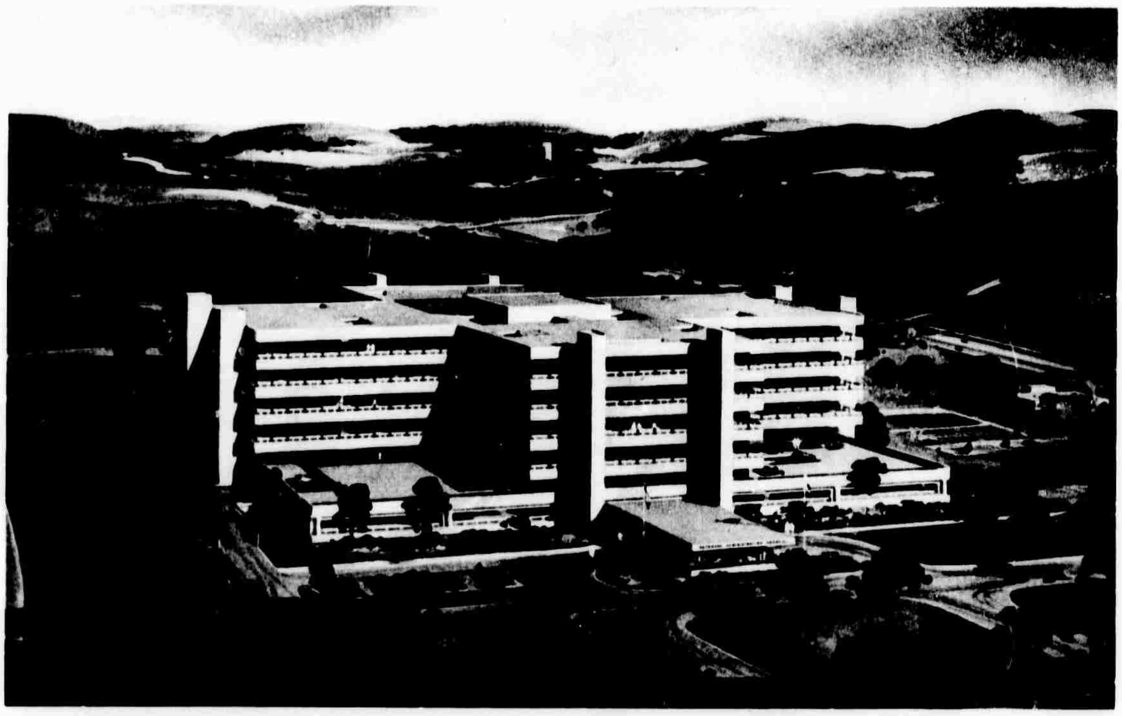
## SECTION 4: TRENDS AND INNOVATIONS IN HOSPITAL BUILDINGS

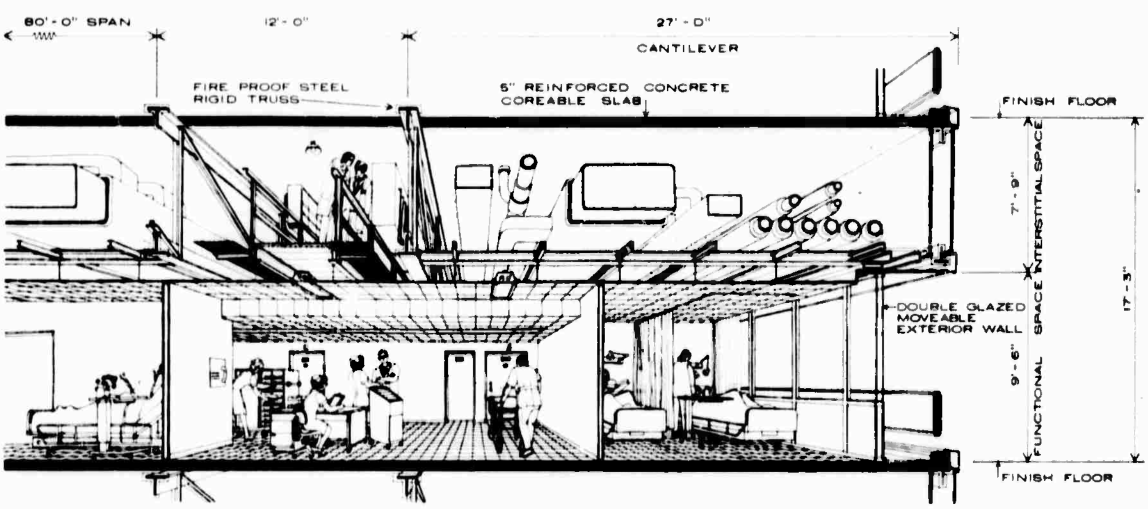
### A) INTERSTITIAL SPACE

Description - "Interstitial Space" refers to the creation of a floor for service distribution and maintenance between conventional use ("primary use" or "functional") floors. Other terms such as "service floors" and "structural-mechanical grid" may be used to describe the same concept. The distinguishing characteristic of interstitial floors is that provision is made for a person to obtain access to the space without disrupting the activities above or below.

The concept is a direct expression of two principles of flexibility: a) Separation of permanent and non-permanent elements, and b) Accessibility to services. The permanent elements here are the structure, the mechanical trunk lines, the floors and the ceilings. There is a sharp demarcation between these and the impermanent elements -- the partitions, doors, electric service, plumbing, and branch ducts. Accessibility is provided by allowing men to get at distribution of services without having to remove any construction or disrupt operations.

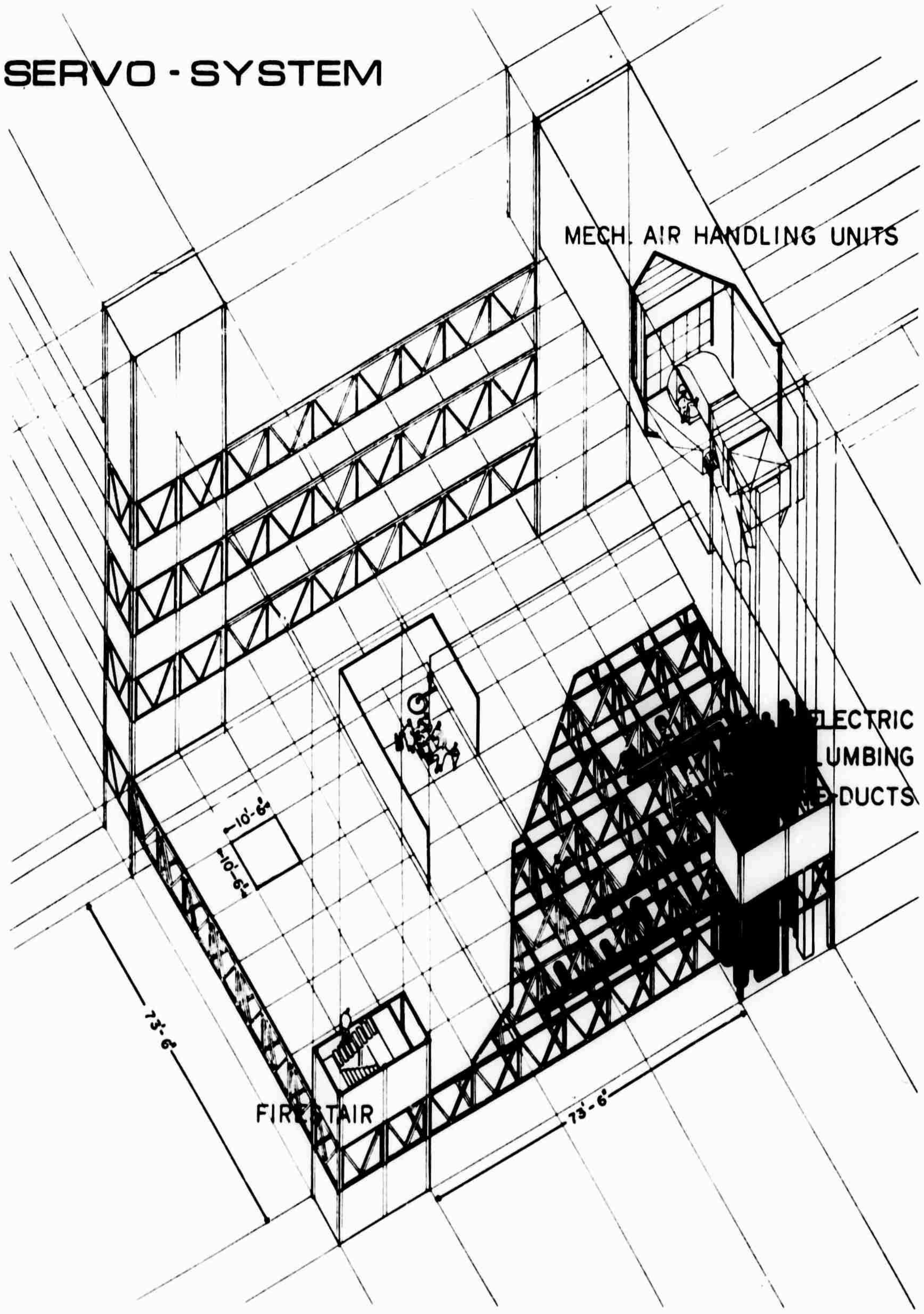
Service floors are a logical extension of a trend toward longer spans, deeper floor depths, more services and easier access. Clear floor space, as provided by long spans, is a virtue in itself. The longer the spans, the deeper the beams or trusses, until the point is approached where it is just as logical to let access to the space be entirely from within rather than from below.






SAN DIEGO VA HOSPITAL - Pictorial Section of Functional Space and Interstitial Space. Drawing is slightly misleading in that trusses also span from side to side (at centers varying from 9' to 13'), reducing clearances in service space.

(Note: Although the hospital shown is a VA hospital, the construction is not that of the VA Hospital System, described later in this volume. The architect for this hospital is Charles Luckman Associates of Los Angeles, and the design pre-dates the development of the VA Hospital System. See also pp. 58, 59.)




McMASTERS UNIVERSITY HEALTH CENTER - Three dimensional cut-away view of structure showing integration of services, vertical circulation, and mechanical equipment. Drawing shows two-way truss system (space frame). Cost of this proved too high, so one way system was used instead, based on primary trusses and secondary trusses at right angles. This preserves column free space between cores.

(Architects: Craig, Zeidler, Strong, of Toronto. See also pp. 56, 57.)

Although adequate space exists for headroom in some places, no one should be misled into viewing the service zone as spacious. Access and movement in most cases involve bending under and sometimes climbing over structure and services.

Relation to building systems

The intent and rationale of interstitial space almost requires some kind of system or rationalization of subsystems. It is possible to have a building system without having interstitial floors, but it is not possible (or certainly not logical) to have interstitial floors without at least some degree of a building system. Most systems developed for use with service floors so far however have been geared to a single large project, with no general applicability.

Benefits

Since systems and interstitial floors have such a close relation, it is not surprising that the benefits of service floors overlap a great deal with those of systems. These are:

a) Flexibility for change. This is made possible by easier replacement of components, both above and below the ceiling.

b) Simplification of maintenance of services, for the same reasons.

c) Potential for more efficient planning, resulting from obstruction-free floor space.

d) Better service distribution, resulting from more adequate service space.

e) Time savings on construction, resulting from starting the structural mechanical grid before the interiors have been designed.

f) Division of the job into two or more separate contracts, allowing more contractors to bid.

g) Improved operating efficiency resulting from the greater ease of making changes, which keeps the building from getting out of date.

h) Time gained on the design process, which allows decisions to be put off until the actual construction of them is closer. This reduces change orders and insures that the building will more nearly reflect current needs when it opens.

i) Some people also claim that construction costs are reduced. In any case, several examples -- Greenwich Hospital, San Diego and McMasters University -- all claim that they are building to the same cost levels as they would with conventional construction.

j) Long term cost savings through simpler maintenance and change. Since a planned addition to Walter Reed Medical Center utilizing interstitial space is currently being designed by architects Stone, Marraccini and Patterson, the Department of Defense will soon have an excellent opportunity to examine these benefits.

Variations

A number of different approaches to interstitial space have been tried. (See Comparative Analysis, page 161.) While most applications provide one service floor for each primary use floor, the architect Rex Whittaker Allen has built or is building three hospitals -- New Dominican in Santa Cruz, Madera General Hospital, California, and Boston City Hospital (with Hugh Stubbins), all of which serve two primary use floors -- one above and one below -- from one service floor. The objections to this is that several different situations are set up, with different floors benefitting to different degrees from the service floor. For instance, some services will feed upward, others down. If air HVC systems are used (and the use of anything else is questionable), then different outlet conditions will exist for the two different floors. Yet one is certain to be better than the other. That one therefore should be used everywhere. Drains always must go down, so some will be in an interstitial space, with easy access, while others will be in a smaller service space, which will have to use a ceiling which can be removed for access. The two different floors will have the same span, but the floor depths will be different, and structure will be different as well.

Other uses of service floors, such as Norton-Childrens Hospital in Louisville, by Candill Rowlett and Scott, provide interstitial space in the medical/administrative areas, but not in nursing. However, with the possibility of nursing areas changing to completely different uses ( as the number of in-patients continues to decrease), there is much in favor of using service floors everywhere. The following section indicates that if hospital plans become more horizontal, there will be still more reason for using the service floor concept uniformly throughout the hospital.

Another variation is in what functions, if any, should be built into the service space in addition to services distribution. One extreme proposes to use some of the space, especially that on the periphery of each floor, for functions such as offices, labs, and storage. The theory implicit in this is that building enclosure has already been created, and therefore money will be saved by using some of that space, especially the less intensively utilized portions. However, this ignores the fact that raw space is cheap and that provision of space for primary type uses will cost much more -- probably enough to make it not worthwhile. For instance, the space would have to have lighting, HVC, and probably windows, walls, floor, wall and ceiling finishes, and communications services added in order to made it habitable as an office. More would be required for labs. It would also have to have direct access. Since corridors in the service zone would probably conflict with HVC distribution, the access would probably be by a series of stairs, the cost of which, in loss of space and estra construction, would probably tip the balance against such double use. Furthermore, the height of the space provided on most interstitial floors would have to be increased, which would affect the entire floor, incurring a disproportionate cost for a questionable gain. Dropping the ceiling at the periphery areas is equally undesirable, since it would loose the flexibility of the constant height ceiling.

A much less clear issue is whether or not to include equipment, tanks, and machinery in the space. Obviously some saving of floor space elsewhere results from putting equipment in the space, and in some cases the equipment has a functional need to be there. On the other hand, location of such elements there may interfere with any attempt to create a system of zones whereby the planners may always know that if their distribution principles are followed, pipes and ducts may alwyas be able to go exactly where they are needed. For this reason, it is intended that the VA system will reserve all service space for distribution of services only. Other systems, which may have more left-over space, may find this not so important. Probably each case must be judged on its individual merits.

Another variation found is in the construction of the ceiling itself. Some installations, such as Santa Cruz and San Diego, provide catwalks suspended above a non-load bearing ceiling. In others, the ceiling is strong enough to support people at least.

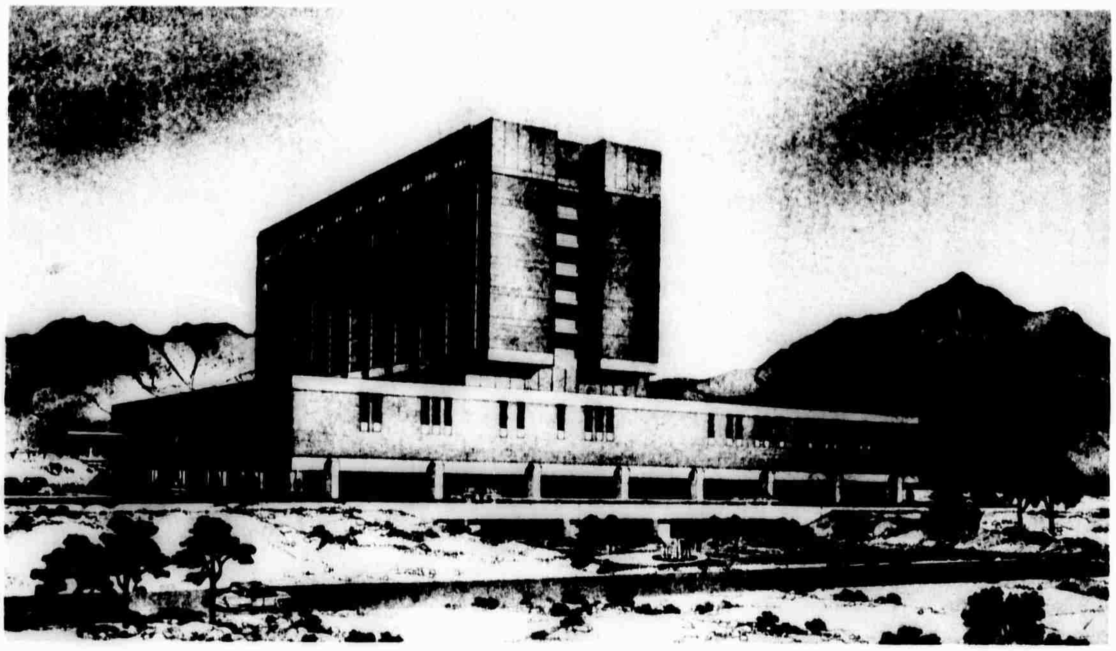
The advantages of the latter are considerable, because if a continuous support surface is provided, workers may go anywhere to deal with any needs that arise. Catwalks impose great limitations on access, and also involve some loss of headroom. Catwalks also have to be specially designed and laid out to fit between structure, services, and equipment. They impose another non-system condition in a situation where maximum simplicity is wanted.

## THE MUFFIN WITHOUT THE MATCHBOX: Horizontal Plan Organization

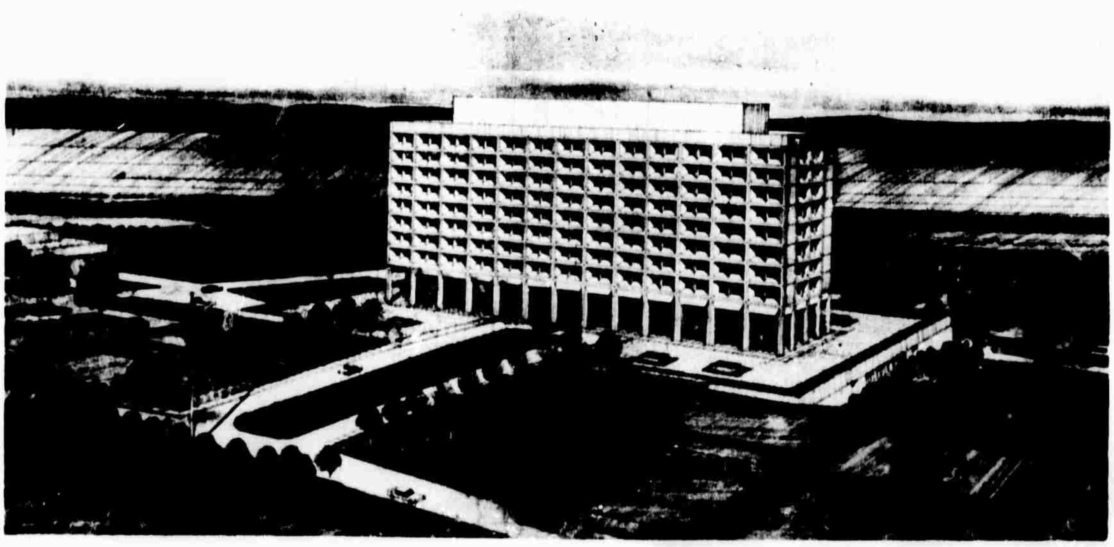
The form of the conventional 1950's and 1960's hospitals consisting of a nursing tower on a base has been described as a matchbox on a muffin. It is the form of many current military hospital designs, and the rules of the game are now so well known that anyone can play. (See illustrations).

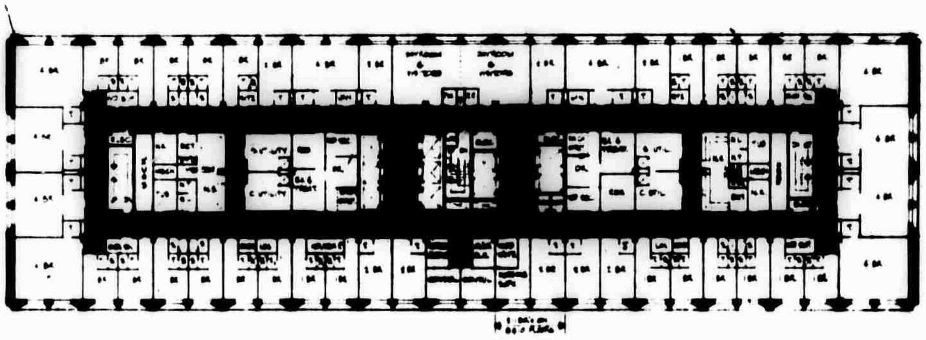
Re-examination of this concept, expecially in light of the need for flexibility, is now pointing toward hospitals which are all muffin -- i.e., all base, with nursing units integrated more closely with other facilities. As evidence, a growing number of new hospitals large and small are exploring ways of organizing nursing into large floors.

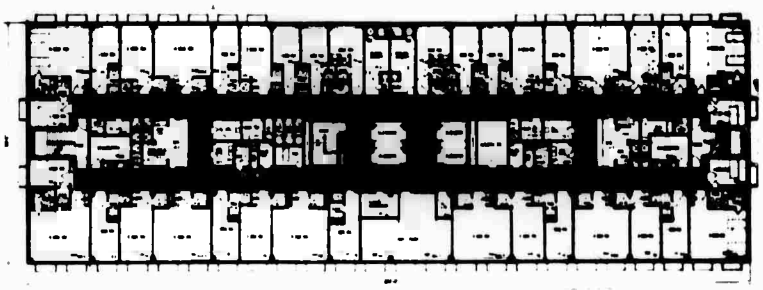
The concept of a horizontal base (the muffin) for the medical and service support facilities is well established. What is not always realized is that the muffin comprises upwards of two thirds or more of the total floor area of the hospital, and that that proportion is increasing. (This will be even more true if light care is taken out of the hospital.) So when we speak of horizontal organization, we are referring to something which is already the pattern for all but a third or less of the building. The question now is primarily whether the hospital will gain by integrating nursing into this large horizontal element.

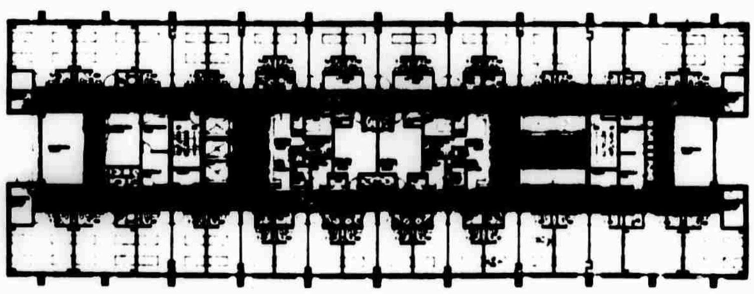


TYPICAL MILITARY HOSPITAL BUILDINGS -
two recent designs following the standard "matchbox-on-a-muffin" form.
Above: Beaumont General Hospital (Army). Welton Becket & Associates, Architects/Engineers
Below: Fort Gordon Hospital (Army). Lyles, Bissett, Carlisle & Wolff, and Patchen, Mingledorf & Associates, Architects/Engineers.
In this case, the muffin is built into the ground, making any possibility of expansion that much less likely.









TYPICAL NURSING FLOOR PLANS OF CURRENT MILITARY HOSPITALS
These plans indicate the degree of uniformity
in current nursing units.

Top: Fort Gordon Army Hospital - 83 beds on per floor

Middle: Pensacola Naval Hospital - 75 beds per floor
Hugh Leitch/Sherlock Smith & Adams - Architects & Engineers

Bottom: William Beaumont Army Hospital - 72 beds per floor

Scale: 1" = 64'

Although the change from an established form may require more skill and effort on the part of the architects, the balance of factors sppear to favor horizontal organization. Some of the main points follow.

The large floors are inherently more flexible. There is therefore more potential for variation of nursing ward plans. Nursing units are commonly regarded as static, but staffing patterns and patient care principles do change. One recent article claims that nursing units become obsolete every ten or twenty years.* And others have indicated a trend to what might be very much larger wards, based on team nursing principles.** It is possible to subdivide large areas in a number of different ways, but it is not possible to reassemble a number of small areas (i.e., tower floors) into something larger.

This will also allow a closer relationship between nursing and medical support facilities. An example of this concept is the new Bellevue Hospital in New York, where each floor is considered a self-sustaining hospital in itself, with nursing around the perimeter. (See illustration)

Expansion is particularly more suited to horizontal structures than vertical. The principle of open end planning was discussed in Section 2 under Principles of Flexibility. Open end planning finds its natural expression in buildings with a horizontal organization and growth pattern.

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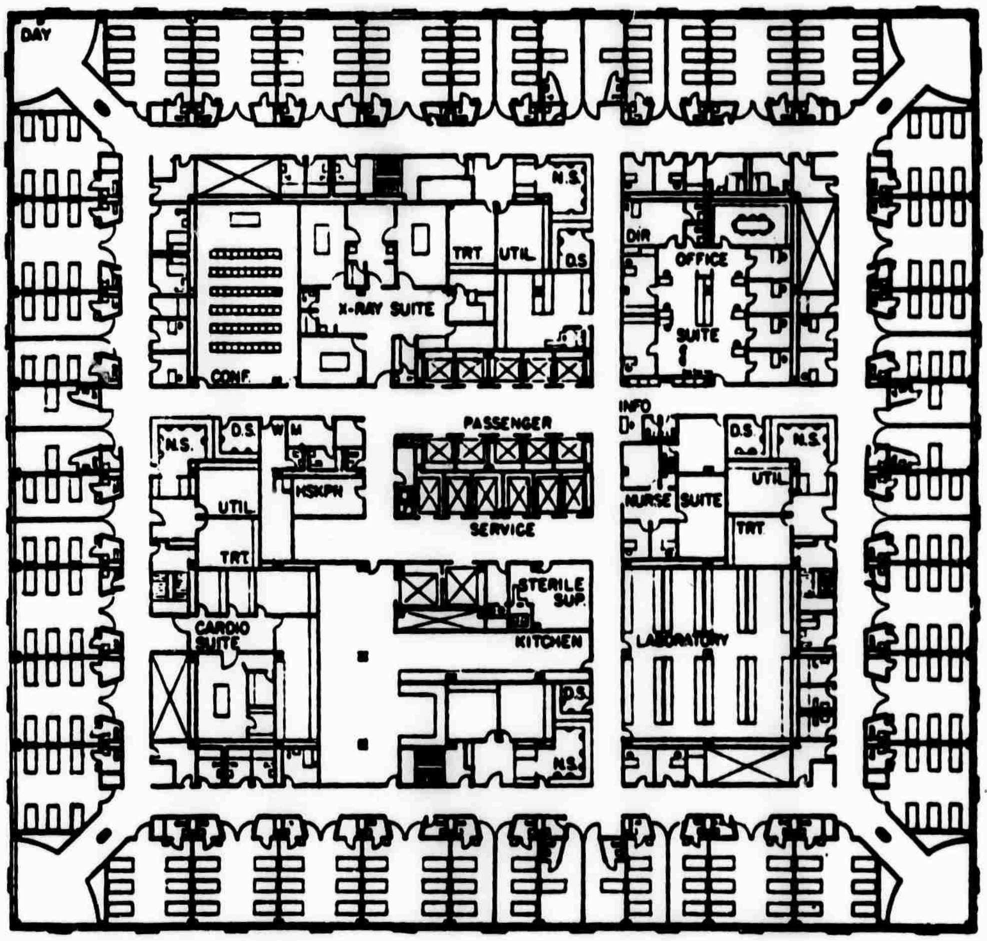
* James Moore: "Wide Span Trusses Will Help Your New Hospital Stay Young While It Gets Older." Modern Hospital. March 1968. pp. 96-98

** Leon Pullen: "Modern Methods Make Larger Nursing Units Practicable." Hospitals, May 1, 1966, Vol. 40. pp. 77-80.
Rex Levering: "Study Convences Hospital That Larger Units Cost Less." Modern Hospital, September, 1968. pp. 120-122




16TH FLOOR: MEDICAL & SURGICAL

BELLEVUE HOSPITAL, NEW YORK - Typical floor plan. Although this building is actually tall, individual floors employ principles found in some horizontally organized plans -- perimeter corridor, proximity to medical suites, and localized support functions.

Architect: Joseph Blumenkratz, A.I.A., of New York.

Although vertical expansion is physically possible, it is expensive and inconvenient. It must be allowed for in advance with oversized columns and foundations, and the actual operation requires the evacuation of one or two floors of the existing building for "insulation" from the noise and in some cases debris of construction above. Access and materials handling are also problems, to the extent that a side of the existing building may also have to be neutralized.

Horizontal expansion by contrast is a relatively straight forward operation. It is simply building a new building up against an old one. Access, materials handling, noise, structure are all simpler.

Cost in many cases favors horizontal organization. Although there are many cost trade-offs between low buildings and high (more roof but less exterior wall; smaller foundations, but more of them; etc.), low buildings frequently cost less per square foot to build. The cost of vertical transportation systems is a major factor.

There are also economies through elimination of duplication of facilities from floor to floor. Greenwich Hospital, London, claimed an 18% reduction in departmental areas* (though a fair comparison would have to identify what it was being compared to). It may also be possible to reduce the proportion of space used for services and circulation.

It is true that more land is required (very little more actually) for horizontal solutions, but in the case of military bases in particular

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* "District Hospital" - The Architects Journal (Information Library) November 26, 1969. p. 1386.

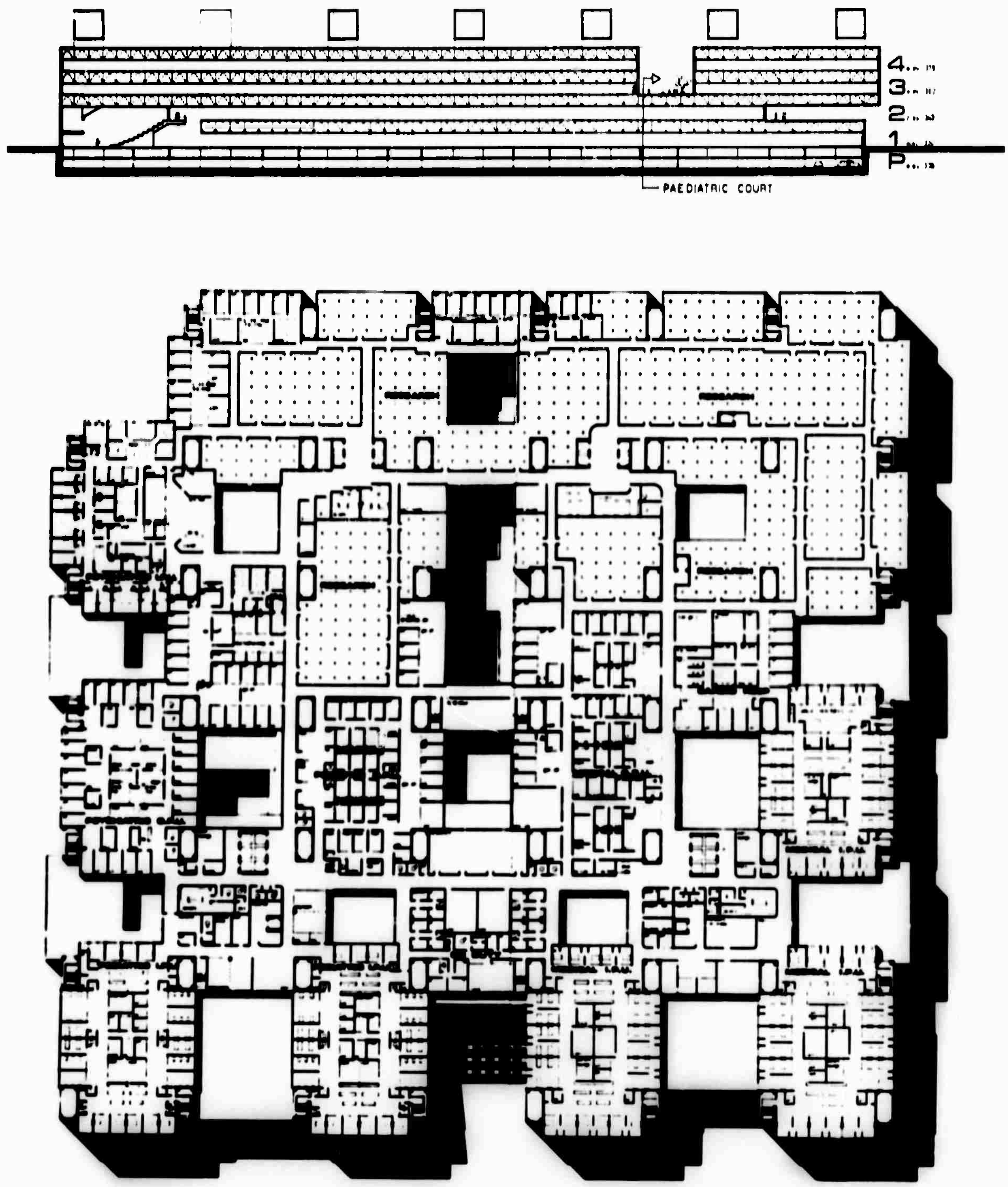
there is not usually a shortage of land. Low buildings may also be able to use sites which would be uneconomical for tall ones because of poor soil conditions.

In the event of fire, it is impossible to evacuate all bedridden patients from the floor of a tower in a short time. In a horizontal building, bedridden patients may be moved horizontally to a separate fire zone.

In the final analysis, however, the decision of whether to build low or high will hinge on two factors: a) Nursing Unit Efficiency - is it possible to design desirable and internally efficient nursing units for horizontal solutions? and b) Inter-Departmental Movement - how is the movement of people and goods between different wards and departments affected?

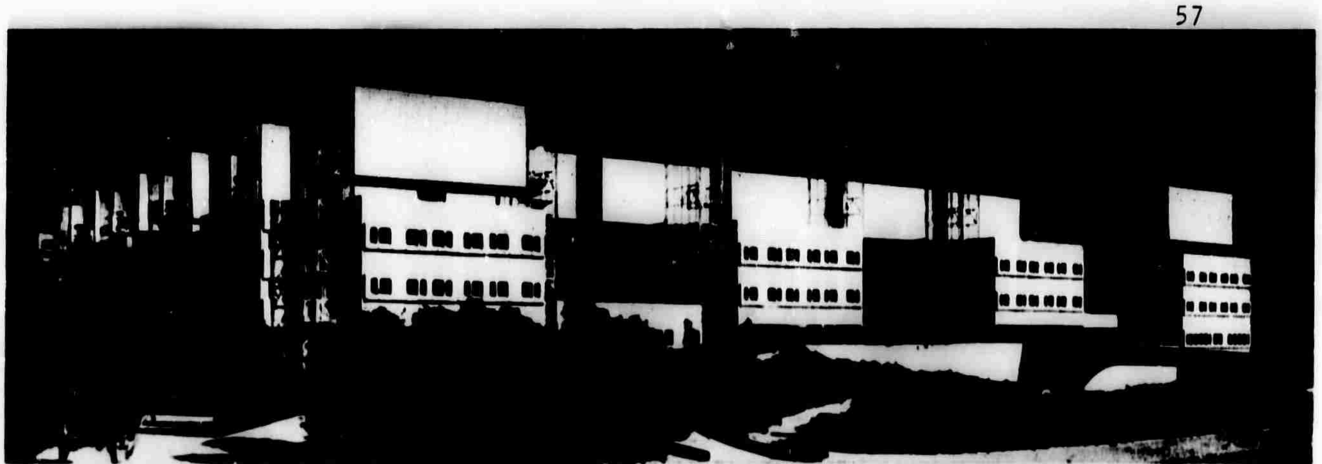
In the first case, there are already a number of examples of very desirable nursing units designed on this basis. McMasters University Health Center, San Diego Veterans Hospital, and Greenwich Hospital, England are examples showing three different approaches. Courtyards for example can be utilized to permit light and views in several directions, although one-sided units around the perimeter can also work. (See illustrations, pp. 56-59, 63-64.)

The question of movement between wards, floors, and departments will be argued for some time to come, but several observations are worth making.

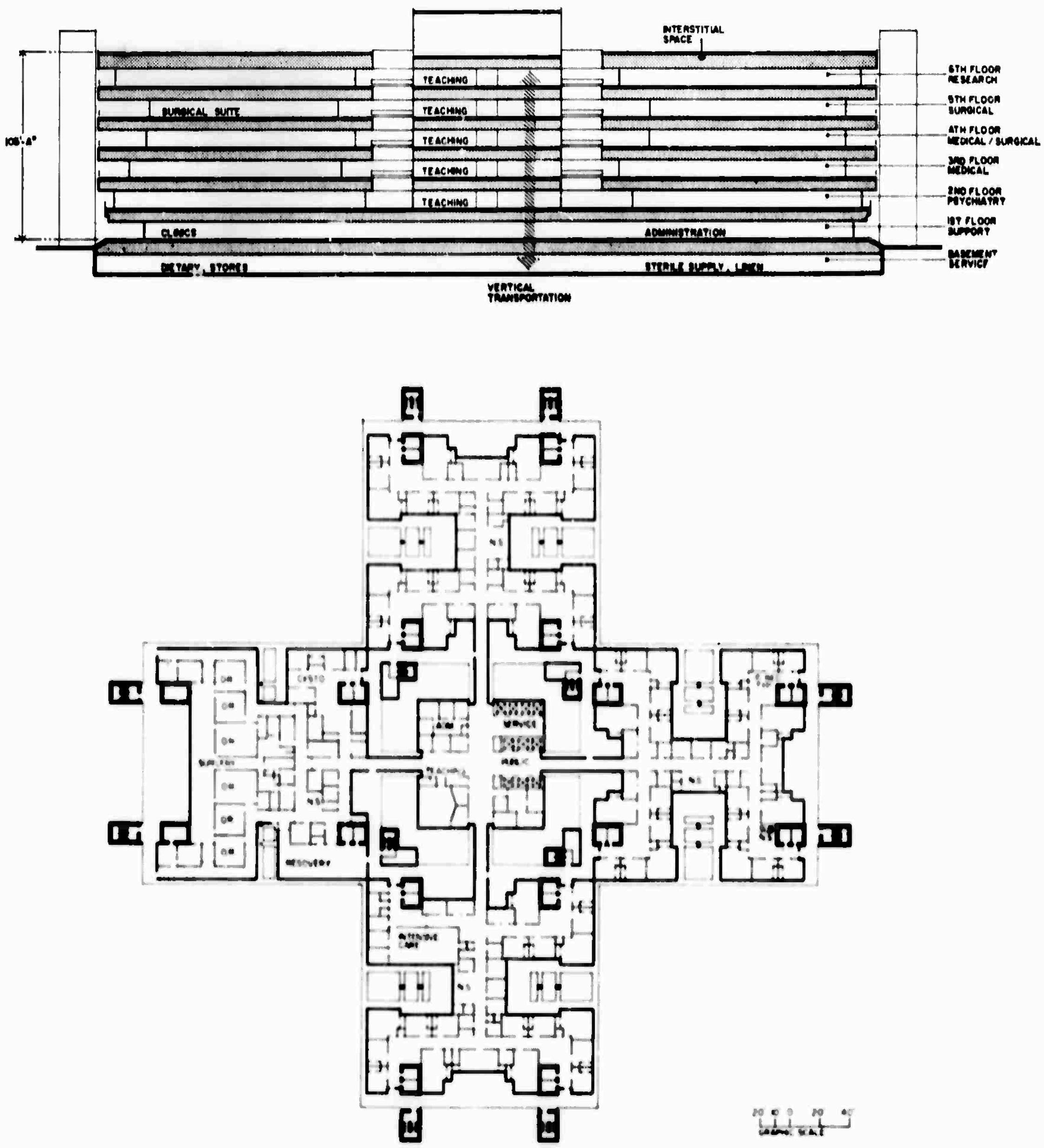



McMASTERS UNIVERSITY HEALTH CENTER - Typical floor plan shows how compact mursing units may be designed as part of ho izontal plan. Section shows continuous space frame over all hospital functional areas.

Architects: Craig, Zeidler, Strong, of Toronto.

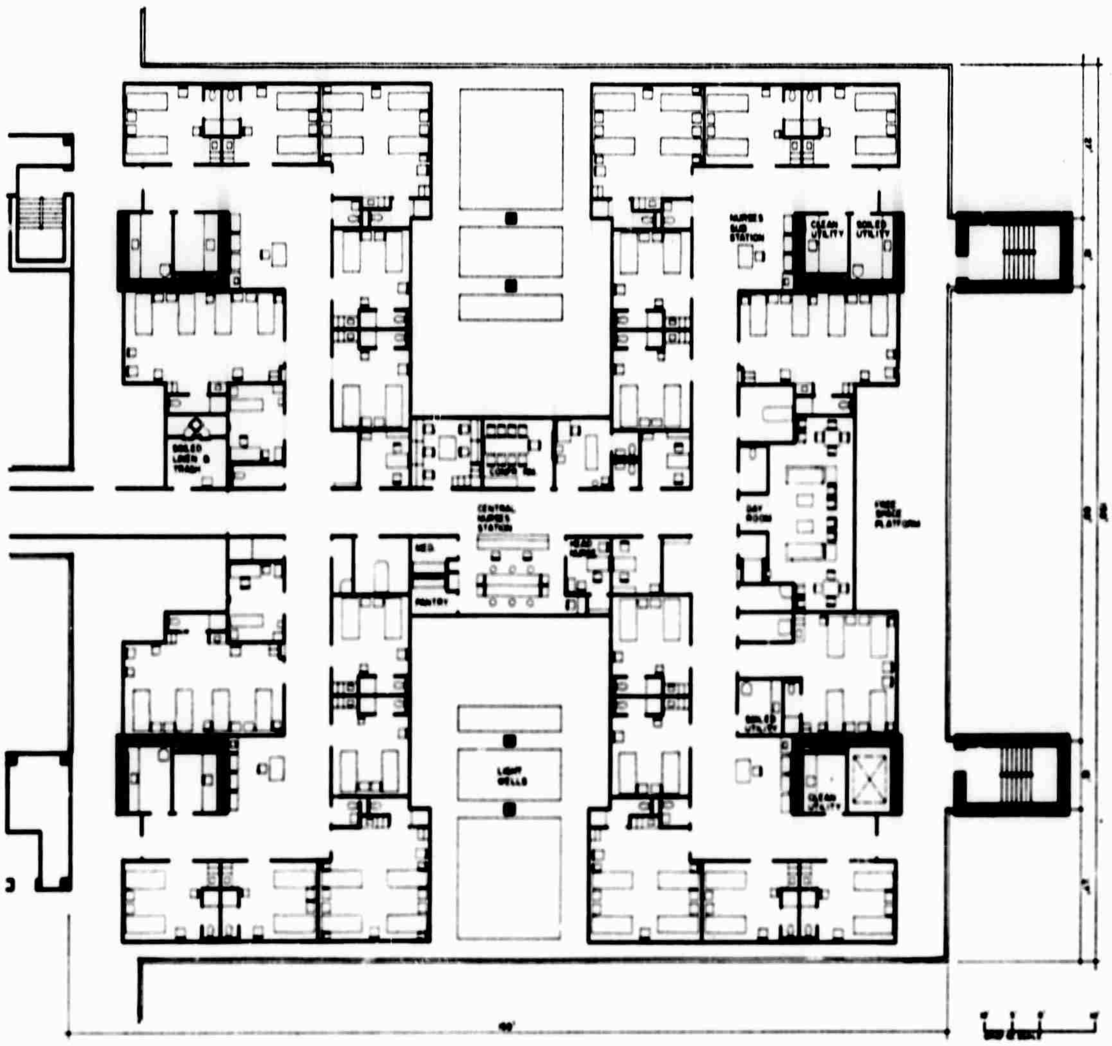


McMASTERS UNIVERSITY HEALTH CENTER - Model of completed building. Huge structures over main mass of building are for air hindling and mechanical equipment. Because of research activities, McMasters has more need for exhausting large quantities of air than conventional military hospital.




**SAN DIEGO VA HOSPITAL - Typical Floor Plan and Section.**

**Architects: Charles Luckman Associates, Los Angeles.**



SAN DIEGO VA HOSPITAL - Plan of typical Quadrant, showing organization of 64 bed ward into four 16 bed "pods". Of particular interest is how irregular outline of exterior wall is obtained within the framework of a highly regular structural system, by not enclosing all the floor space.

If the height of the base is maintained (usually three or four stories), and the nursing areas are incorporated, the increase in width and length would be only 20 - 25% in each direction, since the total area would be increased only 50%. Courtyards may increase the spread more, but dimensions are still not very different from what is usual for hospitals. Walking distances therefore are not significantly increased.

For short distances it is quicker and easier to move horizontally than vertically, though if the horizontal distance becomes great enough vertical movement will be quicker. There is evidence now to indicate that the distance at which horizontal movement loses its advantages is much greater than conventional planning would suggest.

A chart of comparative elevator and walking distances is shown below, based on an assumed eight story building, a 40 second elevator interval, and mixed passenger and wheeled goods traffic.

| Vertical Travel by Elevator | | Number of Stops | Elapsed* Travel Time | Equivalent** Horizontal Walking Distance (moderate) | Equivalent** Horizontal Walking Distance (fast) |
|---|---|---|---|---|---|
| 1-2 | 1 Floor | 0 | 35 Sec. | 139 Feet | 185 Feet |
| 1-3 | 2 Floors | 1 | 59 " | 233 " | 312 " |
| 1-4 | 3 " | 1 | 61 " | 241 " | 322 " |
| 1-5 | 4 " | 2 | 85 " | 366 " | 449 " |
| 1-6 | 5 " | 2 | 87 " | 345 " | 459 " |
| 1-7 | 6 " | 3 | 110 " | 435 " | 581 " |
| 1-8 | 7 " | 3 | 112 " | 444 " | 591 " |

* From unpublished report by Edwin H. Hesselberg, Consulting Elevator Engineer, dated December 22, 1969.

** Hospital Traffic and Supply Problems published by the King Edwards Hospital Fund for London, 1968, pp 50.

In viewing the above figures, it should be remembered that in addition to elevator time, vertical trips will also include the time it took to get to and from the elevator. So the total distance which a person could travel on one floor while someone else is travelling for example from a random point on the fifth floor to a random point on the first floor (approximately 70' and 130' respectively) of a hospital like Fort Gordon, would be 536' at moderate speed, or 649' at a fast pace. This analysis ignores many factors, but it points to the scale at which trade-offs can occur. Note also that in walking it is possible to increase one's speed in an emergency, whereas with elevators nothing can be done about it.

Ministry of Health research study for Greenwich Hospital (England) found that the balance of movement factors favored a horizontal organization. They said, " The simplest way of moving all these things is horizontally, because both people and things can either walk, or be pushed, or be carried, horizontally, far more easily than they can in any other direction. To a great extent this applies to services as well."*

In addition there are less measurable factors like the frustration of waiting for elevators. Horizontal movement also is not subject to stoppages, and requires no maintenance. The opportunity for chance meetings of individuals is increased, and unlike in the case of elevators passing in opposite directions, the individuals can stop briefly for a word or two.

* "The Greenwich District Hospital Development Project" - Ministry of Health, London, England, p. 12 (1968)

An extensive 14 month study* on horizontal organization of hospitals was carried out by the Ministry of Health, toward the development of planning policies for general hospitals. Among the objectives was "to seek the utmost economy in whole hospital design and construction; but still consistent with maintaining acceptable medical and nursing standards. This economy must be related to a proper balance between capital and running costs."

The conclusion of this study was that general hospitals could most efficiently be organized into two story structure with numerous internal courtyards. A 540 bed hospital at Bury St. Edmonds has been designed on these principles and is under construction. (See Illustration)

The heart of the building is the treatment and diagnostic departments, which are surrounded by a ring main corridor. Wards are arranged peripherally, but corridors and work spaces can be double loaded because courtyards provide light and air for the internal rooms. Boiler houses are decentralized and located on the roof of the area they are to serve. The supply center at the rear of the building is lined to the ring main corridor on each floor by a ramp, enabling all deliveries and collections to be undertaken by small electric powered carts, a practice also used in at least one recent U.S. hospital.

Some features of American practice, such as a greater reliance on artificial lighting, higher standards of atmospheric control, and more severe extremes

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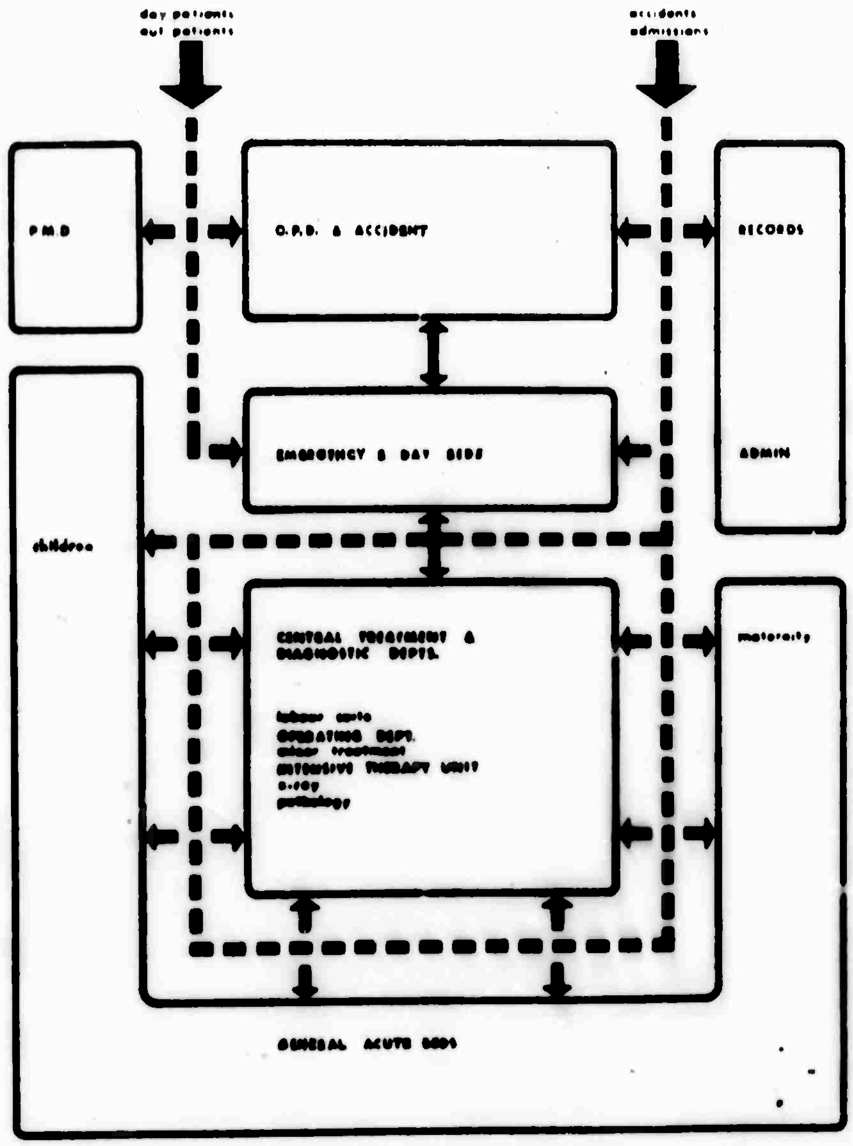
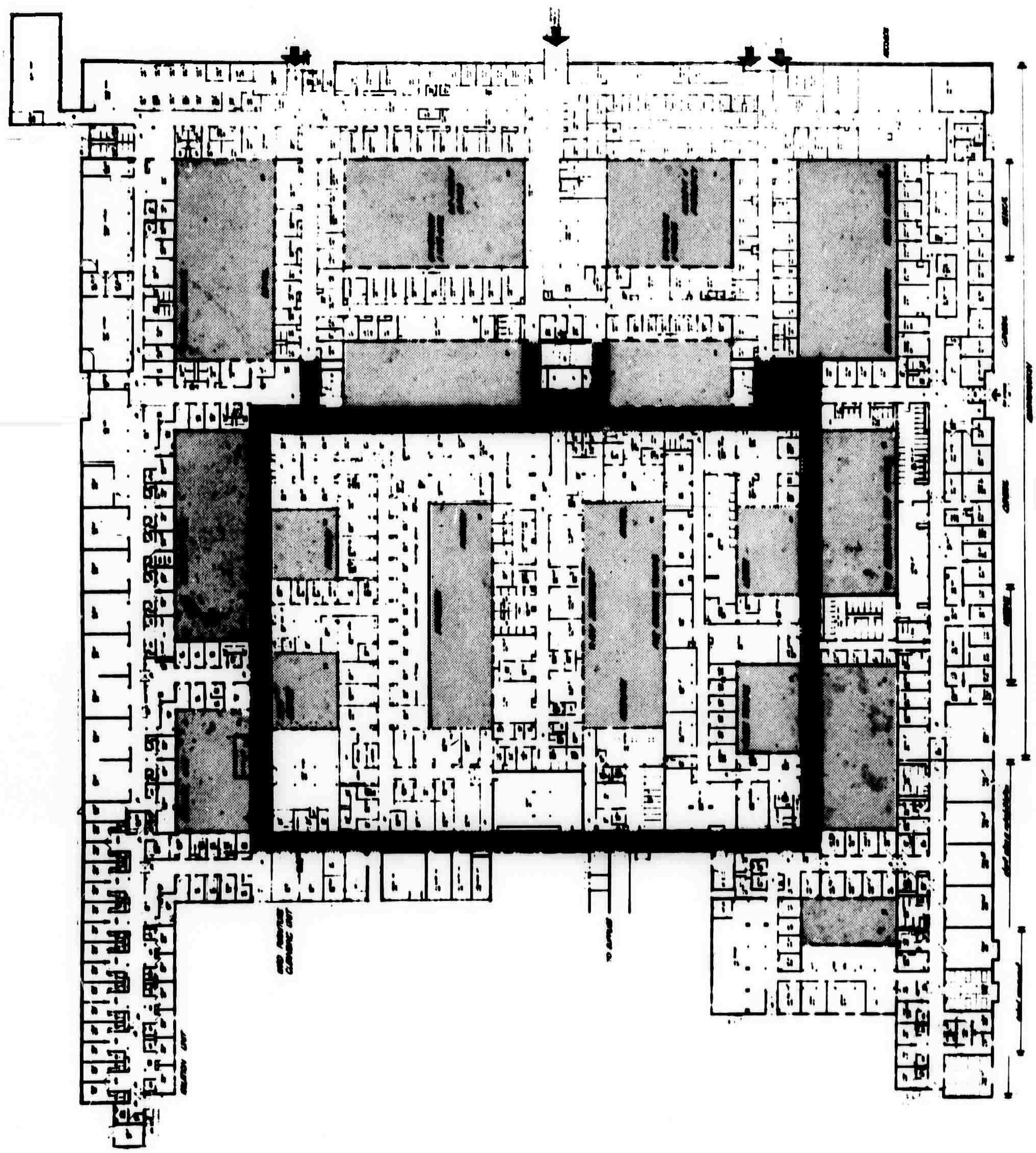
* "Rationalization of Planning and Design". Ministry of Health, London, England. March 1968.




MINISTRY OF HEALTH "BEST BUY" SYSTEM - Diagramatic layout showing general department locations and main curculation system. Concept is a sequel to Greenwich District Hospital, and is intended as prototype for others.

Architects: The Chief Architect, Ministry of Health, London.



MINISTRY OF HEALTH "BEST BUY" SYSTEM - Ground Floor Plan of 2 story hospital at Bury St. Edmonds and Frinley. Overall dimensions are about 450' x 500'. Extensive use of courtyards (shaded grey) and strongly defined main corridor help to maintain orientation. Based on comparative analyses of different kinds of movement, the concept challenges many established ideas about adjacencies and circulation. Scale: 1" = 64'.

of weather, might mitigate for a less sprawling plan. The general principles of adjacencies, circulation, and movement of goods are relevant nevertheless, even if the result is a more compact building than the British prototype.

To some, such an approach may seem like a return to the old canton type hospitals. However, it should be remembered that cantons were more spread out, that circulation was less rationalized, and that many of their shortcomings were the result of factors unrelated to their plan form, such as low quality construction, unsatisfactory heating and ventilation, and inadequate services.

Implications for Building Systems

The "standard" form of hospitals has gone through a number of stages of evolution, and there is no reason to believe that the present form is the "perfect" or ultimate form, or that the form will ever stop evolving.

This section has simply ovserved what may be a shift in the design of many hospitals -- a shift away from towers on a base to a more horizontal, integrated from. It does not claim that future military hospitals must or will take this form. (We do believe a systems analysis of the two concepts would be productive, and that will be discussed in Section 8, Recommendations.)

If such a change occurs, it will have two implications for any hospital building system:

a) The system should be flexible enough to build either tall buildings or low buildings equally efficiently, and

b) The nursing units, being simply an extension of the base structure, will have less reason than ever to have a different kind of structure from that of the main hospital functions.

## SECTION 5: EVALUATION OF CURRENT HOSPITAL BUILDING SYSTEMS

### A) PURPOSE AND CRITERIA FOR EVALUATION

By evaluating those hospital building systems which have so far been developed, the Department of Defense can either select the best (for use on its New Generation Prototype), or it can at least identify errors not to make in developing a new system.

A great deal of effort has been expended by a large number of experienced people in developing systems; to ignore what they have accomplished would be perverse and wasteful. It is in the nature of the systems approach to start wherever possible by building on the work which has already been done.

This section, therefore, first outlines a basis for judging a variety of systems concepts in terms of their potential for use in military hospitals, and evaluates how current systems meet these criteria.

The intended purpose of any system is to save time and money and to improve quality by solving <u>in advance</u> certain recurring problems.

A system can be developed for an extra large single building (a "one-off" system), or it can be developed for use with a series of buildings.

In either case extra effort is put into the project initially, to work out a generalized solution which can be applied to a variety of situations; and because of the extra thought it has received, that solution should be better than what would have been developed for just one problem.

However, not every system which is conceived actually achieves its intended goals. Some which appear plausible do not result in true savings or other benefits when all factors are considered. The level of competence and merit of current systems varies widely from high sophistication and practical realism down to rank amateurism. In fact, some of the most extravagant claims are made for those systems most lacking in merit.

The scope of different systems also varies widely, depending on the intended use for each system. The systems analysis technique is therefore employed in order to examine these systems in a balanced way. It is:

1. To identify those criteria which determine effectiveness and which most clearly distinguish between differing concepts,
2. To analyze the claims made for different proposal (in this case building systems), and
3. To identify the degree to which each proposal does or does not measure up to these criteria.

The prime criterion applied to each system is:

How beneficial would the use of the system be in future military hospitals, and in particular in the projected New Generation Prototype Hospital?

The considerations which result from trying to respond to this criterion fall roughly into three categories.

1. Criteria of availability, scope and general applicability:
   a) Is the system ready for use now, or would further development

be needed before it could be utilized productively? Does its technology or methodology require testing before it could be used without risk or delay?

b) How comprehensive is the system in scope? (Would its use be limited to certain types or parts of hospitals?)

c) Has the system either been tested in the field or else attempted to resolve all the practical difficulties it will face?

d) Can it be used by a variety of hospital architect/engineers, or does it require the proprietary or private knowledge of certain key individuals?

2. Criteria related to user considerations; ie., how good and flexible a hospital can it be used to build:

a) How flexible is the system for future change? How easy will it be to relocate walls, add new services, etc.?

b) How flexible is it for future growth?

c) How adaptable is it? Can it be used for a variety of different building forms, heights, and configurations? Will it fit military programs?

d) Is the system open? I.e., does it have the ability to utilize a variety of different subsystems?

e) Will it have the capacity to evolve into a better system or is it incapable of further development?

3. Criteria related to production and building considerations:

a) Is the methodology simple and straightforward, or is there potential for confusion and delay?

b) Does the system have ways of resolving most relationships (e.g. of subsystem interfaces) without involving special details? A system is a method of solving problems in advance; ideally, a system virtually puts itself together.

c) Can the system be used easily by a variety of contractors?

d) What is the potential for speed of construction? Is fast-tracking part of the methodology? Is site labor minimized? Are subsystems easily available from a variety of suppliers?

e) How compatible are the subsystems?

f) Are the number of parts minimized?

The standard format for evaluation of each system is:

1. Background: sponsorship, stage of development, etc.
2. Description: outline of main features
3. Evaluation: relation of system characteristics to criteria
4. Summary and relevance of the system for use by D.O.D. in the near future.

Current efforts at hospital system development fall into three categories:

1. Components or groups of components (for part of the building only)
2. Factory made rooms or modules (presently suitable mainly for temporary or emergency buildings)
3. Systems for construction of the whole building.

The evaluations of systems have therefore been segregated into separate groups relating to those three categories.

## B) COMPONENTS FOR SYSTEMS

Some work toward systems integration is being done on a small scale, solving the small problems and building up to larger ones. The results of this work is components or sets of components designed specifically for hospitals. Some of these may be viable for use in an integrated building system for complete hospitals, and therefore should be studied. They are also useful for showing in microcosm the problems of systems integration.

These systems are:

1. The Adaptable Building System, developed by Research Institute of Systems Development, Texas A & M University, Texas.

2. Electro Systems "Multi-Wall" Patient Units, developed by Electro Systems, Inc., Richmond, California.

THE ADAPTABLE BUILDING SYSTEM

Developer: Research Institute of Systems Development
Texas A & M University
College Station, Texas

Principal Investigator: James Patterson

This system is the result of work carried out under Public Health Service Grants HM00436 - 01, 02 (development) and HM00589 - 01, 02 (construction and evaluation)

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## A) BACKGROUND

The interior of a cardiac unit at Presbyterian Hospital, Dallas, was built with this system in 1969. The system consists of four components: partitions, patient console, ceilings, and bath. It is also intended to develop a line of accessories such as wall hung cabinets, and perhaps a built-up floor system, such as are in use in computer rooms.

This is one of the first attempts at a hospital system to be built, and therefore warrants discussion, even though it is limited in scope and is questionable in many respects. If nothing else, it illustrates some of the difficulties that may be encountered in developing a system.

## B) DESCRIPTION

The partitions and patient consoles are new products, the bathroom is a modification of an existing product, and the ceiling is a standard product. Each one of the products could be used independent of the others.

The ceiling and partitions are related in that the partition is designed to stop against the underside of the continuous ceiling. The system does not attempt to organize the overhead services other than to have regularly spaced branch stubs located in what are referred to as "Black boxes", from which the services feed down into the patient consoles.

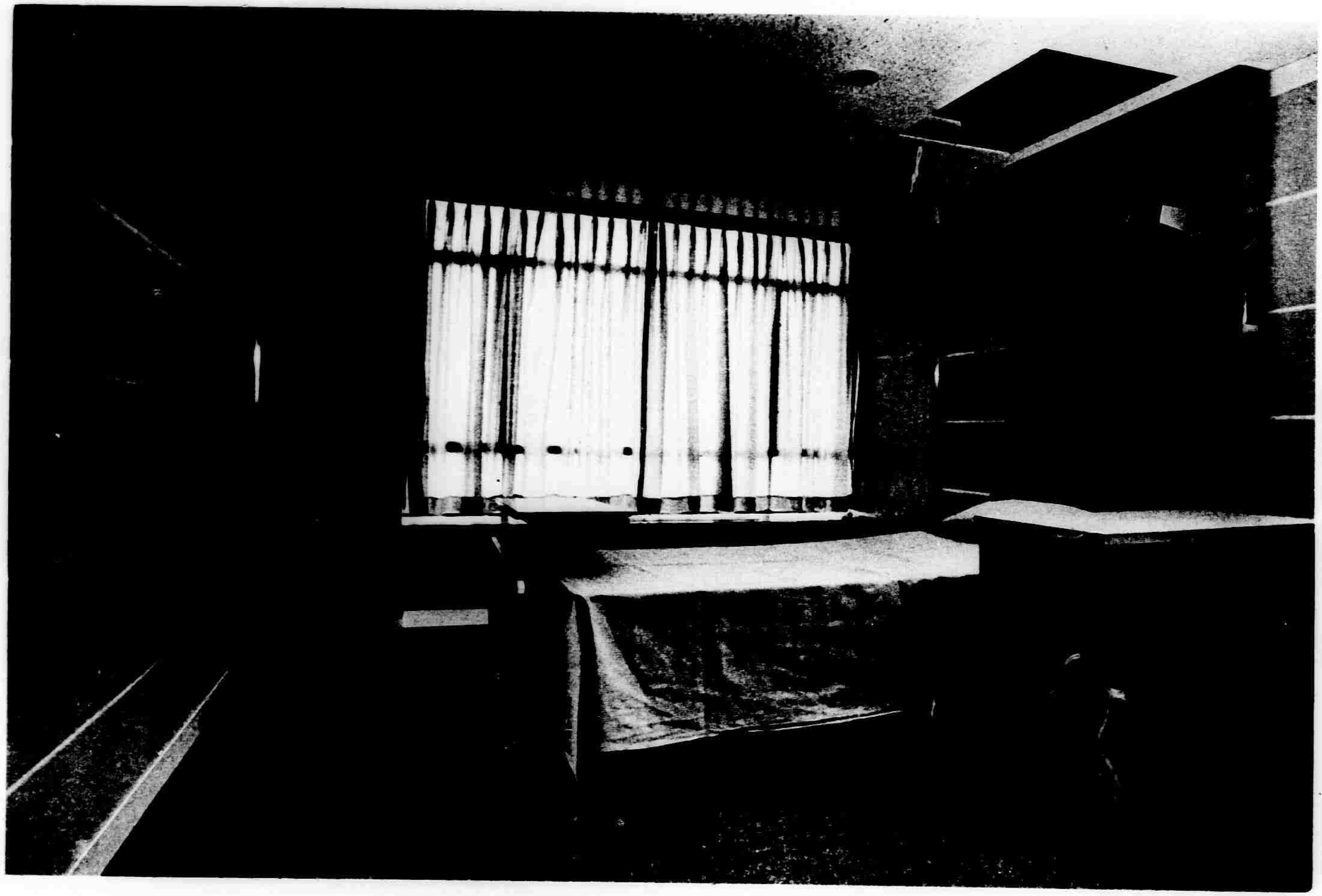
Partitions

The walls have been the center of attention from the start of the research and have passed through three phases.

First (1965) was an eight inch thick wall, with certain patient services built-in. A building system was not attempted at this point.

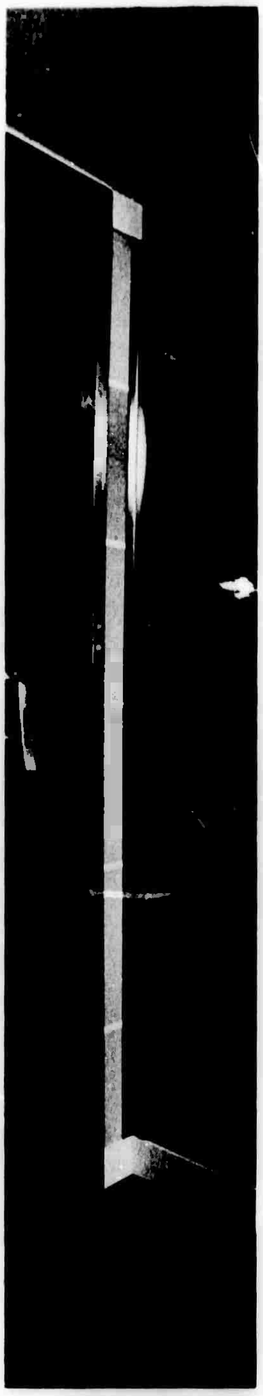
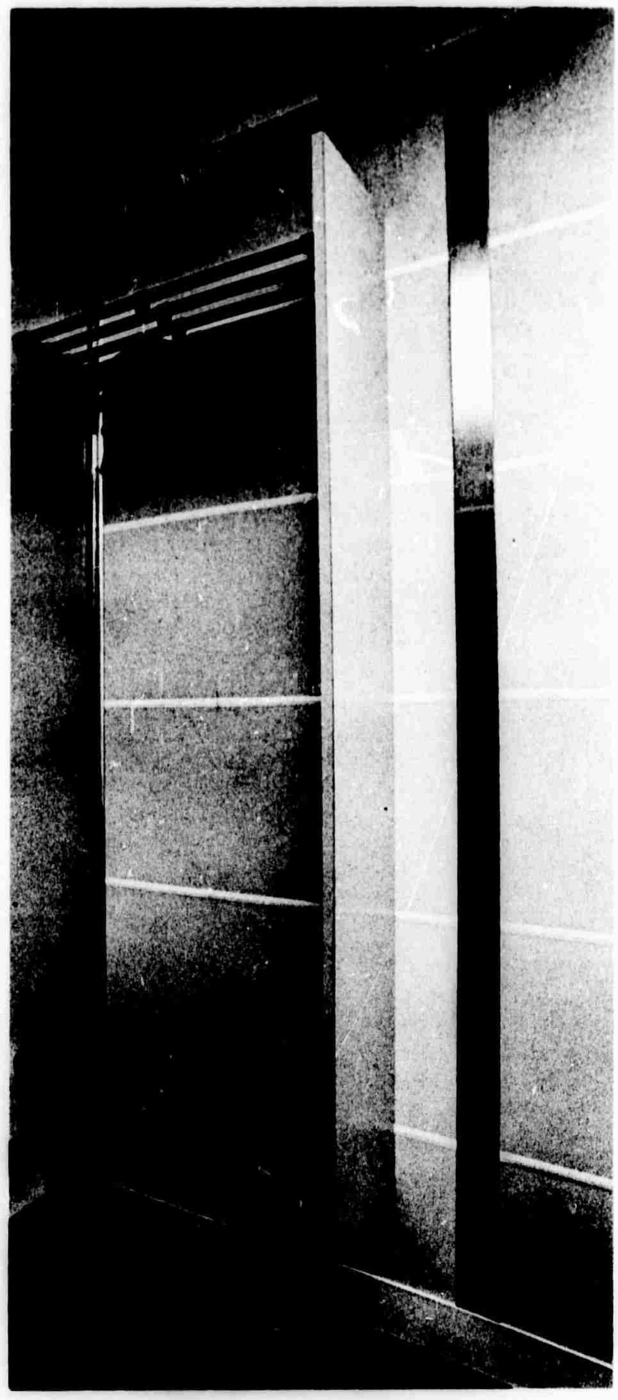
The second stage (1967), was a proposal to build up the wall by horizontal panels stacked on top of one another. To keep the panels from falling over, all walls were to be designed L-shape or U-shape in plan. The panels were 2" thick lightweight sandwich panels held together by vertical tension rods which were stabilized at the floor and ceiling by expanding friction shoes. Horizontal patient consoles could be built into the wall in horizontal units which match some of the dimensions of the wall panels. Each panel was edged with a neoprene seal. However, the wall had an unacceptable fire rating under the new Hill-Burton standards for non-load bearing walls introduced in December 1968, and would have been inadequate in terms of acoustic separation. More significant yet was the unreasonable constraint imposed on the plan by the necessity to always have a bend in each panel.

The third version was developed with the aid of a Public Health Service grant and was installed in Presbyterian Hospital. It retains the horizontal panels, but the construction is now solid gypsum to achieve

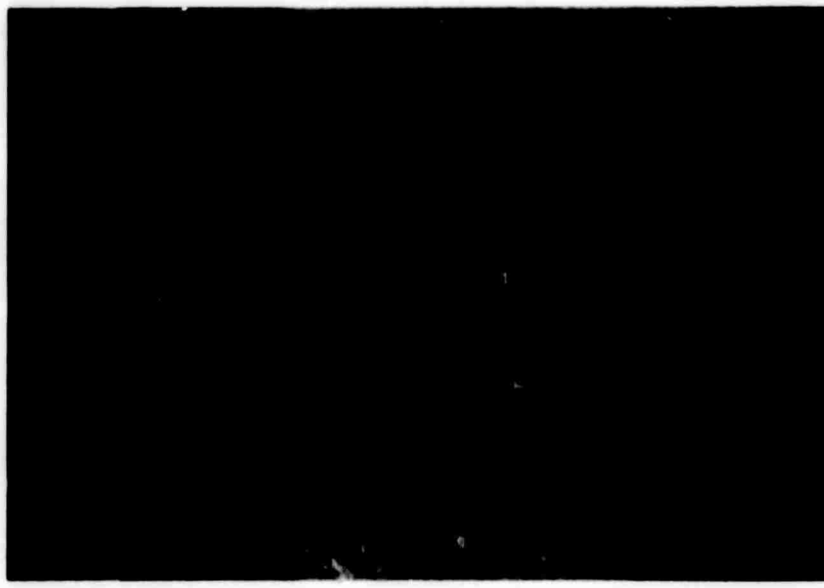


THE ADAPTABLE BUILDING SYSTEM - Patient room at Presbyterian Hospital showing wall panels, patient console, and ceiling. Ceiling panels are shown removed for access.

(All Photographs courtesy of James Patterson.)

THE ADAPTABLE BUILDING SYSTEM - Full height view of wall panels, showing stainless steel plate covering flat vertical joint, and stainless steel angle for corner joint. Cover of head and sill joints is moulded plastic and is notched by knife to fit over vertical plate. Wall hung wardrobe is part of a line of accessories under development.



THE ADAPTABLE BUILDING SYSTEM - Junction of horizontal and vertical joint in horizontal wall panel system. Horizontal joint is covered by snap-in plastic cover; vertical joint is covered by stainless steel plate screwed on.

THE ADAPTABLE BUILDING SYSTEM - System being installed at Presbyterian Hospital, Dallas.

acceptable fire and sound standards. The panels are 16" high x 2" thick straight sections (i.e., the bend is eliminated) of varying lengths. Each horizontal joint incorporates two steel splines, an asbestos blocking strip and two plastic snap-in cover strips. The walls are inherently unstable in this form and so must be supported at the ends of each panel by metal angles or by a 2" wide slot cast into the permanent structure. Because the panels are not long enough to extend the full length of a normal patient room, a vertical joint is needed, this time covered on both sides by a flat stainless steel plate from floor to ceiling. A primary reason for using the horizontal panels was to avoid imposing any lateral load on the ceiling, which does not have the rigidity to resist such loads.

Ceilings

The ceiling is a conventional lightweight "Fireguard" sound absorptive tile, hung from above. The ceiling forms a continuous surface, the partitions stopping at the underside. The ceiling has a one hour fire rating.

Patient Console

The console is a room height panel 4 feet wide and projecting from the wall 4 inches. The purpose of the console is to provide an accessible unit for bringing patient service lines (electricity, communications, oxygen, vacuum, etc.) down from the ceiling into the room without going into the wall. Services in flexible cables or in flexible tubing are pulled through from the ceiling into three raceways down each of the two sides. The rest of the console is mainly empty. The raceways are screwed to the partition. The face panel, which is removed by release of a snap lock, is

3/4" plywood faced with plastic laminate and weighs about 60 pounds. A patient light is fixed to the panel over the bed.

Bathroom

The bathroom is a modification of a standard moulded fibreglas unit by Crane Corporation. The standard unit was designed for apartments. Changes for hospital use were incorporated such as grab bars and a seat in the shower.

C) EVALUATION

The main virtue of the partition system is that the dry construction minimizes noise, mess and disruption. This would be true of most other panel systems as well.

There is little benefit from using horizontal instead of vertical panels and many disadvantages:

a) The promoters of the system have observed that "only" seven lengths of panel were needed to fit out the whole suite. What should be obvious is that vertical panels would require only one length, and, assuming a modular plan grid, only one or at most two widths. The seven lengths are not even necessarily all the lengths that will ever be required, either; another job may require another seven. Besides being an unnecessarily large number of different lengths to make initially, the different lengths will have very little potential re-use, whereas standard height panels would have high re-use.

b) The necessity for stabilization against toppling introduces special end conditions, which means that preparation for partitions must be made at the sides as well as at the top and bottom. Where the partitions meet the permanent structure, this requires special construction, either in the way of a slot in the wall or a method of fixing the steel angles to the concrete. By contrast, vertical panels need to be fixed at top and bottom only.

c) The horizontal joints are said to be useful for hanging equipment from the wall. But if joints are to be used for this, then vertical ones would be more useful, since it is usually more important to be able to make vertical height adjustments than horizontal.

d) A horizontal joint is potentially more of a collector of bacteria than a vertical joint.

e) There are, if we may so describe them, three hierarchies of joints necessary with this system -- first, the horizontal joints between panels; second, the vertical joints at the ends of the panels; and third, the horizontal joints at the floor and ceiling. Each has its own kind of cover strip, one overlapping another where they meet. This creates detail problems for the junction of the 2nd and 3rd strips, which so far has only been resolved by notching the ceiling and floor strips by hand. This is not laborious, but it is not a neat solution. With vertical panels, there would be only two hierarchies of joints, so that the problem would not arise.

f) The slots cast into the permanent structure impose limitations on layout, i.e., there is no point in having panels that can be moved if they always need to meet the exterior wall at a fixed location anyhow.

g) Although services can feed from the console, services cannot be incorporated in the partitions. This limits the usefulness of the partitions for support of equipment, since much equipment requires electricity. For instance, despite the wall being especially designed for support, the TV's in each room must be supported from the ceiling, inches away from the wall.

Ceilings

The ceiling has the virtue of being continuous (i.e., not penetrated by partitions), which simplifies patching when walls are removed. In addition, the tiles are cheap and easily replaced. Although the tiles are lightweight, the transmission of sound from room to room has been tested and an STC of 45 db has been obtained, which is acceptable.

Patient Console

It is a disadvantage for the 4 inch projection to be where the bed is, since the clearance at the end of the bed is the critical one for determining room widths -- i.e., a projection might be acceptable anyplace except at the bed.

The unit is so large considering the little it is used for that it is reasonable to look for ways of either increasing its usefulness or decreasing its size. The two sides, where all the service outlets must be located, are inconveniently small in comparison to the overall unit. It is using a sledge hammer to kill a fly. The concept of using the sides instead of the face is questionable as well. (These and other points are taken up further in the section on the Electro System Patient Units.)

Since the partition panels are horizontal, it would be difficult to run vertical services through them, but it is worth noting that if the panels were vertical, the console might have been integrated with them, perhaps with less projection from the wall, or perhaps in a more convenient location.

Bathrooms

The bathroom is a step in the right direction; but so far the realities of volume manufacturing and production have prevented a satisfactory answer. A hospital bath needs to be specially designed, and adapting an apartment bathroom so far has problems. Such features as a wider doorway (to allow patients to be assisted) were not able to be incorporated, and a particular difficulty was that units are made in one hand only (i.e., the right but no left), with the result that patient rooms which were intended to alternate in order to get back-to-back plumbing and other advantages were obliged to have less convenient plumbing and some special fitting. Efforts by others are being made to use pre-fab baths, and perhaps some of these problems will soon be overcome. The critical factor here is being able to guarantee sufficient volume to persuade industry to produce the needed units.

D) SUMMARY

Despite several years of development, the system is still very limited.

The most disturbing aspect is the lack of any system to it -- special lengths, special end conditions, special plumbing, special joints, etc. Each problem seems to have been solved on an ad hoc basis with little integration of the whole.

Perhaps it was the limitation of scope which limited the development of the individual components, i.e., the walls have been the main area of concentration, yet a much better wall might have been developed if the developers had been willing to consider also improving the ceiling to restrain the wall. This is the nature of the integration of systems.

Texas A & M is now carrying out a program to evaluate their system, and their conclusions will be awaited with interest. Parts of the system may find some application in renovation work, but on the whole the system is less flexible than selected existing products.

ELECTRO SYSTEMS "MULTI-WALL" PATIENT UNITS

Manufacturer & Developer: Electro Systems, Inc., Richmond, California

President: Ronald Meyer

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A) Background

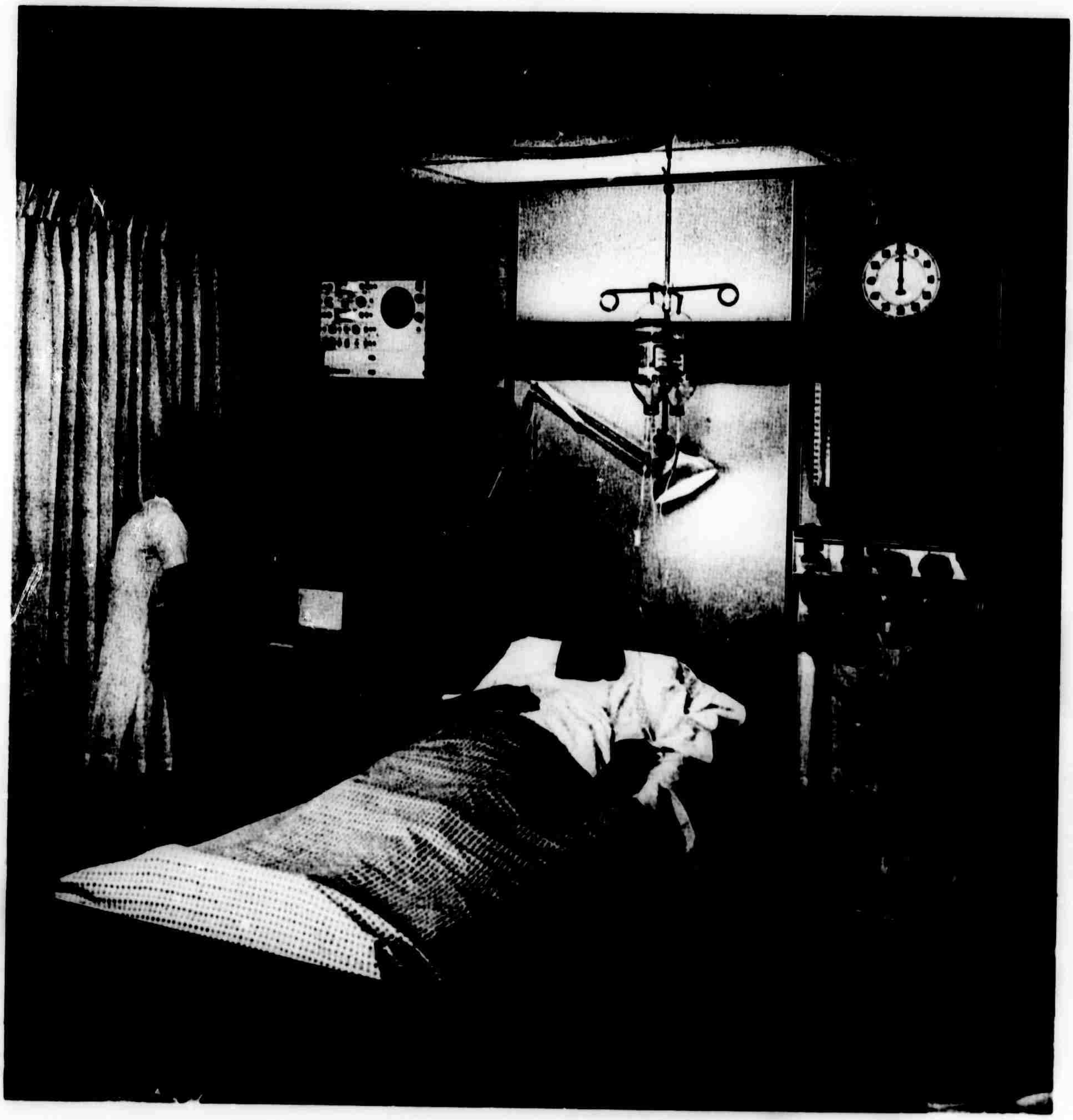
These units are currently in production and have been installed in many hospitals, though no military hospitals to our knowledge. Until recently, the company was the only one manufacturing anything like this, which made a problem for government contracts, since competitive bids were not possible.

B) Description

The company produces a dimensionally coordinated range of different components for different units. These can be assembled in a large number of different permutations, and accessories. The range is seemingly capable of incorporating neatly and elegantly any light equipment which might be associated with any level of patient care. They can be surface mounted on existing walls or built-in flush with new construction.

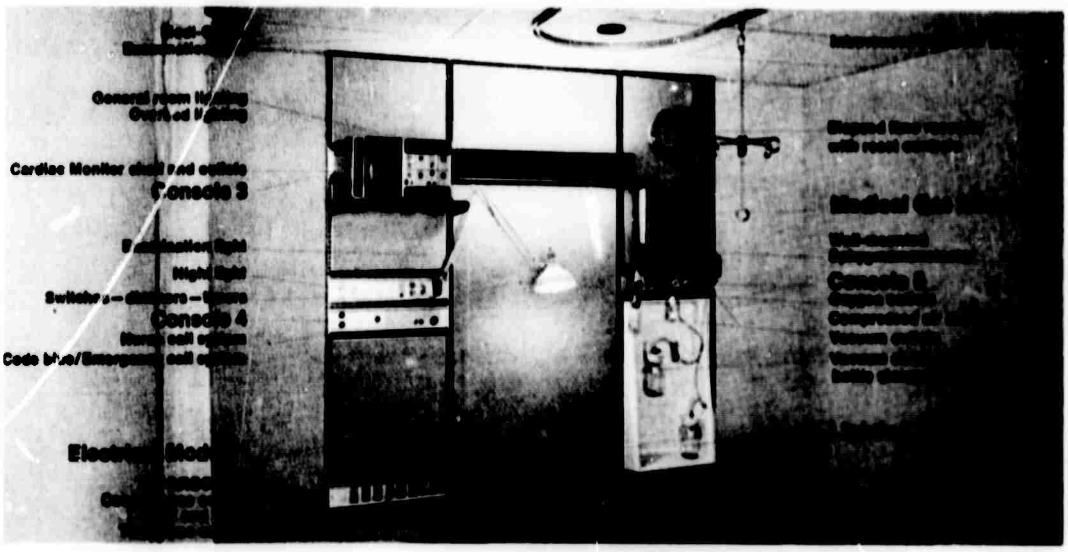
Panels are a standard 4" deep, and 1'-7½", 2'-0", 2'-0½", 3'-3", or 4'-3" wide, with variable heights extending from the ceiling to near the floor. Panels are faced with plastic laminate and are removable for access to .

The simplest unit is the "General Patient Surface Mount", which is a panel for basic medical, electrical and communications services, plus lighting fixtures.

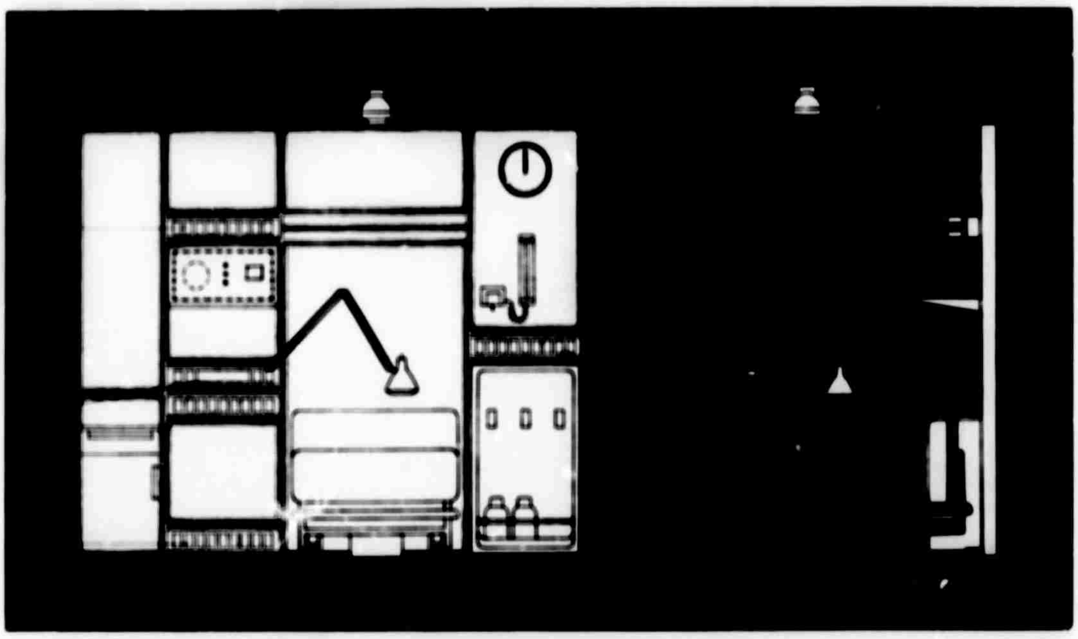


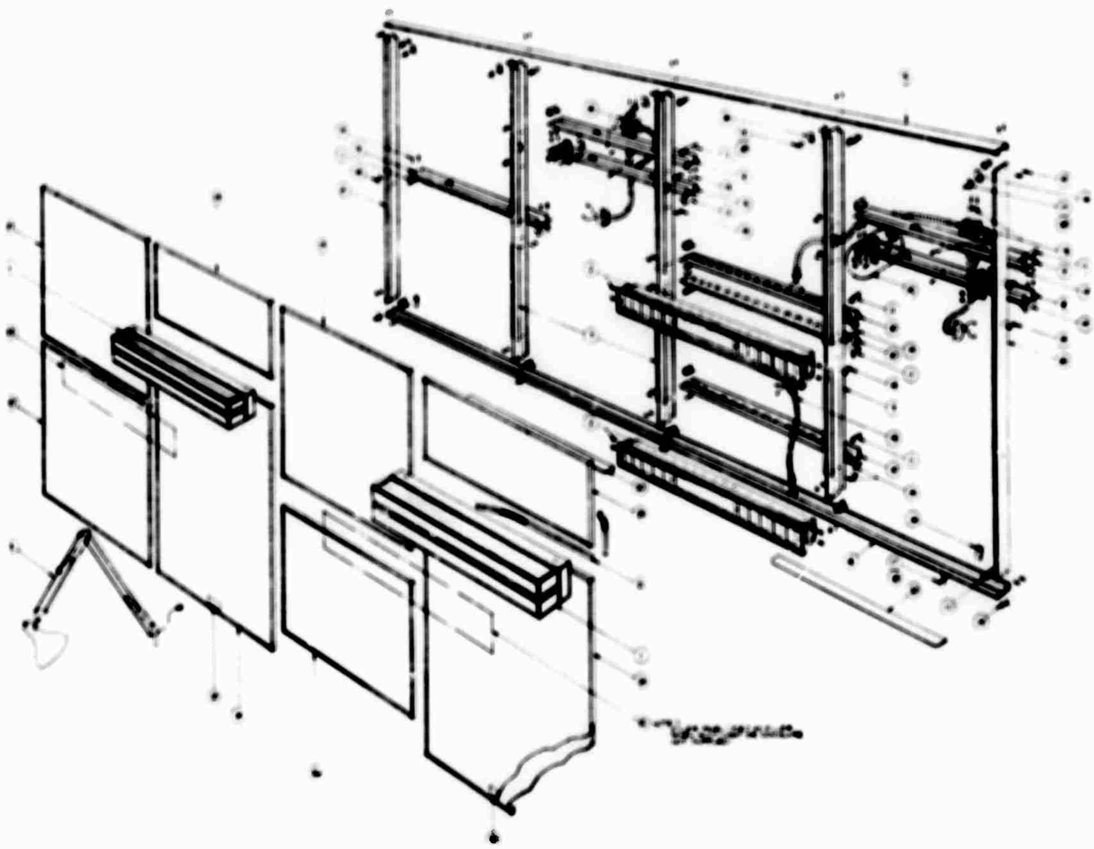
ELECTRO SYSTEMS "MULTI-WALL" - Intensive care unit in use. Included are electric module, lighting module, medical gas module, patient cabinet module, lamp, elapsed time recorder, sphygmomanometer, intravenous arm assembly, and Medi-quartz examination lights.

(All photographs and drawings courtesy of Electro Systems Inc.)



ELECTRO SYSTEMS "MULTI-WALL" - Mock ups of system. Above: Intensive care unit. Below: General patient care unit.





ELECTRO SYSTEMS "MULTI-WALL" - Top: Elevations of one version of intensive Care unit surface mounted.

Bottom: Exploded view of general patient care unit, showing face panels and interior works.

The most complex are the Intensive Care units, which may be several panels wide for the full height of the wall. An example of items which may be incorporated into the wall are general room lighting, cardiac monitor shelf and outlets, examination light, night light, switches, dimmers, timers, nurse call system, code blue/emergency call system, 110 V. and 208 V. electric outlets, telephone outlets, clock or elapsed time recorder, reset controls, sphygmomanometer, oxygen outlets, compressed air outlets, vacuum outlets, vacuum slides, and bottle storage unit. Cabinets, and even the proverbial kitchen sink may also be included.

C) <u>Evaluation</u>

This is a highly sophisticated unit with great flexibility. It can be installed with benefit in new or old hospitals. The system of standard panels also makes it possible to change the system after installation, and to integrate new services and facilities as they are developed.

In view of the increased awareness in recent years of the importance of environment in maintaining positive attitude among patients, it is fair to note that the sophistication and presence of electronic equipment are re-assuring to patients that they are getting special care.

Because the "Multi-Wall" units and the patient console of the "Adaptable Building System" (Texas) are providing some of the same services and for the same purposes, it is natural to make some comparisons between them.

Removal of "Multi-Wall" panels for access is relatively simple because all panels which normally would be removed are accessible and are of a size easily handled by one man. This contrasts with the Texas System where the only panel to be removed is behind the bed, is 4' wide by room height, and in addition has a large light fixture mounted on it.

The services are also well located on the Electro unit for convenience of patients and staff. They are on the face of the unit where they are clearly visible and easily reached. On the Texas console they are on the sides where they are less visible and less accessible.

In the simpler "Multi-Wall" units there is no loss of space behind the bed, all of the unit being above or to the side of the bed. In the intensive care units space is lost behind the bed, but for no more than the depth of the rest of the unit. In other words, the last place from which space is lost is behin the bed. This is again in contrast with the Texas system, in which space is taken away only at the place where it is most needed.

D) Summary

The "Multi-Wall" system is functional and elegant and has already received market acceptance. It should be possible to integrate it with other hospital subsystems, such as walls, ceilings, etc.

We are not in a position to evaluate its "value for money", although the manufacturers naturally state that it is "economical."

C) MODULES

The different uses of the word module are distinguished in Section 3, under Modular Coordination. The reference here is to three dimensional, factory-fabricated, room-sized boxes.

Modules have in the last three years become a very popular concept. Relatively few have been built, but an enormous number are planned, expecially in housing. Small repetitive spaces and low intensity of mechanical services are implicit in modules. For example, the ideal use for modules would be a high security prison.

The theoretical virtue of modules is that rooms and other spaces can be made in a factory and quickly plugged into a master structure on site. Limitations on their usefulness in hospitals stem from the variety of different spaces required and from the constraints which the small spans impose on planning and flexibility.

These systems are:

1. "SUSPENDED ENCAPSULATION" - Proposal for use on Olin Health Center Annex, Michigan State University.

2. ELECTRO SYSTEMS "MODULAR MEDICAL STRUCTURES", Electro Systems, Inc., Richmond, California.

"SUSPENDED ENCAPSULATION" - Proposal for use on Olin Health Center Annex, MICHIGAN STATE UNIVERSITY

Dr. Robert Schuetz, Project Director

Principles employed were developed and patented by Christian Frey of Suspended Structures, Inc., of San Francisco.

Ralph Calder & Associates, Detroit - Architects

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A) BACKGROUND

This is a proposal to build hospitals utilizing suspended disposable modules. The Health Center Annex is to be a "feasibility and demonstration project" and is regarded as experimental.

The project was started in 1966. It has received a $437,572 grant from the Public Health Service -- $188,572 for research and design, and $250,000 to offset some of the construction costs. The promoters of the project are trying to raise further funds to make possible construction of the 18,000 square foot Annex. They would like, if possible, to raise money from firms who might be involved in the production of the project.

According to Hospitals, Feb. 1, 1970, construction was to have begun in Spring, 1970, with completion in three months.* However, as of June 1970, finance is still needed and only preliminary architectural drawings

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* Robert D. Schuetz: "Suspended Encapsulation" - Hospitals, Feb. 1, 1970, Vol. 44

have been made. Union agreement has been obtained to cooperate when the work goes ahead.

B) DESCRIPTION

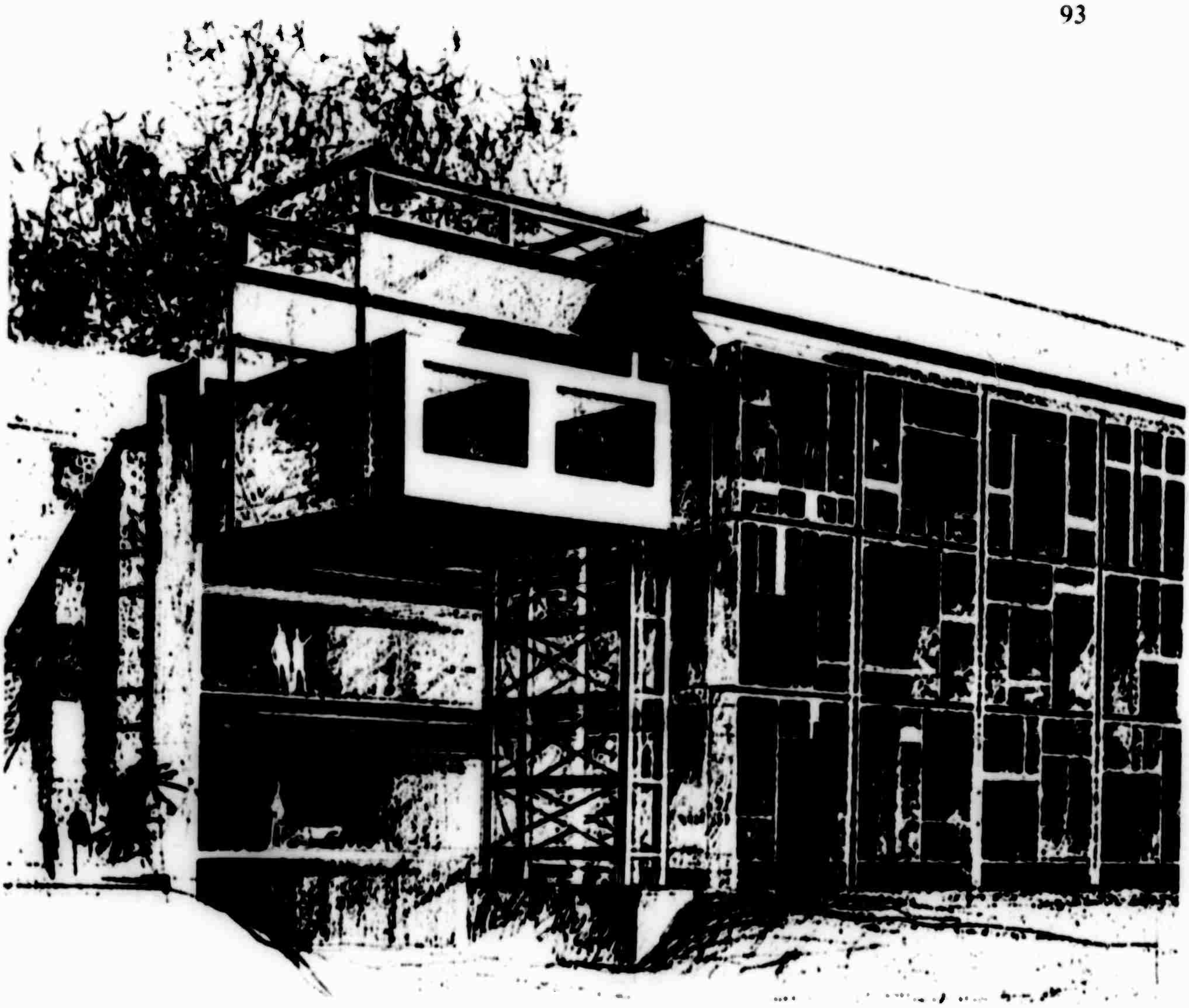
In this concept, disposable modules would be hung from a permanent structure. This is an expression of a basic principle of flexibility: Separation of permanent and non-permanent elements. An essential difference however is that in this case much more is considered disposable -- the ceilings, floors, exterior wall, and some services.

The concept is an amalgam of three different ideas, any one of which could be utilized without the others:

a) Prefabricated modules
b) Suspension type structure
c) Replacement or disposability of parts.

It is useful to deal with these separately, so that those aspects which have some validity need not be rejected just because of flaws in other aspects.

a) Prefabricated modules - Current plans call for the fabrication of 16' x 12' steel framed modules which would be used in pairs to form 16' x 24' units. The sides would be shear walls. Several inches of space would exist between modules. The joints at the exterior wall are to be weatherproofed with a joint cover related to expansion joint technology.



"SUSPENDED ENCAPSULATION" - Sketch of intended method of installation of modules at Olin Health Center Annex, Michigan State University.

(Sketch from Schuetz, "The Hundred Billion Dollar Question."

b) Suspension type structure - The annex is to be a three story building, five modules wide. Each of the five stacks of modules will be suspended from above on four steel bars, approximately 1" x 3" in section. The support structure will be two steel towers bridged by steel trusses from which the modules will hang. Details of the method of placement are still uncertain; as it stands, each 16' x 24' unit will probably be raised individually. Some method of adjustment of modules in place will be necessary to compensate for progressive deflections in the support structure and in the steel bars as more modules are added. In addition to vertical support, the modules will be connected laterally.

c) Replacement or disposability of parts - The developers state simply, "Any module can be removed or replaced. Any section of a hospital could be replaced by a different kind of section at any time."* Current published material does not explain how this is accomplished, and as pointed in the next section, replacement of modules presents a number of important problems.

C) EVALUATION

The scope of the Michigan system is limited to essentially a structural principle and does not begin to show how the really complex problems of integration of services can be dealt with, or how this would streamline the planning and decision making processes of hospitals. It so far focuses on certain aspects of production and erection of certain parts of hospital buildings, but no material is available yet on how it will deal with the central problems of hospital building. Some of the detailed questions will no doubt be resolved if the pilot building for Olin Health Centre goes ahead.

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* Schuetz: Ibid.

"SUSPENDED ENCAPSULATION" SYSTEM - Top: Sketch of complete appearance of Olin Health Center Annex.

Bottom: Sketch of proposed large scale application of system. Text questions benefits of the concept in general and suitability to hospitals in particular.

However, regardless of how some of these potential problems are resolved, there are still serious questions about the viability of the basic principle for application to hospitals. This critique, therefore, limits itself to responding only to what has already been published on this. This is particularly relevant since all three of the concepts (3-d modules, suspension structures, and disposability) are currently popular and have at least some virtue in the appropriate circumstances. What is at issue here is their general applicability to hospitals.

Since the three concepts are not interdependent, it is convenient to examine them separately.

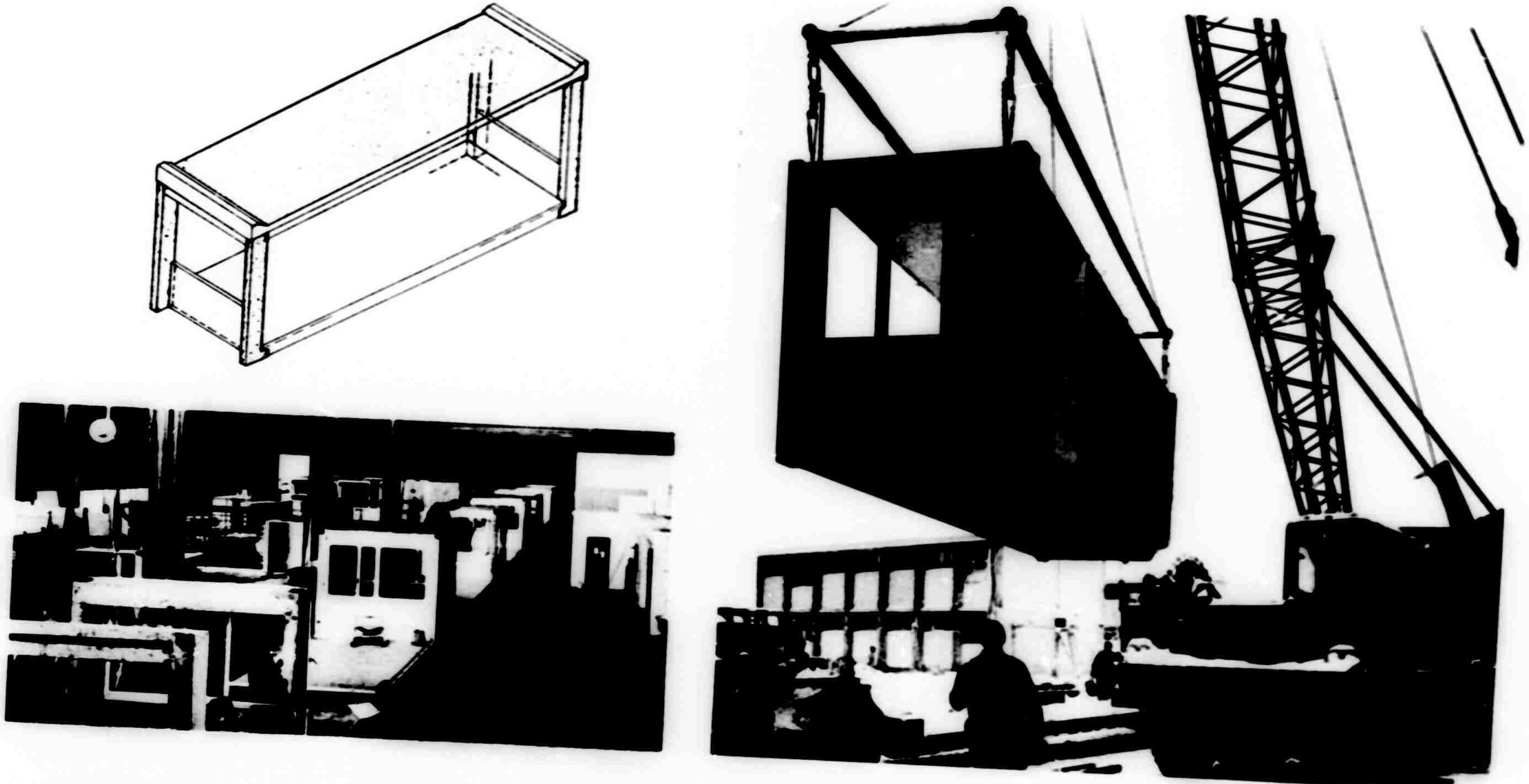
Prefabricated Modules - The main virtue of the Michigan concept is the factory fabrication of the modules which should make possible the rapid erection of buildings, since modules will be delivered to the site largely finished inside. There are economies and efficiencies that can be realized in factory conditions, as well as quality control. If there is enough repetition of elements, assembly line techniques may also be applied. For hospitals, this could apply only to patient rooms and baths, which occupy only 20 - 25 percent of the total area. This will be useful, but the remaining 75 - 80 percent of the hospital would have to be produced on a more individualized basis.

The chief difficulty with the Michigan module is inflexibility. Future rearrangement is limited by the side walls, which are to be used for shear, so that no more than doorway openings may be cut in them. The walls could as well be bearing walls, for all that can be done with them.

With some modification, the problem could be mitigated, but inflexibility to some degree is fundamental to all modules, since something always must hold up the ceiling. These supports will be a permanent part of the module. Columns therefore must occur at least at the sides of each module. If, as is usually the case, the module is fabricated off-site, the width and therefore the spacing of these supports will be limited to 12' or 14' by highway regulations. Site fabrication could alleviate some of these problems, although site factories can rarely operate as efficiently as permanent, fully mechanised factories. Since the ceiling usually wants to be relatively light, long spans in the other direction are also unlikely. Even in the best of circumstances, therefore, there are too many columns.

One of the most advanced efforts in this direction is the Swiss Variel system which produces a basic precast concrete frame module in which only the four corners have columns. (See illustration.) The length of the modules, and therefore the internal clear span, is so far limited to 32' but could presumably be more. Column spacing in the other direction is still limited by width. However, the use of deep beams in both the floor and the ceiling is redundant structurally and limits the clearance for services. The problems therefore are not easily overcome.

By contrast, in a conventional long span structure, these are not problems because the ceiling is hung from the floor above. The frequent supports therefore occur only in the service space, where they are not in the way. Interior joints can be a problem. Walls on modules minimize the



"VARIEL" CONCRETE MODULE SYSTEM - Basic module, factory production line, and site installation. Structure is unique in consisting of floor, ceiling, and four columns only. However, length presently limited to 32', and height is also fixed. Module nevertheless demonstrates some charach-teristics that would be required for a module system if it were to be capable of general application.

problem because the joints are not exposed and therefore will not have to be covered. But fixed walls make an inflexible building, so to be useful, walls will be removable, and modules will have to have joints in floors and ceilings that will be flush, neat, leakproof surfaces that do not collect dirt and bacteria and will not inhibit the relocation of other walls. This will be physically possible, but to allow for tolerances of less than $\pm \frac{1}{2}$" would be unrealistic. Total tolerances must allow for the cumulative effect of errors in the support structure and in the module, plus installation clearances, plus expansion and other movement.

Exterior joints are also a problem. The problem there is to make joints which are waterproof, windproof, heat insulated, movable, and durable. The way the modules are moved into position will affect the kind of joint used. Creation of a good joint is possible of course; it is simply more difficult than joints on buildings put together conventionally.

Suspension type structure - in recent years, suspension type buildings have received much interest, and several have been built, removing some of the burden of experimentation.

Although the demonstration building at Michigan State is low (three stories), the publicity stresses tall buildings, so both are discussed below.

There is an element of redundancy in the suspension concept -- that of building a conventional compression type structure all the way to the top, and then building another structure in tension all the way back down again.

However, there are so many variables in any one situation such as soil conditions, local prices, site restrictions, materials availability, etc., that it is impossible to generalize about the efficiency of the concept in the abstract. As we have observed, the **cost** of the structure itself tends to be less significant than the effect of the structure on planning and other considerations.

In this case, the concept does impose significant constraints on planning. Any suspended part of the building must somehow be related to a support structure nearby. If the building is a tower, and the support is the core, then the core is obliged to be at or near the center. Symmetry is the ideal. Yet a nursing tower may work better with the elevator core taken out of the center. If the building is low and spread out, more problems are imposed, since the support structure must cover any area which is to be used for hospital space. It is hard to see how such trusses and other support structures would have advantages over simple concrete foundations. This point applies to the three story Olin Annex as well.

What is the gain? Many advantages of suspension are claimed, but not all of them stand up to scrutiny.

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* "The $100 Billion Question" - Michigan State University Institute of Biology and Medicine - Principle Investigator, Robert D. Schuetz

One of the initially more plausible of these advantages is that the base of a suspension building would occupy only part of the land under the building, "freeing the land area for other uses." However, as the discussion on horizontal planning indicated (p. 49), the functional relationships within a hospital currently tend to create plans in which 2/3 of the building is in the base floors and only 1/3 in the tower portion. The basic needs of a hospital, therefore, are not a small base with lots of land around it, but a large base with very direct and convenient access at several different places.

One advantage sometimes suggested for suspension structures is that less floor area is taken up by tension cables than by columns. This is not significant for two reasons:

1) The same fireproofing is needed for tension members as for columns, which builds the dimensions out to a considerable size, and
2) The size of the element on the plan is not the problem. A thin cable or a fat column both have the same effect on planning -- rooms and spaces must be planned so that structural elements are not in the way. It is the spacing of these members which matters, not the size.

On the other hand, the problems of suspension structures are very considerable. Most or all are capable of solution, but the solutions are often complex and highly technical. For instance, as the building is progressively loaded at each floor, the tension straps stretch, while the core compresses. The cumulative effect is that the bottom of the tension elements will move downward relative to the base element. This amount of movement must be calculated very accurately in advance. Whereas in a simple structure (e.g., a beam) one makes an allowance for the maximum live load, and designs for that, in this situation the actual live loads must be known. If too much is allowed, then stretch is not adequate, and the floor of the supported space will not line up with the floor of the core. If not enough is allowed, the reverse happens, and again floors do not match. This kind of re-action is difficult to predict, especially since the actual live load changes, even from day to day. Of course special adjustments may be built in, but these adjustments must apply to everyone of the cables equally. In a large building, there could be hundreds of these. Perhaps individually graded adjustments could solve this (etc., etc.). The point is that the situation is inherently complicated, to the degree where the solutions to some problem areas create problems in other areas.

In sum, we see no significant advantage in suspension buildings for hospitals. Whatever else is true of suspension, it is more complicated than conventional construction. In a hospital, the last thing we want is extra complications, especially on an element (the structure) which could be relatively simple.

Replaceability - Another advantage claimed is, "Rapid and economical inter-change of parts. Any modules can be removed and/or replaced."* It is hard to see how the system, as it has been developed so far at the Olin Health Center, can support this claim.

*Michigan State University - Ibid.

As the system is now outlined, this could only be accomplished with enormous cost and disruption, and would impose unreasonable restraints on planning. Yet because the question of change in a hospital is critical, it is perhaps the area to which most serious thought should be given. The concept of replacing modules has many difficulties, especially for use in hospitals.

Since the modules would have to be removed in the reverse of the way they were installed, they would in this system be lowered to the ground from above. This might work for those modules on the bottom row, but for any above that, all the modules below must first be removed, disrupting operations on each floor. If a module at the top is to be removed, operations on every floor would be affected.

Obviously such a procedure is unacceptable, and the suspension method of support for replaceable modules is impractical. If replaceability is to be achieved, what about another method of support?

Some of the Operation Breakthrough housing proposals suggest modules set into rigid steel or concrete framework, and hope to be able to replace obsolete modules with new ones from time to time. The basic difference here is that modules would be set into place horizontally, as drawers in a chest, a concept first suggested by the Swiss architect LeCorbusier over 40 years ago. For hospitals, this application would be limited primarily to the tower portion. If there is no tower, then the application is very limited indeed, since only those parts of the of the building which have exterior wall can be replaced without displacing other parts. Yet the major portion of hospital space tends to be internal. How for instance, in a four story block of construction 400' wide by 300' deep, can a module on the second floor and 100' from either exterior wall be removed without destroying the building? Courtyards and other devices could help, but it should be apparent that the difficulties of providing replaceability would begin to exercise an undue degree of restriction upon the plan of the building.

Lowering modules from above, which incidentally is the simplest, quickest, and cheapest method of installation, would make some differences, but the problem of replacing internal modules would still hold true.

Therefore, if any of these replacement methods were to be employed, it would for practical purposes be limited to spaces on the exterior of the building, which would in most cases mean the patient rooms. Yet these are precisely the spaces with the least requirement of change.

A final obstacle to module replacement is that a great deal of technology would be required for the large number of special connections that are involved. All services and structural supports must connect and disconnect easily. Access to each of these must be provided. Provision for movement into and out of place must be made. The technology can be developed, but the cost must be added on.

The concept is essentially an effort to achieve flexibility, and the principle involved is separation of fixed and unfixed elements. But compared to the use of interstitial spaces, the amount of unfixed, removable elements is enormous. Whereas in an interstitial space the floors, ceilings, exterior walls, and distribution lines all remain, any change of module means replacing everything except the structure and some of the most basic services. In order to remove some elements which are obsolescent, a large amount of completely adequate construction must also be removed. Although some re-use of modules might be possible, the concept appears wasteful.

D SUMMARY

The Michigan State project offers three concepts potentially desirable for military hospitals - suspended structure, replaceability, and prefabricated modules. The suspension concept introduces a number of design constraints which are going to be difficult to overcome. The concept of easily replacing modules does not stand up to scrutiny; although some replacement might be facilitated, exploiting the concept imposes additional constraints on the building configuration. The idea of using modules does have some promise, particularly when a temporary building or quick addition is needed.

The concepts embodied in this project, therefore, introduce more problems than they solve. The project is, of course, experimental, and experience may provide some solutions, but at least for the present there are better alternatives for construction of military hospitals.

ELECTRO SYSTEMS "MODULAR MEDICAL STRUCTURES"

Manufacturer and Developer: Electro Systems Inc., Richmond, California

President: Donald Meyer

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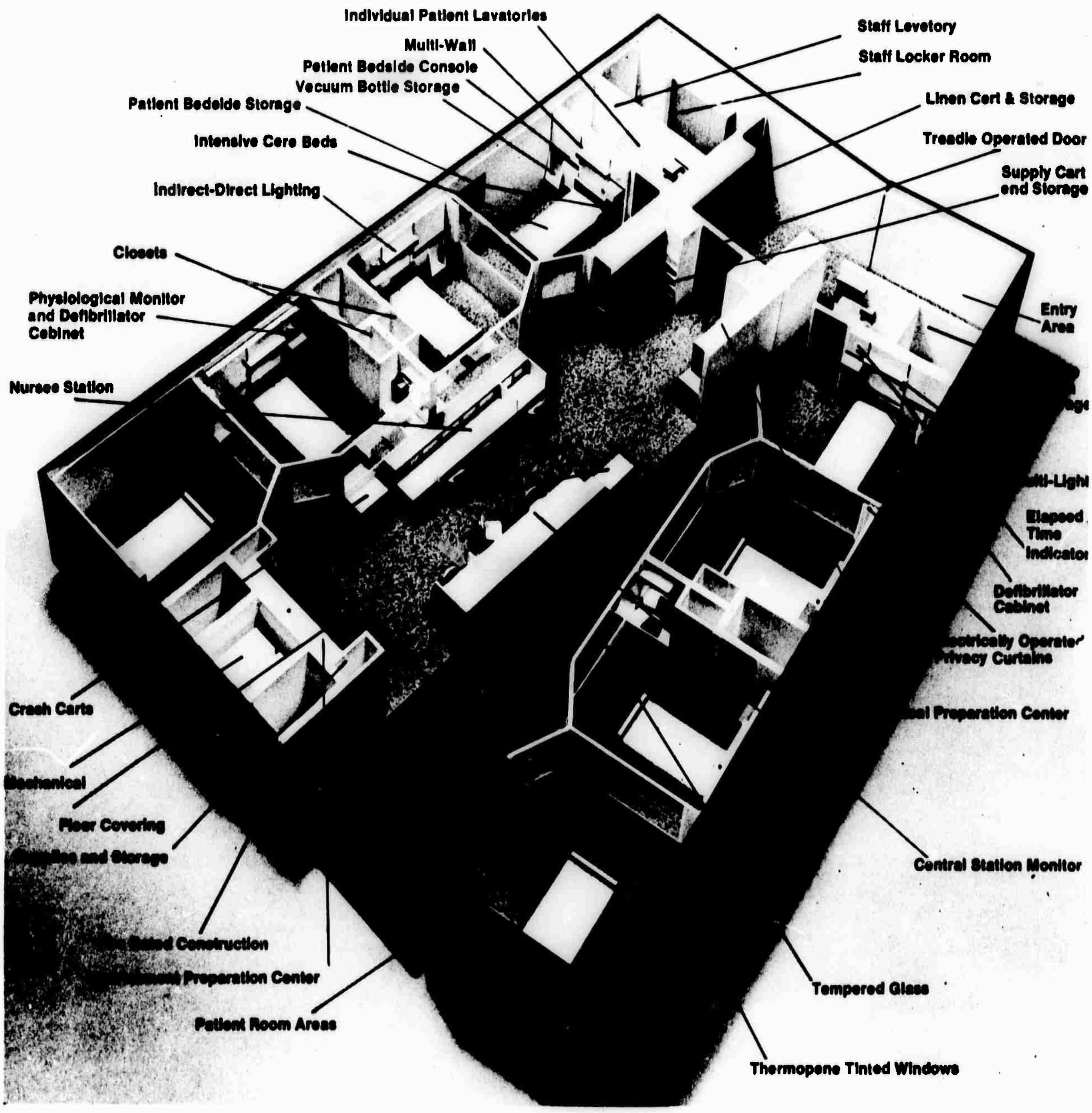
A) BACKGROUND

Electro Systems is developing a family of one story high modules for additions and temporary buildings for hospitals. A 36' x 60' eight patient coronory care unit consisting of three 12' x 60' modules was installed as an addition to Cedars of Lebanon Hospital, Miami, Florida. It opened in December 1969 and is leased for six years until the new hospital building program is complete. Different units can be designed for labs, clinics, ICU's, etc.

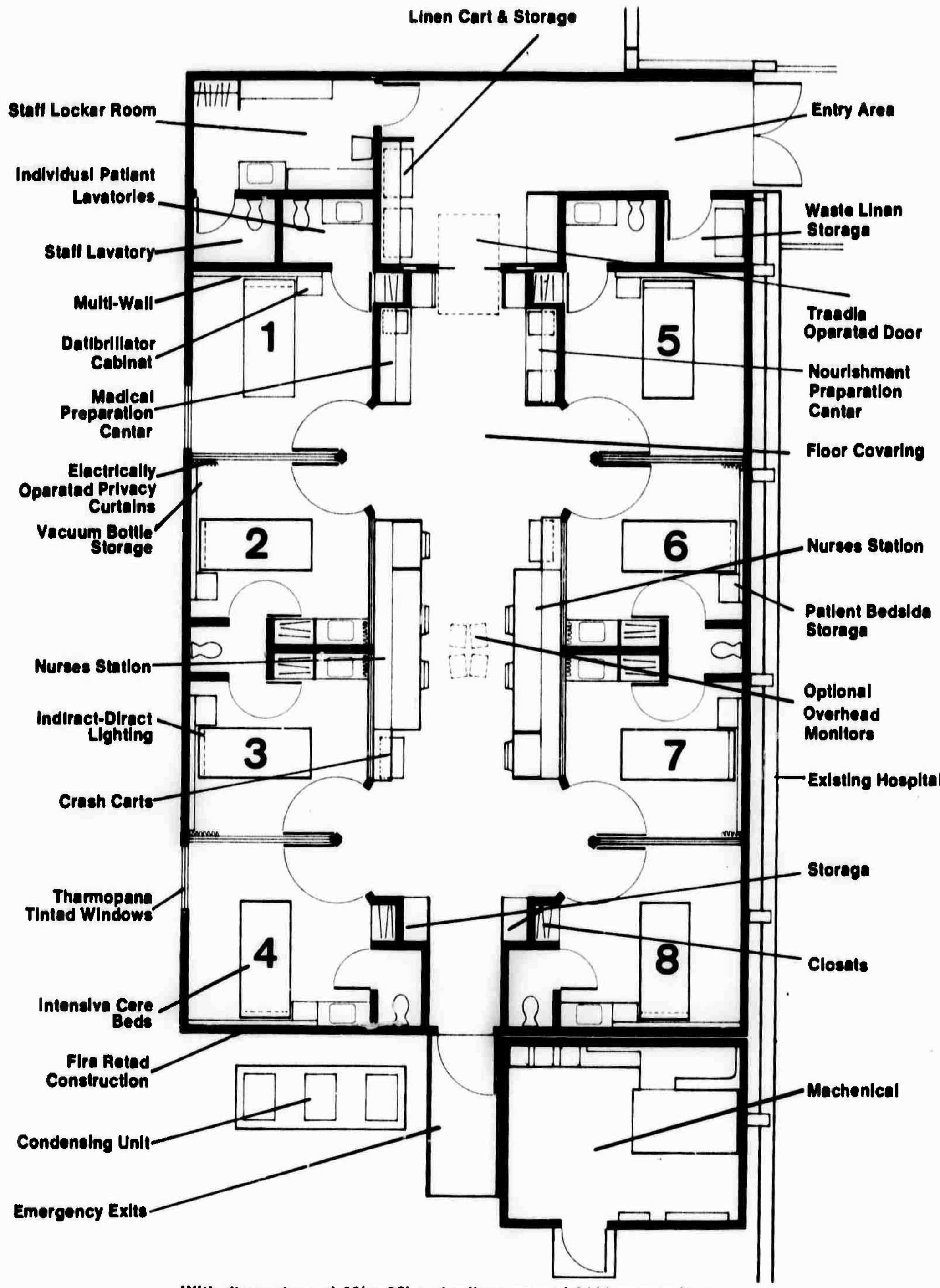
B) DESCRIPTION

The Electro Modules are 12' wide boxes of varying length up to 60'. At least three different combinations have been designed, not surprisingly incorporating the Electro patient console units described above. Construction is lightweight and the units are presently intended for one story height only. Foundations and site services are prepared in advance so that the modules themselves can be installed in a matter of days. The cost at the Miami installation is $7,234.50/month, or $29.60 per patient day.

An extension of the idea being seriously investigated by the manufacturer is a complete hospital built of these units. The structure would be a




ELECTRO SYSTEMS "MODULAR MEDICAL STRUCTURES" - Model of 36' x 60' unit installed in Miami.




With dimensions of 60' x 36' and a floor area of 2160 square feet, the MMS8 is the largest single unit Modular Medical Structure available. The unit provides two nurse control stations, each monitoring four patient beds. The greater size of the unit allows additional storage areas, more spacious quarters for medical preparation and nourishment preparations, and the convenience of treadle-operated entrance doors. The unit is suitable for customizing as with four beds providing one type of specialized care and the other four another type of care, or may be operated as a single facility.

ELECTRO SYSTEMS "MODULAR MEDICAL STRUCTURE" - A 36' x 60' unit, assembled from three 12' x 60' modules, as erected in Miami in 1969.

multistory steel framework into which each module would be slid horizontally. An intriguing feature being considered is the use of a cushion of air (such as is used in Hovercraft) to simplify the problem of inserting the units into the frame. Whereas the Hovercraft needs a 6" high cushion to pass over irregularities of the ground surface, the use of machined surfaces on the module and on the frame would allow the cushion to be reduced to 1/8", which would simplify the problem of tolerances. Details of the plans are not yet available, but it is intended that the units would be replaceable. As with the small additions, the hospitals would be leased.

C) EVALUATION

The use of these modules for temporary buildings is a logical and appropriate use. They will probably also find use as more permanent expansion for hospitals, but this will occur largely as a result of either inadequate forward planning, so that a need occurs before there is time to make more permanent expansion, or as a result of buildings which were incapable of expansion because of structural or planning limitations. Regardless of how good the internal planning of the unit, the concept is a compromise, since the location of the unit must be outside the main body of the hospital, which is unlikely to be where the unit would have wanted to be if it could have been otherwise.

Reports of the CCU in use are mixed.* The equipment and arrangements are

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* Modern Hospital, June 1970. "Here is Nurses' Verdict on Instant CCU: small but good." p. 100.

sophisticated, but nurses complain of the "submarine environment" and that patients feel "lost in time without being able to relate to day and night." These are however features of the design, not the system. The design could presumably be altered in later modules to include windows. The hospital administrator who decided on the module says he does not regret his decision.

The modules are said to be capable of being delivered and in operation within 90 days of an order being placed, and this is impressive. It shows the value of totally pre-designed units at this scale. This is very good for a hospital whose needs change rapidly and unexpectedly, which could be the case for the military. It would not however be able to cope with an emergency situation, which would still require field hospital type facilities.

The extension of the idea into complete hospitals has the same limitations as the disposable modules for Michigan State, though it fortunately is not saddled with the problem of a suspension type structure. The use of a cushion of air for installation may be complex, but would overcome many problems, so could be worth it.

D) SUMMARY

The Electro Modules now on the market are a logical use of large scale factory fabrication. Their use for full scale hospitals will have limitations of overall dimensions and of flexibility.

## D) SYSTEMS FOR COMPLETE BUILDINGS

No system for a complete building is presentiy ready for use "off the shelf" in the same sense that office, school and housing systems are. Development is underway and in a year the picture will be different.

Several "one-off systems" are in use in North America, mainly on large medical centers, which involve teaching and labs. These are special designs for special uses, which limits their usefulness for general acute care hospitals. Other systems have been used outside the country for limited applications.

In all cases it is useful to see how different systems solve their respective problems.

These systems are:

1. VA HOSPITALS SYSTEM DEVELOPMENT STUDY
2. SYSTEM DEVELOPED FOR DISTRICT HOSPITAL AT GREENWICH, LONDON, ENGLAND
3. MINISTRY OF HEALTH "BEST BUY" SYSTEM
4. SYSTEM FOR DADE COUNTY HOSPITAL, Florida
5. SYSTEM FOR UNIVERSITY OF MINNESOTA HEALTH SCIENCE EXPANSION
6. McMASTERS UNIVERSITY HEALTH SCIENCES CENTER, Hamilton, Ontario
7. COUPLED PAN SPACE FRAME SYSTEM

## VA HOSPITALS SYSTEM DEVELOPMENT STUDY*

Sponsors: Research Staff of the Office of Construction, Veterans Administration, Washington, D.C.
George Distelhurst, Director, Research Staff
John Cook, Project Supervisor

Consultants: A Joint Venture of
Stone, Marraccini & Patterson, San Francisco, and
Building Systems Development, Inc. - San Francisco

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### A) BACKGROUND

This project started with a Feasibility Study** which was published by the VA in October 1968. In 1969, the joint venture was awarded a contract for the integration of subsystems in VA Hospitals. The prime goals of the study were increased flexibility, reduced time, improved cost effectiveness, and better performance, but two significant restraints were included:

1) The scope was limited to the "nursing tower", and
2) The only subsystems to be studied were the structure, the partitions, the ceilings lighting and the heating, ventilating and cooling (HVC) systems.

It was also agreed that the proposal would limit itself to products which would be available on the open market by the conclusion of the study. The complete study, which is several hundred pages long in three volumes, was published in February, 1971.

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* Project Title: Application of the Principles of Systems Integration to the Design of the Nursing Tower Portion of a VA Hospital Facility (Phase 2) Project R - 99 - R042

** Project Title: Integration of Mechanical, Electrical, Structural, and Architectural Systems in VA Hospital Facilities (Phase I) - Research Staff, Office of Construction, VA, Washington, D.C., October, 1968.

Based on this work, a further contract is now in progress extending the scope of the study to include the entire hospital. This is programmed for completion later this year.

B) DESCRIPTION

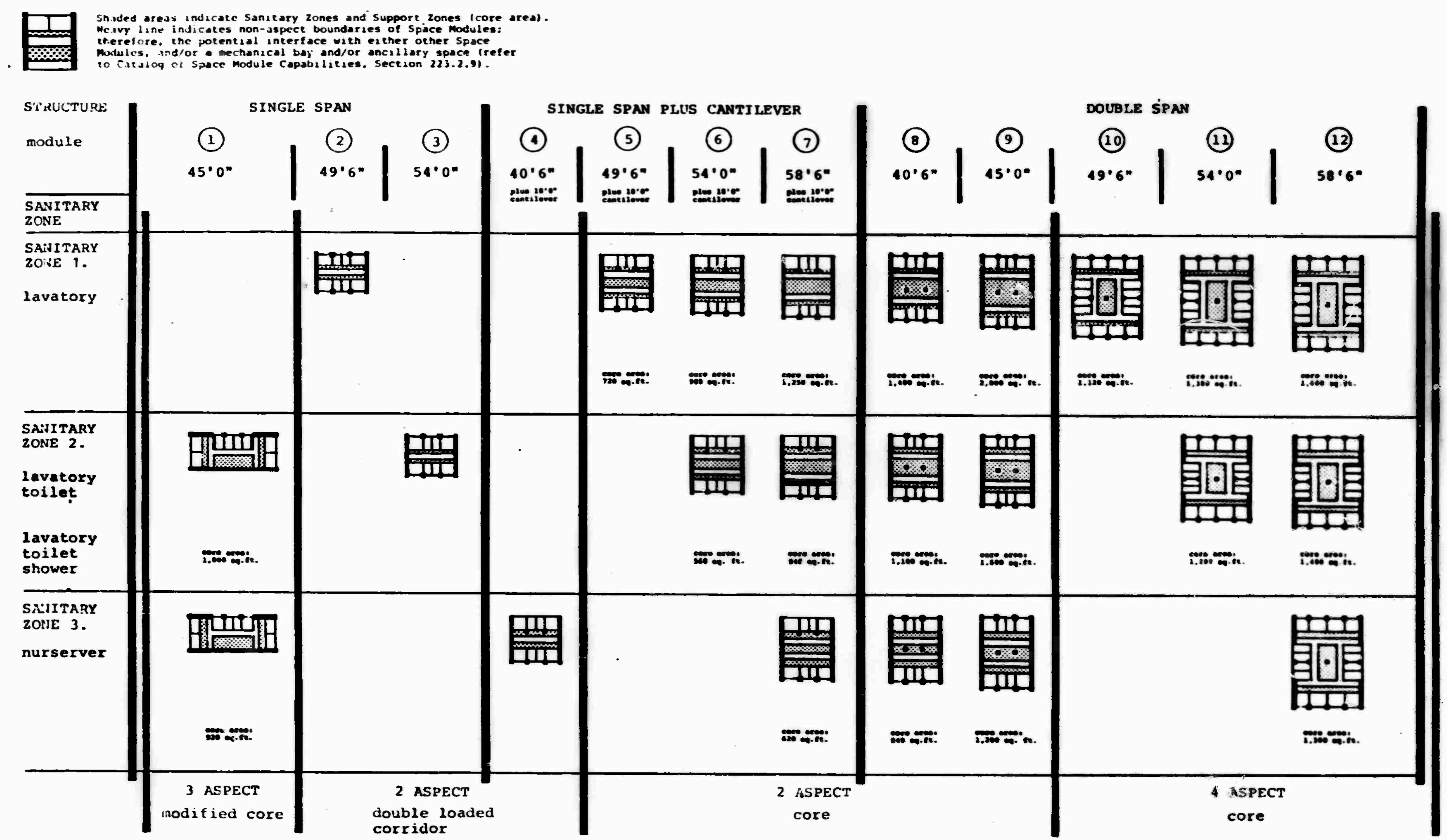
The study started with an analysis of user needs, and the establishment of performance criteria for the different subsystems to be studied. Although the user analysis may not have produced any surprises, it established a baseline of agreement for all concerned parties about what is and is not significant about the needs of VA hospitals.

The performance criteria, while perhaps again not startling, established agreement on first principles and set a standard against which to measure the performance of any system or proposal.

The system concept proposes "space modules" based on the possible ways groups of rooms may be constructed, serviced, and combined. These units are intended as a basic planning tool, and can help reduce programming and design time. A long series of demonstrations were carried out to show that the space module comcept could be applied to a large number of existing hospitals. It is clear for instance that any of the typical army plans illustrated on page 51 could be built up from a selection of space modules. (See illustrations.)

The concept incidentally is not inconsistent with that outlined in Volume IV of this report, "Planning Health Facilities", although details may differ.

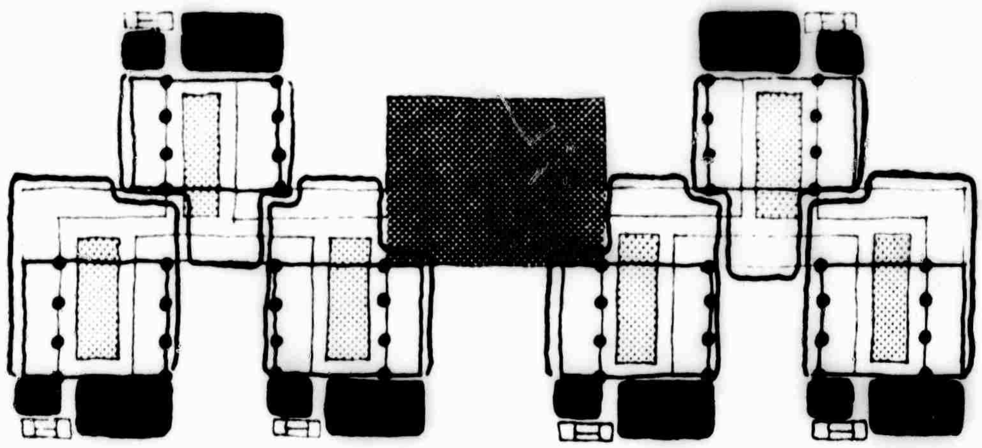
SPACE MODULE SUMMARY SHEET




VA HOSPITALS SYSTEM DEVELOPMENT STUDY. Space Module Summary Sheet.
The modules shown here represent the range of space modules which are regarded as possible or likely.
The main determinant of the size is the area which can be serviced by one mechanical bay (vertical service duct).
Each module is semi-autonomous in terms of services, so these become discreet building blocks. Size is also related to functional considerations, structure, and distance to vertical circulation.

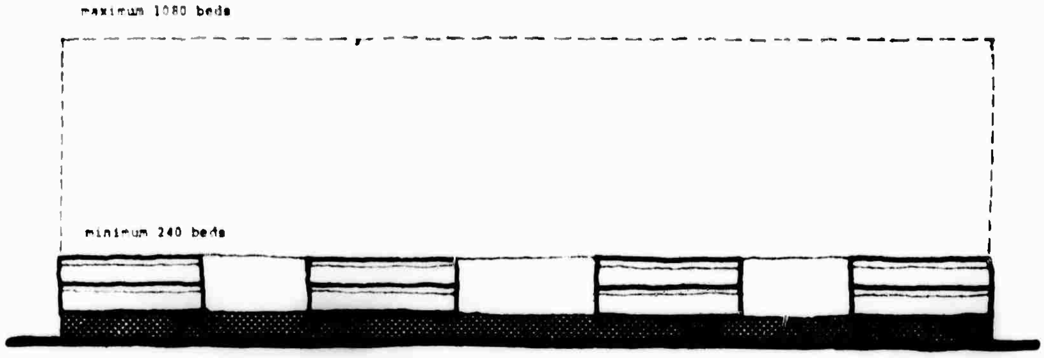
All illustrations are from "Application of the Principles of Systems Integration to the Design of the Nursing Tower Portion of a VA Hospital Facility (Phase 2) Project 99-R042, Vol. I" except where otherwise noted

## SAMPLE CONFIGURATION: 120 beds per floor



plan

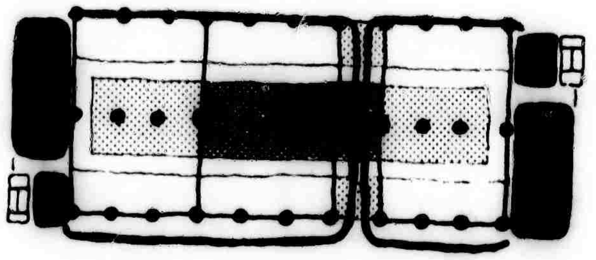
module type 5 6 7 8 9




section

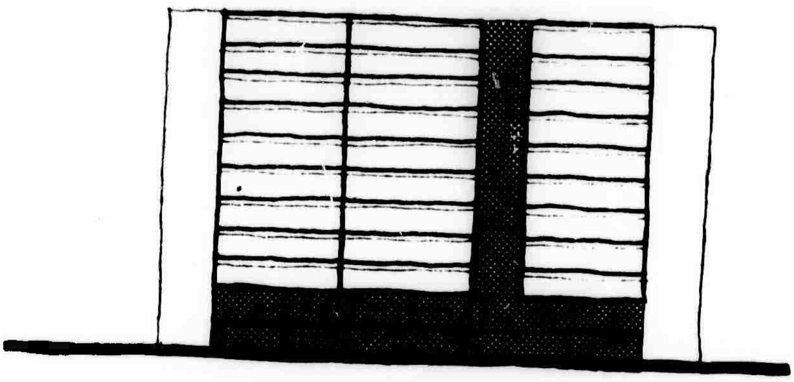

VA HOSPITALS SYSTEM DEVELOPMENT STUDY
This is one of a series of sample studies showing how the system's "space modules" may be combined to make a variety of different hospital designs.

SAMPLE CONFIGURATION: 60 beds per floor



plan

module type (9)



section

space module
ancillary space
direct care support
other hospital functions
mechanical service module
mechanical bay

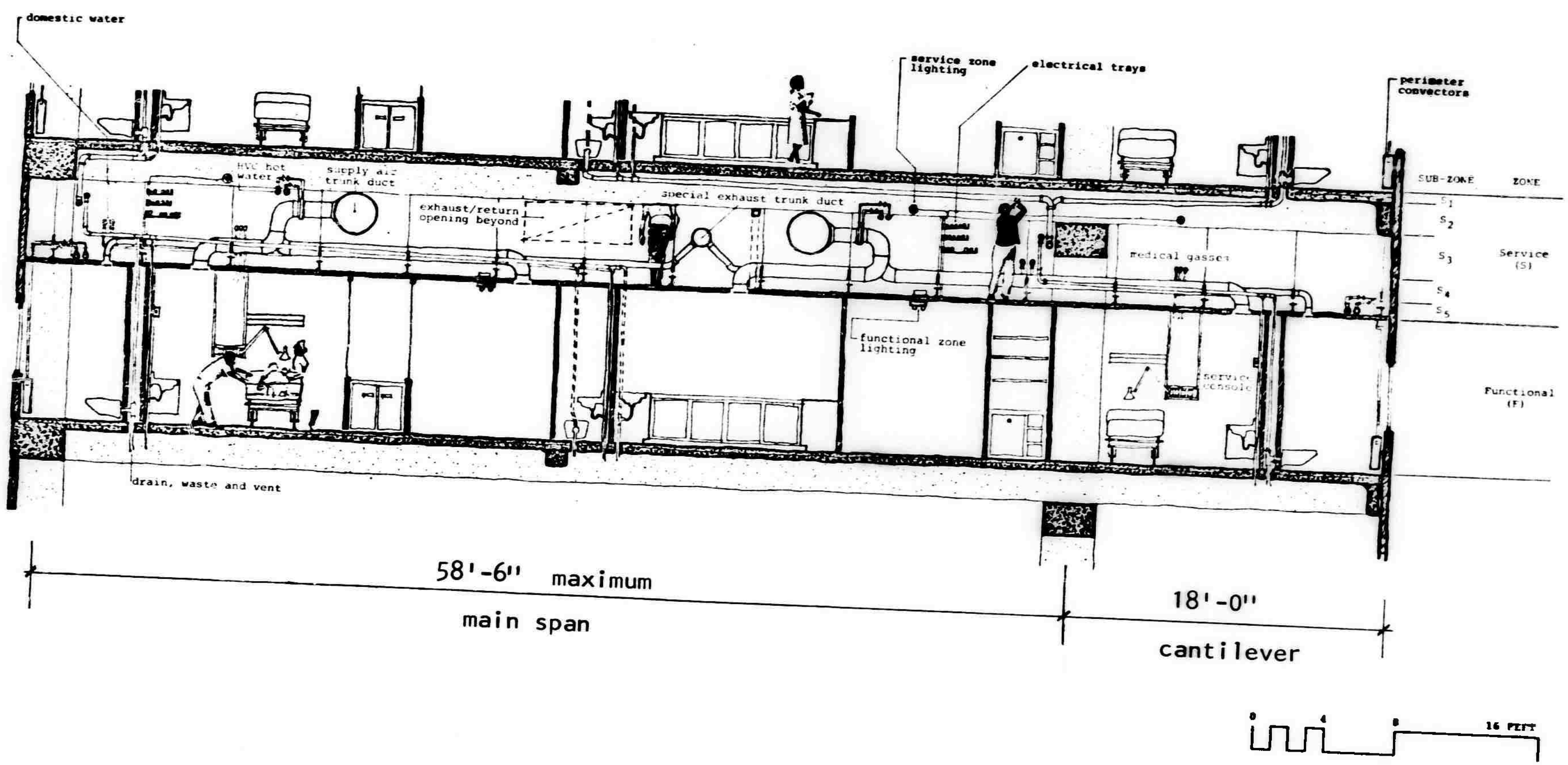
VA HOSPITALS SYSTEM DEVELOPMENT STUDY
This sample study shows the use of two space modules to make a standard race track hospital such as is used in most recent military hospitals.

The method of integration of subsystems is somewhat different from the conventional idea of a building system: It is more nearly a "set of rules" than a "kit of parts". Rather than detailing each component and every connection, it sets zones in which they may occur, and establishes principles of how they are used together. There will be for instance a choice of steel or concrete structure, but direction and variations of span are pre-determined. More than one HVC system is possible, and several different partition systems may be used.

The general form of the system is service platforms (interstitial floors) with a minimum of 6'6" headroom located above functional floors with a uniform 9'0" ceiling height. The service zone will be exclusively for the distribution and maintenance of services. No mechanical equipment, storage tanks or machinery may be put in there: all space is reserved.

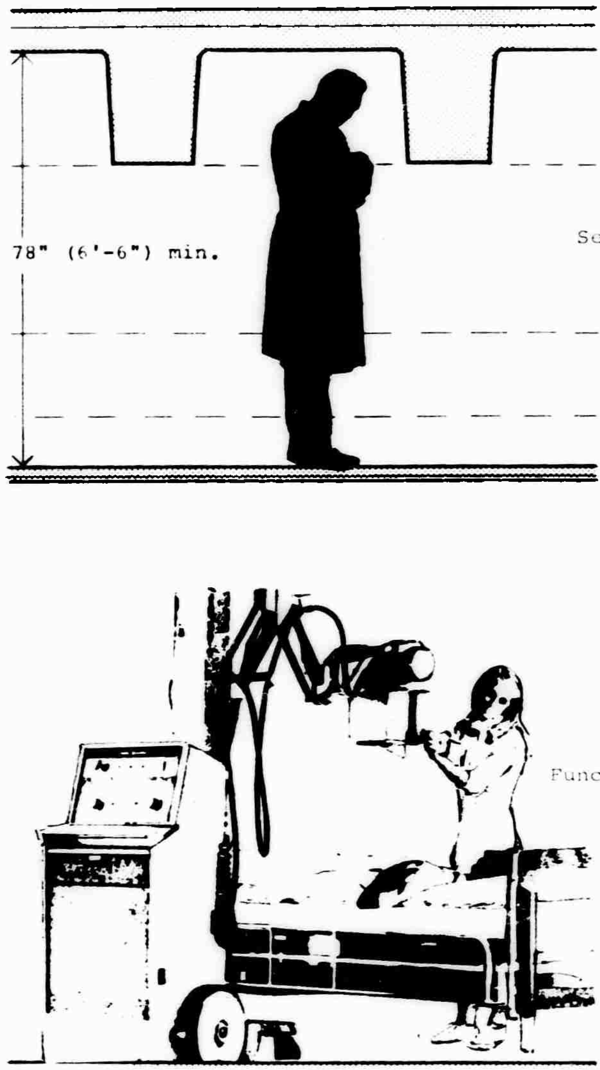
Within each planning module, service distribution occurs overhead only. Main service risers occur in service towers outside the modules. Module areas are kept clean of vertical services.

Structure - The structure is to be column and beam rather than trusses, which are more usual for service floors. The main reasons are economy, simplicity, and efficiency of space utilization. (These are discussed further in the Evaluation section.) The system is one directional, consisting of a layer of 18" to 26" deep beams spanning transversely, resting on 30" deep girders spanning 22'6" in the longitudinal direction. The depths of the beams, the spaces between them, and the different directions are utilized to create a system of layers, or zones, for the different



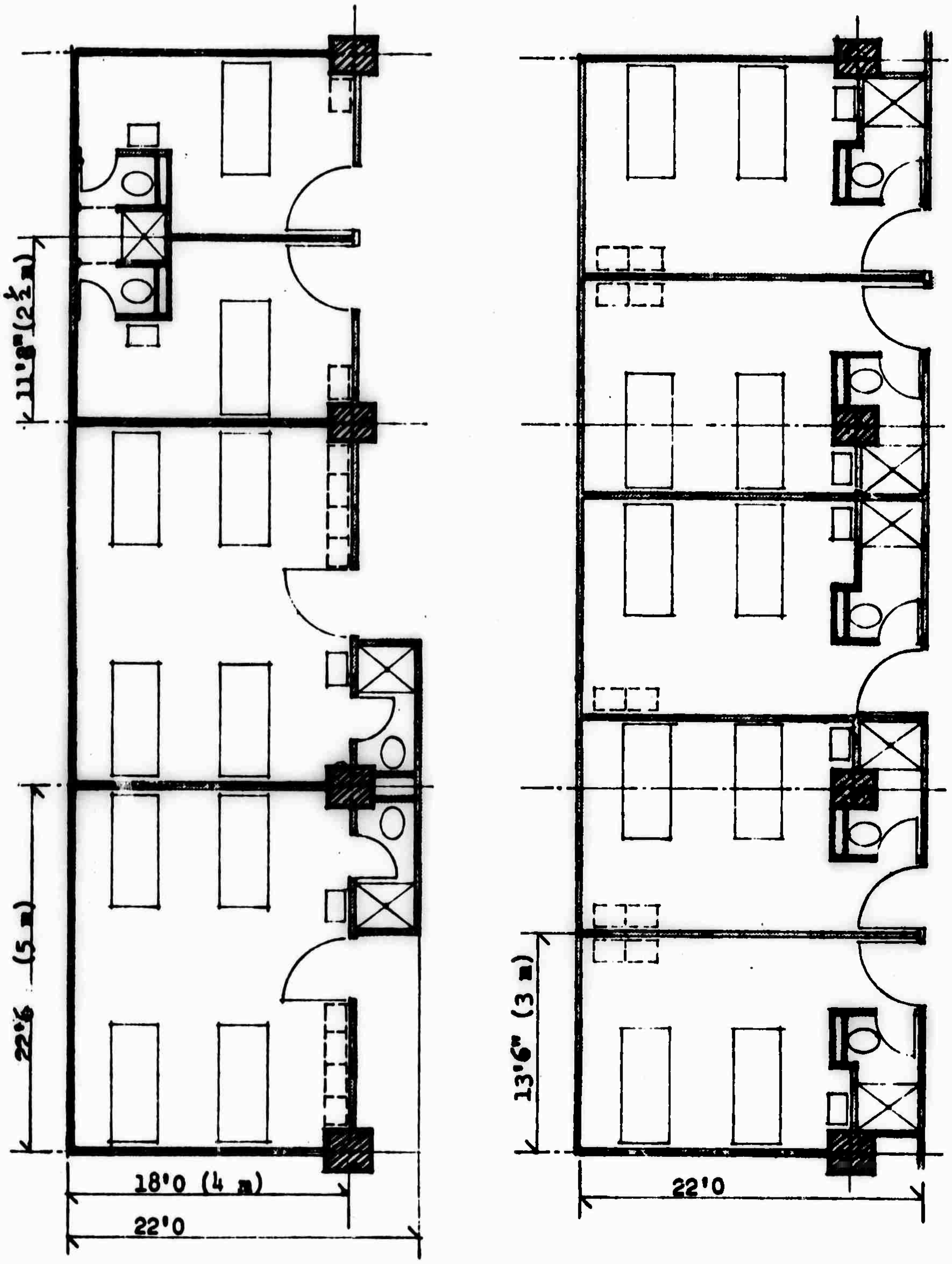

## VA HOSPITALS SYSTEM DEVELOPMENT STUDY

Section. This illustrates the relation of Service and Functional zones, and also shows how the main structural elements and spans relate to the plan.




| ZONE | SUB-ZONE | DEPTH | STRUCTURAL COMPONENTS | OTHER SUB-SYSTEMS |
|---|---|---|---|---|
| Service (S) | $S_1$ | 7.5" min. | Topping Slab @ 3"<br>Slab (deck) @ 4.5" min. | |
| | $S_2$ | 20" min.<br>26" max. | Beams @ 20" min.<br>26" max.<br>Perimeter girder<br>@ depth of beam | Drain/waste branch piping<br>Electrical branch panel boards<br>Service zone lighting |
| | $S_3$ | 30" min.<br>42" max. | Interior girder @ 27" max. | HVC trunk ducts<br>Reheat coils or mixing boxes<br>Drain/waste mains<br>Vent mains<br>Pressure piping mains, including HVC<br>Materials handling freeway<br>Cable trays for electrical and communication |
| | $S_4$ | 16" | | HVC zone ducts<br>Vent piping branches<br>Pressure piping branches |
| | $S_5$ | 12" min. | | Ceiling structure, walking surface, finish<br>HVC boots, terminals and convector piping<br>Electrical conduit and junction boxes |
| Functional (F) | | 108"<br>(9'-0") | | Ceiling-mounted lighting<br>Partitions<br>Casework, furniture and equipment |

**VA HOSPITALS SYSTEM DEVELOPMENT STUDY**
Detailed Section through functional zone and service zone illustrates the basic relationships between each subsystem.



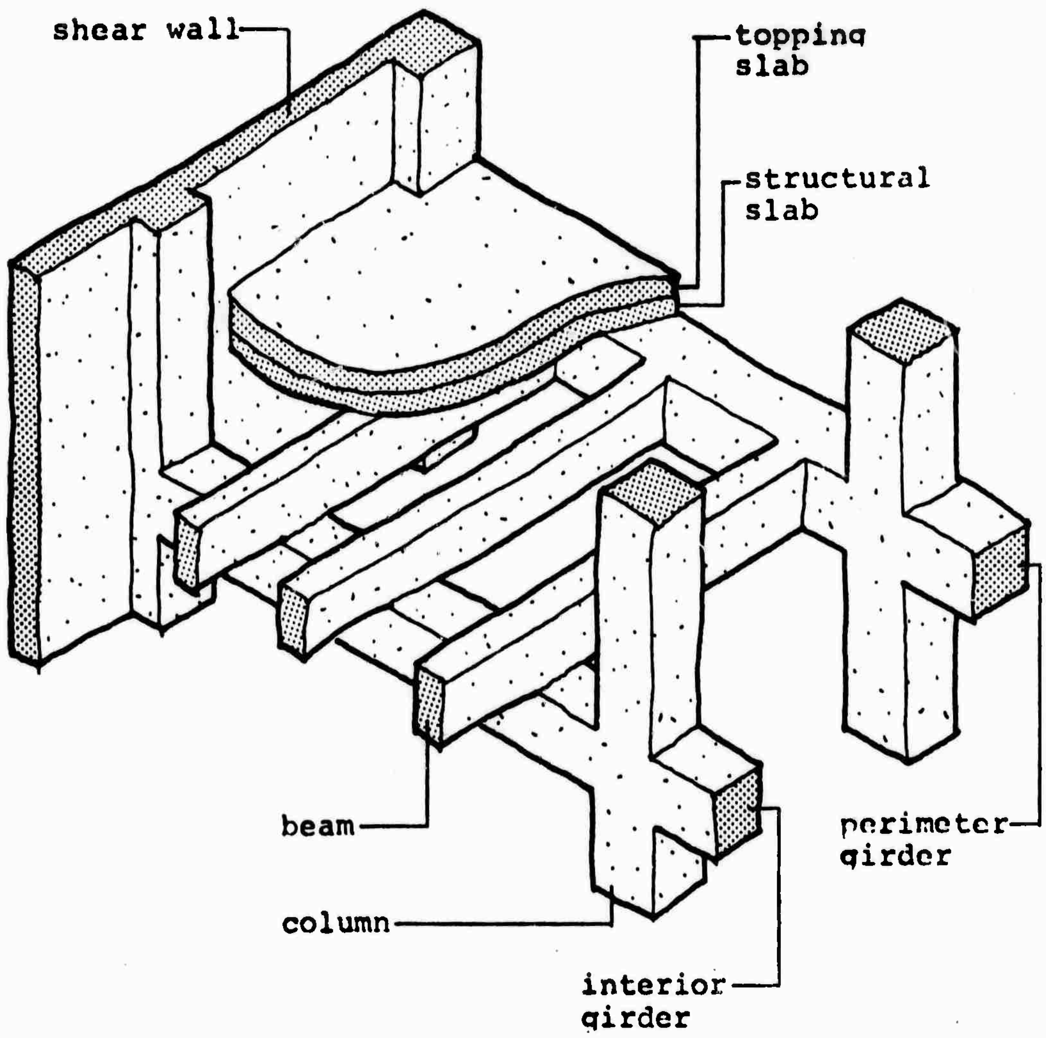

VA HOSPITALS SYSTEM DEVELOPMENT STUDY - The plans illustrate how three different sizes of patient rooms (one bed, two bed, and four bed) can be accommodated within the 22'-6" column spacing when the 18'-0" cantilever is employed. (Drawing from third interim draft report to the VA.)

service requirements. (See illustration) Although girder spans are fixed, spans of beams vary from 40'6" up to 58'6" in 4'6" increments. In addition, one end may cantilever 18' further, making possible a range of widths from 40'6" up to 76'6", supported on two columns. The cantilever of course will introduce internal columns, but the 18' dimension has been selected on the basis of studies of room dimensions and possible corridor locations to insure the minimum likelihood of causing an obstruction. (See illustration.) Three rows of columns, supporting double spans, provide widths up to 117'0". Therefore any likely building width can be accommodated.

<u>Lighting/Ceilings Subsystem</u> - The ceiling will provide the service platform supported from above. The ceiling will be a continuous surface, i.e., partitions will stop against its underside. It will be strong enough to walk on and will be pierced only by services. Lighting will be on walls rather than ceilings were possible in patient rooms. An example of a solution meeting these requirements might be 2" solid gypsum panels.

<u>Partitions and Patient Consoles</u> - Several different types of partitions may be used, according to the requirements at different locations.

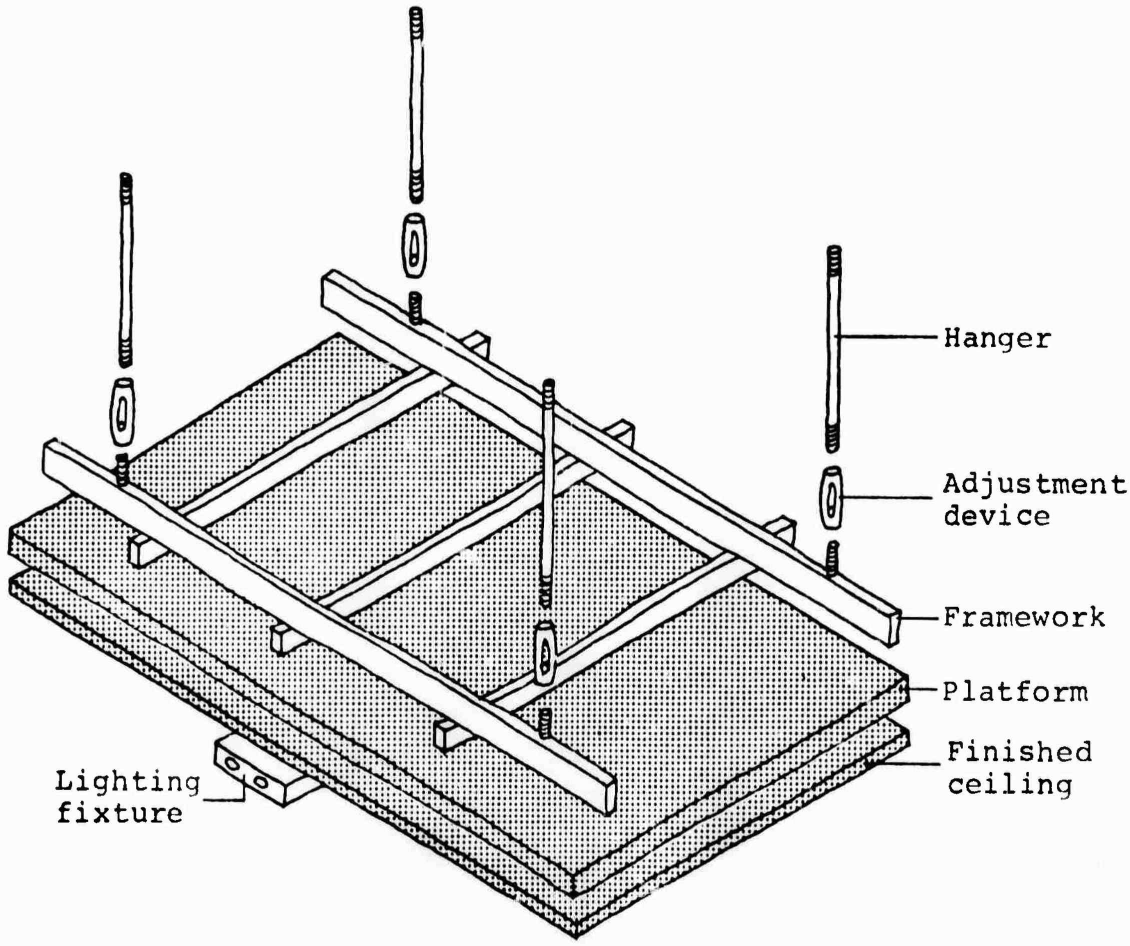
The consultants have reported to us that they plan to recommend the following: Services will be kept out of walls, with the possible exception of plumbing. Bedside services will be brought down into rooms in 4" deep patient consoles which will fit on the walls like cabinets. An important feature of these will be that they are located beside and/or over the beds only, insuring that no passage space is lost at the ends of beds. The sides are more convenient locations than behind the head anyhow. The consoles will



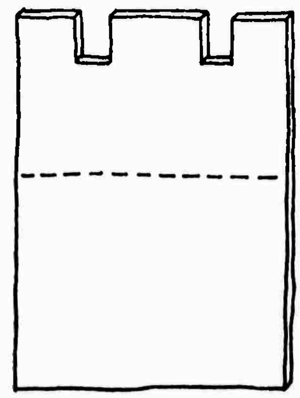

Note: This diagram is not intended to illustrate any particular building material, nor is it drawn to scale. It simply indicates the spatial relationships of basic components.

VA HOSPITALS SYSTEM DEVELOPMENT STUDY
Structural Subsystems. Rather than work out detailed interfaces between subsystems, the system concept provides zones in which each subsystem may occur without interfering with other subsystems. Despite its apparent simplicity, the relationships between beams, columns, and girders have been worked out to provide necessary clearances for services. Dimensions in terms of span, depth, and spacing of beams are variable provided the general locational relationships are maintained.

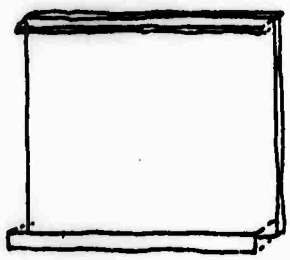
This variability allows the structure to remain economical in a variety of situations. Materials may be either concrete or steel.



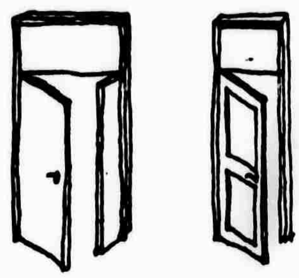

VA HOSPITALS SYSTEM DEVELOPMENT STUDY
Lighting/Ceiling Subsystem. The platform and hangers are considered a permanent part of the building. The lighting and finished ceiling are considered an "adaptable" part, and therefore subject to change.



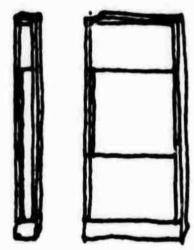
2-hour partitions



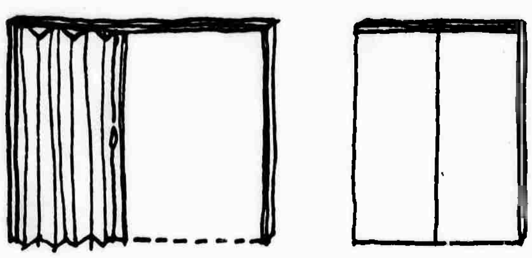
non-rated partitions



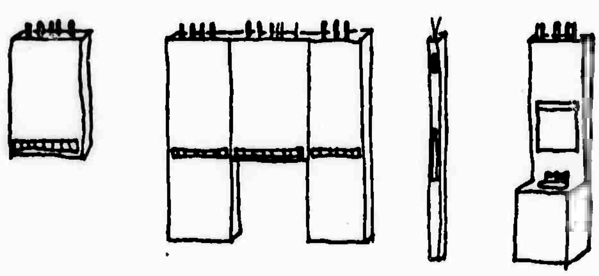
door sets



glazed units

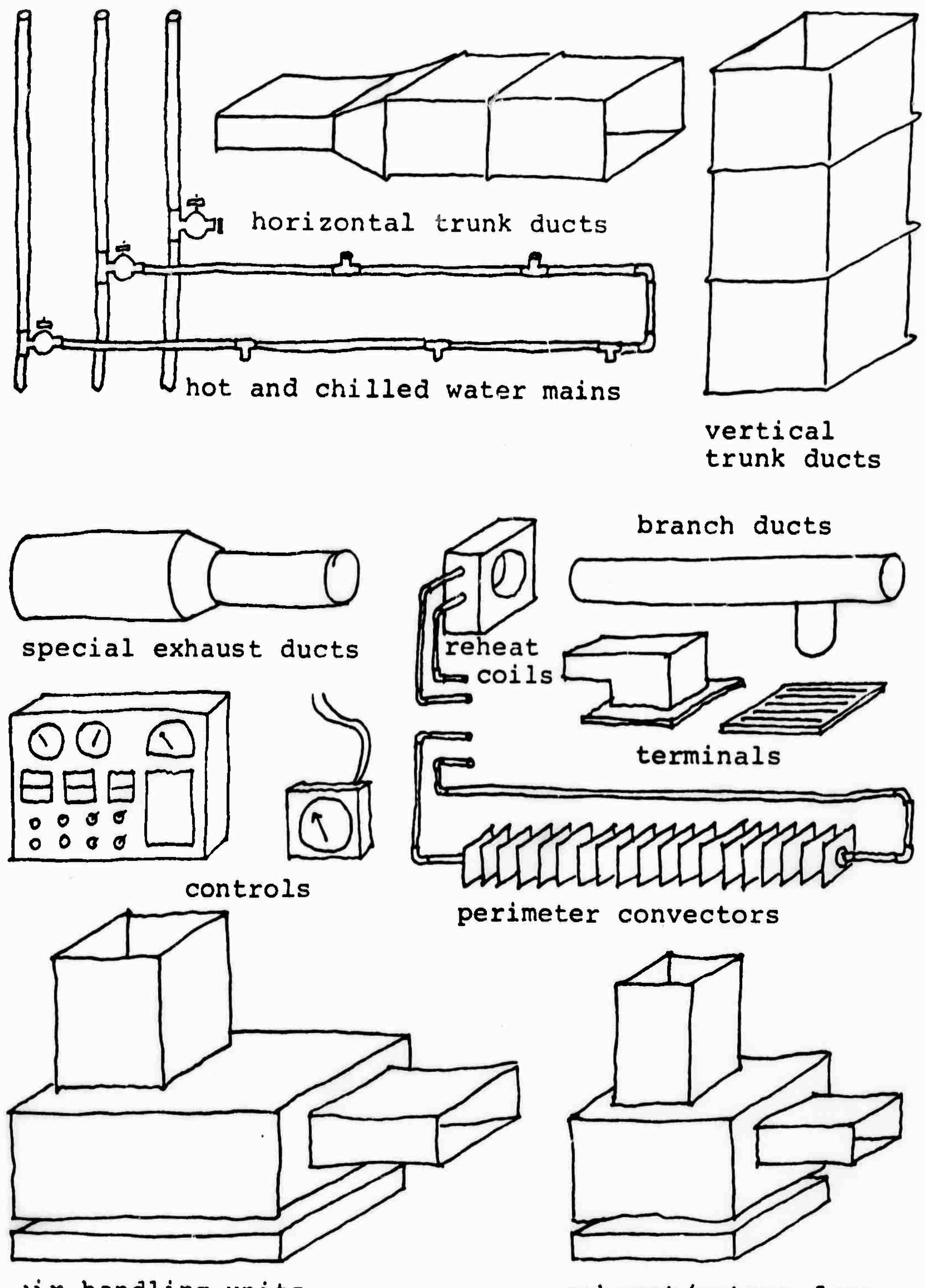


operable and portable



service consoles

VA HOSPITALS SYSTEM DEVELOPMENT STUDY
Partition Subsystem. Only the two hour partition is considered permanent. All other partition components are considered adaptable.




VA HOSPITALS SYSTEM DEVELOPMENT STUDY
H.V.C. Subsystem. The trunk ducts and water mains are permanent.
All other components are adaptable.

vary in width from 2' up to perhaps 10', depending on the services required. The consoles extend down from the ceiling variable distances, but do not meet the floor.

Heating, Ventilation and Cooling (HVC) - Mechanical systems will be either double duct or terminal reheat, discharging and extracting always from the ceiling. On the basis of the performance criteria set up, only air systems were judged to meet the necessary standards of individualized temperature control, humidity, air motion, air pressure, and flexibility for change. Supplementary perimeter convector heating will also be used in cold climates.

C) EVALUATION

The system proposal overall is consistently logical and pragmatic. It should succeed in providing flexibility, saving time, reducing total owner cost, and giving better performance.

Several points concerning the establishment of the program are relevant to military hospital needs.

The system is designed for general application., i.e., it is not designed simply as a way to build a particular design, but rather a way to build any hospital (within limits) which the architects for a variety of projects are likely to design. To be useful to the Department of Defense, this is a necessary characteristic of any system.

Also, the information about the system is well documented and is part of the public domain. This ensures that the rationale can be examined and challenged (and adjustments could be made if necessary). It is set up for use by a variety of designers, not just the developers themselves. This also is most useful.

This documentation has included the establishment of performance requirements. If the Department of Defense would like to employ this system, the criteria would provide a convenient checklist of how suitable the system is to military needs. Most of the requirements will be unchanged, but when something does not fit, it will be clear where the change is needed. With a system which does not set criteria in the first place, it is much more difficult to determine suitability.

Flexibility - The flexibility of the system to make a variety of buildings is established by a series of studies illustrating how a large number of very different hospitals could be built with the system.

The flexibility of the buildings to accommodate future change is also demonstrated. The nature of change has been studied, and it has been learned that the most frequent changes involve plumbing and electricity. Accessibility therefore has been kept simple, both inside the rooms and in the service space.

As with other deep service space type buildings, the continuous ceiling assures that in large scale changes, only that construction which needs to change will change. However, this service space has two advantages over some others:

1) The entire ceiling can be walked on. As discussed in the section on interstitial spaces, this is a big advantage over those systems using catwalks.

2) The use of beams instead of trusses makes more space available inside . Truss systems span the long distance, with the trusses consequently closely spaced. The beams are close spaced also - on 4'6" or 7'6" centers, but are overhead and therefore less in the way. The girders are quite massive, and have less than two feet of clearance below, but these occur infrequently, and are therefore not a great problem. Because of these factors, services will be more easily installed and changed with the VA system.

Time Savings - Schedules and programs suggest that the system can be part of a program to save 1½ to 2 years on VA Hospitals. Because procedures for military hospitals will differ, the particular schedules prepared for the VA will not apply, but the principles of telescoping programming, design and construction will still hold true. There is no reason to expect any less time saving for the Department of Defense.

Costs - Costs are difficult to guarantee, even with rigorous analysis. However, the consultants figures are reasonable in the context of other hospitals and deep service spaces in particular. These indicate that the initial cost may be higher, but that savings will be made on total ownership costs. The difficulty of making meaningful comparisons of this figure especially has been mentioned.

Many people have made an issue of the extra cost of interstitial space. Yet the extra cost is marginal. The consultants have reported to us that cost studies done subsequent to the third interim study indicate that a rough rule-of-thumb for the cost of extra space is five cents per square foot of area for each extra inch of height. Therefore, the difference between a conventional service space of say 4'6" depth, and this interstitial space, which is 7'0" deep, is 5 cents times 30 inches or $1.50 per square foot. Added to current VA construction costs of $43.60 per square foot, this is not so much.

The point about the extra initial cost is that it is to pay for a building giving clearly better performance. With the total annual operating costs of hospitals equal to a third or a half of the construction cost, it does not take long for a marginal saving in operations to more than offset a marginal increase in cost.

Quality and Performance - The creation of performance requirements provides a mechanism for observing deficiencies in current practice and making improvements where they are needed.

The most significant improvement will be in terms of flexibility, and therefore future performance, but there are improvements in initial performance as well. Individual materials and products will be chosen on a systematic basis of performance criteria, ensuring choice based on qualities that are relevant.

## D) SUMMARY

The system is very straightforward in attacking the central problems of hospital construction and could easily be adapted for use in military hospitals.

Although the system was developed initially for "nursing towers" only, the phase of the contract now underway is demonstrating that it is also useful in the main part of the hospital. The consultants indicate that some minor changes may be recommended, but that the basic principles remain as originally developed.

In addition, the scope of the system is now being expanded to include systemitization of the plumbing and electrical distribution networks. This increase in scope will substantially improve the usefulness of the system.

SYSTEM DEVELOPED FOR DISTRICT HOSPITAL AT GREENWICH, LONDON, ENGLAND.

Designers: Department of Health and Social Security Hospital Design Unit, London.

Chief Architect: W. E. Tatton Brown

Assistant Chief Architect: R. H. Goodman

Structural Engineers: Charles Weiss and Partners

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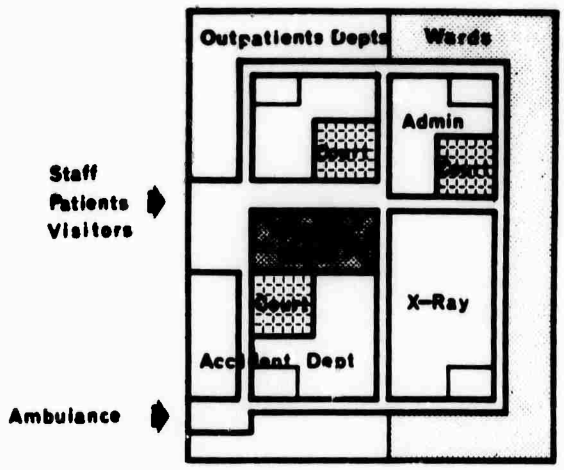
A) BACKGROUND

This system was developed for use in the Greenwich District Hospital, which will be an 800 bed facility when complete, with 50% expansion possible. The design is a 4 story horizontal building, approximately 400' square. The horizontal form was based on research by the Ministry of Health, and was found to be best even though the site is in the city and surrounded by other buildings.

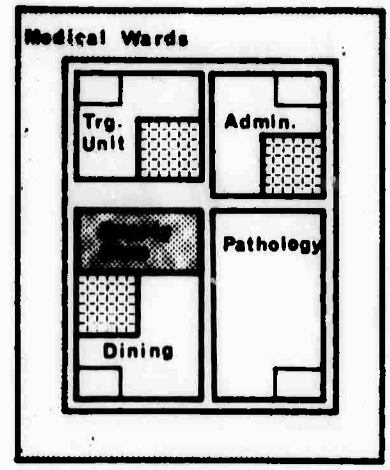
A major problem was to develop a method of construction which could be phased with the removal of an existing old hospital on the same limited ($7\frac{1}{2}$ acre) site. Plannin, started in 1962, Phase I construction was begun in 1966 and completed in 1969. Phase III is due for completion in 1972.

As a result of prior research, a second major aim was to design for "maximum capacity for future change of use, and to show the extent to which this could be achieved within the Ministry's cost limits."

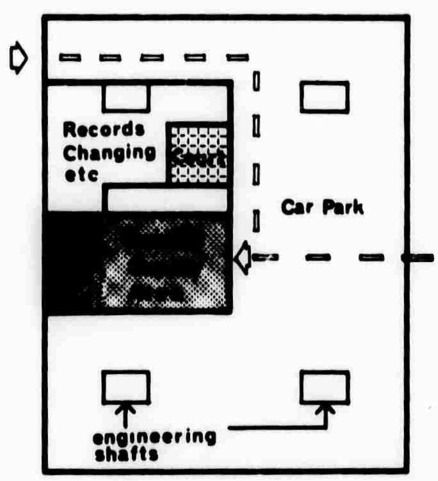
Because it was designed for just one building, its scope as a system was limited mainly to the structure, the ceiling and the partitions, and there



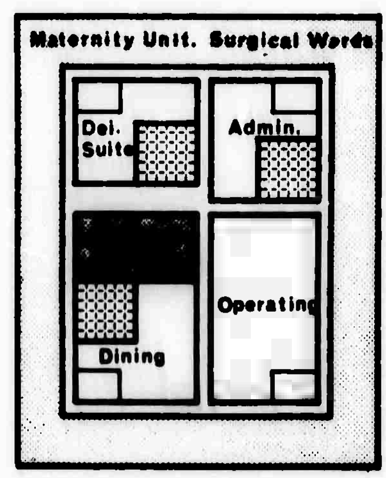

GROUND FLOOR
ZONING PLAN




SECOND FLOOR.
ZONING PLAN.




LOWER GROUND FLOOR
ZONING PLAN




FIRST FLOOR.
ZONING PLAN.

GREENWICH DISTRICT HOSPITAL - Diagramatic plans of horizontally organized hospital, showing simple circulation pattern employing hospital "street". Courtyards are for light, air, and orientation. Service cores in actual building are spaced irregularly (not in corners as shown).

All illustrations courtesy of the Ministry of Health.

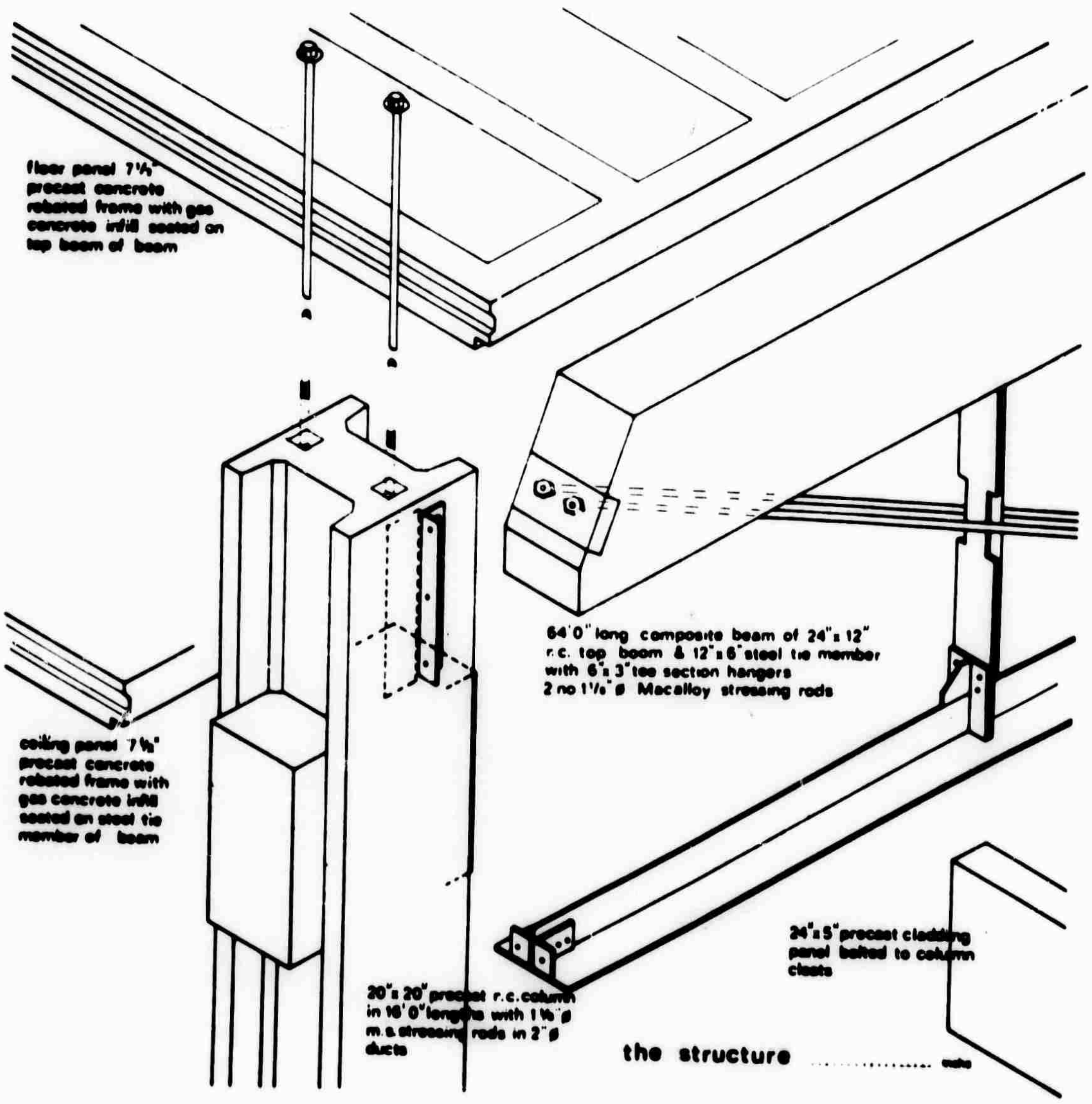
was not an attempt to make the system suitable for a wide range of applications. The requirements of mechanical and other services were of course recognized and are implicit in the design.

B) DESCRIPTION

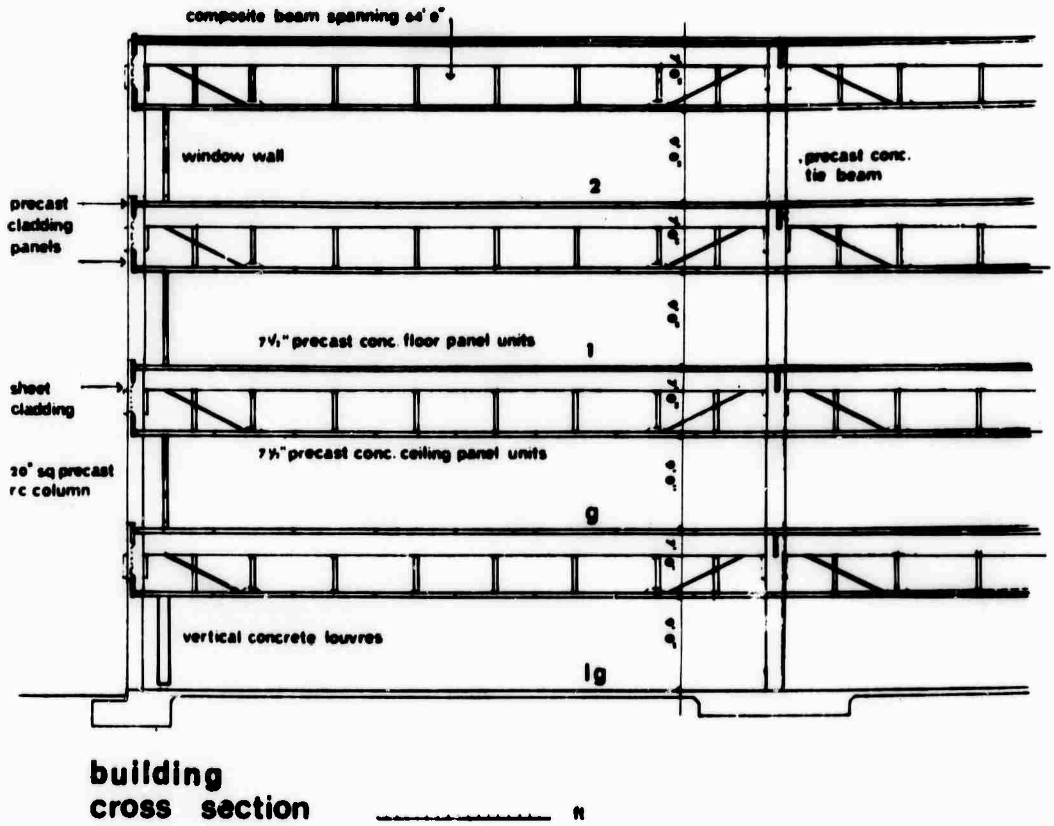
The basic design is an interstitial space system, with 9'-0" clear height in the main floors, and 7'-0" overall for the service floors. A rigid 16' x 64' structural grid is maintained, with a 2' x 1' module for detail planning. A total of four large service shafts will be used. Virtually no vertical services will be carried through any areas other than the service shafts. The shaft locations are not fixed by any rigid pattern. Consequently, although most areas of the hospital are within about 60' of the shafts, but some are as much as 130' away. Three courtyards will provide light, and air at strategic locations and will also serve to maintain orientation.

The structure is designed to consist of only four elements -- main beams, secondary beams, columns, and floor and ceiling slabs. (See isometric diagram). The main beam spans 64' and is of composite construction -- as much a truss as a beam. The top member is a 2' deep concrete beam, and the bottom is a steel tie. Vertical steel chords occur at 8' centers over most of the length.

Twenty-four inch by 5 inch concrete secondary beams span 16' at right angles and are used for lateral restraint and as spandrel panels.




GREENWICH DISTRICT HOSPITAL - Exploded view of assembly of the four structural components -- composite beam, transverse tie beam, column, and floor/ceiling panel. Use of ceiling panel with clear span of 16' gives this system more clear space for services and access than any others studied.




GREENWICH DISTRICT HOSPITAL - Section showing structure.

Columns are 20'' x 20'' precast concrete H-sections, with lugs cast into the channels near the top to support the main beams.

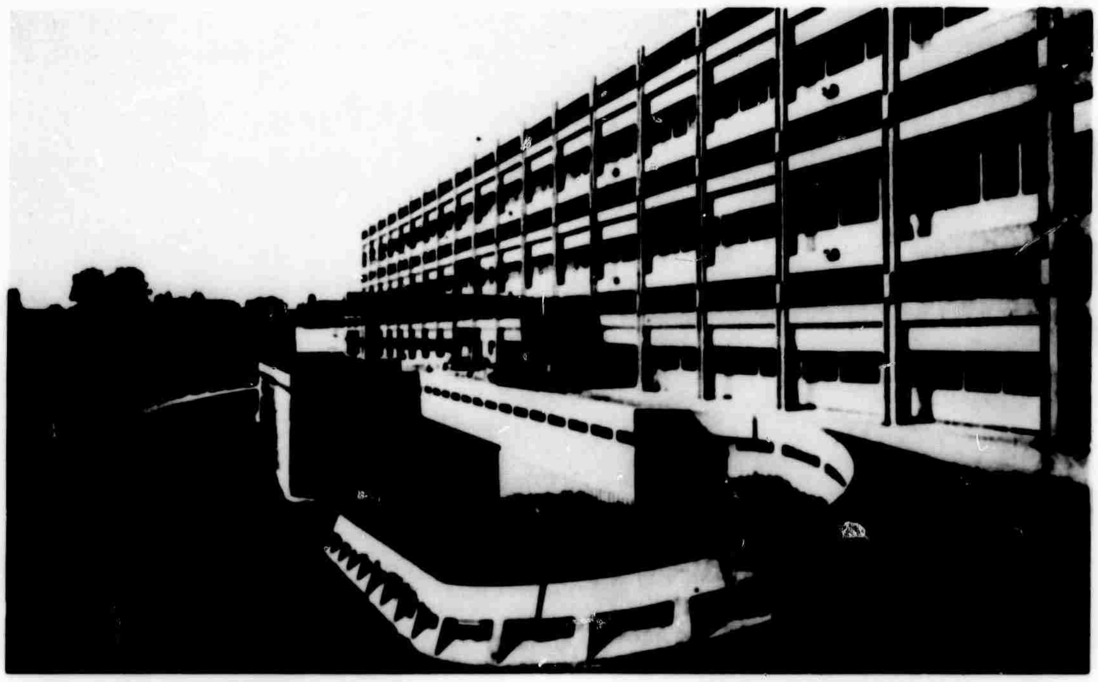
Floor and ceiling slabs -- 8' wide by $7\frac{1}{2}$'' thick and spanning 16' -- are reinforced concrete "grillages" with lightweight foam concrete infilling between the ribs. The infilling can easily be cut to make holes for services. The slabs rest on the top and bottom chords of the composite beam. The ceiling therefore is a continuous structural surface, both on its underside and on top. The service space is just under 6' high inside, with a clearance of about 4' under the main beams.

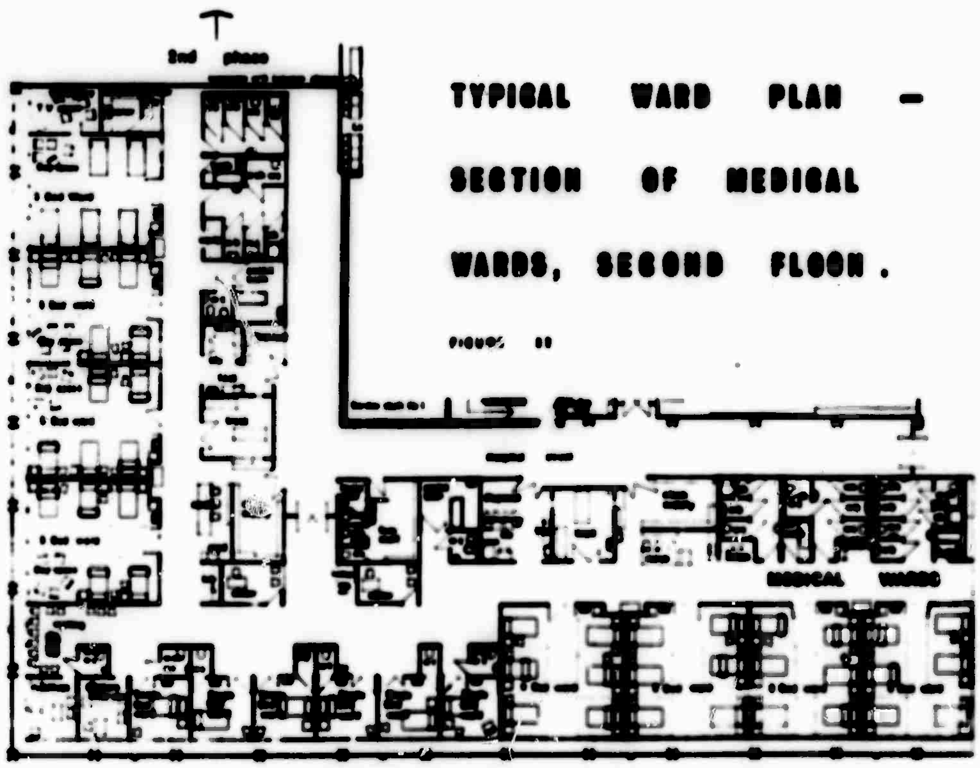
The result is large clear spaces in which partitions may be located at will. Partition materials vary according to the particular needs of different spaces. Selection is based on the Ministry of Health compendium of materials. The exterior wall is in 3' from the face of the building, providing sun shade and also avoiding awkward junctions with exterior columns.

C) EVALUATION

From a purely visual standpoint, Greenwich is one of the most elegant building systems ever to have been designed for any building type. It bears out the claims of the functional school of architectural theorists who state that if a building (or building system) is a direct and functional solution to real user needs, it will also look good.

In keeping with British practice, the cost is very well documented, a custom the U.S. would do well to adopt. Unfortunately the cost, 221 shillings/






GREENWICH DISTRICT HOSPITAL - Top: Exterior of Phase I construction, completed 1969. From a purely esthetic standpoint, this is one of the most elegant building systems developed for any building type.

Bottom: Typical ward plan. Unlike McMasters and San Diego, patient rooms at Greenwich are on perimeter wall only. Large number of patients per room keeps length of ward from becoming excessive.

square foot ($26.50/square foot), cannot meaningfully be related to U.S. costs because of the completely different set of wage and material scales. In terms of British scales, the figure is reasonable, fitting within the same Ministry cost yardstick as is applied to other hospitals. The yardstick, it should be pointed out, is not a flat rate but a variable figure which takes into consideration extra amenity and convenience. The structural elements were more expensive than conventional, but the overall building costs show that reasonable figures can be achieved in spite of such special structures.

In contrast to the VA system, Greenwich accomplishes the coverage of space with structural members in just two directions: i.e., the composite beams in one direction, and the slabs in the other. (The VA System has three: first the girders in one direction, then beams in the other, and then the slab in the first direction.) As a result, the service space is the most open of any of those studied, which is a convenience for access and installation of services (See comparison in Section 7-A, Interstitial Spaces). Where supports do enter the service space, they are mostly vertical, which are less of an obstruction than diagonals.

The top surface of the ceiling is flush, and is strong enough to walk on, a further advantage over San Diego and other systems which have to rely on catwalks.

The use of gas concrete between the ribs of the floor and ceiling slabs is a most useful way to allow holes to be cut for services. The cost of such a structure, at least for the ceiling, however, may be excessive when compared with, say, 2" gypsum.

The single most restrictive feature of the system is the totally fixed structural grid, 16' x 64'. If a building design has already been outlined, and it fits this grid, then it might be appropriate to use it. But to hope that all hospital designs will fit this grid is unrealistic. This would be particularly so for conventional racetrack nursing units, which average about 75'-90' wide in U.S. practice. Whether the structure could be modified for larger spans without significant loss of convenience or economy would have to be demonstrated. The 16' spacing of columns if for many functions inconveniently close; if however, these usually occurred only on the edge of a space, this would not be a problem.

The structure so far has only been designed for low rise. This probably could be overcome. The main consideration, wind bracing, could be taken care of by sheer walls on service shafts.

Services distribution have not been fixed by specific principles as they have for the VA system. However, a system of zones could be established. Although British hospitals tend to have lower service requirements than American, the space provided for services at Greenwich is larger or at least more open than that of any other system, this should not be a problem. This again however is presently not certain and would have to be demonstrated.

D) SUMMARY

The Greenwich system is beautifully simple, and solves most of the same problems other systems try to solve. Any attempt to adapt it for general application to military hospitals would require a closer examination which would answer four questions:

1) Could the spans be varied?
2) Could it be used for taller buildings?
3) Could services systematically be incorporated?
4) Could costs be kept down?

Unless these questions could be answered, the system would have limited application.

## MINISTRY OF HEALTH "BEST BUY" SYSTEM

Sponsor: Ministry of Health, London, England

Architects: Ministry of Health Staff Architects, with the Hospital Design Partnership

Structural Engineers: Charles Weiss & Partners

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### A) BACKGROUND

This project is the prototype for the British "new generation of hospitals" and is the result of research projects carried out during the last decade. It is considered the sequel to Greenwich. One of the prime objectives was "To seek the utmost economy in whole-hospital design and construction," and another was "To design and build each part of the hospital to a standard no higher than is necessary for the function intended".* Recent reports claim that the hospitals are "only half as expensive as buildings in multistory blocks in the center of town."**

### B) DESCRIPTION

The hospitals are sprawling two story buildings making extensive use of courtyards. (The plans were illustrated and described in Section 4, under Horizontal Planning.)

The structure employs precast concrete portal frames. (See photos.)

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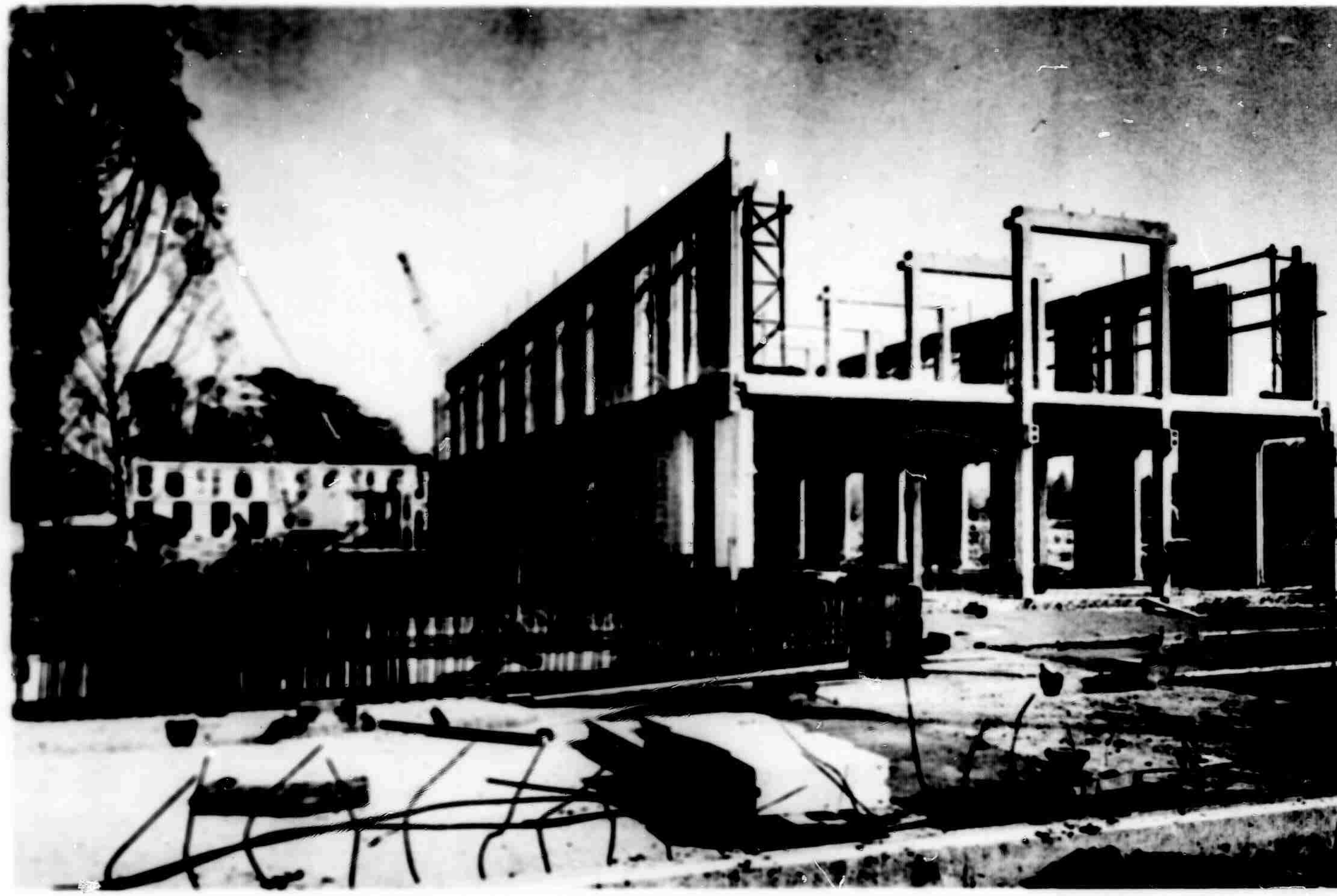
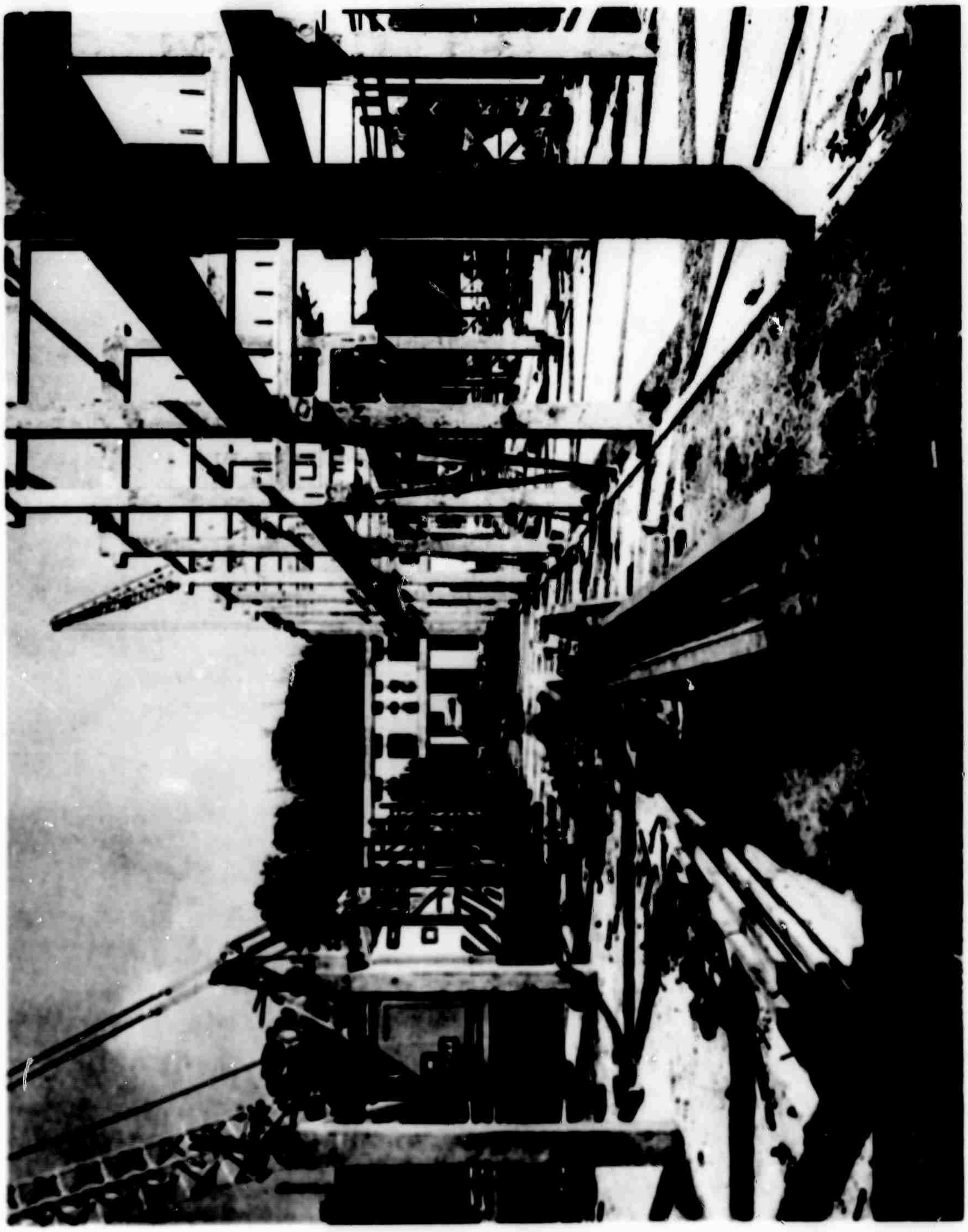
* Ministry of Health: "Rationalization of Planning & Design". March 1968.

** "British Hospital is Design Leader". New York Times, July 6, 1970.



MINISTRY OF HEALTH "BEST BUY" SYSTEM - Under construction at Bury St. Edmunds, England, 1970.

Photographs courtesy of the Ministry of Health.



Standard width for the building is 48', which is subdivided into 16' + 8' + 24' bays. In some places the width reduces to 34', divided 13' + 8' + 13'. The frame is at 11' or 12' centers in the other direction. The frame overall therefore is very lightweight.

Extensive use of natural light and ventilation is used, including employment of clerestory lighting over corridors on the second floor. Mechanical services are decentralized and located on the roofs. It is known that interstitial spaces are not employed, but details of construction have not been obtained.

C) EVALUATION

The dependence on natural light and especially natural ventilation may not be acceptable in American practice, and it is questionable whether it is necessary or efficient to put all departments in buildings only 48' wide. Nevertheless, this was the result of far more detailed and wide ranging cost effectivaness studies than have ever been carried out in this country, so it cannot be dismissed out of hand. Until such work is carried out here, it will be unknown whather the conclusions are the result of different conditions in Graat Britain or if they are also valid for the U.S.

D) SUMMARY

The "Best Buy" system has succeeded in lowering building cost by reducing construction to the bare minimum, yet has still preserved amenity. Final judgement will hava to await more detailed information, but the general principle of organization of the hospital into a limited number of floors with nursing integrated would be valid even if an American version were to produce a more compact and more intensively serviced building.

SYSTEM FOR DADE COUNTY HOSPITAL, Florida

Architects: Perkins & Will, Washington D.C., and The E. Todd Wheeler Partnership

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## A) BACKGROUND

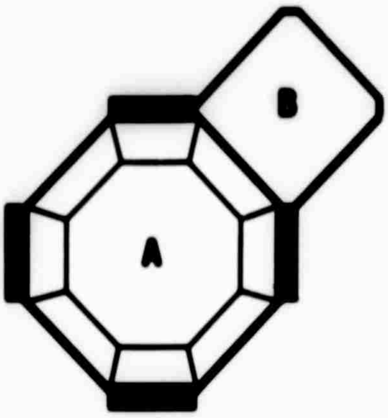
The system is one which has been proposed for use on Dade County Hospital and has been considered for Hamilton Air Force Base Hospital. A study called the "Modular Design Definitive Study for Hospitals" was carried out by Perkins & Will.

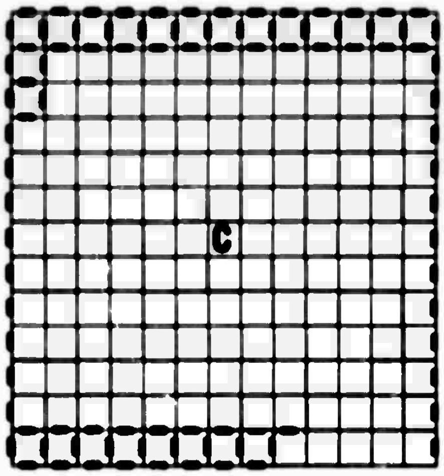
## B) DESCRIPTION

The system is a plan for using flat slab floor construction with all services located in walls and vertical chases. Because there are no overhead services the floor to floor height may be kept to the remarkably low height of 9'-6".

Planning is based on a pattern of 500 square foot octagons (24' across) and 200' squares. (See grid pattern) The octagon is the maximum size room that will be found in the hospital and is based on the requirements for operating rooms. Service chases and columns are combined into 2'-0" x 8'-0" units which separate adjoining octagons, and all services feed directly into or out of the service chases without going into the floor.

The construction is simpler than the octagon pattern would suggest. The octagon pattern is based on squares with their corners cut off, and this is



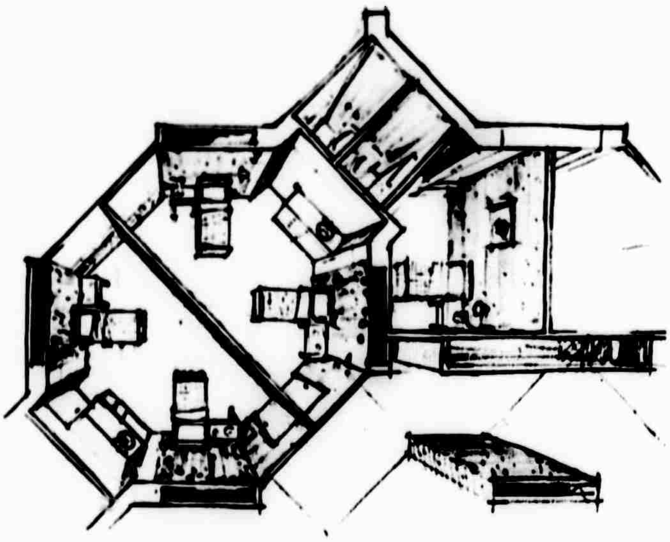



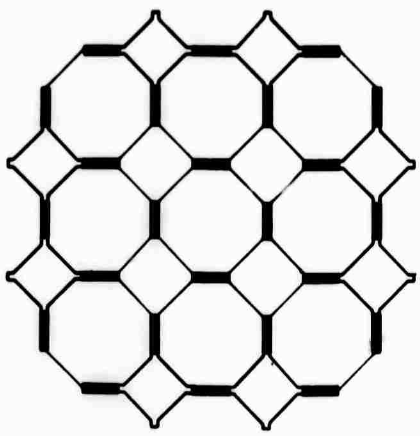

OCTAGONAL CELL SYSTEM - Top: Basic elements of system: A) Octagonal cell containing approximately 500 square feet. B) Related square cell containing approximately 200 square feet. C) Overall service grid. Each service column is capable of carrying ductwork and wiring for heating, ventilation, air conditioning, air vacuum, gases, plumbing and electricity.

Bottom Left: Octagonal cell used for two semi-private patient rooms. Beds are conveniently located for plugging into "service columns"; plumbing less conveniently located, and requires conventional plumbing wall to get pipes over to service column

Bottom Right: Basic pattern of octagons, squares and service columns.

Illustrations from Wheeler and
Perkins & Will. "An Expanding Modular
Cell Hospital for Dade County, Florida





illustrated by the overall service grid (C). The service chases are shown running in two directions at right angles to each other. Of these however, only those running in one direction include columns. The columns occur at both ends of the chases, and the space in between is for services. (This is illustrated in the Comparative Analysis at the end of this Section.) The columns therefore are simply in parallel rows on 26' centers, and are spaced at alternating 6'-6" and 19'-6" centers along those rows. The chases at right angles to this are only "possible" locations for services, and may be omitted if convenient. Access to chases is by removal of bolted panels.

C) EVALUATION

It is worth distinguishing between two aspects of this system, neither of which requires the other. One is the octagonal planning grid and the other is the close-spaced vertical service chases with consequent low floor to floor heights.

The octagonal pattern is not a necessary part or result of the close spaced structure and services; i.e., a totally different arrangement of spaces (perhaps more flexible) based on right angles could be used with the same structure.

Likewise, the service grid is not a necessary part or result of the use of the octagon pattern, since the pattern could as easily (perhaps more easily) be imposed on a large span open space, and octagonal cells can be built anywhere as long as there are no obstructions in the way.

Both features therefore must be able to justify themselves on their own virtues. Neither is necessary to make the other one work.

The imposition of the octagonal grid is hard to justify. It is inherently more difficult to fit all spaces and all functional relationships into such a rigid, arbitrary, and highly specialized grid. In any plan, the detailed design involves shifting the spaces slightly this way or that to make details work better or to accommodate minor changes. The more freedom possible, the more carefully the plan can be worked out. A four or five foot grid usually provides the maximum tolerable adjustment in the interests of efficient utilization of space. Yet the module here is 26'. If a function cannot fit into one cell, it must shift to the next available cell, 26' further on. This is too crude a tool to impose on spaces as critical as hospitals. Another way of looking at it is to ask, how would one adjust the location of an operating room, say 5'?

Equally arbitrary is the imposition of 45 degree and 135 degree angles on so many spaces. Regardless of how fashionable these angles are currently, it is questionable whether spaces other than operating rooms benefit from them, and there are not many operating rooms in hospitals. It is questionable whether the patient rooms benefit. It is also not clear how a requirement, say, for a large number of single bed rooms would be accommodated. There may be some rooms which can work, but to impose such an arbitrary constraint on a plan is simply unnecessary. The designer is always free to make such a plan, but planning considerations do not ordinarily lead to these forms. I.e., you would not end up with such a plan unless you had to.

The second basic feature of the system, the close spacing of the structure and the service chases, may have some economic justification, but it imposes limitations on present and future flexibility, and this is the most fundamental problem of the system. A simple flat slab is an economical structural form, but the structure is only part of the cost of a building. The more important question is how use is affected.

The concept is one extreme of a way to separate permanent and impermanent elements. Interstitial spaces put all the permanent elements in horizontal spaces above, with the absolute minimum of vertical obstructions on the floor. This system by contrast takes all the services out of the horizontal plane and puts them into vertical elements. Other than a possible initial cost saving, it is hard to see what is gained. The use of fixed vertical elements at a close spacing simply introduces obstructions to original and future plan arrangements. Any plan which can be made in a short span structure can also be made in a long span structure, but the reverse is not true. The difficulty here is compounded by the obstructions being not simply columns, but very large panels, so that each one begins to cut the space into little pieces. This is a needless and unacceptable constraint on efficient planning.

Access to services may be considered a virtue of the system, except that any convenient arrangement which is possible with this system is equally possible with systems employing wide spans. The wide span structure however has the additional option of taking the services directly into the floor or ceiling if desired.

D) <u>SUMMARY</u>

Neither of the two features of this system can justify itself on the basis of convenience or long range economy of hospital design.

# SYSTEM FOR UNIVERSITY OF MINNESOTA HEALTH SCIENCES EXPANSION

Architects: The Architects Collaborative, Cambridge, Massachusetts
The Cerny Associates, Minneapolis, Minnesota

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## A) BACKGROUND

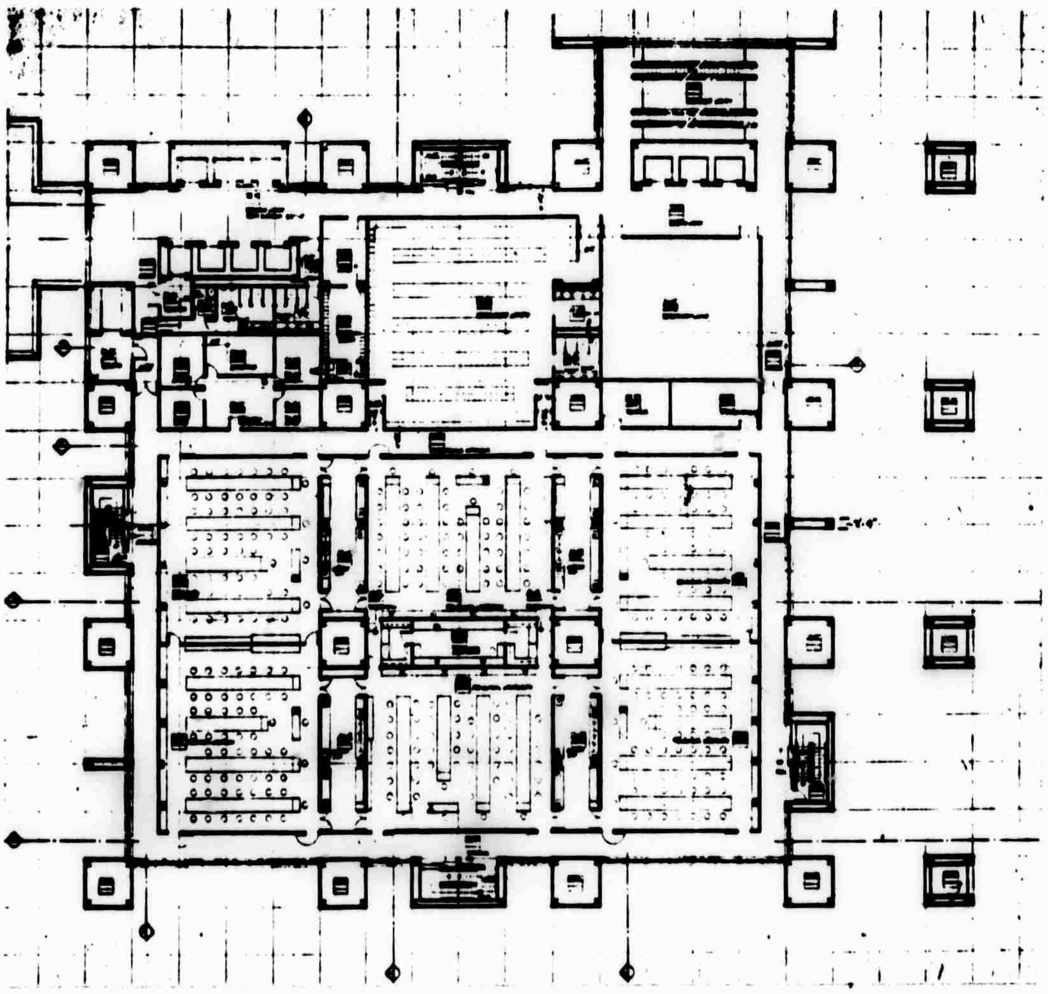
This system has been designed for use on a large health complex, much of which is laboratories and teaching space, so that the system is not necessarily what would have been designed if it were for hospital space only.

The Health Center is a multi-phase development, the first phase of which will be for 1.5 million square feet and will cost $100 million. The architects were appointed in 1967, schematic design was ready in 1968, construction is scheduled to start in October 1970, and the first buildings should be complete in September 1973.

## B) DESCRIPTION

The system is different from others described here in that it does not employ interstitial space. Distribution of services is from above nevertheless (as opposed to Dade County Hospital), so access to services is through the ceiling.

Service towers, 12'-4" x 12'-4" (nominal dimensions) on 61'-8" centers create a tartan grid of 12'-4 " and 49'-4" dimensions alternating in both directions. The space is broken in one direction by pairs of columns midway between the towers, reducing the span in that direction to 24'-8" (nominal).



UNIVERSITY OF MINNESOTA HEALTH CENTER - Plan of one floor of "Unit A". This floor is for research, not medicine, but illustrates possible relationship between service towers and functional spaces.

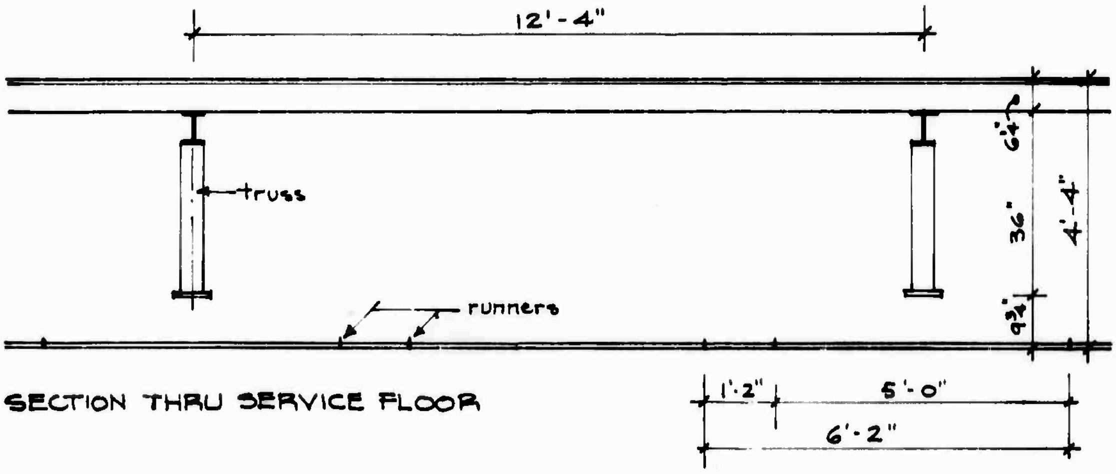
(Preliminary plans by The Architects Collaborative, Cambridge, Mass.)

The frequency of the towers and the short spans allow the floor/services depth to be kept down to 4'-4". The floor to ceiling height is 9'-0", giving a low 13'-4" floor to floor dimension.

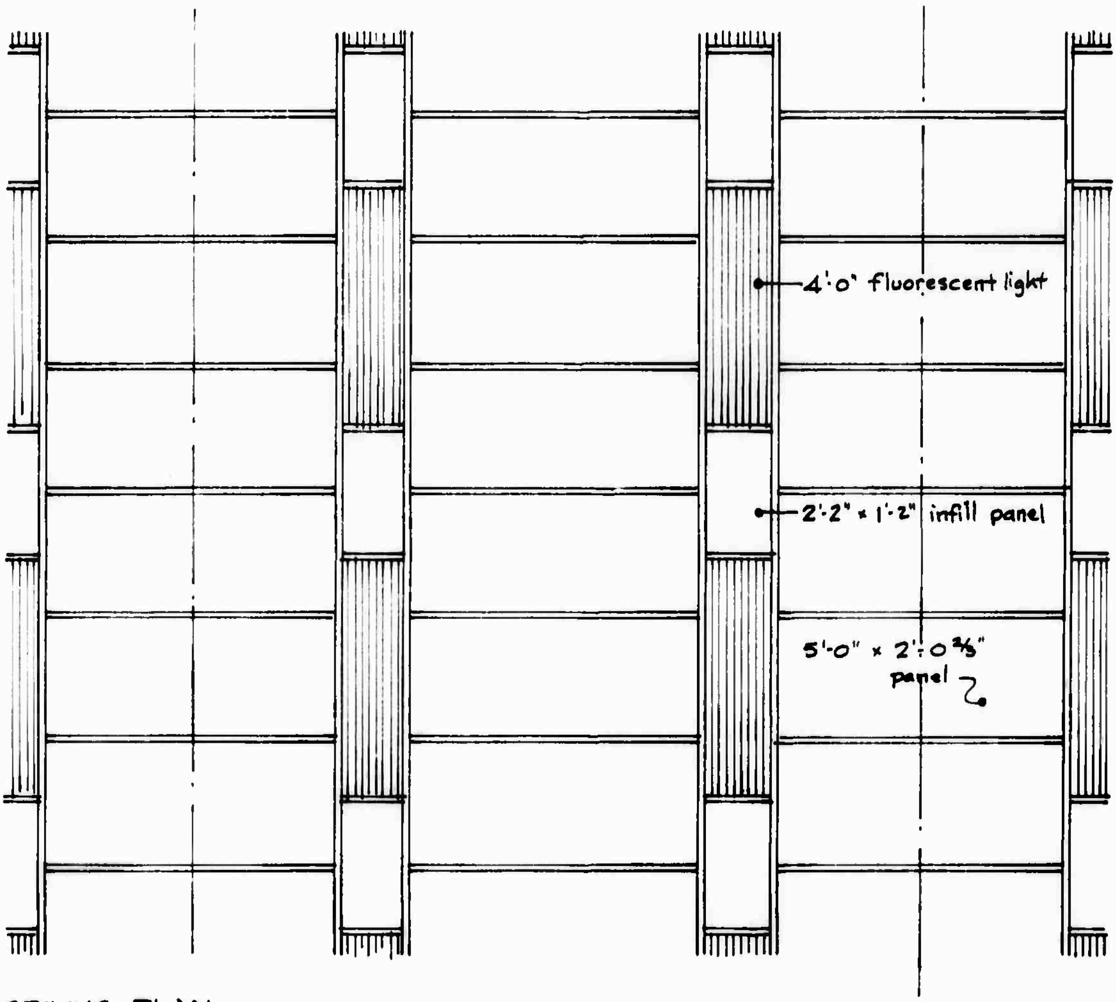
The structure is steel beams spanning in the 24'-8" direction and trusses spanning 49'-4" in the other direction. The bottom chord of the truss is 9" above the underside of the ceiling in order to leave space for service connections into the ceiling. Cantilevers of 12'-4" are possible in both directions, but in the truss direction, beams must be used for the cantilever instead of trusses.

The system is considered to be one directional, but the pattern of service, towers and open spaces and cantilevers is essentially equal in both directions, expressing an idea which is two-directional. In terms of large scale planning, for instance, it is no more difficult to extend the system in one direction than in the other. But on the detail level, it is marginally easier to arrange spaces in one direction than the other.

The ceiling has been the focus of much design effort. It consists of extruded metal tracks (runners) in one direction on alternating 1'-2" and 5'-0" centers (2 x (1'-2" + 5'-0") = 12'-4"). These support discontinuous tracks spanning in the opposite direction. In the 5'-0" zone these are at 2'-02/3" centers and support blank panels (metal pans or acoustic tile). The 1'-2" zone is the service strip, and generally contains a 4'-0" long fluorescent light (recessed) and a 2'-2" long infill panel (2 x (4'-0" + 2'-2") = 12'-4"). The infill panel will accommodate a large number of different kinds of outlets, including sprinklers, downlights, loud speakers,




SECTION THRU SERVICE FLOOR




CEILING PLAN

UNIVERSITY OF MINNESOTA HEALTH SCIENCES EXPANSION
Ceiling system and service space. Scale - 3/8" = 1' - 0"

supply air, return air, smoke detectors, lab services into free standing chases, or combinations of the above. Because the service strip is constrained only on the two sides, position of lights and infill panels are variable in one direction. The ceilings are not fire rated.

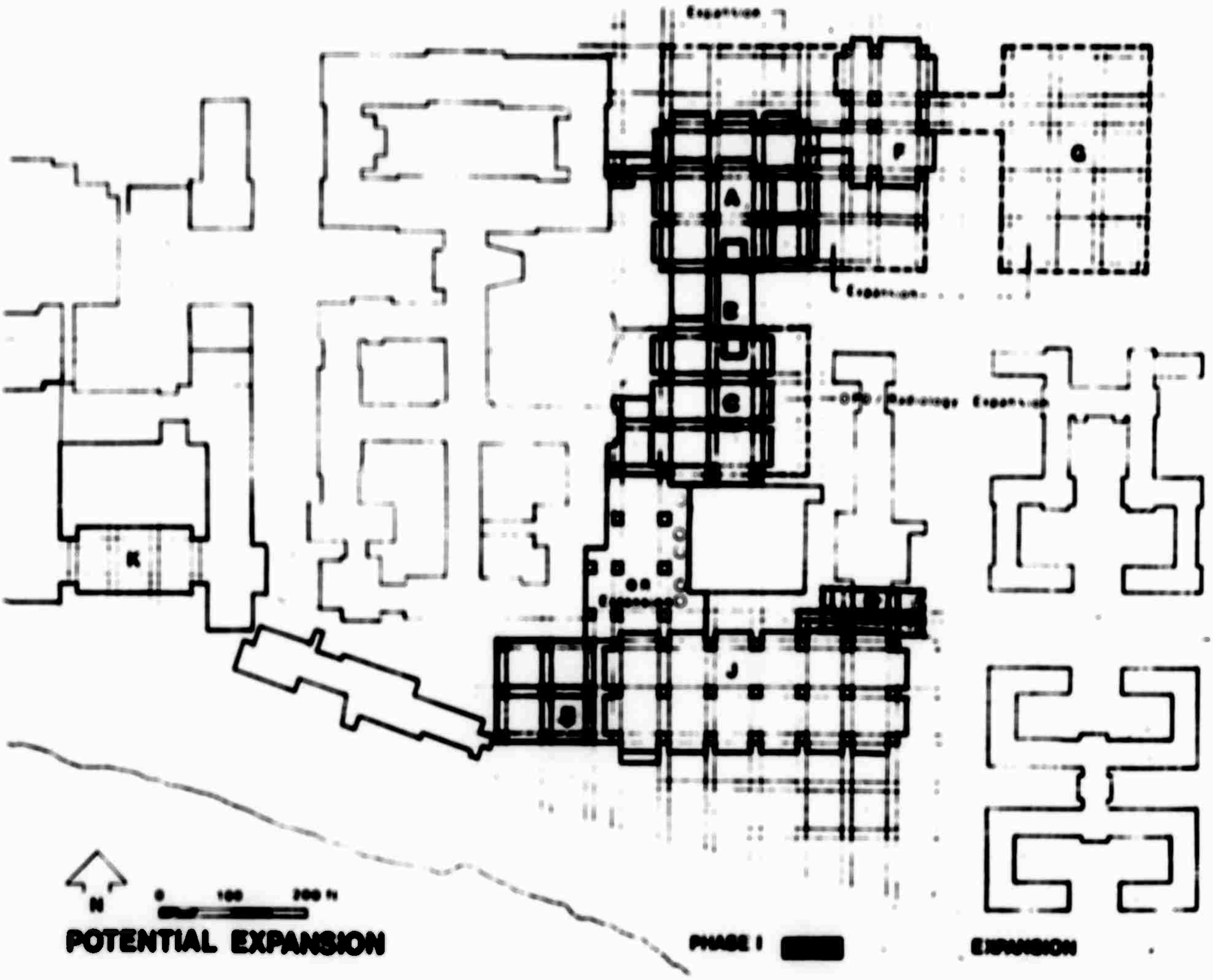
Partitions in one direction meet the ceiling on the short runners between the 5'-0" x 2'-0" tile panels -- i.e., at 2'-02/3" centers. Where this crosses the service strip, fluorescent lights sometimes must be replaced by blank panels. In the other direction, partitions may be located in the middle 4'-0" of the 5'-0" panels, but never on the continuous tracks or in the service strip. In other words, in each 6'-2" width, there is 2'-2" of area in which the partition cannot be located. The partition system is based on steel studs which screw up into the runners.

The stairs have been standardized and will be pre-fabricated in three story high units, with landings which hinge down into place after placement of the overall unit.

The center line of the trusses is through the middle of the 5'-0" spaces, so when the ceiling meets the cores, "half panels" must be employed. Half runners must also be employed around the cores.

C) EVALUATION

The system is particularly interesting as a pattern for growth, which is shown clearly by the expansion plan (see illustration). The system is infinitely extendable by adding more towers and more spaces between them.




UNIVERSITY OF MINNESOTA HEALTH CENTER - Plan illustrates how system relates to complete building. Growth is planned in several stages. Exact requirements of future construction will not be known until later, but service towers and functional spaces are flexible enough to meet needs of teaching, research or medicine. Pattern is also open-ended enough to grow in unexpected directions. Unit "J" is the main medical facility.

The idea is that any functions that may need to be provided can be within this framework. The range of possible dimensions for building width, starting with the narrowest, are 49'-4", 61'-8", 74'-0", 86'-4", 98'-8", 111'-0", etc., so the range could meet most needs. When the regular locations of towers do not suit the plan, it will be possible in some cases to build the four columns but use the space inside for non-service functions.

The system is to a large extent the result of the large air handling requirements for laboratories, which are greater than required for hospitals. Service requirements for hospitals and the kinds of changes required are different from those of labs. The system for the ceiling is ingenious but complex; the main question is whether access from below is desirable for hospitals, regardless of how easy it is to remove panels.

Hospital changes frequently involve running new service lines, and it is hard to see how these can be handled as easily by a ceiling access space as by a service zone in which workmen can simply run their lines, rather than taking out panels along the way and reaching the lines through. Drains in particular, which occur usually in the top part of a service zone, will be more easily handled in a space where men can walk around.

If we accept the idea of access from below, the ceiling is a reasonably flexible solution, but is fairly complex dimensionally, and involves a number of inconsistent features, such as partitions being permitted to cross ceiling panels in one direction but not in the other.

D) SUMMARY

The system at Minnesota University is flexible for growth, which was one of its major requirements but we doubt that the ceiling access is as flexible as interstitial space. There is also some question as to whether a hospital will need that much space for vertical services, and perhaps whether the fixed location of every tower would prove too rigid if it had to be used on many different buildings by many different architects. This is not what it was intended for, but it is what would be required if the Department of Defense was interested in trying to make use of it.

McMASTERS UNIVERSITY HEALTH SCIENCES CENTER, Hamilton, Ontario

Architects: Craig, Zeidler & Strong, Toronto

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SAN DIEGO VA HOSPITAL, California

Architects: Charles Luckman Associates, Los Angeles

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A) BACKGROUND

These two teaching hospitals are discussed together because they have many similarities, and the virtues of one on the whole are the virtues of the other. Both are under construction.

B) DESCRIPTION

Both hospitals are long span truss structures employing interstitial spaces. The depth of service space in each case is 7'-9". McMasters spans open spaces of 73'-6", while San Diego spans 80' and cantilevers an additional 27' at both ends. Both use large service towers to support the load, although the towers at San Diego are not always used for services.

Both of the hospitals employ interstitial space and horizontal planning, so they have already been illustrated and discussed in more detail in earlier sections. They are also discussed in the Comparative Analysis at the end of this section.

C) EVALUATION

Both of these solutions are excellent for their particular situations. However, since the systems were designed for special "one off" uses, difficulty would be encountered in trying to extend either of them as general design principle for a variety of uses. The predetermined spans, depths, and service tower locations are very restrictive. They could only be rationally used for other designs which coincidentally fit into their particular patterns.

If the attempt were made to use the pattern on a shrunken scale, the space would be grossly uneconomical, and dimensions of other elements would be inappropriate as well, such as the size of the service towers. Furthermore, so many changes would have to be introduced that very little of the original would remain as a "system."

D) SUMMARY

Both hospitals have reached the same conclusions about how to meet the needs of their large building programs and how to cope with future changes. Because they are teaching hospitals, their requirements are different from those of general military hospitals. In neither case was the system intended for application to other than the immediate problems at hand.

COUPLED PAN SPACE FRAME SYSTEM

(" DEVELOPMENT OF AN INTEGRATED BUILDING SYSTEM FOR HOSPITALS")

Sponsor: National Institute of Health and U.S. Public Health Service (N.C.H.S.R.&D.)

Principal Investigator: Professor Richard S. Levine

Researchers: Robert J. Koester, V. William Murrell, Larry L. McMahan

Structural Engineers: Dr. Thangamuthu Rangaswami, Dr. Hans Gesund

Developed at the University of Kentucky School of Architecture under a research grant from the National Center for Health Services Research and Development (HM00675)

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A) BACKGROUND

This project is the result of 9 years of research, the last three of which have been funded by the Public Health Service. Completion date for the study is August, 1970. A 60' x 60' section of the structural frame has been built at the University of Kentucky and has undergone structural testing.

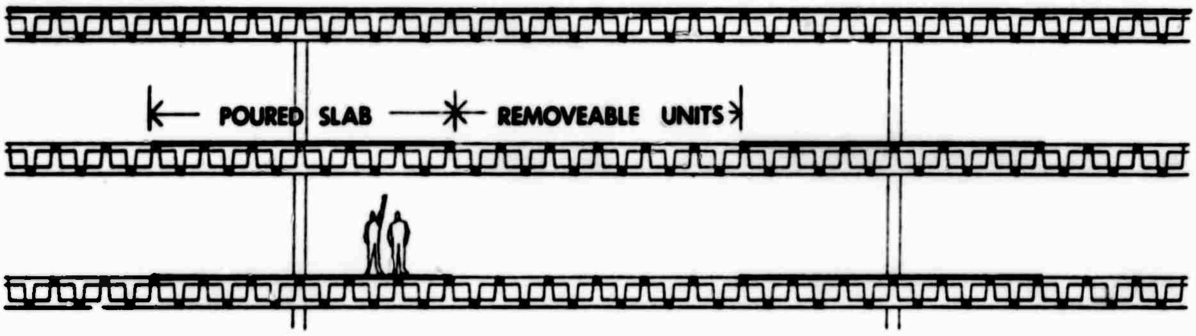
B) DESCRIPTION

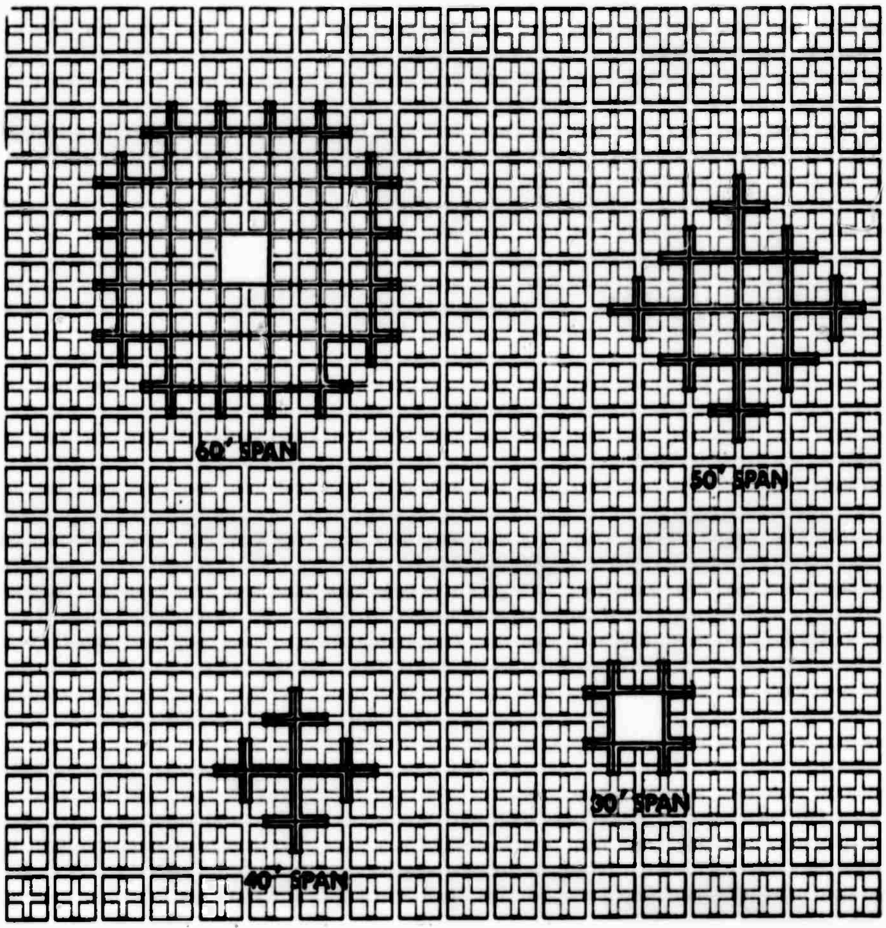
The system is designed for general application to hospitals. Its scope includes the integration of HVC and all other anticipated services into a concrete space frame floor system. Details of ceilings, partitions, lighting, bathrooms and patient services have not been studied, but it should be possible to incorporate subsystems developed elsewhere.

The space frame consists of an upper and a lower 5'-0" x 5'-0" horizontal rectangular concrete grid offset in plan 2'-6" in both directions from each other, and connected by vertical chords at the mid points of each horizontal chord. (See plan, section, and photograph.) The frame is 3'-0" in depth. The 3" deep floor slab extends 2" above the top surface to make a total depth of 3'-2". The frame is post-tensioned and could be used to span areas up to 70' x 70'. The service spaces between the horizontal and vertical chords can be up to 19" x 19" in the main directions and 19' x 27" on the diagonal. However, these openings are reduced by shear requirements near column capitals, especially when the supported area exceeds 40' x 40'. With a 70' x 70' area, a 15' radius "shear head" area is impassable to services. The shear heads will ordinarily be 3'-0" deep shear walls in both of the grid directions over the top of the column and sometimes into the next row or two of grids.

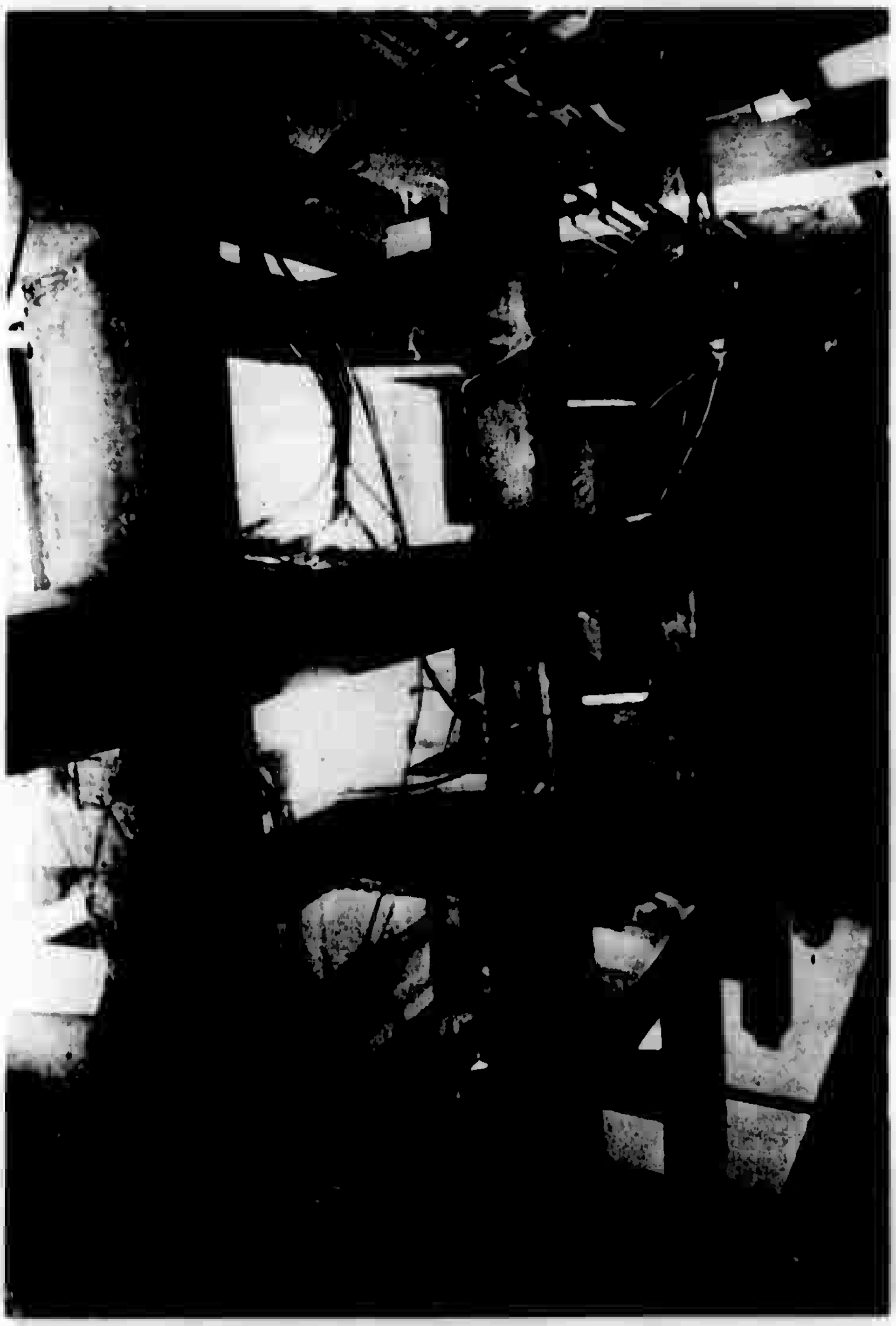
The name of the system relates to a standard repeated pan unit which has been ingeniously devised to fit together to provide the complete formwork for casting the frame. Half the pans face up, and half face down. When the forms are removed, the lower ones are removed from below and the upper ones from above. (See photograph)

Parallel to the structures research is a "Hospital Systems Study" which presents "distributional models" for the combination of all hospital service subsystems and serves as a design tool for using the space frame as a matrix for the integration of services. This system claims to be able to accomodate all hospital systems within the proposed depth.




COUPLED PAN SPACE FRAME - Section is shown with colums 60' apart. Plans illustrate the extent of the shear head conditions for various spans. Scale: 1" = 16'



COUPLED PAN SPACE FRAME (University of Kentucky) - Structural model of space frame undergoing testing.

COUPLED PAN SPACE FRAME - Forms in place for pour of first quadrant of 60' x 60' test structure. The form is made from the repeated use of a standard pan.

This is accomplished through the use of the computer generated distributional models which are a part of the systems studies, and which lead to or assist in the design of the entire hospital. Hospital requirements and planning principles were analyzed in preparation of the program, but the system has not been applied to a real plan yet.

C) EVALUATION

This is an interesting and ambitious approach to building systems and the programming of services by means of the computer is a potentially very valuable design tool.

The structure is unusual and the analysis of the stresses is too complex to be understood by intuition, but it is apparently quite efficient because the developers state that it has less than two thirds as much shear as a comparable Vierendiel space frame, to which it has some resemblance. The creation of such an intricate concrete structure from relatively simple standardized pans is ingenious and workable. Nevertheless, it is a cast-in-place procedure, which is not likely to be as fast as steel or precast concrete.

It is hard to see how the 19" x 19" spaces for services can accomodate all requirements, but it is claimed that the use of the computer program to try out different "distributional models" will make it possible to route services to avoid conflicts in ways which would be too laborious to discover by conventional design procedures. Clarification of this and other matters will have to await publication of the final report.

The use of the "systems study" and the computer involves a great deal of private jargon, or a special language (e.g., "Undifferentiated Distributional Models," "hierarchial system of complex controls", etc.) which suggests that the use of the program is not easy to understand. Private jargon is an indication that existing terminology is not adequate to describe one's subject, and that the subject could not be understood without the creation of new terms of reference. This could be a disadvantage, since the less easily understood is any system or procedure, the less willing is a potential user to commit himself to it. It is reasonable to want to see someone else be the guinea pig for a system which has many uncertainties.

Another matter of some concern is the tendency of computers in programs such as this to design systems in the tightest possible way, so that nothing can be added. This could make problems when other services need to be added in the future. However, the computer program is only a design tool, and the designer is not its slave; it may be possible to provide flexibility for future needs by writing the program to make such allowances.

The matter of most concern however is the impassability of services at the shear heads around columns. If the main service risers are to be coordinated with the structure, they may want to come up alongside the column, and then branch out horizontally. For areas over 40' x 40', this is not possible. The area around the column is the area of maximum structure, yet it will also have the maximum concentration of services, and the two are in conflict. Furthermore, as the spans get greater, the area of impassability increases, yet the service requirements increase also. For large span areas, the developers say that vertical service mains will need to come up in mid span. This of course is possible, but it goes some way to negating the main virtue of long spans, which is clear open space below. This is something which will have to be clearly explained.

One other detail problem is inherent in any space frame, but especially one with such small openings as this and that is the difficulty of installing long straight pieces of equipment into the fixed openings. If the sides of the service space are open, the pieces may be threaded through the openings; but when access is only from above or below, it is only possible to insert short lengths. This is less of a problem with interstitial spaces, in which access is from within.

Our other reservations expressed earlier about ceiling access systems as opposed to interstitial space systems apply here as well (accessibility, maintenance, etc.)

The two main features of the system are separate to a degree: the structure by itself is simply a new building component, and the system design program is a planning technique. However, since the structure would not provide adequate space for hospital subsystems designed in the conventional way, the planning technique must be considered an integral part of it. Likewise, the planning technique is for use only with this particular structure. Therefore the two are inextricably linked, so that a partial commitment to this system would be difficult. Therefore a great deal of "proving-out" will be necessary before the system can be used.

D) SUMMARY

This interesting system packs a great deal into a very small space, and appears to have a handle on how to order and control this. However, the compactness is not a virtue in itself. It will be particularly important to find out how fully a user must commit himself to the design technique, how easy it is to understand the system, and how much flexibility is provided for future change. There may be much more to the system than meets the eye, and final judgment will have to wait until publication of the research report.

PART E.

## COMPARATIVE ANALYSIS OF SIX RELATIONSHIPS OF SERVICE AND STRUCTURE

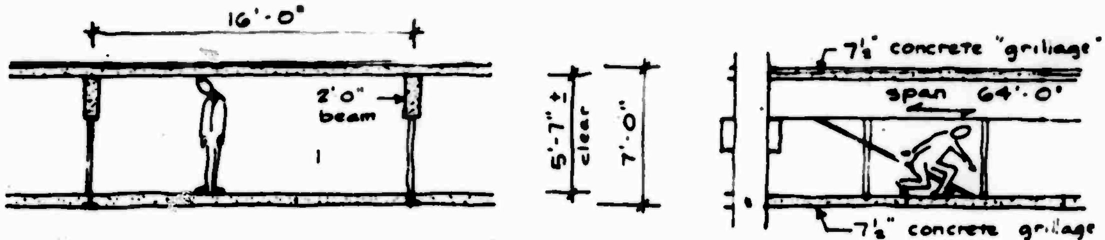
It is useful to examine some of these systems side by side. The dimensional implications of the structures are particularly interesting. Several different systems use interstitial spaces or service floors, but there are distinct differences in how carefully the uses of these spaces have been considered.

Three factors are compared in the following six pages:

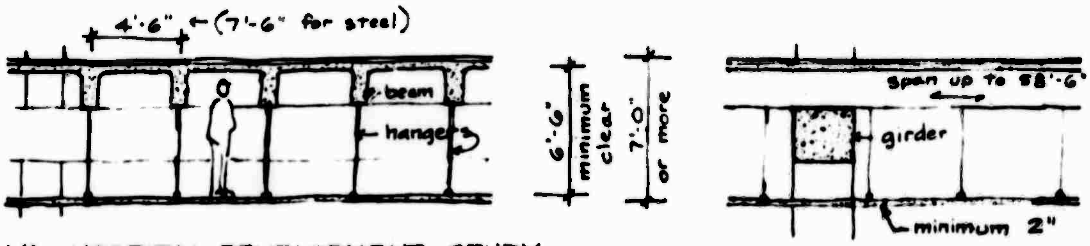
1. Headroom and other clearances within service floors (comparative sections).
2. Usable clear floor space (comparative plans).
3. Usable clear space within service floors (plans).

HEADROOM AND OTHER CLEARANCES WITHIN SERVICE FLOORS

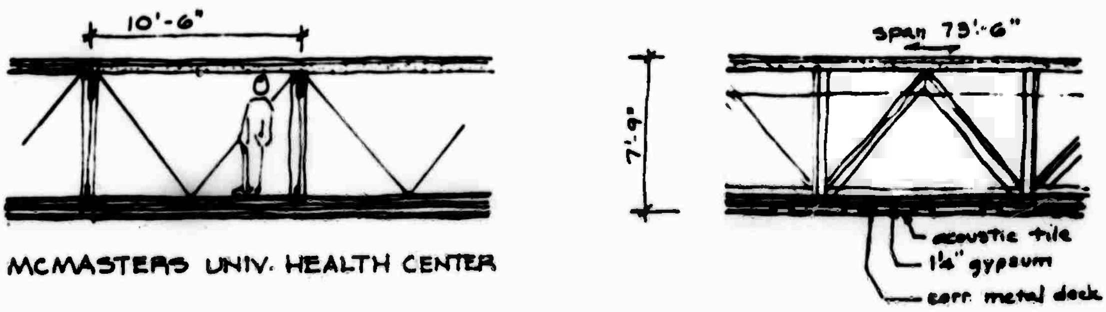
The service spaces of four quite different systems are compared (see illustration). Greenwich would have the most convenient space for access if headroom were just slightly greater. The VA system is expected to set adequate headroom as one of its system specifications. McMasters (as with San Diego) has adequate headroom, but no long clear open spaces except under the diagonals. Minnesota has lower space requirements because the vertical services are closer, and does not attempt to provide access from within the service space. Dade County, not shown, has closer services yet, and eliminates the overhead service zone.



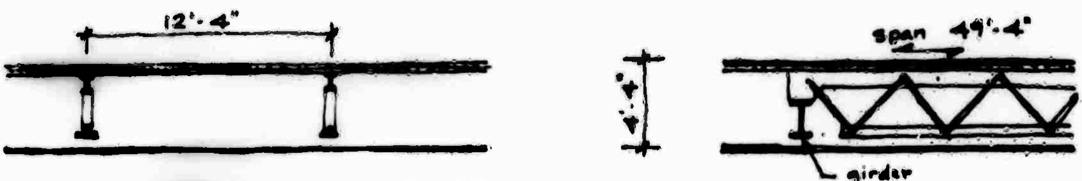

GREENWICH DISTRICT HOSPITAL




VA HOSPITAL DEVELOPMENT STUDY




MCMASTERS UNIV. HEALTH CENTER




UNIV. of MINNESOTA HEALTH CENTER

COMPARATIVE ANALYSIS OF SERVICE SPACES IN HOSPITALS -- Four distinctly different service spaces are illustrated (sections drawn in both directions).

The Greenwich system provides the largest clear area, because the service floor (ceiling panels) span 16', but the headroom is not quite adequate.

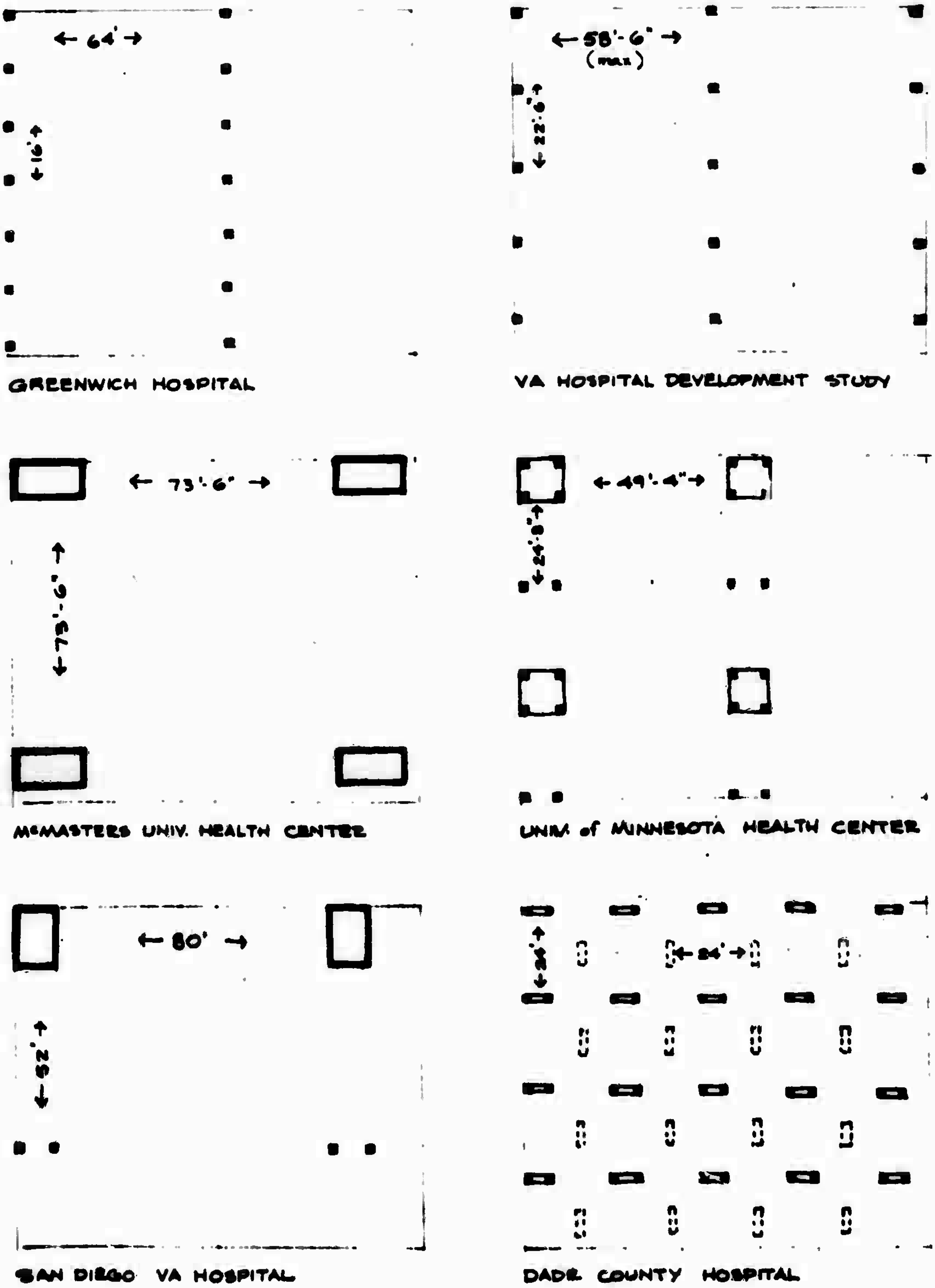
The VA System provides spaces with adequate headroom between the beams. With steel construction, the beam spacing is 7'-6". The beams should be cheaper than truss systems.

McMasters Health Center has adequate headroom, but frequent diagonals which chop space into 10'-6" x 10'-6" boxes.
Lighting is recessed and has fixed location.

Minnesota Health Center relies on access entirely from below and has the shortest span. Lighting is recessed but location is variable in one direction.

USABLE CLEAR FLOOR SPACE

The available space for hospital functions for six hospitals is shown (see illustration). Greenwich Hospital and the VA System are similar in providing fairly wide spaces between rows of columns. Each also have vertical service shafts, the location of which, relative to the structure is not fixed. McMasters and San Diego provide similar spaces between load bearing service shafts. The spans are large in each case, and provide more clear area than any hospitals to date have had. Minnesota follows the McMasters/San Diego pattern of service towers, but at a much closer scale, with a consequent low service space. Dade County Hospital provides structure and service spaces so close that the overhead services are eliminated.

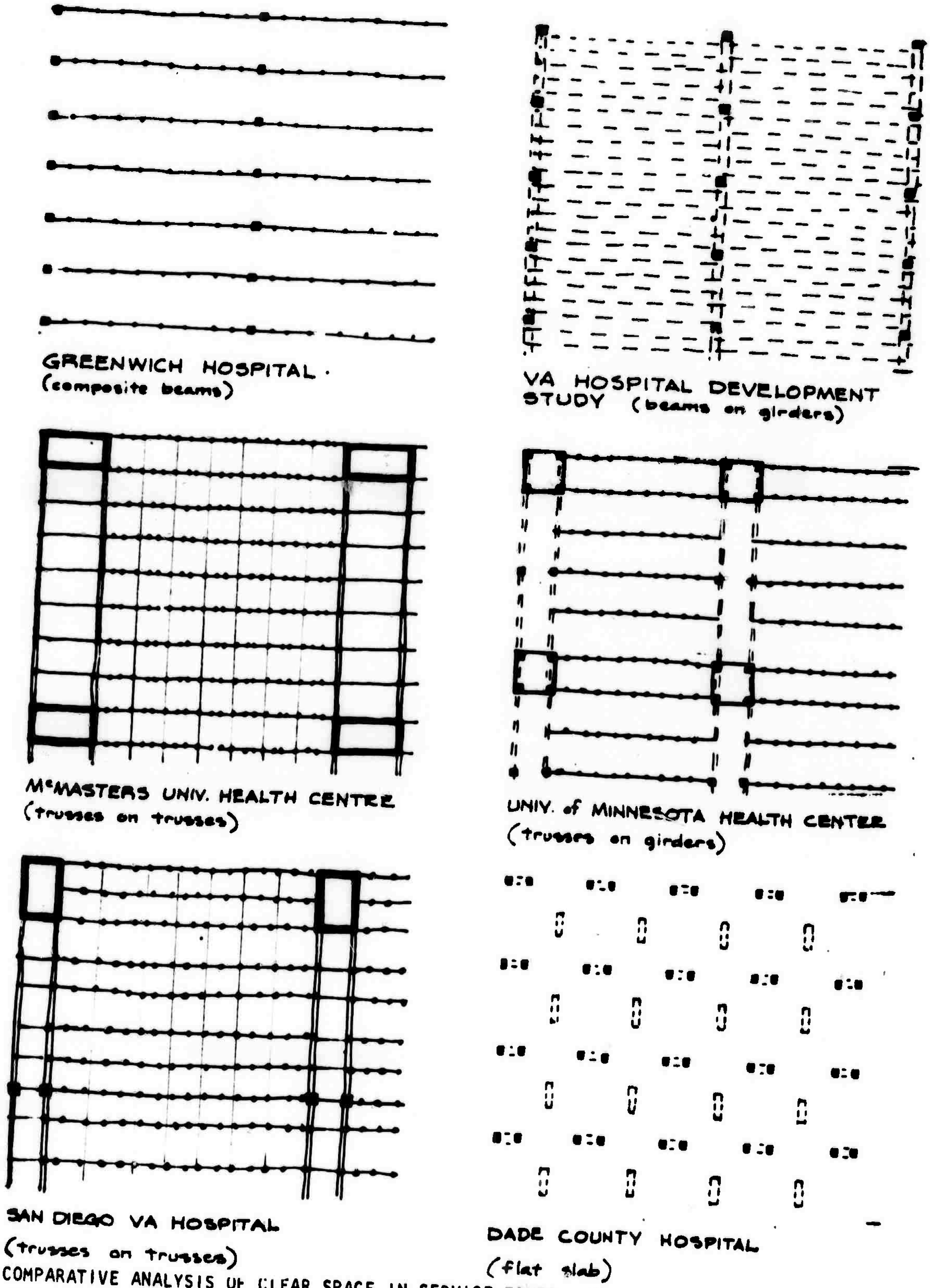



COMPARATIVE ANALYSIS OF CLEAR SPACE IN FUNCTIONAL ZONES - The clear floor space provided by six different hospital systems is illustrated.

USABLE CLEAR SPACE WITHIN SERVICE FLOORS

The space inside the service zones is compared for the same six hospitals (see illustration). Dashed lines indicate beams, solid lines are trusses, dots along the line indicate diagonal and vertical chords. (Cross bracing for McMasters and San Diego is conjectural only.) The openness of the Greenwich system is shown clearly. The VA System has long clear spaces, but between close spaced beams. McMasters and San Diego both involve passing under and over the diagonals in the structure, with a resultant division of space into boxes. Minnesota has access only from below, so space inside its service space is for services only, with no people. Dade County has no service space, so plan is through regular floor space.

If catwalks were illustrated, the limitations of access in San Diego would be further indicated.




COMPARATIVE ANALYSIS OF CLEAR SPACE IN SERVICE ZONES - The clear working space in the service zones of the same hospitals is illustrated.

## SECTION 6: A PROJECTION OF FUTURE DEVELOPMENTS

Change may be unpredictable, but it is better to try to anticipate the course of the future than to ignore it entirely. Therefore, in thinking about systems, it is useful to try to see where things are going in order to anticipate what will affect the pattern of buildings and systems.

The following list of projections are simply extrapolations from existing trends in hospitals and in other fields. No attempt is made to justify the projections; time alone will prove or disprove them.

A) BUILDING PERFORMANCE AND ENVIRONMENT

1) Awareness of patients' needs, long neglected, will increase.
2) Building performance and environmental standards will improve.
3) Buildings will be more flexible. The pace of change will continue to increase.

B) HOSPITAL PLANS AND BUILDING FORM

1) The biggest technical changes will be in the base functions -- the diagnostic and treatment areas.
2) New departments, presently non-existent, will develop.
3) The kitchen, the laundry, and the mechanical plant will become remote or may disappear.
4) The proportion of nursing area to total area will continue to decrease.
5) Nursing units will increase in size, employing concepts of specialization and team nursing.
6) Automation and communication developments will permit more separation of functions.

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7) Building organization will become more horizontal.

C) <u>OWNERSHIP AND CONSTRUCTION PROCESS</u>

1) Large business consortia may design, build and market hospitals as a product for a fixed price. Or they may design and build the hospital and lease it to a user. The result will be closer attention to cost effectiveness and scheduling.

D) <u>SERVICES AND STRUCTURE</u>

1) Services to all departments will increase.

2) Spans and floor depth will continue to increase.

E) <u>BUILDING SYSTEMS</u>

1) Integrated building systems will take over the hospital market.

2) Systems will become more competitive because of rising labor costs and a larger supply of integrated components and subsystems.

3) New systems will be developed out of the present beginnings of systems, and will themselves evolve into better systems.

4) Systems will become better understood by architects, builders, and clients.

5) Systems will become recognized by building codes and regulations.

6) More hospital equipment will be movable and capable of being plugged in at the patient's bedside.

7) Disposability of major structures is unlikely.

# SECTION 7: RECOMMENDATIONS AND IMPLEMENTATION PROGRAM

## A) THE FEASIBILITY OF BUILDING SYSTEMS FOR MILITARY HOSPITALS

Military hospital buildings and the hospital building program are ideally suited to the introduction of building systems.

The volume of construction ($50 to $60 million/year) would warrant at least the rationalization of components. An investment in the adoption of an existing system or in the development of a new system would repay benefits in time, cost, flexibility and quality for several years to come.

The needs of military hospitals are relatively repetitive, making possible continuous review and improvement of products and techniques. The centrallization of authority of the military structure also makes it possible to require that the system be used in at least several hospitals to achieve the full benefits of any system, which only accrue from repeated re-use.

The Department of Defense could also guarantee a market for new products if they were developed.

B) SYSTEMS DEVELOPMENT: POSSIBLE OPTIONS

Having determined that building systems are feasible for military hospitals, there are two development procedures that the Department of Defense could follow to implement systems. Each of these courses would be followed by design and construction of a prototype hospital employing a system and an evaluation of the system in use.

Option 1 - Adopt an existing system (with modifications as necessary).

The procedure would be:

a) Identify a system for adoption.

b) Establish a working relationship with the developers of the system.

c) Demonstrate the value of the system for building hospitals. Establish that the system can fulfill any planning requirements that it might be asked to meet. This has been started in the foregoing Evaluation (Section 6), but the Department of Defense will undoubtedly want to go into further detail.

d) Demonstrate the relevance of the system to the particular context of Department of Defense administrative methods, bidding and contract procedures, construction standards, and cost levels.

e) Identify any changes that will be needed, either in the system or in Department of Defense procedures and/or standards.

f) Set up a detailed program for use of the system on a prototype hospital: Procedures, costs and timetables.

Most of this work, which is essentially a liaison and evaluation procedure, could be done while the system was still being developed. The time for the procedure therefore would depend on the completion date of the system development, but would in no case be less than six months.

Option 2 - Develop a new system.

This course would require the following steps:

a) Set up a development team of architects, engineers, and consultants who would deal with the Surgeon General's office.

b) Decide on the scope of the system -- what subsystems would be included, how general would be its application to hospitals, the degree of new product development to be carried out, the number of hospitals required to be built with the system to justify its development cost, the depth of study to be carried out, and the development budget and timetable.

c) Carry out a building systems development program, as outlined in "Development Procedure", (Section 3-D).

User needs analysis
Performance requirements
System design
Performance specifications, for new products, if any
New product development, if any
Bidding on new products, if any

Minimum time: 2 to 4 years.

C) RECOMMENDATIONS

The following are primary recommendations for immediate implementation:

1) An existing system should be used - We recommend that Option 1 (Adopt

an Existing System) be adopted for these reasons:

a) At least one good system, namely the VA Hospital System, is under development and would suit the needs of military hospitals.

b) It is desirable to begin working with systems as soon as possible. The development of a new system would take longer and could not be ready for incorporation into the 1973 New Generation prototype. An existing system could be vetted and modified in time for the prototype.

c) The development of a new system would cost more money. A system already developed can be introduced with a much more modest investment.

d) Adoption of an existing system in no way rules out the development of a new system. But if a new system is to be developed, this earlier experience with an existing system will have been beneficial.

2) <u>The system used should be the VA Hospital System</u> - We recommend that the Department of Defense employ the system developed in the VA Hospitals System Development Study for the following reasons:

a) It is the best system developed so far, in that

(1) It is suitable for general application to a variety of different plans, so that one may be reasonably sure that it can be employed in the prototype.

(2) It is comprehensive; it deals with all major problems and leaves the fewest questions unanswered.

(3) It is realistic and pragmatic in that it does not require new product development.

Such a study could be started as private research project and ultimately be taken over by Department of Defense staff. Setting up such a study and getting it started would take at least a year.

4) A comparative analysis of horizontal and vertical hospitals should be made. - We recommend that the Department of Defense institute a study of the relative economics of horizontally and vertically planned hospitals, with a view to establishing a design policy for future hospitals. The study would analyze initial construction costs, the cost of alterations, total operating costs, and the cost of not making changes, and would attempt to establish a formula for relating these factors. The study could be carried out in 12 to 18 months.

D) ACTION PROGRAM

1) Study and Development program (6 to 9 month). - In order to implement the primary recommendations of this report, the following Action Plan could be followed:

The Department of Defense should at the earliest time possible set up a short term (6 to 9 months) Study and Development Program. Its main functions would be:

a) To establish a working arrangement with the VA.
b) To make a closer examination of the VA building system and to gain greater familiarity with its principles.
c) To ascertain that the VA system will fit the needs of military hospitals as set forth in the Department of Defense planning criteria and building regulations.

(4) The system will provide flexibility, high performance, quicker design and construction, and low total ownership costs.

b) It can be ready for use in time for a prototype hospital.

c) It has been developed for another government agency, which gives promise for interagency cooperation with wide ranging benefits of operation, purchasing, data collection, and so on.

d) Its development is well documented so that its rationale can be checked.

e) It has been designed with a view to being used by a variety of different architects. It, therefore, does not rely on any special or private knowledge or skills of individuals within a single firm.

f) Military hospitals are closer in character to VA general hospitals than to any other hospital for which a system has so far been developed. I.e., McMasters, San Diego, and Minnesota are all teaching and research hospitals which have a number of unique requirements.

The following are further recommendations for matters not directly related to systems, but very relevant to better military hospital buildings in general:

3) A continuing study of user needs should be instituted. - We recommend that the Department of Defense institute a continuing study of user needs in hospitals, which would be subject to continuous revision.

d) To ascertain that the costs of the VA system are acceptable for military hospitals.

e) To set up a realistic schedule for use of the system and for construction of the prototype military hospital.

f) To identify and set up the procedural and contractual changes which may be needed in order to use the system effectively.

2) Procedure - Using outside consultants - Set up a task force to meet with and assist the Surgeon General. The team members would include:

a) Representatives of the Surgeon General to provide detailed information on Department of Defense requirements, and to ultimately recommend approval.

b) Representatives of the VA Research Staff on an occasional basis, to give the benefit of their experience.

c) Representatives of the consultants, Stone, Marraccini and Paterson, and Building Systems Development Inc, to provide information on the system.

d) An outside Consulting Team comprising at different times a building systems analyst, a hospital consultant, a contract administrator, and a cost consultant to coordinate the work and to provide impartial, technically informed advice.

The Consulting Team would have the responsibility of carrying out the above tasks in cooperation with the other task force members. This responsibility would conclude with presentation of a report of their findings and proposals.

3) <u>Alternative Procedure</u> - <u>No outside consultants</u> - If the Department of Defense has the in-house capacity to carry out the Study and Development program without the Consulting Team, they could deal directly with the VA and the system consultants.

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1. Establish primary & secondary corridor patterns.
2. Avoid fixed equipment.
3. Keep services out of walls.
4. Keep nursing tower away from center of base.
5. Keep boiler plant and mechanical equipment remote from hospital.
6. Considerations for planned expansion.
7. Flexible partitions.
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