A SYSTEM FOR A MULTI-STORY
ACADEMIC RESEARCH BUILDING
FOR SCIENCE AND TECHNOLOGY

A thesis submitted in partial fulfillment of the
requirements for the degree of Master in Architecture
at the Massachusetts Institute of Technology

June 5 1964

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I hereby submit this thesis entitled, A SYSTEM FOR A MULTI-STORY ACADEMIC RESEARCH BUILDING FOR SCIENCE AND TECHNOLOGY, in partial fulfillment of the requirements for the degree of Master in Architecture.

Respectfully,

Guntis Plesums
ABSTRACT

The aim of this thesis is to design a multi-story academic research building for science and technology as a total system in construction and function. Special emphasis is put on the structural and the mechanical systems as an unseparable whole with various change cycles, on the construction of a space truss with flat linear precast concrete elements, and on the use of the space truss in a multi-story structure.
ACKNOWLEDGEMENTS

The following persons have been instrumental in the development of this thesis:

Professor Eduardo F. Catalano, thesis supervisor
Mrs. Deborah Forsman, Cambridge, Massachusetts
Mr. Sital Daryanani, Long Island, New York

Members of the M.I.T. faculty who participated in the preliminary thesis juries.
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THE MEANING OF SYSTEMS

A system is an organic order united by interaction and interdependence of the parts to the whole. A system can have subsystems. The entire universe from the galaxies and solar systems down to atoms is an accumulation of most ingenious systems, always present, always changing. The human body is a beautiful example of a rational system with many subsystems and sub-subsystems.
SYSTEMS IN CONSTRUCTION AND ARCHITECTURE

To conceive construction and architecture as a system is not a capricious trend but means to elevate architecture above the short-lived fashions of today which only result in forms that contribute little towards man's attempts to humanize nature. The population explosion and the increasing demands for high-performance buildings presupposes more sophisticated construction methods. The traditional design approach has resulted in arbitrary decisions and superficial forms. Our technology and science has created unlimited potential for endless indisputable products and forms which are universal and beyond personal interpretation. Aesthetic sensation from purely intellectual comprehension of a system based on logic is appreciated by the rational man.

In a creative endeavor it is very difficult to separate the technician from the artist. An artist must be first of all in full command of the technique - the process of work which leads to a higher level of aesthetic expression. "The essence of a structure and the widest field for the manifestation of personal sensitivity consists in accepting, interpreting, and rendering visible its objective requirements."¹ The development of the method or the work process is impaired by our present social attitudes towards work and in the disinterest and often even hostility against the requirements. Only the process of work which is the

product of inner conviction of the necessity of the technique can manifest itself in a convincing environment. Architecture then will transcend into a part of our approaching culture of science.
DESIGN PREMISES

PROGRAM

The thesis is a design for a building of 1,000,000 - 1,500,000 sq. ft. to house academic research activities in the fields of science and technology. Minimum required floor area is 40,000 sq. ft. Floor to ceiling height can be constant or variable. There can be a variety of activities on the same level or the activities can be segregated by levels. Minimum required span is 40 ft., and there can be a variety of spans within the building. The building must have a module based on lighting fixtures and minimum width of the corridors. Assumed superimposed live load is 125 pounds per sq. ft. There can be local demountability of structure for vertical expansion. Some noise control must be provided from room to room. Sun control can be part of the unified solution.

The building is to be a collection of many interdependent departments of various sizes. The departmental areas will be dedicated to workshops, instructional and research laboratories, class rooms, small departmental research libraries, department headquarters, administrative, faculty and research offices, lounges, exhibition rooms, drafting rooms, storage spaces, etc. The square foot requirements of these activities will vary from department to department.

Lounges, lecture rooms, library, cafeteria, etc. for use by all of the inhabitants of the building should easily fit into the provided spaces.
CHANGE IN USE THROUGH TIME

The design was approached as a total construction system and a prototype for many other buildings for similar uses which could be built from the same components, using the same system.

Academic research activities require space of utmost flexibility. Departments cease to exist and new departments are formed. A classroom or office might become a laboratory, library, or a workshop. Such changes in function demand anonymous flexible space with large spans, possibility of various partition arrangements and accessibility of all utilities for laboratories. It is not enough for the structure to perform as a machine, to be a dynamic organism in a constant state of animation with a life cycle for its activities, but it should also create life and space for the inhabitants within which cannot be so easily destroyed in the course of the life of the building.
PERMANENT AND TEMPORARY SYSTEMS IN BUILDING

Since the erection of the earliest shelter, architecture is physically a product of structure. Structure is the most permanent part of the building. The structure of the building as a whole has a long-term change cycle. The number of years are relative. The structure of a part of a building may very well have a short-term change cycle – part of it may be demounted or added to without affecting the overall confirmation of the structure. The cells of the body of an organism renew themselves, but the body itself remains stable. Our present methods of construction facilitate easy change of the building envelope, also it is less likely that this will occur. The partitions in this type of building are one of the most flexible features.

Most of the vertical circulation is also a permanent system of the building. Elevators or parts of them may be periodically replaced or altered but they will always be essential. Fire stairs are a permanent part of the building, however, other stairs between individual floors can be added or removed. Toilets, janitors closets, vertical shafts and chases are permanent features, but toilet and closet spaces can be changed into more critical lifelines for additional utilities or vertical circulation.

There is a hierarchy in horizontal circulation. Major horizontal circulation and the center of activities area is the result of the building core, and they become a permanent part of the building. Other more dispersed circulatory systems are subject to changes with the change in the
function of the building.

Mechanical systems have a short-term life cycle. The environmental control systems are less likely to demand periodic replacement, but changes in building function, higher demands and new developments require easy accessibility for eventual modifications. The same applies to electrical distribution. Communication systems, pipes with numerous utilities and exhaust ducts demand constant and unpredictable changes.

In a building for research purposes it is virtually impossible to foresee and to anticipate changes in the mechanical systems. Whole surfaces may become sources of illumination, power and heat. Hitherto unknown requirements and demands may be a reality in a decade.
DESCRIPTION OF THE APPROACH

A structure for maximum flexibility of mechanical systems was the basic design criteria chosen. The use of such structural system for a multi-story building was the second major consideration.

STRUCTURAL SYSTEM

Space Truss

Free passage of mechanical systems through the structure with easy access and the ability to erect partitions on a module presupposed some form of space structure. This would avoid the use of valuable space below the structural system for passage of ducts and pipes and eliminate the need of an expensive hung ceiling for sake of appearance. A space frame was eliminated due to the weight of the large amount of concrete and steel required for the rigid connections. A space truss is a structure built-up from linear trusses spanning in two directions forming a planar space structure. It is a common mistake by architects and engineers alike to call space trusses space frames. In a frame the forces are transmitted by rigid joints. In a truss direction of forces is turned toward supports through material vector separation. These we can call vector-resistant structures.

In practise most of the truss joints are rigid connections. According to Paul Weidlinger a concrete truss will transmit axial loads only if the
individual members are very slender in their dimensions. One such example is the use of precast, prestressed concrete trusses for a maintenance hangar at London's Gatwick Airport. Heavy concrete trusses regardless of the geometry will act as rigid Vierendeel frames.

In a space truss concentrated loads acting upon any given part of the structure are resisted not only by the directly loaded member, but also by other members at a considerable distance from the point of application. The high stresses in the directly loaded members are then decreased and the stresses in the more distant members are increased, thus a fairly even stress distribution is achieved over the whole structure. In fact, local areas can be safely overloaded without a failure of the structure. Because of such wider distribution of stresses throughout the structure, the location of supports becomes much less critical.

In addition to more even stress distribution considerably greater spans are possible for any given construction height. "... while the depth of a truss with horizontal upper and lower chords is of the order of one-tenth the span, space frames may have depth as small as one-twentieth or one-thirtieth of the span." Due to the large amount of mechanical services penetrating the structure the depth to span ratio in this design was kept to approximately one to sixteen.

The structural design of a space truss by conventional means is very time consuming. The highly indeterminate nature of the structure ruled out any attempt to dimension the component parts. In reality the analysis of this type of structure would be greatly facilitated with the help of a computer. An analogy to a plate or an estimate of the distribution of stresses in the system by coefficients similar to the ones recommended for use in the design of reinforced concrete flat plate systems would have produced a very conservative estimate and resulted in a waste of material and poor engineering approach.

It is a common fallacy to think of space truss as a structure for large spans only. In fact, few such large structures have been as of yet erected. Most space trusses that have been built such as the Unistrut system are for modest spans of 40 to 60 feet. The selection of space truss is not determined by span alone. Many microorganisms consist of microscopic space trusses. The human bone is a space truss eminently suitable for its function and in scale with the material and the span.

The structural behavior of space trusses can best be imagined when compared to the action of reinforced concrete slab or membrane. Space configurations may be substituted for flat slabs, folded plates and curved shells provided that this is economically feasible. The advantage in this is the reduction of the weight of the structure, increase of span, elimination of formwork by precasting, and the possible integration of mechanical systems.
One of the chief drawbacks to a wider use of space structures is the joint which is a potential source of difficulties. The design of the whole structure is very closely dependent on the design of the connection. The optimum joint should eliminate eccentricity in the transmission of forces to minimize bending in the component members.

Space Truss Configurations

The following geometric configurations of planar space truss systems are based on a comprehensive study of "Architectural Structure Systems" on which I have collaborated with Dr. Heinrich Engel, architect and former professor at the University of Minnesota. They are included here to illustrate the space truss systems available, the geometric configurations and the reasons for selection of the planar space truss system composed of quadrangular and triangular pyramids. The above system provides easy passage and maximum concealment of ducts. The methods of construction of these basic systems are infinite and offer numerous possibilities of expression. This thesis will only investigate the construction of the above mentioned space truss with flat linear precast concrete elements.
GEOMETRIC CONFIGURATION

ELEVATION

PLAN

SYSTEM WITH TETRAHEDRA AND HALF OCTAHEDRA

PLANAR SPACE TRUS SYSTEM COMPOSED OF QUADRANGULAR AND TRIANGULAR PYRAMIDS
GEOMETRIC CONFIGURATION

ELEVATION

PLAN

SYSTEM WITH TETRAHEDRA AND OCTAHEDRA

PLANAR SPACE TRUSS SYSTEM COMPOSED OF TETRAHEDRON AND OCTAHEDRON UNITS
GEOMETRIC CONFIGURATION

ELEVATION

PLAN

SYSTEM WITH HEXAGONAL PYRAMIDS AND IRREGULAR POLYHEDRA

PLANAR SPACE TRUSS SYSTEM COMPOSED OF HEXAGONAL PYRAMIDS AND IRREGULAR POLYHEDRA
GEOMETRIC CONFIGURATION

ELEVATIONS

PLAN

SYSTEM WITH SINGLE TRUSSING OF SLOPED PRISM FACES

PLANAR SPACE TRUSS SYSTEM COMPOSED OF TWO SETS OF TRIANGULAR PRISMS - TYPE I
GEOMETRIC CONFIGURATION

ELEVATIONS

PLAN

SYSTEM WITH ROOF TRUSSING OF SLOPED PRISM FACES

PLANE SPACE TRUSS SYSTEM COMPOSED OF TWO SETS OF TRIANGULAR PRISMS - TYPE 2
GEOMETRIC
CONFIGURATION

ELEVATION

PLAN

SYSTEM WITH SINGLE
TRUSSING OF VERTICAL
PRISM FACES

PLANAR SPACE TRUSS SYSTEM (COMPOSED OF RECTANGULAR PRISMS-TYPE)
GEOMETRIC CONFIGURATION

ELEVATION

PLAN

SYSTEM WITH DOUBLE TRUSSING OF VERTICAL PRISM FACES

PLANAR SPACE TRUSS SYSTEM COMPOSED OF RECTANGULAR PRISMS-TYPE 2
GEOMETRIC CONFIGURATION

ELEVATION

PLAN

SYSTEM WITH CROSSWISE TRUSSING OF PRISM CORNERS

FLANAR SPACE TRUSS SYSTEM COMPOSED OF RECTANGULAR PRISMS - TYPES
GEOMETRIC CONFIGURATION

ELEVATION

PLAN

SYSTEM WITH SINGLE TRUSING OF VERTICAL PRISM FACES

PLANAR SPACE TRUS SYSTEM COMPOSED OF TRIANGULAR FRISMS-TYPE I
GEOMETRIC CONFIGURATION

ELEVATION

PLAN

SYSTEM WITH DOUBLE TRUSING OF VERTICAL FRAMING MEMBERS

PLANAR SPACE TRUSS SYSTEM COMPOSED OF TRIANGULAR FRAMES - TYPE 2
GEOMETRIC CONFIGURATION

SIDE ELEVATION

ELEVATION

PLAN

SYSTEM WITH CROSSWISE TRUSING OF PRISM

PLANAR SPACE TRUSS SYSTEM COMPOSED OF HEXAGONAL PRISMS
Use of Space Truss in a Multi-story Structure

The use of space truss in a multi-story structure hardly has a precedence. Louis Kahn's "Tomorrow's City Hall" is one of the few examples of such a study.

In low-story structures the columns can easily penetrate the structure without complications, but this solution was rejected here. Penetration of columns would limit the flexibility of space, add to the problems of assembly of the precast space truss from linear elements, and the increase of column cross section due to the height of the structure would further complicate construction.

An exterior bearing wall with load carrying mullions at each or at alternating modular is a possible solution which could also provide sun control. However, such a method of support would not be in scale with the building and would result in a highly ornamental surface.

The loads of the space truss can also be collected by a perimeter beam and transferred to the columns on the exterior of the structure.
CONSTRUCTION METHODS, PROCEDURE AND THE RESULTANT STRUCTURE

Space truss

The method of construction of the concrete space truss evolved from the premise that long precast components would eliminate most scaffolding and greatly speed up construction. The handling of large concrete units present no serious problem in the United States. Because of the high cost of labor economical construction can be achieved only by the utmost simplification and reduction of construction work in the field.

The shape of the precast concrete unit was, in turn, determined by ease of precasting, storage and delivery to the site. What resulted is a kind of concrete bar joist 11 modules or 51'-4" long. The module of the building is 4'-8". Other lengths of joists are used for the conditions at the core. The reinforcing steel for the concrete joists is welded from steel angles and reinforcing bars similar in appearance to steel joists and then placed into the form. In precasting fine members it is very hard to achieve concrete which is less than 8000 psi. It is safe to assume that minimum of 6000 psi concrete would be figured for all precast pieces. Concrete joists are placed against each other at a 60 degree angle. This forms a one-way space structure.

To make the structure act in two directions steel bars are welded perpendicularly to the exposed steel in the bottom joints and surrounded with a precast concrete channel 4 modules or 18'-3" long. These channels and
joints then are grouted. Bulb-tees are spot-welded to the continuous exposed steel angle in the top chord of the concrete joists, wood fiber plank such as "Tectum" is placed between the bulb-tees and the upper chord and a reinforced 4" concrete slab is poured on top to act as the compression member for the space truss. Reinforcing in the concrete slab is perpendicular to the top chords of the linear members at the point of intersection of the diagonals. Other reinforcing is provided for partition loads and thermal expansion. The wood fiber plank provides formwork for the slab and acts as an acoustical absorbitive material in most parts of the building where the structure is left exposed.

Vertical Supports

The space truss transmits a load of 125 pounds per sq. ft. to the load bearing concrete walls around the cores and to the exterior wall. Linear members of the space truss are set on the walls around the cores and the reinforcing of the concrete slab is anchored in the load bearing wall.

The loads on the exterior of the building are transmitted by a precast concrete wall. This wall consists of a column at every other module with a beam as a part of the column at every floor. The beam has an edge with recesses for the linear members of the space truss and exposed reinforcing to provide the necessary tie for the slab. The load bearing wall provides a more even bearing condition, eliminates the need for the scaffolding on the perimeter of the building, and provides sun control to the glass areas.
A floor high transfer girder above the main lobby and the intermediate sky-lobby transmits the forces from the load bearing wall to the columns on the exterior. This provides large unobstructed spaces on the ground floor and the sky-lobbies and eliminates the need for increase of the small column dimensions due to the accumulated loads.

The large exterior columns carry the loads of the transfer girders and the space truss next to the columns. These columns are precast and they have a changing cross-sectional area.

Resultant Building

The final building with 32 stories above the ground is the result of the development of the structural and spatial concept for the 1,500,000 sq. ft. area for the academic research facilities. Each of the typical floors have an area of 50,176 sq. ft. The module is 4'-8". The building is 224 ft. by 224 ft. on the interior and approximately 540 ft. above the ground. The construction height is 4 ft. with 10'-0" clear height from the floor to the ceiling for the 12 typical floors, 15'-0" for the two higher intermediate levels and 24'-0" for the three lobby levels.

The exterior of the building is an attempt to express only the structural system and the building envelope, a curtain wall.
SCALE AND THE HIERARCHY OF SPACE

The image of the building and the city is that of the nineteenth or the first half of the twentieth century. These were still scaled to the size of man. New dynamic structures such as highways and large buildings of super-human scale have been created by technology. Little has been done to bring the super-human scale in harmony with the human scale.

The transition between this super-human scale and the human scale can only be achieved through a hierarchy of space. Only an order of scale sequences between the building and the city or the building and the spaces within the building can establish the spatial flow and climaxes to harmonize the human scale with the super-human scale.

The structure and the size of the academic research building has a super-human scale. The human scale is manifested by the larger spaces unifying the two floors between the cores. The sky-lobbies are an attempt to relate the human spaces within the building to the super-human spaces on the outside and to provide a spatial climax in vertical circulation.
CORE AND CIRCULATION

Role of the Core

The most important factor in making the building as well as the city an organic entity is the core. The core and the spaces related to the core permit the individual to orientate and to identify himself within the system.

In a multi-story building the type and layout of the core is determined by the nature and purpose of the building. In an office or similar commercial building with large open floor areas the purpose of the core is to provide vertical transportation and building services. The interaction of the personnel will be less influenced by the core.

In an academic research building the core becomes the center of life of the building. The floor area is divided into many small spaces with often little opportunity for communication. The core has to provide not only the vertical circulation and the building services, but ample possibilities for meeting of minds and exchange of ideas. The interior life of the floor or the combined two floors was created by dividing the core into four parts with an open space in the center of every other floor.

Elevators

The design of the elevators for a multi-story academic research building
is governed by numerous peak loads. Maximum load on an elevator system usually occurs during class changes. In undergraduate institutions 30 to 50 percent of the population may require elevator service within 5 minutes. An office building has peak loads early in the morning and at night. A research building may very well have a constant load on the elevators at one hour intervals.

To minimize the number of elevators, 4000 pound elevators with a speed of 1000 FPM are selected. The elevators are zoned with 12 serving the upper part of the building and 12 the lower part only. All elevators stop at the intermediate sky-lobby. Change of elevators is required to go from the lower to the upper part of the building. There is also one 10,000 pound service elevator.

Passenger Elevator Design Data

For the Lower part of the Building

1. Total area served by elevators 695,200 sq. ft.
   Typical floor area 50,000 sq. ft.
   Typical floor to floor height 14 ft.
   Total elevator rise 242 ft.

2. Population served at 150 sq. ft. per person
   \[
   \frac{695,200}{150} = 4635 \text{ persons}
   \]
3. Per cent of population to be served in 5 minutes assumed at 13 per cent.
   \[ 4650 \times 0.13 = 610 \text{ persons} \]

4. Selection of 4000 pound capacity elevators with 27 passengers per trip with a speed of 1000 FPM
   \[ 242 \text{ ft.} = 20 \text{ floors at 12 ft.} \]
   \[ \text{round trip time} = 150 \text{ seconds} \]

5. Number of passengers carried per car in 5 minutes (300 sec.)
   \[ \frac{300 \text{ sec.} \times 27 \text{ pas. per trip}}{150 \text{ sec.}} = 51 \text{ passengers} \]

6. Number of elevators required
   \[ \frac{610 \text{ passengers}}{51 \text{ passengers in 5 min.}} = 12 \text{ elevators} \]

7. Number of elevators required per bank
   \[ \frac{150 \text{ sec. round trip time}}{35 \text{ sec. time interval}} = 4.3 \text{ therefore minimum of 5 elevators per bank.} \]

For the Upper Part of the Building

1. Total area served by elevators 695,200 sq. ft.
   Typical floor area 50,000 sq. ft.
   Typical floor to floor height 14 ft.
   Total elevator rise 242 ft. plus 218 ft.
2. Population served at 150 sq. ft. per person

\[
\frac{695,200}{150} = 4650 \text{ persons}
\]

3. Per cent of population to be served in 5 minutes assumed at 13 per cent.

\[
4650 \times 0.13 = 610 \text{ passengers}
\]

4. Selection of 4,000 pound capacity elevators with 27 passengers per trip with a speed of 1000 FPM

\[
242 \text{ ft.} = 20 \text{ floors at 12 ft.}
\]

round trip time = 150 seconds plus 13 seconds (for travel to ground floor) = 163 seconds

5. Number of passengers carried per car in 5 minutes (300 sec.)

\[
\frac{300 \text{ sec.} \times 27 \text{ pas. per trip}}{163 \text{ sec.}} = 50 \text{ passengers}
\]

6. Number of elevators required

\[
\frac{610 \text{ passengers}}{50 \text{ passengers in 5 min.}} = 12 \text{ elevators}
\]

7. Number of elevators required per bank

\[
\frac{163 \text{ sec. round trip time}}{35 \text{ sec. time interval}} = 4.7 \text{ therefore minimum of 5 elevators per bank}
\]
Stairs

Four fire stairs are within 125 ft. from the furthest point in the building assuming the most critical arrangement of partitions. There is a limited possibility for grand stairs at the center of the building within individual departments.

Toilets and Closets

The number of toilet fixtures is based on the assumed population of 150 sq. ft. per person with 60 per cent being men and 40 per cent women. Each floor has two toilet rooms - one each for men and women.

Each floor has a janitor's closet, two communications and electrical closets and four pipe and duct shafts. Public telephones will be located as furniture in the lounges.

Horizontal Circulation

The location of the service core in the building predetermines a major corridor around the core. Secondary corridors would not be a permanent part of the structure but would be determined by partition layout. The lower half of the building has two lounges per floor, but the upper half, with the elimination of 12 elevators create more flexibility in lounge size and location.
MECHANICAL AND ELECTRICAL SYSTEMS

As stated previously the mechanical systems in an academic research building requires easy access and utmost flexibility for interchanging or adding of utilities. The complexity of modern research buildings present unprecedented problems. The attempt of this thesis is not to provide every module with all the utilities, but to have them readily available if needed.

The architect exercises no control on the positioning of mechanical and electrical systems during the life of the building. At best, he can hope to provide some order which would not interfere with the utilization of the spaces.

Environmental Control System

Unpredictable cooling loads on the interior of a research building due to different requirements demand a more elaborate environmental control system than an office building might need. "Generally, the most effective way to control space temperature is to supply a constant volume of air, while varying the air temperature and humidity content in accordance with the demands of changing interior and exterior loads." A single-duct, low velocity air supply system is selected here with a hot water heating coil at every outlet where needed. Air is supplied at a low temperature

of 60 or 65 degrees. No cold water line is needed for the interior system. The light fixtures alone will raise the air temperature 6 to 10 degrees, thus eliminating reheating at some areas. The heating coils and air outlets and returns are integrated with lighting fixtures. Most of the supply and return air ducts are 4 modules or 18'-8" on center with a possible extension to any module. Triangular sheet metal return air and insulated supply air ducts are used for all horizontal distribution to conform with the structure and to be less noticeable from below. Two different duct sizes are used to adjust to the increase or decrease in the volume of the air. The ducts have a cross sectional area of 2.8 sq. ft. and 4.4 sq. ft. The dimensions of the ducts were based on the required 2 sq. ft. of duct area per 1000 sq. ft. of area served.

No additional air is provided for the exterior zone. Hot and cold water lines and a return line is extended around the perimeter of the building with fan-coil units below the glass to counteract drafts.

There are four vertical duct and pipe chases for passage of supply and return air, exhaust air and all pipes. Vertically the air is supplied by a high velocity system and then changed to a low velocity at each floor outlet.

Air handling units are located on three mechanical floors. The mechanical floor above the main lobby conditions the air for the basement, lobby and the first seven floors above the mechanical floor. The intermediate mechanical floor supplies the air to the six floors below the mechanical
floor, the sky-lobby and to the seven floors above the mechanical floor. The mechanical floor on the top conditions the air for the upper sky-lobby and the six floors below the lobby. This mechanical floor also contains the boiler, the cooling tower and the refrigeration units. Transformer and all supply lines of utilities are located in a basement mechanical floor.

Exhaust Air

A laboratory building requires removal of air from fume hoods or from the entire laboratory. Often the exhaust air from one experiment cannot be mixed with the exhaust air from a different room. This might require many different air exhaust ducts dependent on the nature of the activities in the laboratories. The experiments cannot be anticipated and are subject to change from time to time. Thus, exhaust air ducts are highly flexible and will be installed only when needed between supply and return ducts, in place of return ducts, or like pipes over and perpendicular to smaller air ducts. All exhaust air will be collected in the four vertical shafts and exhausted through the roof.

Laboratory Utility Pipes

There are four major vertical pipe distribution shafts with easy access for inspection and maintenance. Each vertical shaft in turn provides two horizontal distribution areas as shown in plans. Any utility can be further supplied to the smallest rooms as required by extending the pipes
between or over the air ducts. Some of the utilities which will be installed are natural gas line, compressed air line, steam line, vacuum line, hot and cold water supply, drain and chemical waste line. Additional utilities can be installed if needed. The vertical shafts will also contain roof drain lines and soil stacks.

Electrical System

Each floor has access to two continuous vertical electrical closets for distribution of all normal building laboratory electrical facilities. 110 and 220 AC electrical lines are supplied to each alternating module. Laboratory electrical services will be connected directly to the electrical closets.

Communications System

Each floor has access to two continuous vertical communications closets for distribution of telephone, closed circuit T.V., computer lines or other communication facilities. Telephone distribution lines are in each alternating module for easy access.

Illumination

Every module is provided with a square lighting fixture that may contain two or four fluorescent light tubes. 60 footcandles are considered a minimum standard for illumination. It is very likely that 100 footcandles will be considered normal practise in future.
PARTITIONING OF SPACES AND ACOUSTICAL PRIVACY

Maximum flexibility in mechanical services create problems in acoustical isolation. Partitions can be erected on the 4'-8" module at the ceiling and sealed effectively with numerous available sealing compounds or gaskets. The architect has little control on the type of partitions used during the life of the building. Metal studs with gypsum board or concrete block are the most likely partitions used at present. Many areas in a building of this kind can be left open. The wood fiber panels used as forms for concrete slab will also serve as an acoustical absorbative material. Many interfering sounds can be effectively minimized by introducing "acoustical perfume" - a 30 decibel bland and continuous noise through the ventilation system. One is never conscious of such a background noise. Large rooms will be isolated by inserting precast concrete panels between the space truss and by plastering in the areas if utilities penetrate the spaces. Wire mesh and plaster is the only presently available solution to such conditions. Smaller rooms and offices will be isolated by metal panels filled with fiberglass which will be inserted around the lighting fixture.
CONCLUSION

In conclusion it is evident that the project was over ambitious and the problems connected with a research building enormous. This thesis can be only considered as an attempt to depart from the more traditional solutions and as an exploration in a new direction. Many aspects of the design became clear during the course of the study.

Some of the contributions and advantages of the thesis:

1. The assembly of a precast concrete space truss from linear components is an efficient method of construction.
2. Maximum flexibility for mechanical systems is possible.
3. Use of a space truss in multi-story construction create greater design freedom.
4. A space truss in a multi-story structure can be supported by a load bearing exterior wall.
5. Multi-story structure for academic research purposes can create a desirable environment.

Some of the disadvantages and areas needing further investigation:

1. Assembly of a space truss from linear components results in slight differences in appearance.
2. Alternate methods of construction of the space truss
system composed of quadrangular and triangular pyramids - by closing of some sides for example - might also provide flexible space for utilities.

3. The geometry of the structure demands new installation methods for the ducts once the structure is complete.

4. Series of configurations of plans, sections and cores would more closely illustrate a system as a design potential.

5. Elimination of the core as a load bearing element could simplify construction and provide greater flexibility.

It is important to remember that a system should be a background for life and not an end in itself - a life richer in spatial experiences that what our present buildings can provide us.
BIBLIOGRAPHY


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