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CRITICAL FOR PLANNING AND DEVELOPMENT OF INDUSTRIAL RESEARCH AND DEVELOPMENT CENTRES 1/

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SUMMARY

Geographic characteristics including site considerations are controlling factors in drawing competent staff. Site selection should emphasize proximity to the kind of cultural and educational resources that interest creative scientists. In addition, the institute should be sited to maximize the interaction with other relevant organizations.

The Institute's design should revolve around the principle of adaptability, that is, flexibility structured to that degree required by each building subsystem and providing only that much flexibility as is appropriate to the changes that can be anticipated for a specific building subsystem.

Larger institutes should maintain as small a scale of physical plant as is possible without sacrificing the need for fairly large groupings of laboratories. The relationship between the laboratory and the office should be close in the case of experimental research facilities.

The movement of materials in and out of the building should take into account the largest "transport-module" that will be moved through the project. This will define the width, height, and extent of the corridor system and maximizes the distribution potential for large packaged items. Generally this limitation is established by transport or truck dimensions.

The construction materials are a function of local technology, however, consideration must be given for developing a laboratory design that does not produce undesirable side effects which could interfere with equipment operation.

In general, laboratory spaces require fairly closely controlled environments and therefore the outside world constitutes a burden rather than a benefit in most cases.

It is the laboratory module which is the key to good design. The size, shape, and groupings of the modules should be such that they are fairly simple and grouped together in reasonable numbers.

The materials of the laboratory should be designed to withstand the effects of continual change. The walls separating laboratories should be designed as a service distribution system so as to allow relocation of the furniture without causing major service relocations.

The plan of the laboratory should create reasonably large laboratory areas since this will encourage the interactions between disciplines and experimentors.

Air conditioning is desirable in a laboratory because of the tremendous variety of load characteristics.

The use of an adaptable furniture system, which can be easily moved, must be recognized. It must provide for that minimum amount of draws and cabinet space as is appropriate for a given laboratory, allowing for quick additions and deletions as is required. The fume hood is one of the most critical pieces of equipment. Its location and the control of its waste products is a matter for serious concern.

In conclusion, an effective laboratory is designed to respond in the manner of a complex organic system. The design of individual spaces is not so much a matter of a specific set of functions but is the result of the recognition that a space responds to a wide variety of utilization to which it can be put over an extended period of time and is, therefore, constructed to permit reorganization as time and need requires.

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INTRODUCTION

One of the more difficult planning and design problems to confront the architect in the twentiath century has been that of the industrial or research laboratory facility. It is a complex organism, whose character raquires many complax considerations to respond to the myrad utilizations expected and yat raspond to continual changa in the unpradictable changing world of science.

A facility must be devaloped such that it provides accass to the fundamental services and skills that ara necassary to make it operative, but it must work in such a way as to respond to the changing character of those it servas. For this reason it is more desirable for an architect to concentrate on the complexities of the intardependencias of activities that take placa within this kind of facility than it is for him to study the mechanics of a specific laboratory. While aquipment undergoes changes, certain basic and inaltarabla facts of laboratory design have remained intact sinca the time that Galileo first established the concept of empirical research.

Therefore, an examination will be mada of tha processas by which a facility is converted from an idea into an operational building by dealing with general theory (and the particulars where it is appropriate). The goal will be to have a facility with the capacity to raspond to the wide range of research demands made upon it by diverse sciences.

I. SELECTION OF A RESEARCH INSTITUTE'S LOCATION

The location of an institute is the most sensitive decision that can be made by a planning group. The institute's location can, to a great extent, determine its potential for success. It should be located such that it will draw individuals of the highest quality, since it is the character of the staff that is the most critical aspect in the success of an institute. Its physical location will impact the willingness of people to locate in an area with which they are unfamiliar.

A. Geographical Location

The geographical location of an institute is generally a function of the role the institute is intended to fulfill. As an example, if it is a facility studying ocean life or behavior, the location would be more suitable adjacent to the open waters of the seas. The geographic location then to a great extent is a function of the specific character of the research program. If the character is generalized, rather than specific, the location then becomes a more complex judgment than it is in the case of a rather definitive or narrow scope facility. The generalized facility's location is more often a function of the proximity of a great variety of staff skills and services than it is the proximity of research data.

B. Proximity To Other Relevant Organizations

The availability of staff from other organizations provide for interchanges, healthy competition for staff, and the availability of experienced supportive personnel who can find reasonable employment opportunities. The kinds of facilities that will mutually benefit from proximity are, of course, universities (with extensive science orientations). Of course, proximity to other institutes, industrial centers, provide a strong base, though care must be taken not to duplicate functions which are already provided in the other institutes.

C. Working Environment for Employees

As has previous been indicated, an institute's location determines its ability to draw competent staff. So to with the character of the working environment since here is where the creative work must be performed. It must be the kind of an environment which does not present a restraint on the seriousness of a scientist's endeavor or interfere with his creativity. Distractions created by difficult commuting, poor local housing, lack of cultural activities, and insufficient recreational facilities can contribute to significantly reducing the willingness of competent people to relocate in developing areas. Staff will be drawn to these institutions because they believe that the work environment is creative, the facilities contemporary, and that the attitude of the administration will enable them to continue their interesting and creative research work. It is important that the character of the environment provide for their skills with as little interference with the creative process, since there can be nothing more undesirable than an institute poorly located with poor cultural and social facilities and one in which there is a compromise of the research environment for other purposes.

D. Availability of Services

Most of the services required for the operation of a laboratory present problems which are associated more with scale than with type of services.

1. The tremendous demand for electricity can create drains for power that are equal to that of a small city.

2. It is desirable to have a fairly abundant supply of water though this seldom is a constraint on the location of an institute. If the quality is poor, the water can be treated if there is sufficient power available.

3. Gas is becoming less and less a necessary research service.

4. The treatment of sewage is not as significant as the treatment of pollutants discharged from chemical and physical research processes.

The control of air pollutants is important in the siting of the building, whether it is nestled on the side of a mountain or at the base of a valley, since air currents can control the possible recirculation of pollutants generated by the institute back into the facility or into neighboring buildings or sites. A wind tunnel test is strongly advised using scale models to analyze the effect of air currents or thermal inversions that are known to exist at the site.

E. Proximity to Potential Clients

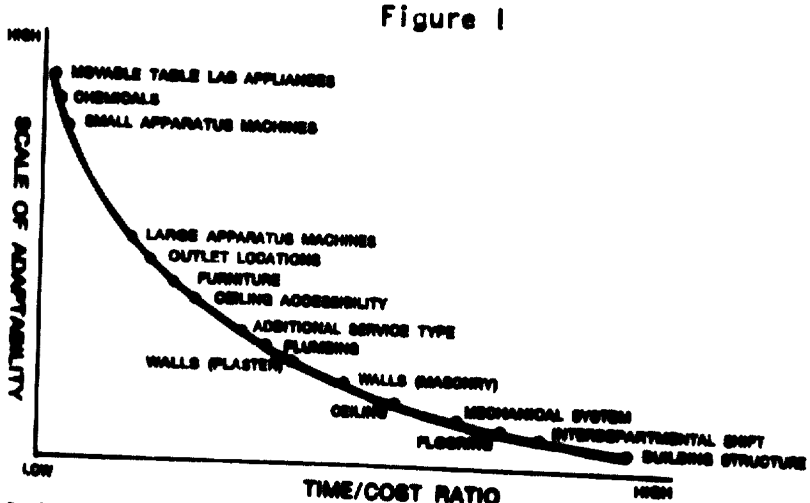
The proximity of the Institute to the potential clients is probably one of the less important criteria. Even with good transport facilities, the volume of movement in this area tends to be relatively small. The research process does not involve continual or intimate interaction between clients and research participants. If proximity to potential clients is possible it is, of course, an enhancing factor.

II. CONSIDERATIONS FOR BUILDING DESIGN

A. Functions of the Institute

If the Institute is intended for generalized scientific research, rather than limited to one specific area of study such as oceanographic research, it will be required to have the appropriate degree of "flexibility" in order to respond to the variety of possible uses. The word "flexibility" is fraught with all sorts of problems. It is best to modify the word to give it a definition which allows it to work more as a tool in defining appropriate degrees of flexibility than to imply the facility has an open-ended or undifferentiated degree of capability for changes. It is desirable to put a valve on the need for flexibility which would better be called "adaptability". Adaptability is defined so that changeability is in direct proportion to the frequency of change a subsystem will probably experience in a given time frame. Obviously, the more frequent the change the more adaptable the system. Change, of course, is measured in terms of potential, expected, or anticipated change. Those systems having the lowest frequency of change would be designed with little potential for modification.

Figure I



Scale of gradient adaptability (above) graphically shows relationship between cost and incidence of adaptability. Items at top of chart are highly adaptable at comparatively low cost.

CEILING ADAPTABILITY

Scale of Gradient Adaptability
Graduate Physics/Mathematics Building at Stony Brook, New York

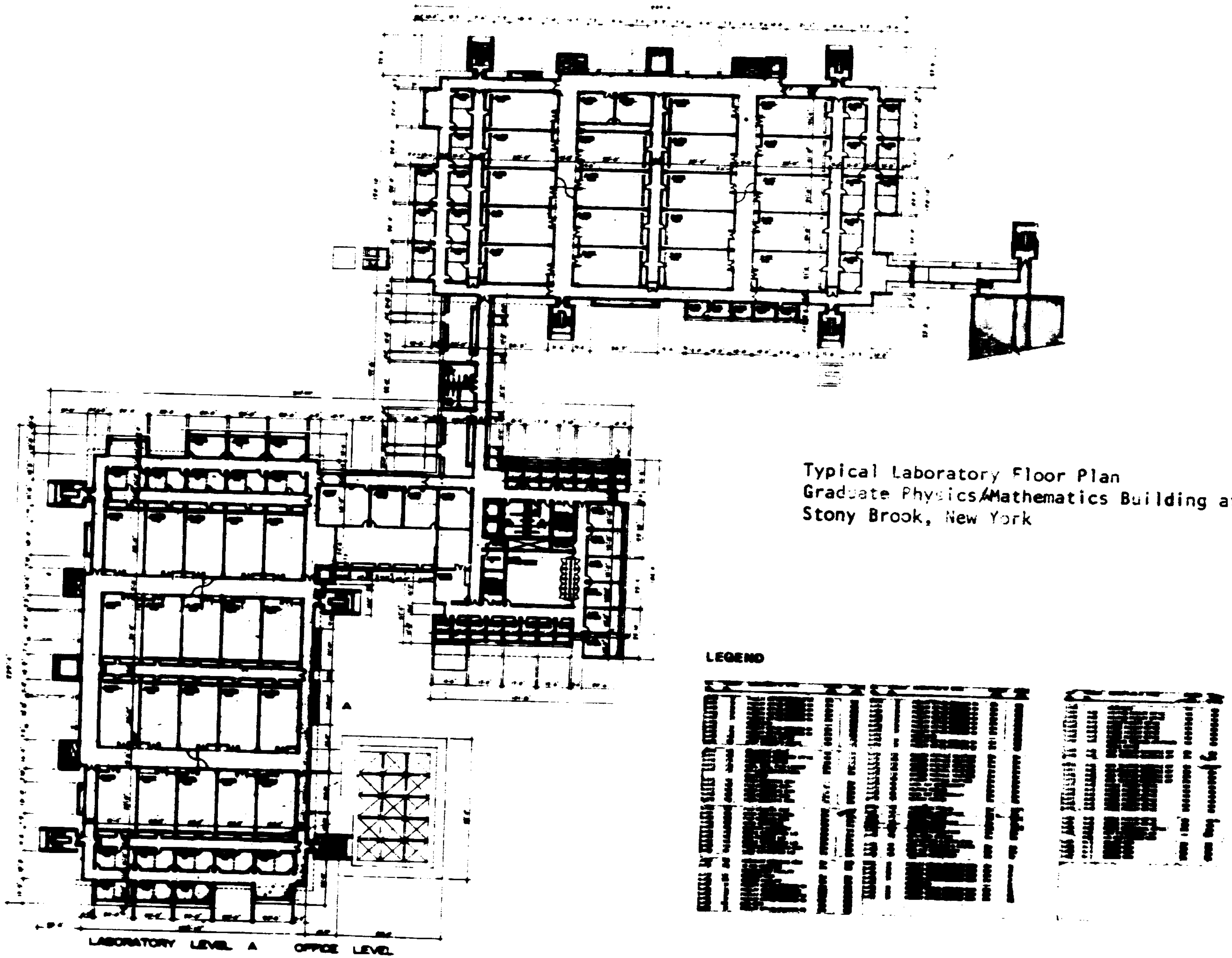
B. Flexibility to Accommodate Future Expanded Activities

The Institute research spaces should be modularized, that is, it should be built of elements of an appropriate size such that the elements can be grouped to form spaces of varying size to meet any set of given functions as required.

In the facilities developed for the Graduate Physics/Mathematics Building at Stony Brook, New York*, this concept was developed. It is designed so that a laboratory can expand or contract from a given use without modification of the buildings systems. The modular plan shown indicates the planning methodology by which one to five laboratories can be grouped together to form one uninterrupted serviceable space. No grouping should be less than three. The configuration of the laboratory should lay within a fairly constricted proportion, that is, the proportion should be such that the laboratory is a unit of modules between ten and twelve feet wide with depths varying from thirty to forty feet with the smaller modules for those facilities with high fire hazard. In all cases, laboratories should be conceived of as having essentially two ways of exiting which are remote from each other and are set up in such a way that the expansion from one laboratory to another does not negate this egress potential

Figure II
View Looking North
Graduate Physics/Mathematics Building at
Stony Brook, New York

Figure III
View Looking East
Graduate Physics/Mathematics Building at
Stony Brook, New York



Typical Laboratory Floor Plan
Graduate Physics/Mathematics Building at
Stony Brook, New York

Figure IV

C. Internal Administrative Set-Up of the Institute

Centres are usually structured on a departmental basis. Overall control is usually exerted by an administrative head. However, the distribution and allocation of spaces and services are something which requires a laboratory director whose overall responsibility is to control this distribution and allocation. This, in effect, provides safety control. Overall safety control is required to prevent dangerous utilization of the building which could effect the functions of other laboratories and their personnel.

D. Number of Departments in the Institute

There appears to be no need to limit the number of departments in an institute. The only singular problem that can exist is that smaller, less well-funded departments often suffer the consequences of being second class research citizens in such a research community.

E. Number of Persons to Use the Building

There should be no need for the restriction of the population of the building. However, the specific individuals that have access to the building is of considerable importance. Control of unauthorized movement of personnel is of great concern since extremely valuable and sensitive equipment is usually left out easily accessible to unauthorized personnel. The building must be planned for security.

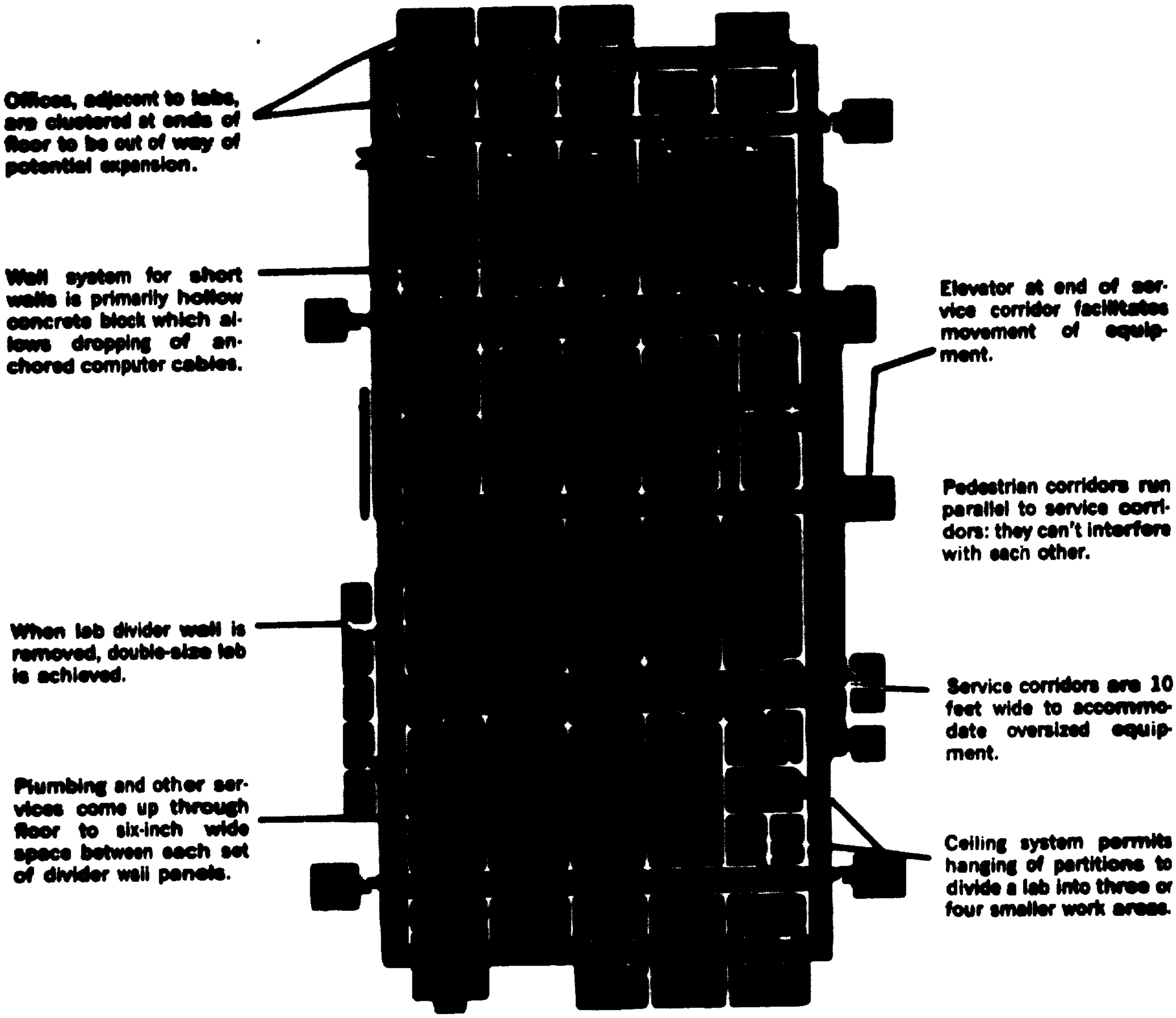
F. Relationship Between Offices and Laboratory

The relationship between the office of a user and his laboratory is an important relationship. Proximity is of the essence. It is often desirable to utilize part of the office as a part of the laboratory space. This means that it is desirable to locate the laboratory and the offices in an adjacency so that they can both utilize the same service system. The arrangement should make it possible to move between the office and laboratory without using the public corridor system. A conventional office is more appropriate to the theoretical scientist who does not require conventional laboratory apparatus. Their offices are often best grouped very close to each other and in proximity to the laboratory facility but not necessarily located within the laboratory area.

G. Movement of Materials In, Out, and Within The Building

The service distribution pattern makes it desirable to establish a "transport module" as was done in the case of the Graduate Physics/ Mathematics Building at Stony Brook, New York. The facility was developed around the capability of transporting an eight foot cube weighing five tons to any laboratory in the building. The corridor width, height and layout, the design of the entrance to the laboratory, and the location of vertical transport all become determined by the size and character of the transport module. It is critical, therefore, that an early determination be made as to the largest single transport module which is acceptable. In the United States the customary restriction is the limitation imposed by the size of truck transport. The plan of the Graduate Physics/Mathematics Building represents a careful development of this planning constraint. The movement is simple and direct.

Figure V



Floor Plan Organization and Service Concept
Graduate Physics/Mathematics Building at
Stony Brook, New York

H. Construction Materials

The construction technology of a generalized research laboratory is seldom the result of the kind of experiments anticipated as much as it is the result of available construction systems. However, laboratories with electronic sensitivity requirements should be constructed of materials which do not develop the inherent electrical short-comings that are characteristic of steel-frame buildings. The trend towards a multi-disciplinary scientific facility leads to the conclusion that the selection of materials must be such that they will not interfere with the operation of sensitive apparatus from many fields. The materials must account for the need for control of vibration, noise level, as well as fire limitation, smoke and dangerous chemical fumes. Soft materials with sensitive finishes are not appropriate to research facilities. Materials which are capable of being repaired, replaced, and revised or relocated without significant effect upon the operation of the building are far more suitable. An examination of the Graduate Physics/Mathematics Building at Stony Brook shows the kind of construction technology that is appropriate to a laboratory system. The interior partitions are constructed of sheet matal which is capable of being demounted and relocated so that it is possible to modify the shape and size of a laboratory quickly and simply with little noise or debris. The fire areas of the corridors are formed by concrete block. Within the laboratory itself, the floors, walls, and ceilings are maintained as natural relatively simply unadorned materials leaving the interior to be finished in all its exotic scientific detail by the user.

[illegible] Road
[illegible]/[illegible]atics Figure VI[illegible]
[illegible] Brook, New York

Typical Specialized Laboratory
Graduate Physics/Mathematics
Building at Stony Brook, New York

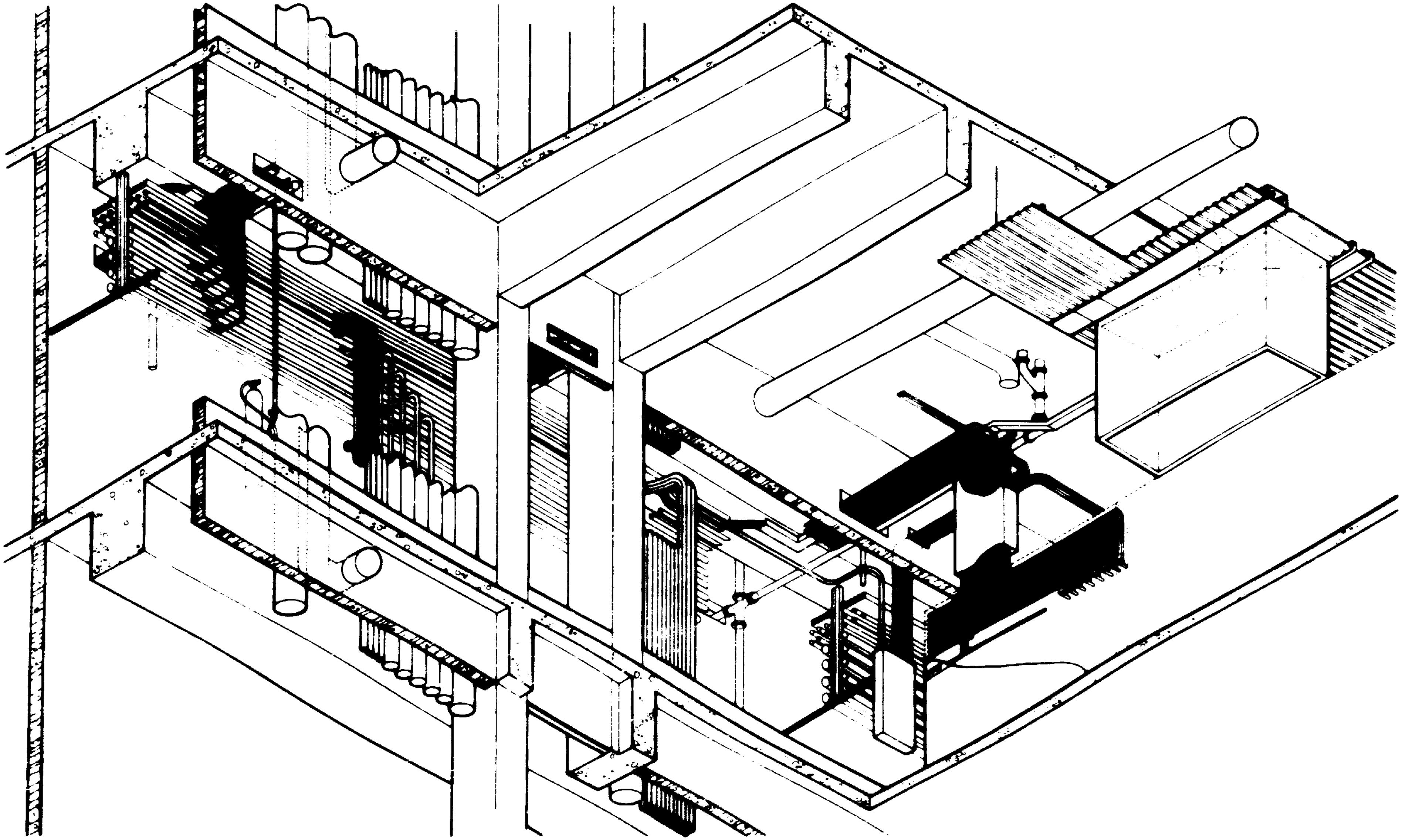
Figure VIII

I. Environment and Pollution

The exterior and interior environment of the building are important constraints on the shape and positioning of the building. The environment must be, first of all, clean; it must be healthful, free of contaminants and pollution; it must be comfortable and must be free of the kinds of temperature extremes that could interfere with accurate performance of apparatus. Much can be said for a fully air-conditioned, self-contained environment where both lights and temperature are within the realm of individual control.

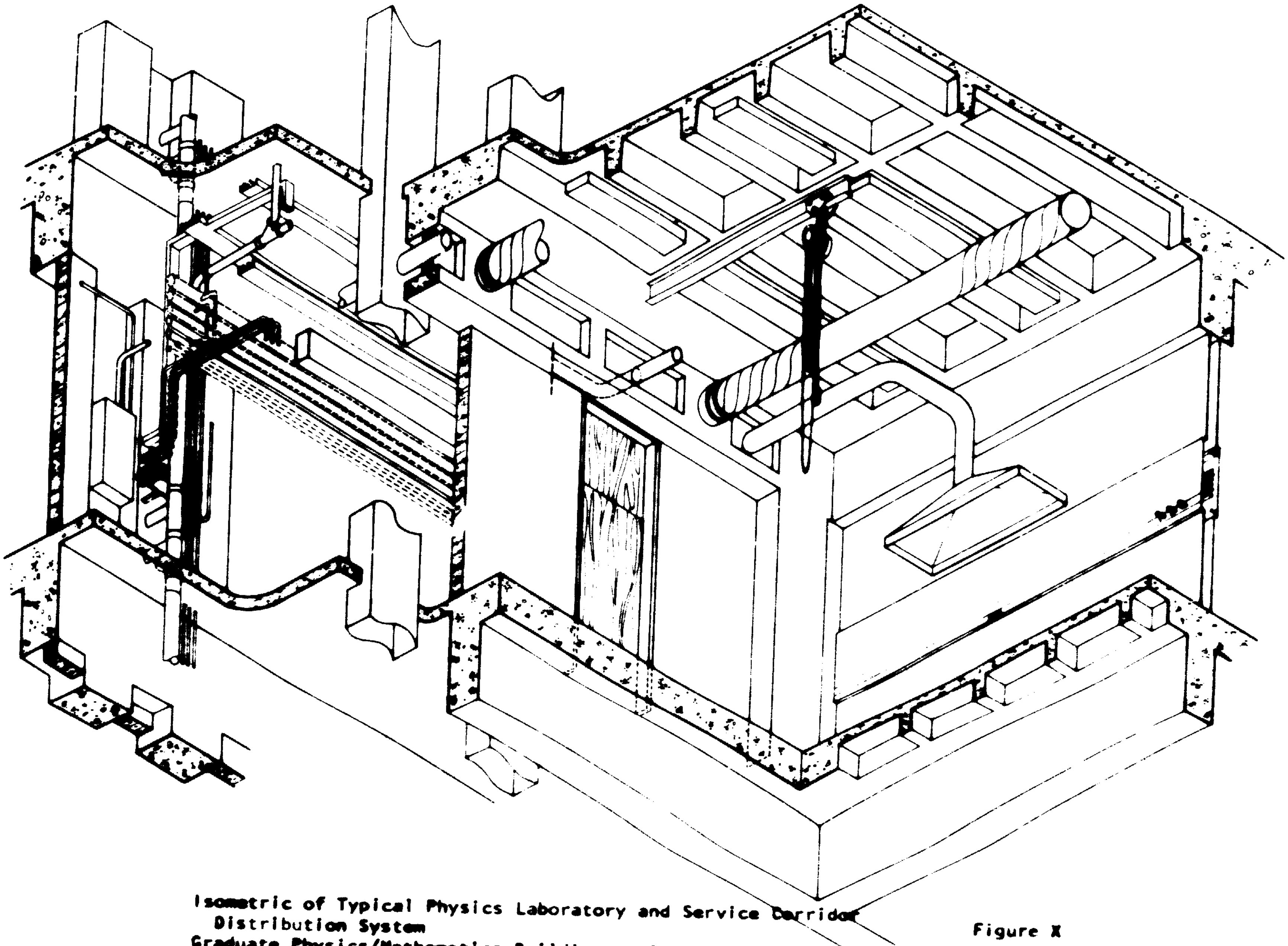
Pollutants generated within the laboratory must be safely transported out of the laboratory quickly and efficiently. An emphasis must be placed upon the removal of toxic or noxious substances. They must be removed expeditiously through a conduit system which is organized to prevent intermingling with pollutants removed from other laboratories. While it is true that a small number of laboratories could be grouped together and their exhaust systems containing harmful pollutants run through the same basic system, great care must be taken to make certain that these laboratories are adjacent to one another where it is possible to control any process that might produce explosive or combustible conditions.

Of course, the pleasantness of the environment is an aesthetic attribute which can make it much more desirable for the performance of work.



Isometric of Typical Chemistry Laboratory and Service Corridor Distribution System
Graduate Physics/Mathematics Building at Stony Brook, New York

Figure IX



Isometric of Typical Physics Laboratory and Service Corridor Distribution System
Graduate Physics/Mathematics Building at Stony Brook, New York

Figure X

J. Climatic Conditions

Climate should play a minor role in the general research facilities design, except as it determines the particular exterior architectural character of the building. The climate can be construed as a factor which means certain additional expenditures to provide for cooling in warm climates and heating in cold climates. Control of natural light, temperature, and humidity is a requirement under any climatic circumstances. The interior laboratory environment should be thought of for the most part as being "climate free" shutting out the exterior world so that it is possible within the laboratory to maintain a fairly rigid set of climatic conditions.

K. Social Aspects

The Institute should provide for a wide variety of opportunities for people to interact with each other on various levels. Science is a subject where individuals are the final measure of potential. Their capabilities, their willingness for cooperation and joint effort are essential to effective performance. Therefore, great effort must be placed in creating convenient places with comfortable accessories which can be used for the social aspects of the scientific program. Such places should be equipped with chalkboards, with facilities for limited snack preparation, and for casual and informal meetings. It should stress comfort, relaxation, and diversion.

L. Cost

It is difficult to specifically define what the cost effects would be for the choice of one system over another in different localities. The availability of material, local economics, and native techniques are all important factors which determine the suitability of one system over another. What can be said generally about cost is that it is important to determine not simply the cost of a system for construction but to look at the life cycle cost. It is important to recognize that the initial cost is not the only, nor the most important factor. If the modifications are frequent it is important that the system be adaptable at reasonable cost.

III. DETAILED BUILDING LAYOUT CONSIDERATIONS

The layout of a building is determined by its functions. These functions should be defined in a program statement which outlines the specific end goals of the entire Institute. Rather than design a laboratory facility on the basis of simply defining a list of spaces and designing each space to a unique set of circumstances, the most appropriate approach is to define an overall goal and then develop a laboratory type which will be suitable to all the variety of circumstances that can be anticipated. Thus, the most appropriate design approach is one that develops a universal planning module with the capacity to add and delete spaces and services.

A. General Functions of the Institute

There are many detailed outlines available noting the kinds of a functions that are performed within an Institute. However, the laboratory space is the focus of the operation and the activities within that laboratory are supported by services which feed in and out through the enclosuring surfaces.

B. Industrial and Technological Research

There is little difference in the design of a research facility used for generalized or Industrial technological research. However, from one area of an industry to another the differences can be significant. Facilities tend to be very specialized and involve the use of special laboratory configurations and are quite unlike the modularity associated with the generalized research spaces.

C. Safety

The planning of a laboratory involves designing for fire safety and against dangerous fumes generated from experiments. The traffic flow, the egress pattern, and the proportions of the laboratory all contribute to its safety. The greatest need for safety planning is, of course, within the laboratory where the greatest degree of danger exist. Obviously, research involving explosives, radiation, or dangerous substances should be housed in appropriately built separate facilities. Their isolation is not only desirable but essential to the safety of an Institute's operation.

D. Storage

The storage areas are the great distribution centers from which all the equipment that is obtained and held for distribution is consigned. The availability of second level "local" storage capability within the laboratory groupings is also important. The control of the goods being brought in and moved out must be such so as to prevent pilfering and loss. Storage capability within the laboratory should be limited. Storage cabients and below-counter cabinets should be kept to an absolute minimum so that they are only available as needed. A furniture system which provides endless cabinets which are under-utilized is not only expensive but becomes a storage place for large volumes of valuable material that is permanently lost to other users causing unnecessary restocking of otherwise available goods.

E. Conference Halls and Meeting Rooms

An institute requires appropriate meeting spaces for intra and inter institute meetings. There should be a sufficient variety of sizes so that the rooms are not too large for a small conference or too small for a large conference. The institute should provide for meetings with reception areas for registration, dining (if possible), and limited overnight accommodations. Meeting rooms are best dispersed throughout the facility though a concentration of them is possible if the facility is not too large. There should, however, be small conference rooms or assembly spaces which can be utilized both as lounges and as small meeting spaces within the laboratory groupings.

F. Reception and Telephone Exchange

The character of the point of arrival is always one of great importance to the proper experience and administration of an institute. There is little else that need be said except that reception should be central and accessible to the public and should act as a control point restricting the free movement beyond that point into the remainder of the building.

The telephone exchange can be located anywhere within the building that is most appropriate from strictly mechanical criteria. In most cases, it is independent of reception. If the building and telephone system are small, it is possible to combine the reception area with the telephone exchange.

G. Workshops

Workshops are those supportive spaces that are necessary for the preparation of experimental apparatus used in the laboratory. These are tha kinds of spaces which include glass blowing shops, metal shops, woodworking shops, and similar kinds of electronic and equipment shops. They provide the "backbone" servicas required by the laboratory. For example, glass blowing shops hava a specific requirement in that they should have axcellant natural lighting.

IV. TECHNICAL CONSIDERATIONS FOR CONSTRUCTION

It is usually in the technical aspects of a laboratory construction that the proof of the facility's ability to respond to changing requirements is indicated. The thrust of a design must emphasize the idea of the laboratory as a series of elements whether they be planning modules or furniture modules that are capable of adaptation in a reasonable period of time with a minimum amount of noise, waste, and cost.

A. Modular Concept

A properly planned laboratory begins with a planning module. The size and shape of the planning module is probably the most difficult, single decision that the planner is confronted with. The module must be such that it is flexible enough to meet the range of laboratory utilization and size requirements that can be anticipated. The module must not be so small that by necessity it must be grouped with other modules simply to make it function. It must not be so large that it cannot be adequately subdivided for those uses that require smaller spaces. It must be served with services required to operate the laboratory. Elaborate geometry tends to end with confused and difficult to modify plans, so simple geometry is best. Simple rectangular geometry allows for easy groupings. Such modules used to form groupings generally run between ten and twelve feet wide while the depth of a laboratory should be a function of the safe walking distance to an egress. The usual range of depth between thirty and forty feet is optimum. It is also best to consider the module as part of a "groupable" function with accessible preparation spaces connected by a service corridor.

B. Materials

The materials of a laboratory are more a function of the operations that take place within the laboratory than they are necessarily of the kinds of available products that are natural to the area. Laboratories dealing with chemicals require surfaces which are capable of resisting their actions. Therefore, the design of the furniture and the design of the structure are closely related to the utilization. Laboratory furniture of a highly adaptable nature similar to that developed by Carl L. Walls Associates of LaJolla, California, characterize the kind of a laboratory system which is both sturdy, resistent to considerable damage, and capable of easy and inexpensive modification. Some structures create special problems as to the choice of building and laboratory furniture material so then it becomes necessary to know the specific application as precisely as is possible. If a small number of laboratories develop a very special set of difficult problems, it is best to isolate these from the building and build a facility separate from the other. The choice of structure and structural materials are all a function of defining these limits. How much electro-static properties/how much conductivity/how much resistance to fuel damage/how much resistance to breakage/how much loading capability/how much fracture resistance/how much changeability/how much adaptability/how much room usability are all factors that must be defined carefully. It is a complex problem; it cannot be simply described in terms of a few short parameters.

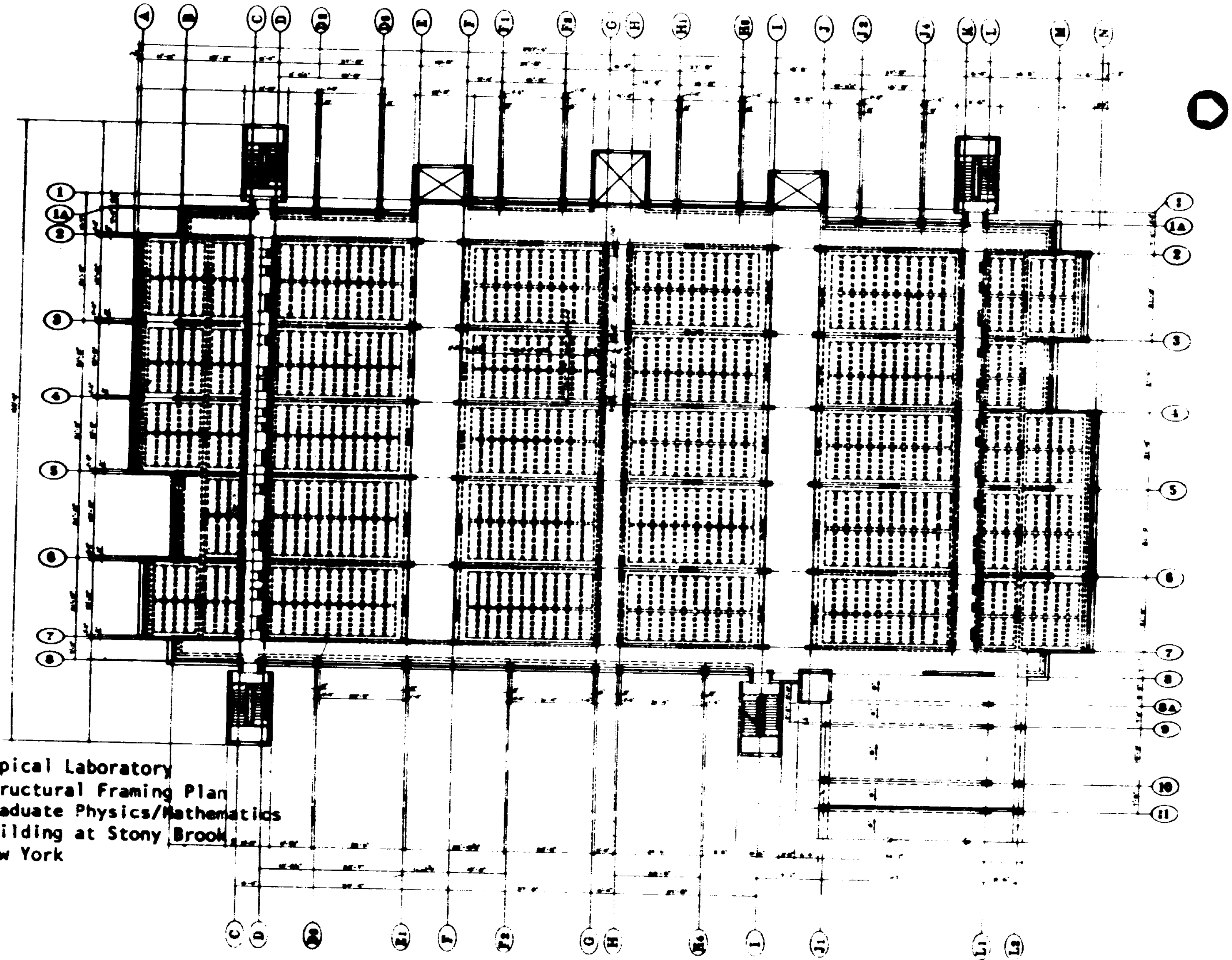
C. Types of Structures

There are no specific types of structures which are limited to laboratories. There are situations where long span structures are desirable and there are situations where short span structures are adequate. There are structures which use interstatial spaces and there are structures which do not require the large flexible potential that the interstatial concept permits. Degrees of adaptability of all the systems and subsystems define the type and character of the structure best.

To a great extent the decision as to the choice of structure depends upon the available resources. Structures which are basically steel frame may require certain special considerations because of fire safety, conductivity of materials, and interference of large quantities of steels with radio frequency and non-shielded equipment. Concrete of course has a disadvantage of great weight. However, concrete tends to be more rigid and vibration free than steel structures.

D. External and Internal Finishing

The external and internal finishing of the building should be able to withstand its utilization. It is recommend that considerable surfaces be put aside both internally and externally for the mounting of chalkboards. There is little reason to presume that chalkboards should be limited to simply the interior of laboratories and meeting seminar spaces. Basically the external and internal finishing should be resistant to the kinds of a chemicals and corrosive properties that are generally associated with the fumes and waste generated by the laboratories.



Typical Laboratory
Structural Framing Plan
Graduate Physics/Mathematics
Building at Stony Brook
New York

Figure XI

E. Walls

The external partitions, or the enclosing walls, are a matter of architectural preference. There seems to be little reason to be concerned with the character of the external walls except to indicate that a control of light, heat, or generally the outside environment is highly desirable. As for the internal partitions, which subdivide laboratories into module groupings, these should be a highly adaptable system. The partition should be movable and recoverable in a minimum of time with a minimum of noise and interference in the operation of the laboratory. The walls, which enclose the laboratory groupings, need not possess this kind of a flexibility.

F. Floors, Ceiling, and Roof

The floor finish of a laboratory is generally one of the more problematic areas that architects are concerned with. Ordinary laboratory use does damage to the surface of the floor. Many systems have been considered and experience has proven most of them to be inadequate. For example, material like concrete show irregular finish markings while painted concrete wears pathways. Generally, good floor materials do not pay for their investment. Experience indicates that a minimum investment like concrete can give satisfactory results if the aesthetics limits can be accepted. In those areas where more expensive tile and epoxy are desired the cost implications should be understood.

G. Windows and Doors

Laboratories often function poorly when natural light is provided. Windows generally let in light which is uncontrolled or difficult to control. Natural light does not enter in a manner which is easily controlled and is generally not uniform throughout the room. Windows within the laboratory are, therefore, considered a liability rather than an asset. In other locations, like offices or laboratory-office combinations, consideration can be given to providing a treatment using natural light.

Door sizes to a laboratory should be based on the design of a transport module. As has been previously noted in the planning criteria, a planning module should be used similar to the eight foot cube noted.

Positive control features to restrict access to the laboratories and laboratory areas are very important. Door materials need not be rigidly defined; any material which is able to take the kind of a heavy duty use that is associated with the facility can be considered--kick plates and bumper rails are important features on doors and should be provided. Lever door handles tend to be more comfortable and safe in the operation of a laboratory because it is possible to open the door carrying something in both hands with one's elbow.

H. Staircases and Elevators

Staircases and elevators should be used as little as is possible, and when required it should be used with relatively large floor areas. A tall, small floor area building depends very heavily upon vertical transport and is highly undesirable. Small floor areas minimize the groupings of modules and minimizes the flexibility in the plan by encouraging isolation of groups on floors. Staircases should be primarily conceived of as egress in case of fire. To utilize staircases for intra-building traffic requires very subtle planning. Generally, it is not desirable to depend upon stairs.

The design of elevators is most critical to the operation of the facility. An adequate number of passenger elevators is a sensitive planning problem. It should be assumed that the arrival time of the staff is during a relatively short period in the morning and that movement in and out of the building is consistently high during the day. Movement within the building is, of course, an important problem and by virtue of the plan can be kept to a minimum by providing relatively large floor areas. In addition, elevators should not be structured so that they serve the dual purpose of passenger and service use. The plan of the service elevator must, of course, accommodate the transport module that has been decided upon.

I. Safety Considerations

Safety considerations cannot help from becoming a governing concern in the planning of a laboratory. Sufficient consideration for the amount and location of fire extinguishers, stand pipe systems, and the availability of sprinkler systems (both conventional water and carbon dioxide) are necessary. However, to design the laboratory to cover every kind of a safety consideration would be most difficult. It is better, therefore, to define the level of safety for the most general applications and provide supplementary systems in special higher hazard areas. Other safety considerations, beyond fire safety, cover the design of the building's subsystems and materials. Materials must be chosen which are not likely to collect substances which could become contaminants, explosive or toxic. Exhaust systems must be designed so that the danger of mixing explosive substances or toxic substances is minimized.

V. HEATING, AIR CONDITIONING, VENTILATION

The environmental systems that are required to maintain a comfortable working environment within the laboratory depend upon the load characteristics of the spaces. It is very difficult in most cases to define the specific load characteristics of generalized spaces. It has become customary therefore to design the space so that the systems are able to respond to a fairly wide range of loads with the capability for expanding the capacity to handle unusually large loads.

A. Heating

Most laboratory systems, because of the character of the laboratory, cannot function exclusively on the use of a heating system. It must be considered a fairly common part of the laboratory design to provide a fully air-conditioned operation.

B. Air-Conditioning

There are a number of air-conditioning systems which provide both heating and cooling. The one that is specifically suitable for a giving laboratory is far more a function of local technology, local preferences, and traditions than it is a question of whether or not there is a best in any case. Separate systems for laboratory groupings are not required except in those cases where the experiments being performed are of such sensitive character that even a slight interruption in the supply of air-conditioning could destroy the experiment's accuracy. Obviously, computers and other high heat-generating equipment must be given special consideration. This can be done by supplementing the basic system with a secondary system.

C. Ventilation

Ventilation is generally a supportive system which is available to provide additional large quantities of air without cooling when a space requires such additional air quantities. It is more suitable in spaces which are not associated with laboratory use. Generally if the laboratory is designed with a large portion of interior space, it is necessary to provide the cooling required by these interior spaces which do not have available to them directly a large source of outside air.

D. Fume Hood

The fume hood is the focus of operation of most chemical laboratories and appears in almost all the other natural science laboratories. The circulation of air away from the occupant and into the hood avoiding back pressure causing the passage of fumes into the space is, of course, the critical parameter in the planning of a fume hood. Fume hood exhaust must be grouped together so as to prevent the mixture of substances which could be explosive. The choice of material and the choice of construction of the hood and exhaust system are very important. Because it is not possible to determine the specific use of laboratory space, the fume hood should be considered as movable laboratory furniture.

VI. FACILITIES

The range of laboratory facilities should be determined as a function of what is the minimum that should be provided in every laboratory and what is the maximum that will be required by the facility as a whole. The design of the facility should be such that the maximum is there in potential but the minimum is there in distribution.

A. Water Supply

The water supply should be pure, free from dilatorious substances, and of a relatively neutral quality. It should be available hot and cold and need not be available in the distilled form at the laboratory desk, except in those laboratories which have a consistant and high rate of utilization.

B. Power Supply

The biggest single service to provide for is electricity. The voltages should be over a range. In the United States it ranges from 120v to 208v. The amperages are generally set so that the total wattage is about 4 watts per square foot of laboratory area. Of course, supplementary distribution capability must be provided so that it is possible to increase significantly the electrical power available in one laboratory

C. Gas Supply

A centralized distribution for gas supply is becoming less and less necessary as more and more gas systems are being replaced by electrical systems. Cylinder sources are just as good as central system.

D. Internal Communications

Laboratories should be provided with a telephone system which allows for interconnection with other laboratories and non-laboratory spaces as well as the "outside world". An intercom system is best if it is properly designed and intergrated into the telephone system.

VII. FURNITURE AND FINISHINGS

Laboratory furniture must be sturdy to withstand the heavy utilization to which it will be put. It must be capable of easy modification and must be able to withstand the kinds of loadings that characterize laboratories. The laboratory furniture system previously described is a useful model of a kind of system that meets the general requirements for good laboratory furniture and is discussed below.

A. Materials

The frame is basically a steel "C" which can be taken down to a series of relatively small transportable pieces. The cabinets are suspended from the frame and can be removed and carted away quite easily. The cabinets can be made of any number of materials: wood, plastic laminant, metal, or other types of rigid construction.

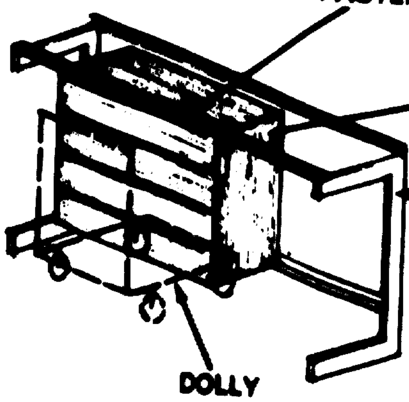
B. Desks, Draws, Cupboards, and Stools

Desks should be designed to fit into the laboratory system and should be construed as part of the laboratory table system. Draws should be fully extendible and preferably self-retracting.

C. Sinks

Sinks can be basically divided into two categories: cup sinks and regular counter sinks. Cup sinks are very suitable for laboratory use and can be built into the wall system freeing up the furniture system. This makes it easier to move the furniture about. The larger sinks are usually for equipment and other washing purposes. Cement asbestos, special stainless steels, and "duriron" (a highly chemical resistant material) are usually most suitable.

Figure XII



Typical Laboratory Furniture System
Graduate Physics/Mathematics Building at
Stony Brook, New York

D. Water and Gas Taps

Taps are best built into the wall system and free of the laboratory furniture. This allows for easy movement of the furniture without necessarily interrupting the operation of these systems and allows for the basic distribution to remain in operating order despite the fact that the laboratories equipment is being rearranged.

E. Desk Covers and Protection

Covers for desks and similar protective devices are not a desirable feature in a laboratory. The basic desk top should itself be a protective surface; it should be a surface which is capable of resisting chemical damage and abusive use. A good practice is to provide the same basic top for the laboratory desks as for the laboratory furniture.

VIII. LIGHTING

A. Daylight

As it has been previously indicated, the concern for the type of a light in a laboratory actually rests upon the question of whether or not a daylight source is at all desirable. It has been strongly felt that daylight in most instances in laboratories is an undesirable feature requiring considerable effort to control.

B. Artificial

The answer to the type of lighting does not simply lie in the application of artificial lighting. Care must be taken in selecting the fixture type and light level which both effect the quality of the environment and the costs of operation.

IX. DECORATION

This is the area in which the architect probably can be said to have his greatest range of personal decision and individual expression. The external design and the choice of materials are much more a matter of his aesthetic judgment than is any other area in the building

X. COST CONSIDERATIONS

A. Size and Space Requirements

There is an intimate relationship between the size of an institute, the requirements that produce that size, and the cost. Laboratories tend to develop a certain quality of construction; little skimping can be achieved through elaborate substitutions or by a significant cut back in quality. Obviously, other considerations like the scale and the scope of the project and the overall size impacts its cost. Nothing is more meaningful to a general laboratory's cost than the overall size. The facility tends to have a certain minimum quantity of services and, therefore, a certain minimum quantity of space.

B. Construction Materials

As for the general construction materials of a building, choice is determined by national characteristics as well as by the necessity for the materials to perform certain definitive functions.

C. Optimization of Savings

The optimization of savings is related to the design of a facility which generates a minimal amount of gross area in proportion to its net space. It is supportive space that adds most significantly to variation in the cost of a building. If the basic character of the building's laboratory, structural, and environmental systems are maintained unadorned, this will contribute to minimizing the costs of construction.

CONCLUSION

In conclusion, it can be said that the design of a laboratory is a complex organic process involving the definition of each individual space in terms of the specific function for which it is intended but then converting that definition or set of definitions into a single planning element or a limited series of elements which can be modified with reasonable expenditure of time and effort at a minimum cost to respond to the wide range of programmatic functions as well as the range of reasonable anticipated change that the laboratory will experience. The laboratory should be planned on a relatively simple geometric module which can be grouped together in such a way as to permit the reorganization of the laboratory spaces so that one can have minimum and maximum laboratory sizes and such that the average laboratory unit should permit groupings up to five modules.

Safety is a fundamental design problem in laboratory systems and great effort should be expended on making certain that safe emergency egress is provided from the laboratory and that all contaminants and pollutants generated by the laboratory are safely carried away through a direct system which restricts the mixing with other contaminants.

The laboratory should be designed with a minimum of centralized services or facilities to allow for the expansion or introduction of such facilities in local areas where they are required with a minimum of adaption. The internal laboratory systems for furnishing the space should be adaptable, movable, and modifiable with a minimum amount of effort and expenditure. All in all the laboratory is a system. As a building type it is greatly dependent upon a sympathetic understanding of the wide variety of uses that go on within the laboratory and at the same time recognizes the significant cost of laboratories and the need for capacity to change with at a minimum cost.

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