In the Quest of an Adaptable Built Form: Studying Transformations in the MIT Campus

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Submitted to the Department of Architecture on May 25, 2006 in Partial Fulfillment of the Requirements for the Degree of Master of Science in Architecture Studies at the Massachusetts Institute of Technology, June 2006.

ABSTRACT Adaptability of the built form has for a long time been the concern of many designers. Driven by different motives such as the accommodation of "uncertainty," the pursue of an "economical space", the restoration of the user's "control" over the form, and the pursue of "fit," designers and scholars have proposed various formal means in order to achieve an architecture that would provide for change. The purpose of this thesis is to add to this discussion, proposing particular design strategies. In order to do this, transformations are documented and measured in the Main Buildings of the MIT Campus, which have often been cited for their ability to accommodate change. The thesis hypothesizes that the buildings in question contained in their body a certain DNA that enabled them to transform easily and effectively. Through the analysis of the original system of buildings and its transformations, which are divided into the two categories of growth and internal change, this DNA is exposed and juxtaposed to the formal means that have been suggested in the ideas of designers and scholars. The DNA is argued to consist of stems, knuckles, "unit-sections," courts, add- on facades and an underlying circulation system. The result of this thesis is a tested, in terms of effectiveness, series of specific formal means, comprised of MIT's DNA and the other designers' propositions, which can be outlined as three general strategies; provision of extra space, "open- endedness" and delineation of a comprehensive framework along which transformations can take place. At the same time, a physical history of the early years of the Cambridge Campus is produced, ranging from 1912 to 1933.

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And to Kostas for standing by me.

To my parents

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INTRODUCTION

INTRODUCTION

Buildings are big material products, not easily returnable and not easily disposable. While this characteristic of the architectural artifact may be essential for both our spatial and temporal perception, it seems to be an obstruction when the built environment has to respond to new and different purposes. In such cases, the original building has to be transformed, to undergo a change itself, in order to 'fit' the new user or the user's new needs. The degree to which this transformation can take place easily, economically and effectively has for a long time been the concern of several designers, many of whom have suggested both formal and planning tools in order to achieve an adaptable architecture. With this thesis I try to explore the efficiency of a number of the formal tools that have already been proposed, commenting not only on their ability to support change, but also on this change as an outcome.

In which other way could one measure the effectiveness of such tools than by observing and measuring change itself? This thesis is based on the record of the transformations that an architectural product has undergone through time. The product is the Main Campus of the Massachusetts Institute of Technology and the documentation begins from the original condition of the 1916 Campus in Cambridge. Thus, this thesis is in a way an architectural history of MIT, but one of a different kind than the ones the reader may be most familiar with. For while it is still pre- occupied with the evolution of the built form through time, it does not try to introduce a discussion of architectural style or of evolution of construction techniques. It is rather an attempt to illustrate through transformations this idea of tentative "fine tuning," introduced by Kevin Lynch in his *Theory of Good City Form*, that is, of the effort to adjust space, and in this case the physical part of MIT, to each moment's present needs.[1]

The Main Campus of MIT was carefully chosen as a case study for the following reason. MIT is firmly correlated with science, and science, as is commonly known, evolves and changes rapidly. The original buildings of MIT seem to have, more than efficiently, been able to keep up with this evolution and they still house an important number of the Departments they did initially. In fact, there has been a great discussion about the frequency and easiness by which the buildings in question have undergone transformations. The architect Eero Saarinen, commenting on this issue, has exemplified the MIT Main Campus buildings as an extremely "economical space," while, according to an anecdote, the architect Shadrach Woods, considering the low height of the buildings and their expansion and development as interconnected branches, has characterized them as a “ground- scraper.”[2] However, no measurements have ever been done to show how this change or development has actually taken place. This thesis, in sympathy with the aforementioned discussions, tries to do exactly this, hypothesizing that the original buildings of the Main MIT Campus contained in their body a certain DNA that enabled them to change without the creation of major “friction.” This DNA has presented different degrees of persistence, through time, causing different kinds of transformations.

Right from this early point of this thesis an issue of terminology arises. What is the proper language that one can use in order to describe formal changes or transformations? One of the most evident questions is the one of object and background, or in other words, what is changing against what? For example, it is quite straightforward that if the shell of a building is being kept intact while the interior space gets altered, we can talk about change in this building. What happens, though, when a new wing is added to an existing building without affecting it? Previous studies have named this kind of change growth, but can we so easily distinguish between these two cases? Isn’t growth itself a kind of change? Or when an internal partition in a building is demolished, isn’t this a kind of growth of an interior space, taking place simultaneously with the disappearance of another? While the vocabulary to be used will be formed step by step during the text, I would like to address this very question, at least in a preliminary way, right now, as it is essential for the work of this thesis. In order to do that I will initially rely on the studies of N. John Habraken because of the very systematic analysis of the built form he has provided. During my readings I have formed the belief that he has achieved, through the formation of a language, a most successful and clear way of dealing with the aforementioned issues, managing essentially to differentiate between the notions of use, space and built form. While the distinction between the first two might be easy, the one between the last two is not, as we tend to use daily the same words in order to describe them. The word “room,” brought up by Habraken himself, is perhaps the best example[3]. When we talk about a room changing, do we refer to the walls of the room or its interior arrangement? The following paragraph draws from the terminology of Habraken. (His argument for an adaptable or “controllable” form in the book *Supports* will be mentioned later.)[4]

According to Habraken the built form consists of the “configurations” or “groups” of what he calls “elements” or “material volumes.” These configurations can range from a wall with a window, to a structural framework or to a whole building. The kind of elements is named “selection” while the way they are combined is called “distribution.” The transformations of the built form can be categorized in three types: “addition,” “elimination,” or “movement” of elements.[5] In my quest for an adaptable form I will concentrate exactly on these

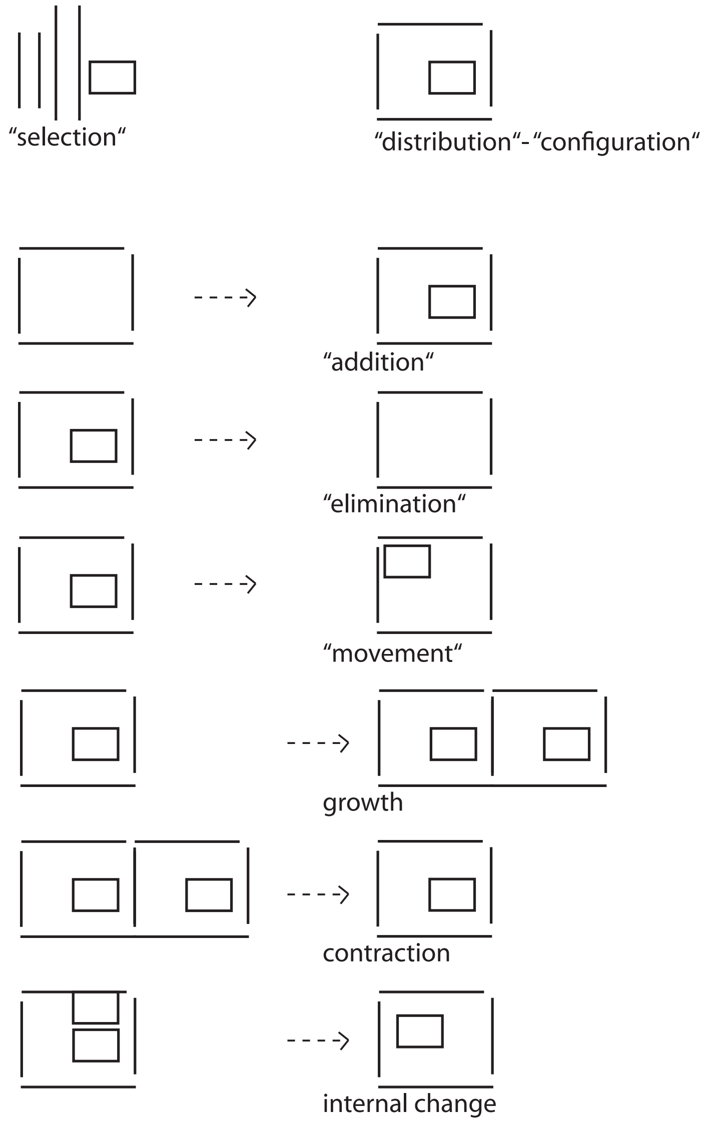

Fig. 01: An attempt to illustrate the terminology of Habraken, as well as the terminology of this thesis, using a visual vocabulary similar to his.

“configurations of elements.” I will try to show that in the case of MIT “selection” and “distribution” were such that they have allowed for any “addition,” “elimination” or “movement” to take place easily; and this assortment of “material volumes” will be my DNA. I will use the word *growth* when “configurations” of the type of buildings are added and the word *contraction* when such configurations are eliminated. I will use the term *internal change* when “configurations” of a smaller scale and less complex type are added, eliminated or moved **[01]**. Thus, to return to the question of object and background, I will study the process of ‘fine tuning’ of what was considered to be the material, physical part of MIT in 1916, that is, its original group of buildings. For practical reasons the research is limited to the academic buildings of MIT and does not include dormitories or athletic facilities.

The thesis is outlined as follows:

In the first chapter previous relevant studies and writings are presented. During my research I have not found any study that follows the transformations of a building, or a group of buildings of this scale, step by step, like I am attempting to do here. There have been some similar studies, but they have been at a much larger scale. Examples are the studies of the urban geographer, M. R. G. Conzen regarding the historic townscapes of England, as well as a study of Anne Vernez Moudon regarding the neighborhood around Alamo Square in San Francisco.[6] Despite the likeness of nature of these studies and mine, the difference in scale, clearly urban for the first ones and architectural- urban for this one, distinguishes their frame and scope, and as a result they are not presented here in more detail. The theoretical and instrumental background of this thesis is based more on the work of people who, although not having recorded physical change in such a thorough and qualitative way, have been preoccupied with it, each having a different departure. Therefore, the writings of the architects of Team 10, Habraken, the members of the Bartlett Society, and Lynch are presented in an effort to engage a discussion of "uncertainty," "control," "economical space" and "fit." As the text of the thesis goes on, I keep referring to the ideas and diagrams of these people, attempting something like the layout of the *Team 10 Primer*.[7] The idea is to show how formal tools that have been suggested by them had already been used in MIT.

The second chapter comprises the main body of the thesis. "Fine tuning" is presented as a non- stop process, which begins with planning and design and continues through the occupation of the user. The chapter begins with a short history of the buildings that had housed MIT prior to the Institute's move in Cambridge and it continues with the selection of a site for the new Institute, when this move was decided in the early 1900's. At the following, the spatial needs that the new plan would have to respond to are mentioned and two studies that preceded the plan of William Welles Bosworth are presented, as schemes that affected the final plan. It is important to note here that these two studies are not the only ones that were considered by the Institute prior to the one of Bosworth. Although this procedure of selection among plans is part of what in this thesis is considered "fine tuning," only two are mentioned here, as greater emphasis needs to be given to the transformations of the built form. For a more detailed presentation of all preceding schemes, the reader could see Mark Jarzombek's *Designing MIT: Bosworth's New Tech*.[8] The chapter continues with the analysis of the Bosworth plan that finally was built and during this analysis the DNA of the buildings is exposed.

After the delineation of the first signs of the buildings' performance, physical transformations are presented as series of steps of "fine tuning." At first, *growth*, as defined above, is considered. For *growth*, the time frame of this study, given the time limitations of this thesis, is limited to the first 17 years of the new campus. Occasionally, I will jump in time in order to show how the expectations accompanying certain decisions were finally fulfilled. The additions presented are the Pratt School of Naval Architecture (Building 5), the Guggenheim Laboratory for Aeronautical Engineering (Building 33), the Homberg Memorial Infirmary (Building 11), the Sloan Laboratories (Building 31), and finally the Eastman Laboratories (Building 6). While this documentation takes place, the changing needs of the Institute are also described. Finally, at the end of the first chapter *internal change*, as defined above, is recorded. For this case, the time frame of the thesis expands and reaches the middle 1990s. However, I am limiting my study to the case of Building 3, as the study of more buildings was impossible in the time period of this thesis. The choice of Building 3 was not based on any particular criteria. I tend to believe that whatever the choice, the findings would be equally representative.

The documentation of any physical change is based on the collection of drawings found in the Archive of the MIT Department of Facilities. The collection includes scans of the original drawings of every MIT building and a series of alteration drawings depicting any change that has occurred to these buildings. However, the description of *internal change* in the last part of the chapter should not be considered as completely accurate but rather indicative. The reason is that, going through the drawings, I realized that for some of the changes, plans had not been kept as the existing condition of a space in an alteration drawing was not in total accord with the final condition in the previous one. In addition, the first alteration drawings included in the Archive collection are only dated from the 1950s although alterations had taken place before. These alterations are described verbally in the *Annual Reports to the President* and occasionally in *Technology Review* but not accurately enough in order for me to reproduce them on drawings. Nevertheless, since in most changes the existing condition is depicted, we can have a good idea of how the change took place. More details on this subject are given as the text goes on.

Finally in the third and last chapter, a synopsis of the transformations studied is presented. During this synopsis the role that each part of the DNA of the original buildings played is outlined and the degree to which this DNA allowed for an easy and effective transformation is commented. Easiness is measured according to the burden that occurred to the original building during the transformation, while effectiveness, according to the ability of the building to function as a whole, after the completion of the transformation. The thesis concludes with a series of very specific formal means and a number of general strategies that one can use in order to achieve adaptability.

(Endnotes)

[1] For "fine tuning" see chapter 1 and Kevin Lynch, *Good City Form* (Cambridge: The MIT Press, 1984): 151- 186.

[2] For the quote of Saarinen see Francis E. Wylie, *M.I.T. in Perspective: A Pictorial History of the Massachusetts Institute of Technology* (Boston, Toronto: Little, Brown and Company, 1975): 51.

[3] N. J. Habraken, *The Structure of the Ordinary: Form and Control in the Built Environment* (Cambridge: The MIT Press, 2000): 64.

[4] Habraken, N. J., *Supports: An Alternative to Mass Housing*. Translated by B. Valkenburg. New York, Washington: Praeger Publishers, 1972.

[5] For the terminology of Habraken see N. J. Habraken, *Transformations of the Site* (Cambridge Mass.: Awater Press, 1988): 6-11.

[6] See Conzen, M. R. G. *Thinking about Urban Form: Papers on Urban Morphology, 1932- 1998*. Edited by Michael P. Conzen. Oxford: New York: Peter Lang, 2004, and Moudon, Anne Vernez. *Built for Change: Neighborhood Architecture in San Francisco*. Cambridge, Massachusetts: The MIT Press, 1986.

[7] Smithson, Alison, ed. *Team 10 Primer*. Cambridge, Massachusetts: The MIT Press, 1968.

[8] Jarzombek, Mark. *Designing MIT: Bosworth's New Tech*. Boston: Northeastern University Press, 2004.

CHAPTER 1: THEORETICAL BACKGROUND

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There are many reasons for which a designer might want to investigate the issue of adaptability. In my own quest for an adaptable form I have been driven mainly by a kind of anxiety due to the rigidity and permanence of the built form. However, behind this feeling there were more subtle motivations which found their counterparts in the writings of Team 10, Habraken, the Bartlett Society, and Lynch. Thus, this chapter is an attempt to set the theoretical stage for the analysis that is going to follow. While this attempt admittedly carries the marks of a subjective selection, I consider it representative enough as it manages to engage in a discussion about all the possible departures for the use of adaptable forms, namely 'uncertainty,' a desire for a 'controllable' form, the need for "economical space" and the pursue of 'fit.' In the presentation of each scholar or group, more emphasis is given to the ideas, rather than to the formal means that they suggest. The latter appear later in the text, in the context of their application in MIT.

Team 10 and "uncertainty"

It is curious how the most voluminous and, up until now, most complete publication regarding Team 10 starts with a pronouncement of "uncertainty":

"Reconstructing a history of Team 10 is not an easy matter. The group's history challenges conventional historiography, as well as the more specific historiography of modern architecture. To draw a straight line from a clear beginning to a clear end is impossible. The picture is more like the 'Play Brubeck' ideogram drawn by Peter Smithson, which shows a collection of points in time and space and without any obvious hierarchy, connected by a multitude of intersecting lines."[1]

Of course there are reasons for this hesitation and they are explicitly stated by the writers. The informal composition of the group, their unofficial meetings, as well as the lack of a unified approach after the end of these meetings, made the delineation of the story a difficult endeavor. What cannot be explained easily, though, is how Team 10 managed to imbue not only their own existence and structure but the repercussions of their movement, too, with the basic principle they were after in design; the absence of a definite and absolute form.

Perhaps it was their reaction to the C.I.A.M. that permeated them, as every revolution does, with the "rightfulness" of their purpose. Team 10 emerged from the "younger" groups of the C.I.A.M. in order to question the universal formal language that the Congress had imposed and the separation of the city into the four functions “Dwelling,” “Working,” “Cultivating the Body and the Mind,” and “Circulation.” To replace these concepts, Team 10 suggested that architecture should be able to respond to and express the individuality of each user as well as the distinctive characteristics of each culture and locus. Thus, whatever form a professional architect would give, it should be one that would be able to be transformed, according to the user’s own will. In addition, the city should be no longer zoned but rather integrate in its context the everyday activities, and designers should keep in mind that it would grow organically and change and that any form given by them should not exclude any such possibility, but on the contrary it should leave room for the unforeseen. [2] As such, the basic principles of Team 10 were closely related to adaptability, even if this word was not often used to describe any of them.

As much as the form should be “uncertain,” the members of Team 10 still had to provide one in the multiple competitions they participated in and projects they undertook. This oscillation between a concrete form and the provision for change led to various degrees of indeterminacy in their designs and to a constant debate among them on what was considered “understatement” and what “over-design.”[3] Some of the formal tools and models that were proposed are the following: **the “circulation spine,” “backbone,” or “stem,”** a core infrastructure element that could grow and on which the rest of the buildings could be plugged-in, subtracted or modified, as in the examples of the Bochum University competition or the extension of the city of Toulouse, by Candilis, Josic and Woods; **“identifying elements”** that would provide some indications for future change but permit “free growth,” as in the diagram for Tel Aviv by Bakema; **“determinate and indeterminate elements”** of which the first would form a nucleus of services, as in the dwellings for Bagnols- sur- Céze by Candilis, Josic and Woods; **“clusters”** of interconnected buildings where new buildings of any size and nature could keep being added, as in the diagrams of Peter Smithson; **“webs” and “grids”** of paths and corridors, as elements to carry growth, as in the Berlin Free University of Candilis, Josic, Woods and Schiedhelm.[4]

Each of these formal means was a “design argument” or a “built manifesto” which, according to Team 10, the professional architect should carry. It would be interesting to measure change in the projects of Team 10 that were finally realized. It would be a good way to test these manifestos and to provide a much more concrete discussion about the role of the designers today. This thesis, in its own way, will try to provide some answers. Many of the aforementioned formal tools were used in the case of MIT, but under the umbrella of a more practical approach towards design.

Habraken and "control"

At the same time, another manifesto touching on similar issues, but completely "formless" this time, appeared. Habraken wrote his book *Supports* as a reaction to mass housing and to the "ideal" form of dwelling sought by modernism.[5] In order to show a way out of the kind of environment that the adoption of mass housing as a method created, he starts deconstructing the method and presents its flaws. He indicates that mass housing, did not fulfill its purpose neither in terms of an adequate production nor in terms of quality, the reasons being that, on the one hand this kind of production method did not finally coincide with industrialization, while on the other, its final and finished form annulled the meaning of dwelling itself, which according to Habraken is "indissolubly connected with building, with forming the protective environment."[6] The second remark of Habraken regards one of the basic ideas that he introduces in his writings, namely the production of the environment as the result of man's actions on matter, which he calls a "natural relationship," believing that it is inherent in man's nature.[7] The solution he suggests to the housing problem is one that seeks to restore, exactly, this "natural relationship." Thus, it appears that Habraken seeks to restore the naturally driven "control" of man, over built form.

This quest for a "controllable" form is intrinsically related to adaptability, in the following ways. First, considering that Habraken wants to combine industrialization and a professionally produced architecture with the preservation of the "natural relationship," we could say that he essentially seeks for a conceptually adaptable formal framework, an abstract adjustable syntax, which during its materialization can lead to different forms. Furthermore, this argument for "control" does not stop at the design- production stage of housing. Habraken explicitly states the need for a form that, once built, can be transformed in the hands of its users; "In order to understand fully the evil results of the absence of the natural relationship it is necessary to judge the town not only as design but also as a living phenomenon which is in a constant state of change," while "The test of the ability of a town to cope with time lies in its ability to adapt to change, to assimilate the new, to alter part by part, and yet to maintain its identity."[8] As a result, we could say that Habraken's preoccupations are similar to those of Team 10, with the difference that Habraken tries to introduce adaptability at an earlier stage before the physical production of architecture.

The conceptual, adaptable framework that Habraken proposes can be described as a 3- dimensional urbanism. Trying to combine the construction of autonomous dwellings with the superimposition of one over the over, a condition imposed by the lack of space, he proposes a sort of **3-dimensional grid** which he calls "Supports."

The grid consists of elevated streets, the one over the other, adjacent to which are series of **"cases"** which play the role of urban lots. Each case can be described as an immaterial cube which can be filled in with a dwelling unit. The dwelling units are prefabricated and custom designed out of a rich variety of components according to each user's needs. The system permits for infinite expansion of the "Supports," continuous addition, elimination or movement of dwelling units, as well as an upgrade and update of units themselves. Vertical circulation is put at the exterior of the street system providing for continuity in circulation and communication.[9] Although at the time Habraken does not propose any specific form for the "Supports," later on in his book *Variations*, trying to provide a method for designing them, he presents some more detailed examples.[10] In any case, the original description of "Supports" presents, as will be shown later, similarities in terms of principles, to the structural organization of MIT.

The Bartlett Society and "economical space"

The English Bartlett Society meets and writes concurrently with Team 10 and Habraken. However, a different departure can be discerned in their writings, which leads to a more methodological, analytical and descriptive approach to what concerns change. If "uncertainty" and the restoration of "control" were the motives of Team 10 and Habraken in their quest for an adaptable form, the awareness of the accumulation of building stock seems to be the motivation of the members of the Bartlett Society. In their writings they tend to emphasize space as a commodity, as a good, the production, use and reuse of which can be and should be quantified, patterned and computed in order for predictions about future spatial needs to be possible. Thus, one could say that they are after an "economical space," a space that can be adaptable though not more than it should be; "But how far will it be worthwhile to make the insides of buildings adjustable to these changes? For human activities are adjustable to many different physical situations; and a single unit of space will often accommodate a wide variety of human activities."[11] In the majority of the writings studied here, less interest, than in the case of Team 10 and Habraken, is expressed in the formal characteristics of an adaptable space. However, some are proposed by Weeks and Aylwards. Generally, despite the questions that this "scientific" approach towards adaptability poses, the Bartlett Society's propositions tackle the phenomenon of change and offer the basis for a descriptive language.

During the formation of this language, the same issues raised at the beginning of this thesis are raised in these writings. Cowan, recognizing the difficulty of categorizing change, consciously borrows concepts and ideas from the fields of biology and anthropology.

He pairs the words “size” and “growth,” “shape” and “change,” “function” and “ageing” using the second parts of the pairs in order to describe what he calls “evolutionary developments in buildings.”[12] He invents the following parameters in his effort to find laws, functions, or patterns in the way buildings and organizations change; number of activities performed in various room sizes; “rate of growth”; “differential growth rate”, since parts of buildings grow at different rates; “average rate of growth per decade or “velocity””; “rate at which the velocity increases or decreases per decade or “acceleration””; “growth by new building”; “growth by increase in floor space”; “survivorship curve”; “index of performance”, divided in “structural degeneration” and “functional obsolescence”, against time; “size distribution of buildings”. [13] Although this statistical analysis doesn’t seem to lead to any clear conclusions about the patterns that govern change in buildings, in a study regarding change and growth in hospitals he suggests that more extensive research with a bigger sample might produce useful results. In this thesis, in the part documenting internal change, similar terms are used, oriented, however, towards a more qualitative description.

What seems to me more interesting though in Cowan’s language is his use of the terms “evolutionary development.” In one of his first papers for the meetings of the Bartlett Society he states the question “Do building types exhibit the general characteristics of evolving systems?”[14] His answer at the time seems to be affirmative as he considers the experience of the designer as a parameter affecting decisions and leading to the refinement of already tried formal means. Approximately six years later, in “On Irreversibility,” he reframes the question; “We can certainly regard the city as evolving in Lotka’s definition of the term as a system undergoing irreversible changes. If we accept this view- that changes once made cannot be unmade and therefore condition subsequent changes- we may ask, does the city evolve selectively? That is, are favorable adaptations preserved and unfavorable ones destroyed?”[15] This time he seems less sure of an affirmative answer, as he needs more data regarding the appropriateness of surviving forms for each use and vice versa. Undeniably, the matching of form and activity cannot easily be measured. According to Lynch, a possible way to measure this is by detailed observation of the behavior of users of a place or by directly interviewing these users.[16]

However, I would like to stay with Cowan’s first answer and emphasize the influence of people on the built environment. People, in a more or less successful way, affect the form of the environment they live in and change it when the physical attributes of the environment and administration procedures permit it, undoubtedly always with the intention of providing a more adequate form for the present needs. Habraken’s “natural relationship,” mentioned above, indicates this. Successful or not the intervention may be, the user's intention for the improved spatial arrangement exists, and it is this which, in my point of view, makes the built environment analogous to an evolving system. In the case of MIT, constant transformations have not only led to the survival of the main MIT buildings, but also to their preservation as a vigorous and still very robust environment. My analogy of the built environment with an evolving system starts and ends here. The use of the words DNA and body, in order to describe the phenomenon of "fine tuning" in the case of MIT, does not imply that I view the built form as an organism. My DNA is rather the means that permit evolution or the realization of the user's benign intention to take place. I would like to think, as will be discussed later, that my approach to built form is much closer to Lynch's view of the city as a "learning ecology."[17]

As interesting and useful as the language of Cowan might be, his categorizations of change still bare the aforementioned confusion among the notions of use, space and built form. A step towards a more clarified vocabulary is taken by Aylward who divides the environment into two main ingredients, namely "Activity" and "Space," and studies them under the condition of change.[18] He observes the following three phenomena, "Expansion," "Contraction" and "Internal Change" as a reaction of each of the two components to a change of the other one. However, the categorization he proposes is still difficult to follow as he considers built form and space changes to be the same. For example while he describes one type of space expansion as "accretion of small space additions" he describes a type of space contraction as "physical demountability (sic) of primary elements".[19] Nevertheless, I borrow the terms "contraction" and "internal change," for use with the word growth as I consider them particularly descriptive. I hope that these terms, in combination with Habraken's analysis, will help the reader to understand the changes that are described in this paper without making him or her go through a very scrutinized, and difficult to follow, categorization.

Before moving on with the ideas of Lynch on adaptability I would like to refer to a number of formal strategies proposed in the framework of the Bartlett Transactions. Weeks, in his paper "Indeterminate Architecture" declares; "I have tried to show that the aim of achieving an indeterminate architecture can be a positive factor in design and that control exercised over the way a building will grow is not achieved through indecision, but by decisions taken at every point in design."[20] With this statement, he seems as if he gives his own answer to the undergoing debate of Team 10 at the time regarding "understatement" and "over-design." Using as precedents a 19th century hospital at Renkioi, the Crystal Palace and Gatwick Airport he indicates, as crucial design decisions; **open- endedness**; **standardization**; **provision of basic services**; and **modularity**.

Aylward, on his part, without drawing from specific examples, adds to this "list"; the separation of **"fixed"** and **"fluid"** zones, a concept similar to the "determinate and indeterminate elements" of Team 10; the acquisition of **extra space**; **ephemeral constructions**; **portable structures**; **plug- ins** and multiple **alternatives** for the structural system. As with the formal tools of Team 10 and Habraken, I will come back to these, in order to show how they were part of the MIT DNA.

Lynch and 'fit'

Lynch introduces a discussion on adaptability in the framework of his quest for a normative theory of urban form. Admitting that a normative theory would unavoidably include elements of a descriptive or functional theory, and vice-versa, he bases his own on the idea of the city as an "evolving learning ecology."[21] He uses the term "learning" in order to emphasize the role that humans, as conscious beings, play in the evolution of the environment, whether this environment finds itself in an existing, becoming, or planning stage. Within this scope, he sets out a number of "performance dimensions" in which, each planner, designer or user can define an optimum degree of achievement according to his or her own ideas of "goodness." These "performance dimensions" are; "Vitality," "Sense," "Fit," "Access," and "Control." Among these, it is 'Fit' which is of particular interest in this thesis. According, to Lynch, 'fit' is defined as the degree of appropriateness between spatial form and activity patterns, and it can be enhanced by the modification of the first or the second. He suggests that screening and "fine tuning," or, in other words, the constant "care and attention" of a space is the recipe for good 'fit.'[22]

Adaptability comes in at this point as an essential measure to allow for "fine- tuning" to take place. Lynch defines adaptability as the "reciprocal of the future cost, discounted to the present, of adapting the spatial system of form and activity to possible future functions."[23] The use of finance language in order to define adaptability, the pre-occupation with the cost, as well as the aforementioned discussion about the view of cities as "evolving ecologies" reveal a similarity in Lynch's thought with the approach of the Bartlett Society. However, Lynch seems to take these thoughts a little bit further as he tries to examine the measure not only from the perspective of the planner who needs to predict in order to save money, but also from the perspective of the user; for Lynch, degrees of adaptability should vary in different spaces not only because of the ability of a space to usually house more than one use, but also because of the different expectations that prospective users might have; "Adaptability is a concern for all cultures. But the span of concern depends on cultural values and knowledge."[24] Furthermore, by bringing "fine- tuning" to the foreground, he differentiates himself from the statistical and quantitative approach of the Bartlett Society, as he emphasizes transformation as a procedure, which initiated by people cannot do otherwise than be personal and biased. It is in sympathy with this view that the MIT transformations in this thesis are examined. There is, thus, an effort to present the social and academic history of MIT in parallel with the physical one.

Lynch, enlarging his own definition of adaptability, presents two other sub-measures which he considers operational; "manipulability" and "reversibility." Emphasizing the subjective dimension that his definition of adaptability entails, by saying that future cost is difficult to define, he introduces "manipulability" and "reversibility" as measures which could be more easily estimated in the present. Although, the second one, defined as the cost of annulling an environmental intervention, by effacing its results, seems quite extreme, the first one, defined as the "extent to which a behavior setting can presently be changed in its use or form, in an easy and incremental fashion, and whether that ability to respond is likely to be maintained in the predictable near future," seems to be very realistic and useful. [25] It is through this ability to constantly make small and gradual changes, through this procedure of tentative "fine tuning," that a user can achieve a better "fit" in his or her environment. By the documentation of this procedure, this paper will try to show that MIT was, and still is, a highly manipulable environment.

A number of formal means are suggested by Lynch in order to achieve adaptability. These can be outlined as following; the provision of **extra** space or of the necessary structural support in order for new built space to be added later; the enhancement of the **communication and transportation network** in order to achieve efficiency in information dissemination and thus ensure a prompt reaction in any change; the **autonomy** of parts, in order to permit transformations in a system without affecting the others; the use of **modular systems** that can accommodate different uses and can provide multiple spatial articulations; and finally the use of **light materials**. [26] However, as he says, these propositions are not based on an organized study but rather on intuitive and common discussions.[27] It is exciting to be able to verify his propositions through the study of a space with which Lynch was so familiar and to which he was so related. Although he himself cites MIT as a paradigm for the use of modular systems and "regular connections" between buildings, he does not mention any of the other means in relation to it.[28] I should note however, that nowhere in this thesis is the cost of applying such means or of the transformations themselves, which was a big part of Lynch's discussion, calculated, for the obvious practical reasons.

(Endnotes)

[1] Dirk van den Heuvel and Max Risselada, “Introduction: Looking into the mirror of Team 10,” in *Team 10: In Search of a Utopia of the Present*, ed. Dirk van den Heuvel and Max Risselada (Rotterdam: NAi Publishers, 2005): 11

[2] For a quick reference to Team 10 see http://ocw.mit.edu/OcwWeb/Architecture/4-241JSpring2004/LectureNotes/detail/lecture20.htm. For a more analytical description about the emergence of Team 10 from the C.I.A.M. see Heuvel et al (2005): 18- 79.

[3] For “understatement” and “overdesign,” as well as for relative projects see Heuvel et al (2005): 121- 140.

[4] The quoted words are all terms that were used by the member of Team 10 as founded in the *Team 10 Primer* and in the *Team 10: In Search of a Utopia of the Present*. a) For “circulation spine,” “backbone,” and “stem” see Smithson, (1968): 9 and Heuvel et al (2005): 167. b) For “identifying elements” and “free growth” see Smithson (1968): 28. c) For “determinate and indeterminate elements” see Heuvel et al (2005):84- 86. d) For “clusters” see Smithson (1968): 54. e) For “webs” and “grids” see Smithson (1968): 59- 62 and Heuvel et al (2005): 188- 194. See also next chapter in the thesis.

[5] Habraken (1972): 10.

[6] For the deconstruction of the Mass Housing Method see Habraken (1972): 6- 9. For the meaning of dwelling see Habraken (1972): 15- 20.

[7] Habraken (1972): 18.

[8] Habraken (1972): 35.

[9] Habraken (1972): 59- 69.

[10] Habraken, N.J., J.T. Boekholt, A.P. Thijssen, P.J.M. Dinjens. *Variations: The Systematic Design of Supports*. Translated by W. Wiewel. Edited by Gibbons Sue. Cambridge: Laboratory of Architecture and Planning at MIT, 1976.

[11] Peter Cowan, “Studies in the Growth, Change and Ageing of Buildings,” *Transactions of the Bartlett Society* vol. 1 (London: Bartlett School of Architecture; School of Environmental Studies, 1962- 1963): 57.

[12] Cowan (1962- 1963): 56.

[13] For all these terms see Cowan (1962- 1963): 55-83 and Peter Cowan and Jill Nicholson, “Growth and Change in Hospitals,” *Transactions of the Bartlett Society* vol.3 (London: Bartlett School of Architecture; School of Environmental Studies, 1964- 1965): 63- 88.

[14] Cowan (1962- 1963): 72

[15] Peter Cowan, “On Irreversibility,” *Architectural Design* vol.39 (September 1969): 486.

[16] Kevin Lynch, *Good City Form* (Cambridge: The MIT Press, 1984): 153- 154.

[17] Lynch (1984): 114- 118.

[18] Graeme M. Aylward, “Towards a Theory for Describing and Designing Adaptability in the Built Environment,” Transactions of the Bartlett Society vol.7 (1968- 1969): 130.

[19] Aylward (1968- 1969): 137.

[20] John Weeks, “Indeterminate Architecture,” *Transactions of the Bartlett Society* vol.2 (London: Bartlett School of Architecture; School of Environmental Studies, 1963- 1964): 104.

[21] Lynch (1984): 114.

[22] For the 5 five “performance dimensions” see Lynch (1984): 118- 119. For “fine tuning” see Lynch (1984): 161- 163.

[23] Lynch (1984): 170. See also, Kevin Lynch and Mike O’ Hare, “Some Notes on “Adaptability”” (Cambridge MIT: unpublished notes, Spring 1978); notes written in the framework of MIT course 11.330. They can be found in the current reader of MIT 11.330J.

[24] Lynch (1984): 170.

[25] Lynch (1984): 170- 174. See also, Lynch et al (Spring 1978).

[26] For the formal means that Lynch suggests see Lynch (1984): 176- 181.

[27] Lynch (1984): 176.

[28] Lynch (1984): 168.

CHAPTER 2: TRANSFORMATIONS IN MIT

CHAPTER 2: TRANSFORMATIONS IN MIT

"*Into the Rogers Building, we have builded (sic) the multiform labors of 100 great leaders and thousands of their neophytes, all seeking the one enduring thing in life, the truth; all scorning to reach their ends by any other road than that of hard work; all ambitious, but for the general good; all fired with the desire to contribute something toward the bettering of human conditions and the uplifting of the world; all striving for the greatest of human possessions, character." "But the soul of it, the legacy of Presidents Rogers, Runkle and Walker and all the rest, we take with us, not in memory, but in actuality, and we believe that in conveying it across the Charles we are leading it to opportunities, far more full of promise than even those which today we so proudly and gratefully commemorate*."[1]

Anyone who has ever walked in the corridors of MIT can understand what this soul that James P. Monroe talked about is. The walls seem to speak, to radiate an *Infinite* amount of knowledge reflecting the universal achievements that have been, and still are, realized in-between them. For me, this is the result not only of an honorable academic history but also of a spatial robustness, of buildings that have managed to endure time in an astonishing way. One could argue that this endurance is due to the respect that the academic community of MIT has shown to these buildings and to the valued care of the Buildings and Power and MIT Facilities. However, as has been asserted before in this thesis, it is also due to the ability of the buildings to get transformed and to adapt to the changing needs of the Institute, in the hands of their users. Thus, to follow the transformations of the MIT would be interesting not only because of the general concern of this thesis for an adaptable architecture, but also because it might help to retrace step by step, the inscription of this soul to its physical body.

The physical history of MIT began in the downtown of industrial Boston, in the Mercantile Library Association Building, on December 17, 1862, where the Society of the Arts was gathered for the first time in a "public meeting."[2] The Society of the Arts was one of the three divisions of the Massachusetts Institute of Technology as founded by William Barton Rogers, the other two being the School of the Industrial Science and the Museum of Technology. Although the last one was never realized as a project, the School of Industrial Science picked up on the academic endeavor that the Society had initiated and on February 20, 1865, classes started in the Institute's few rooms in the Mercantile Library. Students in this first year were only 23 while the courses six, namely, Physics, Mathematics, Civil Construction, Chemistry, French and Free- hand Drawing. Almost one year and a half later, the Rogers building on Back Bay near to the Museum of Natural History, was ready, and the School settled there, with more than 70 students.[3]

Enrollment soon outnumbered the capacity of the new building and MIT started to grow through a continuous process of colonization in the Copley area. By 1910 MIT was comprised by 1,506 students and by the following 12 Departments; Civil Engineering; Mechanical Engineering and Applied Mechanics; Mining and Geology; Architecture; Physics; Electrical Engineering; Literature, History, and Political Economy; Modern Languages and English; Mathematics; Chemistry and Chemical Engineering; Biology; and Naval Architecture.[4] At the same time, the physical part of MIT had become a sort of campus. The first growth occurred with the construction of the Women's Laboratory just adjacent the Roger's building in 1871, which later on got demolished and in its place the Walker Building got built in 1883. After the Walker, MIT jumped to Trinity Place where five new buildings were built until 1903; Engineering Buildings A, B, and C, the Henry L. Pierce Building for Architecture and the Lowell Laboratory for Electrical Engineers. In the meantime, a Gymnasium and a lab for the Mechanical Engineers, on Exeter and Garrison Street, respectively, were also in use of the Institute.[5] However, space was still not enough, and with the appointment of Richard C. Maclaurin as President in 1909, who undertook the long discussed issue of complete relocation, "the transformation of the MIT we know today began to take place."[6]

(Endnotes)

[1] James P. Munroe during the Dedication Exercises for the new MIT buildings, as quoted in "Dedication of New Technology Buildings," *Society Affairs* (July 1916): 572.

[2] Samuel C. Prescott, *When M.I.T. was "Boston Tech" 1861- 1916* (Cambridge: The Technology Press, 1954): 36.

[3] For the first years of MIT at the Mercantile Library Building see Prescott (1954): 35- 55.

[4] Number of students as reported during the registration on November 1, 1910; see *Massachusetts Institute of Technology President's Report* (Cambridge Massachusetts, 1911): 50. Departments as outlined on the list with the visiting committees, see *Massachusetts Institute of Technology President's Report* (Cambridge Massachusetts, 1911): 7.

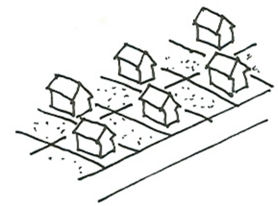
[5] See Caroline Shillaber, "Architecture of MIT Buildings: Part I," *Technology Review* vol. 56 (April 1954): 298- 230.

[6] Mark Jarzombek, *Designing MIT: Bosworth's New Tech* (Boston: Northeastern University Press, 2004): 17.

(1st step of tuning, before design) Site Selection.

One could argue that the procedure of "fine- tuning" begins with the site selection and it would be interesting to see what the reasons that made the present site of MIT a potential one were. According to the Site Committee appointed by President Richard Maclaurin in June 1910, the new site should respond to the following issues; MIT at the time was already a school of national and international range. In 1910 American students came from 40 different states while foreign ones from 36 different countries. However, 50.6% of the students were still coming from Massachusetts.[1] It appears that most of local students were still living in their homes while studying at MIT and probably for this reason, it was deemed necessary by the Committee that the new site should be conveniently accessible and placed near contemporary means of public transportation. This would enhance access to professors and other visitors. At the same time, it should preferably be placed away from any other institution, provision that most probably referred to Harvard University, but still close to the City of Boston.[2] Furthermore, the land chosen should be cheap, but not such that a sophisticated and costly construction of foundations would be needed, and should allow for any kind of architecture to be realized, especially one that would reflect the significance of the Institute.[3] Finally the site should be big enough in order to accommodate for the needs of the school. According to a preliminary report of George Wigglesworth, a member of the Corporation, which is mentioned in relative correspondence, at the time the Institute occupied a floor area of 354,000 square feet which in the new buildings should augment to 491,000 with a total footprint of 148,000 square feet. In addition, it appears that there was a desire for enough room so that provision would be made not only for administrative and service purposes but also for an athletic field and dormitories, as well as for future extension.[4]

Under such conditions many sites were considered but the Site Committee suggested that the following three seemed to be the most appropriate to pursue; the "Allston Golf Club" site on Commonwealth Avenue, the "Riverbank land east of Massachusetts Avenue," and the "Fenway sites."[5] It is not exactly clear what were the reasons that led to the purchase of the "Riverbank" site since, while complying with many of the prerequisites, it also presented some disadvantages like being close to Harvard. There are however two interesting details in this story. First, in the evaluation of this site by the Committee the point that it was "of such a shape as to divide up easily and properly into quadrangles" was made.[6] Secondly, while the choice and purchase were considered, Coleman du Pont, who played a crucial role in the story by finally offering 500,000 dollars, urged for the acquisition of more than 25 acres which was the initial extent of land considered by the Institute; "I don't like the look of twenty- five acres. It seems to me too small. Almost invariably when a man comes to me to approve plans of a new factory"-…-"I tell him to double the size of everything, and almost invariably I wish afterward that I had used a larger factor of safety. Technology will occupy a great position in the future and must have room to grow. I don't feel much attracted by twenty- five acres, but I should be interested in fifty."[7] The Cambridge site, as bought, was a 50 acre site; either it was initially that big, or it was smaller but there was the possibility of expanding it, a possibility that might not exist with the other ones. In any case, whatever the role of these characteristics during the selection, somewhere in the procedure a first step of tuning had been made; the physical space in which the new Institute would operate responded to most of its functional needs. Furthermore, the site could be easily "grid-ed," as obviously desired, and it was big enough to allow for future growth; the site was adjusted to the needs **[Quote 1]**. The next step was to come up with an equally responsive plan.



[1]["*One formal means is to provide excess capacity: a framework strong enough to take extra stories on top of a structure, the provision of extra space to grow in, or sewers large enough to handle population growth*."
Kevin Lynch, *Good City Form* (Cambridge: The MIT Press, 1984): 176.]

(Endnotes)

[1] see *Massachusetts Institute of Technology President's Report* (Cambridge Massachusetts, 1911): 52.

[2] Harvard at the time was willing to merge with MIT. This, however, initiated a lot of reactions from the part of MIT's students and alumni. For more details see Jarzombek (2004): 18- 19.

[3] Letter of the Site Committee to President Richard C. Maclaurin, October 27, 1910, p.1-2 [Office of the President AC 13, Box #3, Folder 85, MIT Archives]. The local character of the Institute is explicitly stated as location criterion in unsigned and undated notes in the same folder. However, it is also confirmed by the Registrar's Report as shown in note 6.

[4] In a letter of the Site Committee to the President it is referred that in the Allston site, there is enough room for an athletic field and dormitories if these are "desired." See Letter of the Site Committee to President Richard C. Maclaurin, December 15, 1910, p. 1 [Office of the President AC 13, Box #3, Folder 85, MIT Archives].

[5] Since a lot of time had passed between this letter of the Committee and the purchase of the site (March 12, see reference to Mark Jarzombek below) it cannot be absolutely sure whether these were the last three choices considered or whether this was the only Site Committee appointed. The story of the purchase of the site is difficult to follow since it is based only on reports that have survived. However, I believe that we could safely draw from this letter information about the expectations from the site and also, based on the result, we could assume that these were indeed the choices that were considered the most. Furthermore, this letter gives information on what made the "Riverbank" site a potential one, and I believe that this is what is important. See, Letter of the Site Committee to President Richard C. Maclaurin, October 27, 1910, p.2-3 [Office of the President AC 13, Box #3, Folder 85, MIT Archives]. For more info on the issue see also Jarzombek (2004): 19.

[6] Letter of the Site Committee to President Richard C. Maclaurin, October 27, 1910, p.7 [Office of the President AC 13, Box #3, Folder 85, MIT Archives].

[7] Coleman du Pont as quoted by Richard C. Maclaurin in a message of his, read by Professor Sedgwick during the banquet of the Alumni Association on January 10, 1920, see *Massachusetts Institute of Technology President's Report* (Cambridge Massachusetts, January 1920): 11- 12.

(2nd step of tuning, design) Plan of Bosworth: spatial needs, influences and presentation of the system.

In order, however, to judge the responsiveness of a plan or in Lynch's words 'fit,' it is necessary to get an idea first of the needs that a plan had to accommodate. In this case, the needs for ample space, as well as for the inclusion of dormitories and athletic fields, have already been mentioned. It rests to see what the needs in the academic and administrative departments were. However, it would be a painstaking and probably ineffectual procedure to unfold here a detailed presentation regarding exact dimensions, area measurements and equipment of the spaces that each department needed. The reason is that MIT was not designed as a synthesis of these needs, but rather through a back-and-forth procedure. This is not only evident in the formal tools that were used for this plan, as we will see later in the analysis of the scheme, but it is also explicitly stated in reports;

"The thoughts and work of the various members of the staff have in large measure centred (sic) upon the new quarters soon to be occupied by the Department. The original detailed plans, tentatively presented in such form as best to make clear the needs of the Department, were worked out by the architect, who, with great skill, adapted them to the form and scale of the building which it had meanwhile been decided to erect. These plans with the necessary rearrangement of certain details will probably give all that it is practicable to secure in view of the necessary limitations of the space available." [1]

In other words, it appears that after some general principles were derived from the needs and a plan was sorted out, Bosworth got back to adapt each Department's demands to the general plan. Although one could argue that in this case a reverse procedure of fine tuning occurred, I would argue that this is a necessary process in such a big project and that what at the end matters is the fact that the plan of Bosworth, or the physical space that was finally proposed, was able to preserve the right degree of generality demanded.

These general needs to which the plan had to respond can be derived from the relative Faculty Reports, mentioned in the quote, that were compiled after the suggestion of President Maclaurin.
In most cases, the reports of the various Departments called for communication and proximity with other disciplines. For example, in the report of the Department of Mathematics, a tight relation with the Departments of Physics and Mechanics was requested, as well as to the students of the first year.[2] This seemed like a natural reaction to the fact that in the Boston Campus, the various buildings used by MIT

were quite apart from each other. Furthermore, efficiency, practicality and convenience are what are discerned as general guides for planning and design; “For the sake of economy of space, economical cooperation in the use of lecture and recitation rooms, economy of administration, and efficiency of work, it appears to me essential to have the departments of English, Modern Languages, Economics and History located in the same building, together with their libraries and the General Library.”[3] In addition, in most cases rooms had to be well lighted, be high enough and be well ventilated. Finally, a general list of types of spaces can be derived from the report; the plan had to accommodate classes, recitation rooms, labs, offices, libraries and lecture rooms and, of course, various service spaces.

As mentioned in the Introduction, other studies had preceded the plan that finally got built. Between April 1911 and January 1913 seven different proposals had been made, two of these in more than one version. From these studies particular two are of interest, as they exhibit similarities with Bosworth’s proposal. The first one is Despradelles’s plan of 1912 which, in contrast to the previous studies that were based on a group of independent buildings, this one was based on a mega-structure of unified buildings. This mega-structure seemed to lie along an invisible grid which was refined in the six later versions of the scheme **[02- 04]**. The plan was not approved and was left pending mainly because of inefficient

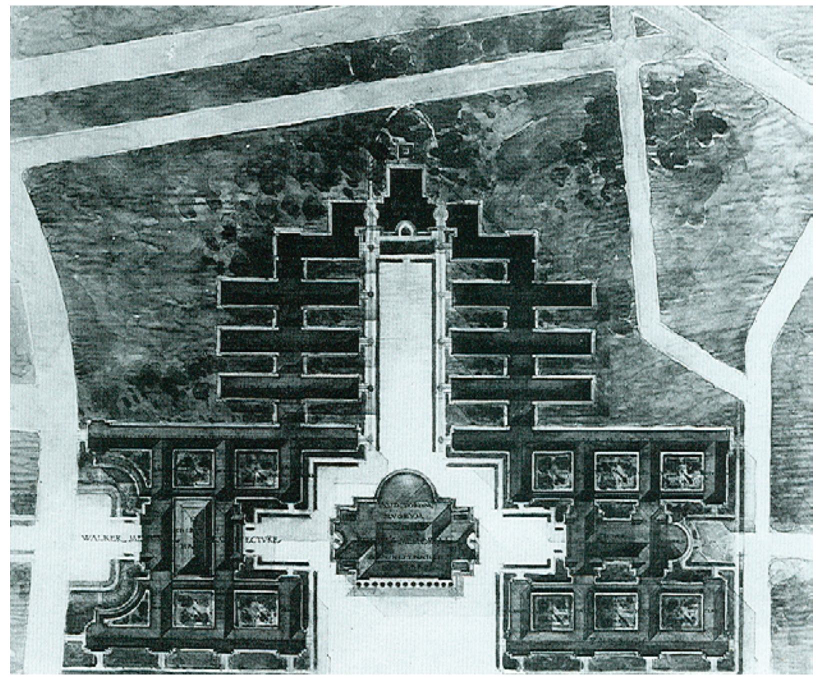
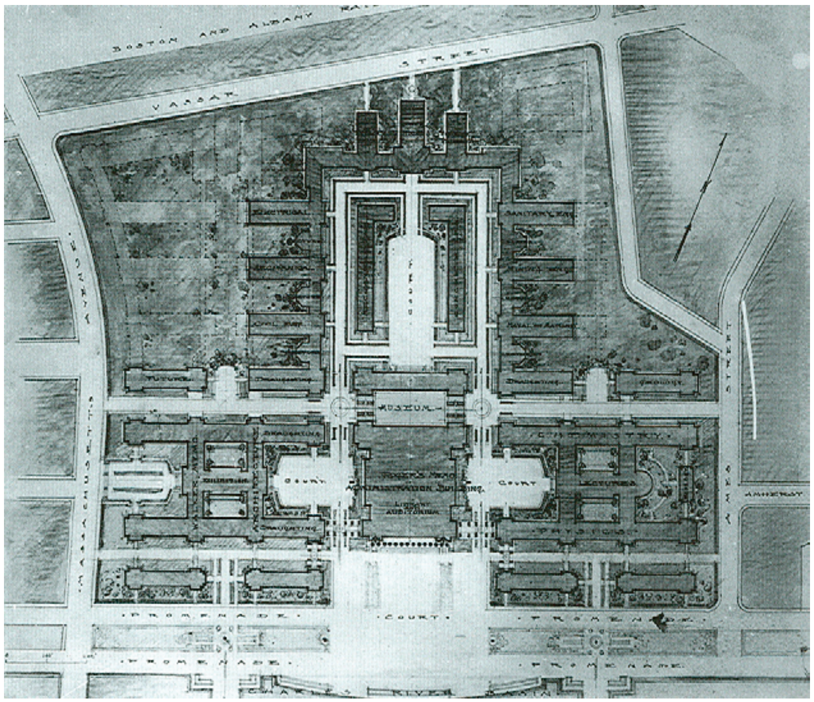


Fig. 02: Version of Despradelle’s scheme.



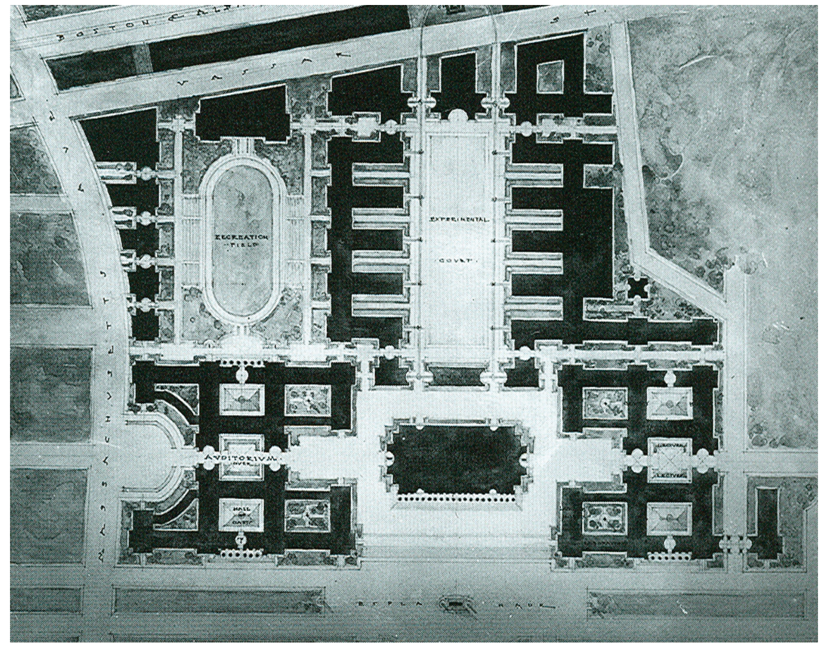


Fig. 03: Version of Despradelle's scheme.

Fig. 04: Version of Despradelle's scheme.

spatial organization.[4] However, as we will see later, the grid, and the constant width of buildings and courtyards that its use resulted in were present as formal tools in Bosworth's plan. Although I am not in a position to know whether an influence existed or not, I can almost positively state that in the case of the second interesting study, namely that of John R. Freeman it did. The same point of view is shared by Jarzombek; "But there is no denying that many of Freeman's suggestions found their way into the project under the overall umbrella of Bosworth's aesthetics."[5] As we will see, these suggestions played a crucial role in the MIT thereafter transformations. For this reason, a more thorough presentation of the proposal in question is needed.

The study of Freeman, or "Study no 7," was the result of a very detailed analysis regarding the needs of the Institute. Freeman did not only scrutinize the Faculty Reports, but he also explored the way that similar needs were satisfied in other, both American and foreign, schools. The plan he finally proposed was a purely functional one, which, according to him, derived its logic from factory design and reflected, according to Jarzombek, the Taylorist principles, that had recently debuted in the academic circles, namely principles that were represented by the words "efficiency," "management," and "scientific."[6] Jarzombek provides a very detailed discussion on Freeman's interest in Taylorism and as a result I am not going to refer to it in depth here. Keeping, however, these words in my mind, I am going to add to his discussion about the form and I am going to emphasize the means that Freeman used to express these principles, concentrating on the following elements: on the one hand, the single structure or interconnected buildings in relation to corridor and the number of floors, and on the other, the "bookcases" system in relation to structural system and free- plan.

As is probably already assumed, Freeman's scheme was based on a single structure of unified buildings **[05]**. Although this could have been an influence of Despradelle's scheme, Freeman's verbal notes accompanying his drawings left no doubt about his own fervent beliefs on the issue. Drawing from the most significant universities in Europe, he presented the unified group of buildings as the proper answer to all the problems, which according to him the separate buildings of the American campuses presented, problems that in a different manner had also been pointed out in the Faculty Reports; first, the isolation of each Department head in the autonomous building and therefore, one can assume, the lack of contact between disciplines; second, the frequent exposure of students to the cold weather between classes; and third, the lack of communication between professors and students caused by the hasty departure of the student from class in order to reach the other classroom on time.[7] In order to further deal with these problems, Freeman based

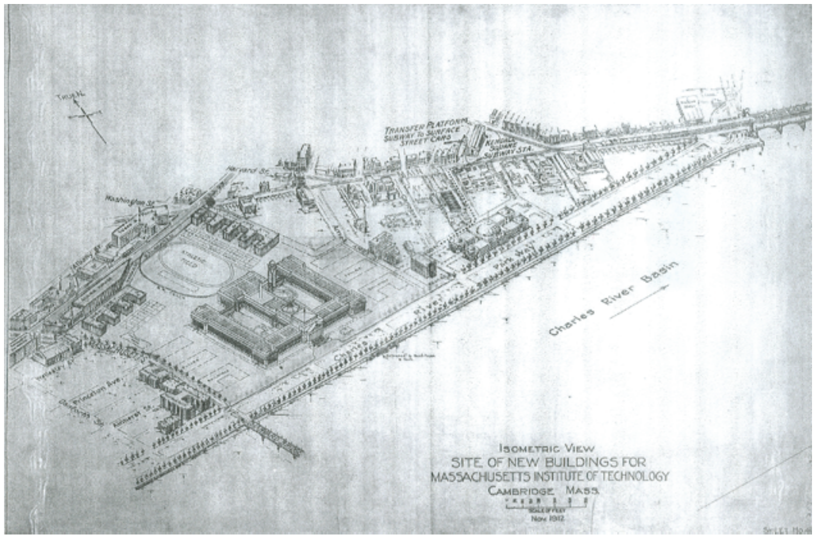


Fig. 05: Campus Plan of Freeman.

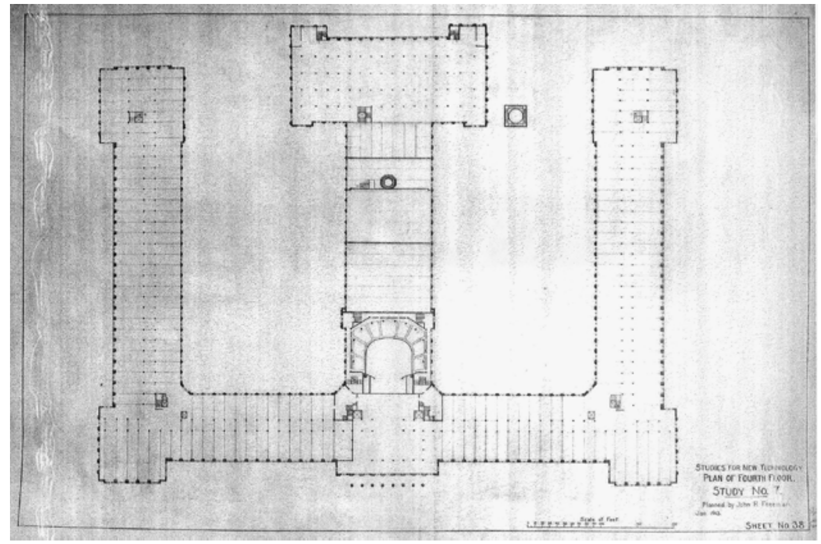


Fig. 06: 4th floor plan of the academic building. The central series of the structural columns define the double loaded corridor.

the organization of the single building on a double- loaded corridor system **[06]**. The corridor, excessively wide from 15’8” to 21’, was “designed to serve both as a highway for travel and for a general place of meeting and mixing of the student body and as a sort of hall of fame.”[8] Benches and exhibitions of scientific accomplishments would provide not only the spatial, but also the intellectual means, by which discussion and communication would be encouraged, while the residual width would serve as the circulation space. This efficient circulation system was further enhanced by the constraint of the number of floors to four, which according to Freeman would allow for the use of stairs exclusively and would render the use of elevators unnecessary **[07]**.[9] Although right now only the relation of these characteristics to efficiency is being outlined, it will be shown later in the thesis how these characteristics also allowed for easy transformations.

The second formal tool introduced by Freeman, explicitly for reasons of adaptability, was the “unit section,” deriving, as he said, as a concept from the “modern sectional bookcases.”[10] The system featured on the one hand, a permanent structure comprised of columns and exterior skin and, on the other, independent interior partitions made up of light materials which could be easily, added, removed or simply moved irrespective of location. The spacing of the columns was unvarying, while in between them windows were placed. The “unit section” was exactly the space defined by each bay and its dimensions were carefully sorted out by Freeman in order for this to be able to function not only on its own, but also as subdivided or multiplied, according to the use it would accommodate **[08- 09]**. Freeman based the dimensions of the unit, namely width, height and length, on the dimensions of the classroom, which was considered at the time to be “most efficient and economical for instruction”.[11] Studying issues like circulation or surface of blackboards, he proposed a bay of 15’ resulting in a unit- section with 14’ 6” width which could become 17’ if the interior partitions were placed at the edges of the columns. The depth was to be 32’ or 36’ while the height would vary among floors from 16’- 17’; however both dimensions were so defined in order for daylight to reach each corner of the unit- section. Furthermore, ventilation ducts were placed next to each column. As a result, a fully serviced, in terms of natural light, fresh air (window) and ventilation, unit- section was formed. Finally, all unit-sections could be equipped with uniform furniture. In other words, Freeman worked on the basic principles of a modular system, taking into deep thought its dimensions and overcoming in this way one of the common inefficiencies, according to Lynch, of modularity, namely the random dimensions.[12]

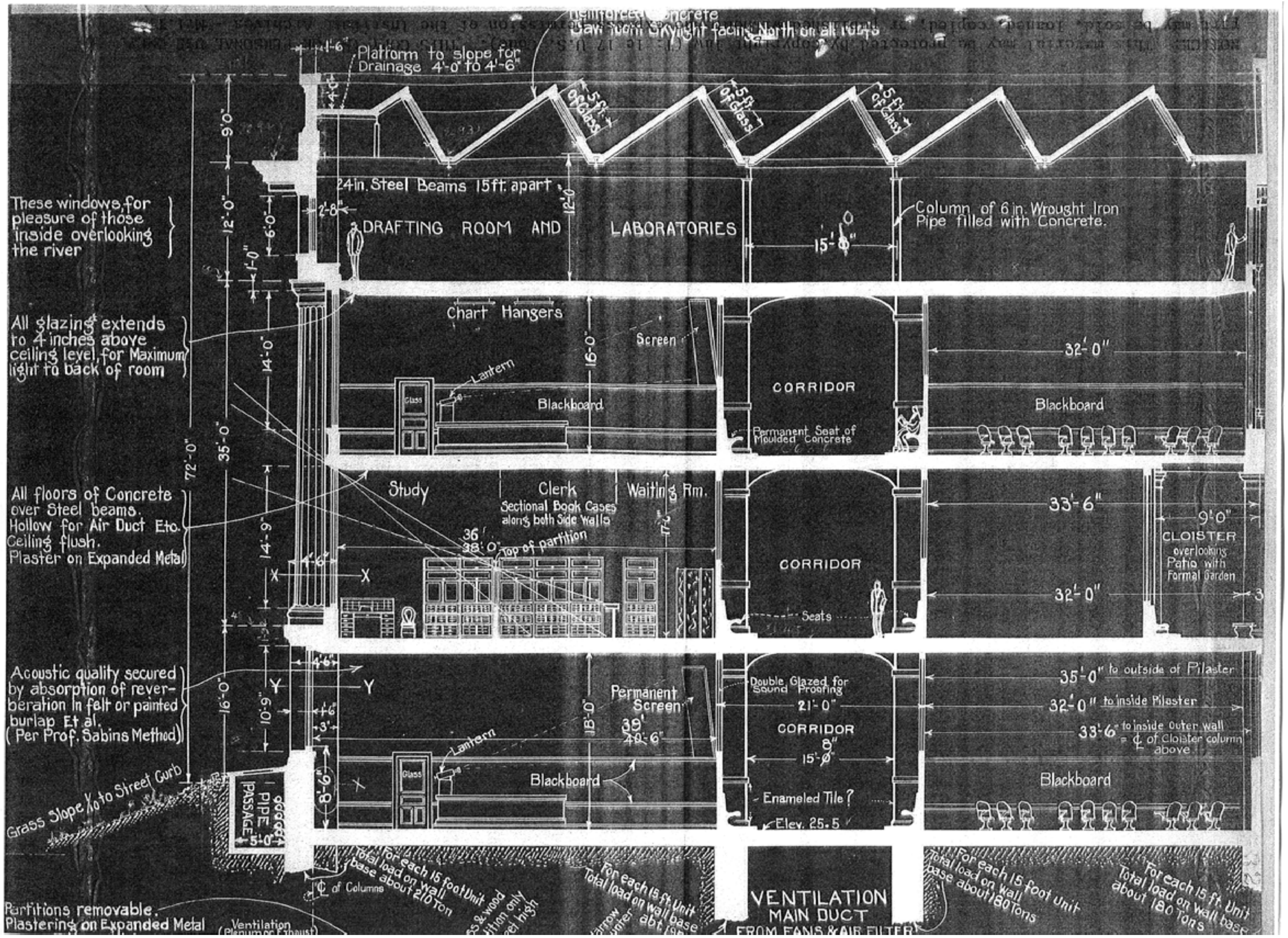


Fig. 07: Section of the single megastructucture showing the corridor as well as the tabulation of the natural light angles.

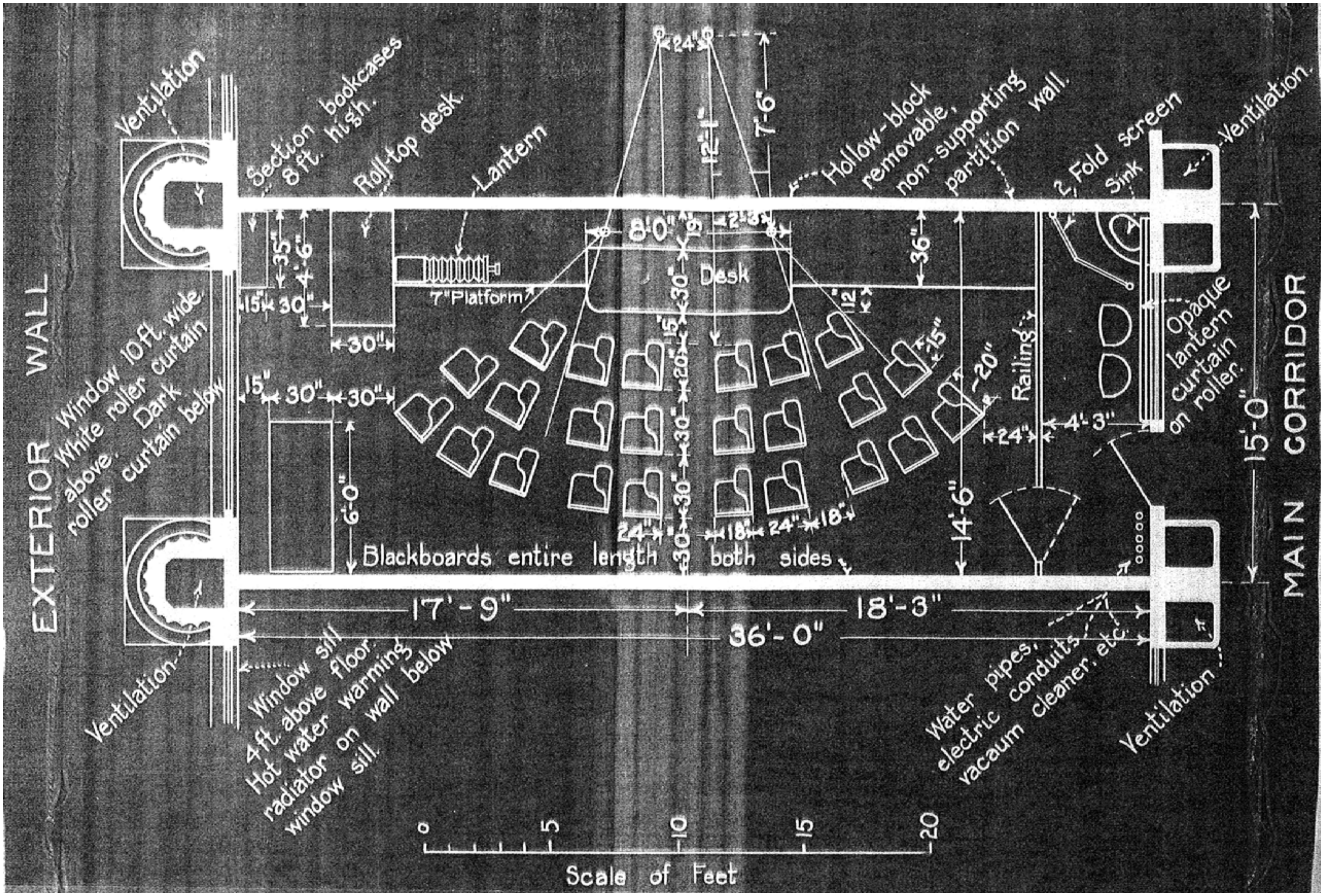


Fig. 08: Unit- section of Freeman.

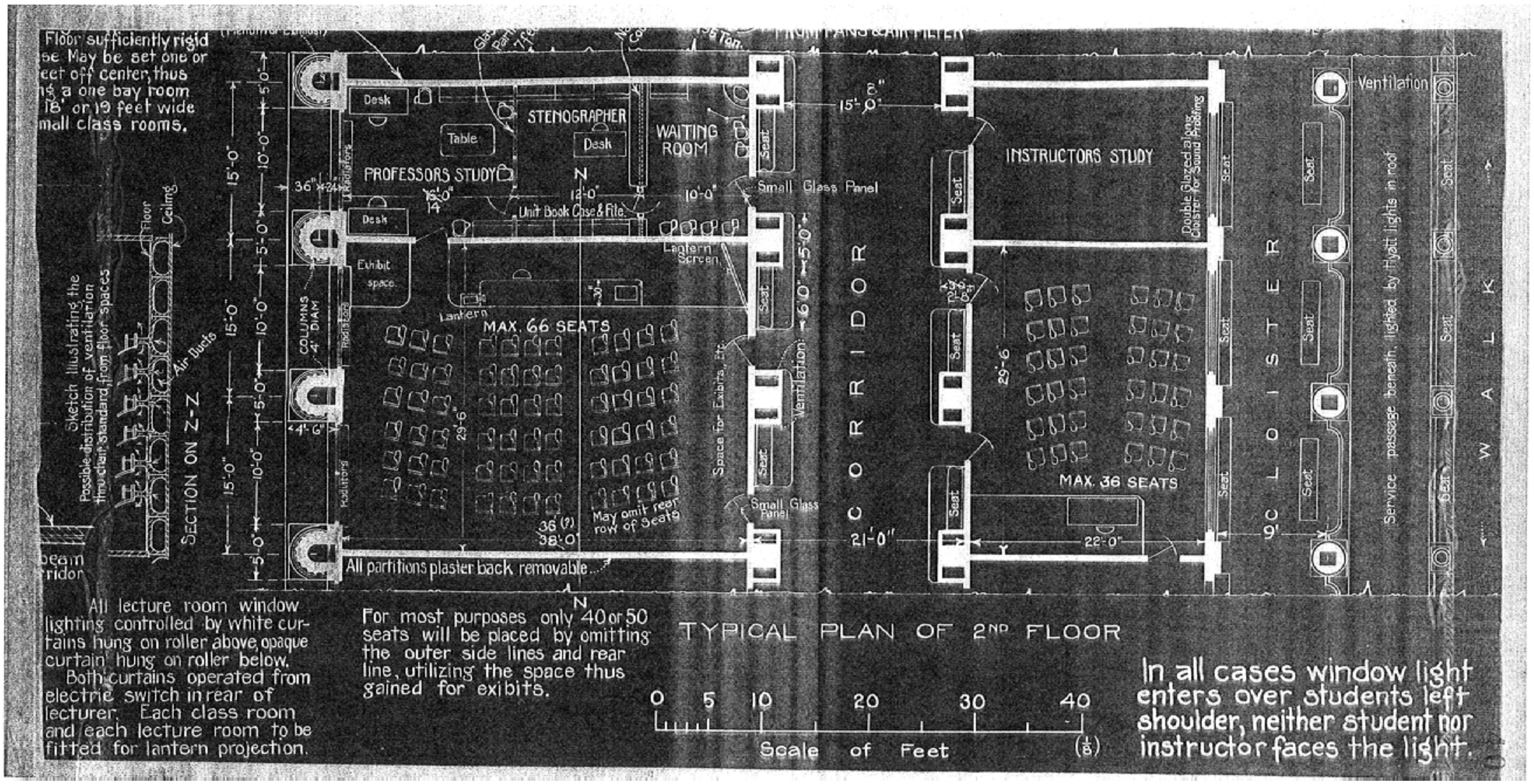


Fig. 09: Subdivision and combination of the unit- sections.

Despite the passion that Freeman put into his work, and his well considered propositions, his plan, was never approved and in December of 1913 construction was initiated according to the plan of William Welles Bosworth, an MIT graduate.[13] This plan, combining Despradelle's unified grid-ed building with the structural principles and interior organization of Freeman, as we will see in more detail later, was based on a group of orthogonally jointed buildings, arranged around a big central court **[10]**. The layout was almost symmetrical and on the symmetrical axis was a central building which roofed by a preponderate big dome was to be the main entrance to the group **[11- 12]**. Apart from accommodating all the academic needs, the plan provided in a most adequate way, on the one hand, for future extension and on the other, for dormitories and athletic facilities. Thus the plan already satisfied a number of the needs of the Institute as have been stated before: the eager anticipation of grandeur and dignity, adequate residential and recreational spaces, interconnection and communication, and provision for future growth. This urban scale 'fit' was further enhanced by the arrangement of the Departments. The necessary propinquity was kept wherever possible; Mining was placed close to Physics and Chemistry, Naval Architecture close to Mechanical Engineering while all General Studies were concentrated on one edge. This arrangement was very satisfactory also in terms of future extension. The Departments that were expected to grow with faster rhythms were placed at the points

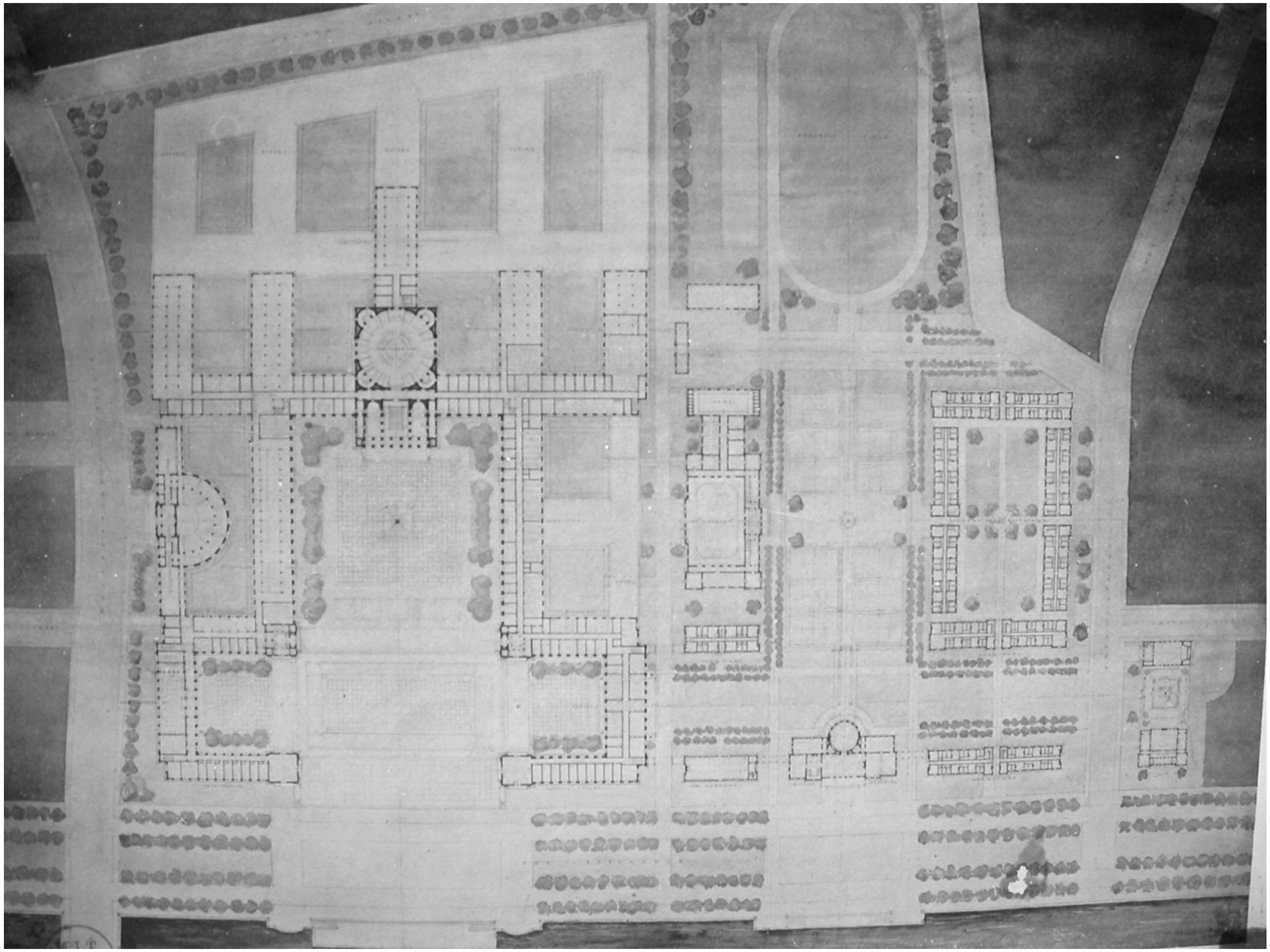


Fig. 10: Photograph of Bosworth's plan as published in *The Architectural Review* in September 1913 . Dormitories are located at the right half of the plan

Fig. 11: Perspective of the new academic buildings.

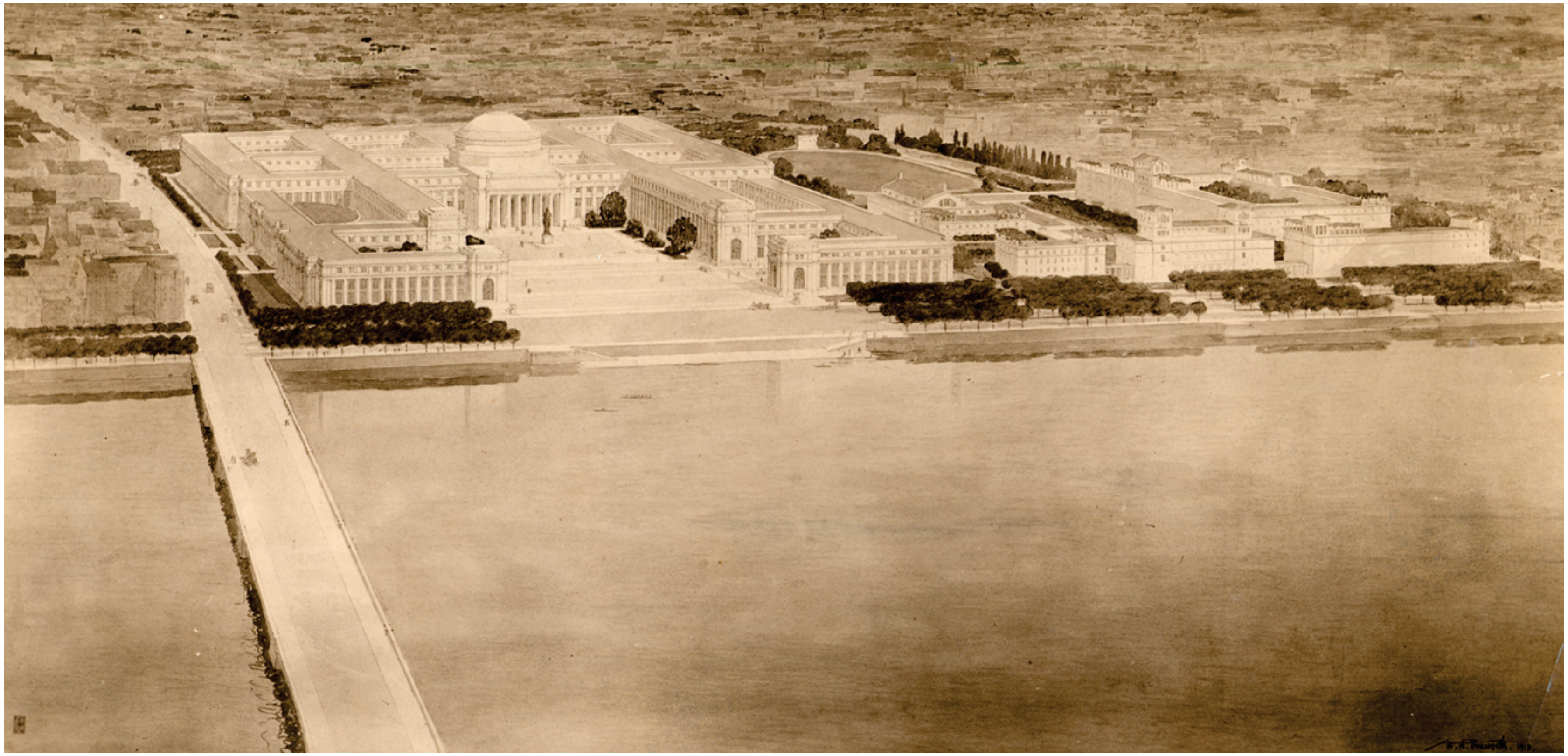


Fig. 12: Bird's eye view of the new Campus.

where such extension could take place. For example the Mechanical Engineers were located on the northwest corner of the building where they could expand towards Vassar Street, while the Department of Biology which at the time was very important because it integrated Public Health in its Curriculum could be expanded through the building that would enclose the east small court. On the contrary, the General Studies which were expected to grow more slowly were the ones to be put at the south edge where there was no possibility of expansion since the central Court was a place that should not be altered at any cost **[13]**. This arrangement was characterized even then as "practical" and very "flexible."[14] However, it was not the one that was implemented.

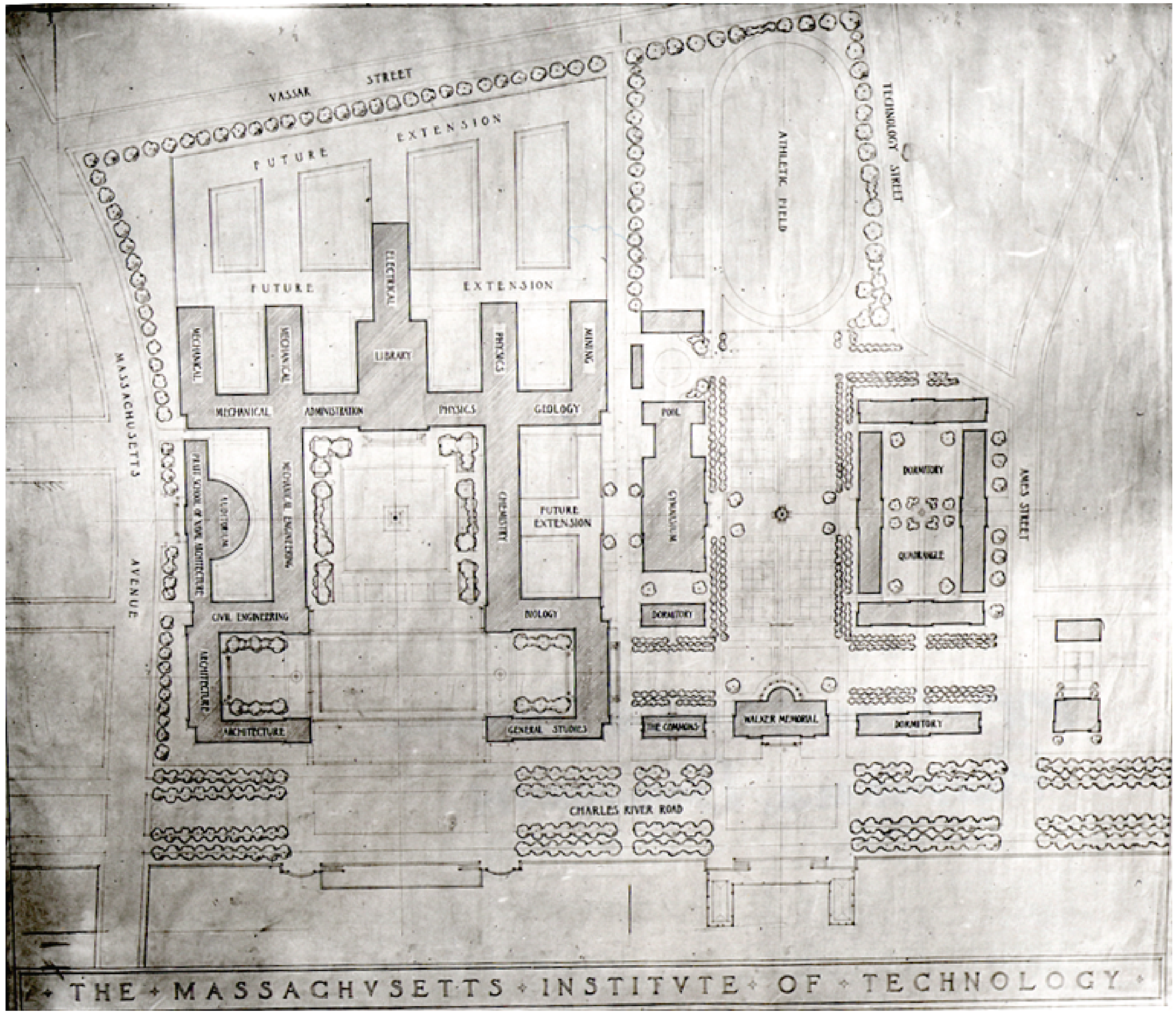


Fig. 13: Bosworth's Plan, 1913.

(Endnotes)

[1] *Massachusetts Institute of Technology President's Report* (Cambridge Massachusetts, January 1914): 94.

[2] "Report for the Department of Mathematics," p. 1 [Freeman Collection, MC 51, Box # 42 A, Folder: M.I.T. Cambridge Campus: "Faculty Estimate of Space, no.1," MIT Archives].

[3] Charles F. A Currrier, "Suggestions for New Buildings: Department of History," p.1 [Freeman Collection, MC 51, Box # 42 A, Folder: M.I.T. Cambridge Campus: "Faculty Estimate of Space, no.1," MIT Archives].

[4] See Jarzombek (2004): 26- 35. For the rest of the preceding studies see Jarzombek (2004): 23- 36.

[5] Jarzombek (2004): 85.

[6] Jarzombek (2004): 41. Generally for Freeman's study see Jarzombek (2004): 40- 52 and 116- 131, as well as John R. Freeman, "NOTES ON "STUDY NO. 7" FOR NEW TECHNOLOGY (and on Various Studies made during the year 1912)" [Freeman Collection, Box #41, MIT Archives].

[7] See Jarzombek (2004): 46, and Freeman's Notes on "Study No. 7" as quoted in Jarzombek (2004): 128, and John R. Freeman, "NOTES ON "STUDY NO. 7" FOR NEW TECHNOLOGY (and on Various Studies made during the year 1912)," p. 5-9 [Freeman, Box #41, MIT Archives].

[8] John R. Freeman, "NOTES ON "STUDY NO. 7" FOR NEW TECHNOLOGY (and on Various Studies made during the year 1912)," p. 41 [Freeman, Box #41, MIT Archives].

[9] John R. Freeman, "NOTES ON "STUDY NO. 7" FOR NEW TECHNOLOGY (and on Various Studies made during the year 1912)," p. 26 [Freeman, Box #41, MIT Archives]

[10] John R. Freeman, "NOTES ON "STUDY NO. 7" FOR NEW TECHNOLOGY (and on Various Studies made during the year 1912)," p. 17 [Freeman, Box #41, MIT Archives]. Generally for the "unit section" see Freeman's Notes on "Study No. 7," p. 16- 17, 26- 44 [Freeman, Box #41, MIT Archives]

[11] John R. Freeman, "NOTES ON "STUDY NO. 7" FOR NEW TECHNOLOGY (and on Various Studies made during the year 1912)," p. 28 [Freeman, Box #41, MIT Archives].

[12] Kevin Lynch, *Good City Form* (Cambridge: The MIT Press, 1984): 180.

[13] "Interesting History of Institute Buildings recently Completed," *The Tech* (Cambridge Mass., Tuesday, December 27, 1921): 1.

[14] "Connected Buildings Arranged in Harmony With the Ideal Location," *The Tech* (Boston, Mass., Saturday, November 8, 1913): 3-4.

(3rd step of tuning, implementation) Built Plan: analysis of the system

One could say that during construction the absolute 'fine tuning' takes place. Undeniably, it is during implementation that the designer, "builder" and user co-operate in the most intensive way in order to produce the most appropriate physical space that will comply with the expectations of all three. It would be impossible to describe here all the revisions that the drawings of the new buildings underwent individually. Nevertheless, it is possible to describe the most noteworthy one, namely the change regarding the general plan.

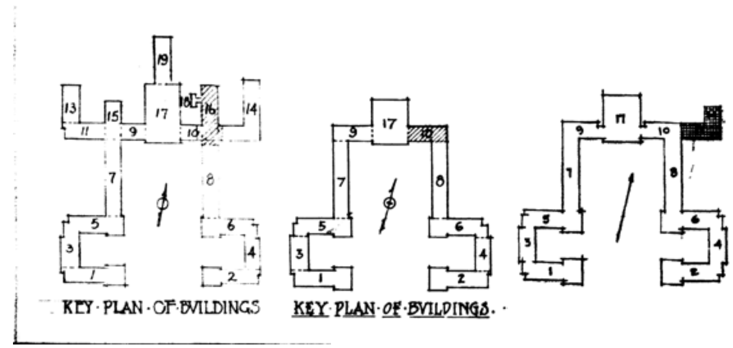


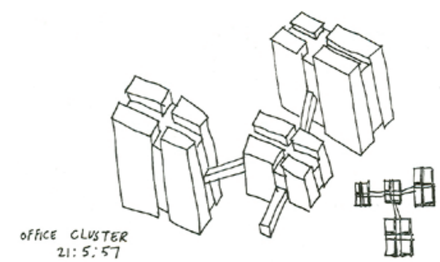
Fig. 14: Different key plans on the drawings of the buildings.

The construction of the buildings began in December of 1913 and continued at a very high rate, thanks to the design which, as we will see later, permitted independency in construction. However, in the fall of 1914 a court decision rendered the sale of the buildings in Back Bay unfeasible. The result was, that due to the lack of income that this sale would bring, the construction of the north wings had to be temporarily canceled.[1] In order not to repeat the congested circumstances of the Boston Campus, MIT decided that some Departments should remain in the Back Bay so that at the same time the property there would not be rendered useless. Considering the relationships between Departments it was deemed that Architecture and Mining could be more easily separated than the others. The first would occupy the Rogers and the second the Walker building. However, in the meantime adequate funds were donated to the Institute by General du Pont and Mr. Hayden for the erection of the Mining building, and as a result Buildings 12 and 14, or present 8, remained in the plan, with 14 being slightly shorter than it was to be initially in the north south direction **[14]**.[2] The rest of the Departments also were rearranged, and changes, as we will see, also occurred to the structural system. Construction finally finished in 1916 and MIT, although planned symmetrical acquired a more "irregular" form.

I would argue that this "irregular," half-finished form, expressed more clearly the intentions of the plan. The asymmetry caused by Building 12 and its deviant form not only revealed the potential for future growth, making it evident even to someone who might not have seen the initial plan, but also implied the existence of a special design, of some kind of joint, that permitted for the building's adhesion to the rest of the symmetrical group to take place. In other words, building 12 betrayed the existence of some kind of system **[15- 19]**. A closer look to the built form of MIT will make the elements of this system clear while it will prepare the grounds for a discussion of the transformations that took place; it seems like stems, fully equipped "unit- sections," knuckles, an underlying grid-ed and open ended circulation system, courts and add- on facades were the basic elements that comprised MIT. All these cannot easily be separated from each other as most of the times they overlap. However, as much interwoven as these formal characteristics are, they are the DNA that allowed free growth and free internal change **[Quote 2]**.

[2] ["*After consideration, there can be no doubt that the adoption of a single building to house all classrooms and departments was the practical solution. This makes it possible to pass from class to class without going outdoors and with a minimum loss of time. The problem of future extension, at first sight, more complicated, may prove that one building will be rather an advantage than otherwise; especially if it could have been in the center of the tract, with future extensions attached at any one of the numerous joints of its articulations. Granting restrictions at east and west, this development is still provided along the entire northern side, making possible the growth of the various departments in different directions within the structure, gradually forcing northward those intentionally located along that side.*"

"New Buildings for the Massachusetts Institute of Technology," *The Architectural Review* 2/9 New Series (September, 1913): 239.



"*The studies of association and identity led to the development of systems of linked building complexes which were intended to correspond more closely to the network of social relationships, as they now exist, than the existing patterns of finite spaces and self contained buildings. These freer systems are more capable of change, and particularly in new communities, of mutating in scale and intention as they go along.*"

Alison and Peter Smithson, *Team 10 Primer*, ed. Alison Smithson (Cambridge, Massachusetts: MIT Press, 1968): 52-54.]

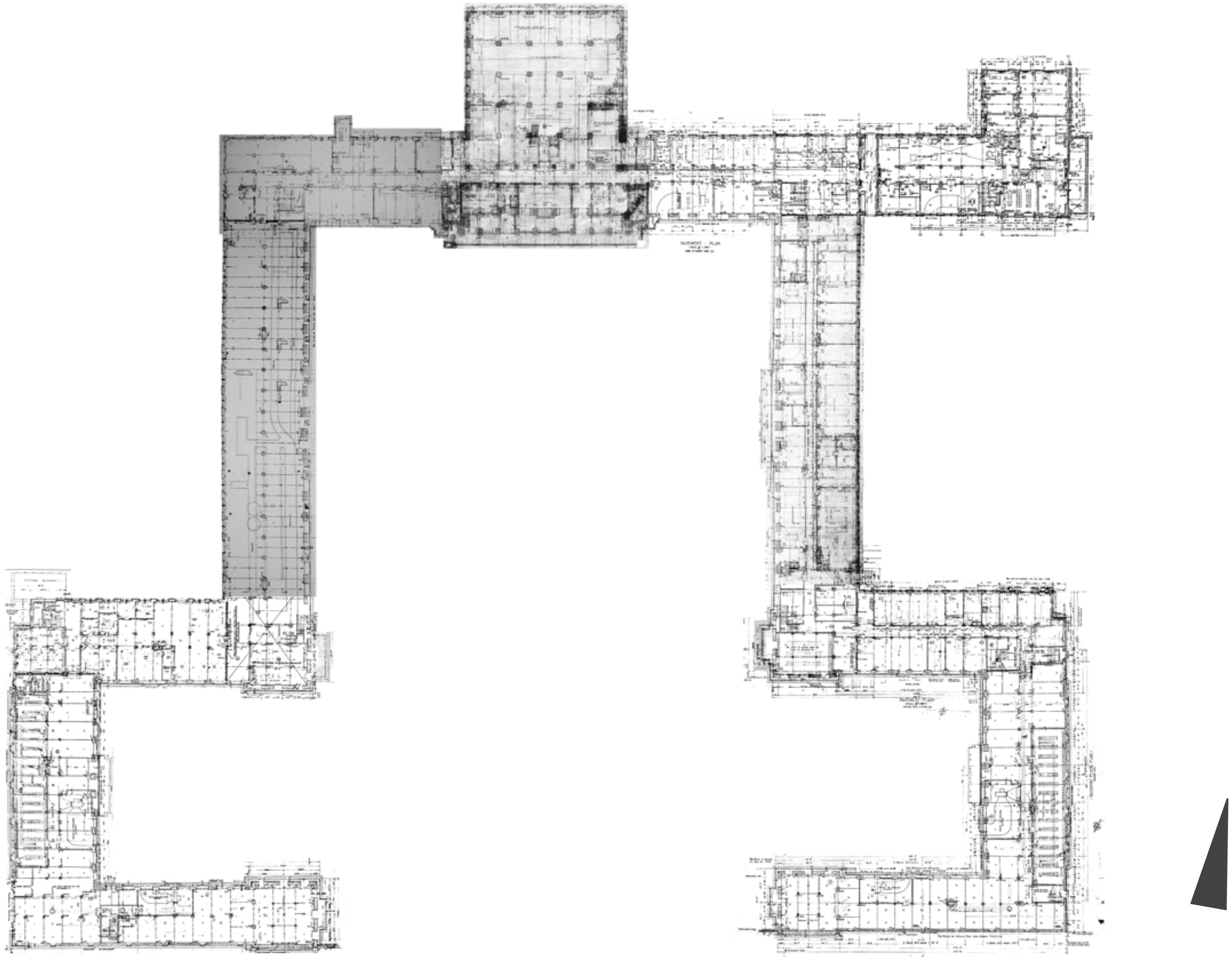


Fig. 15: Floor Plan- Basement (Collage of separate drawings) .

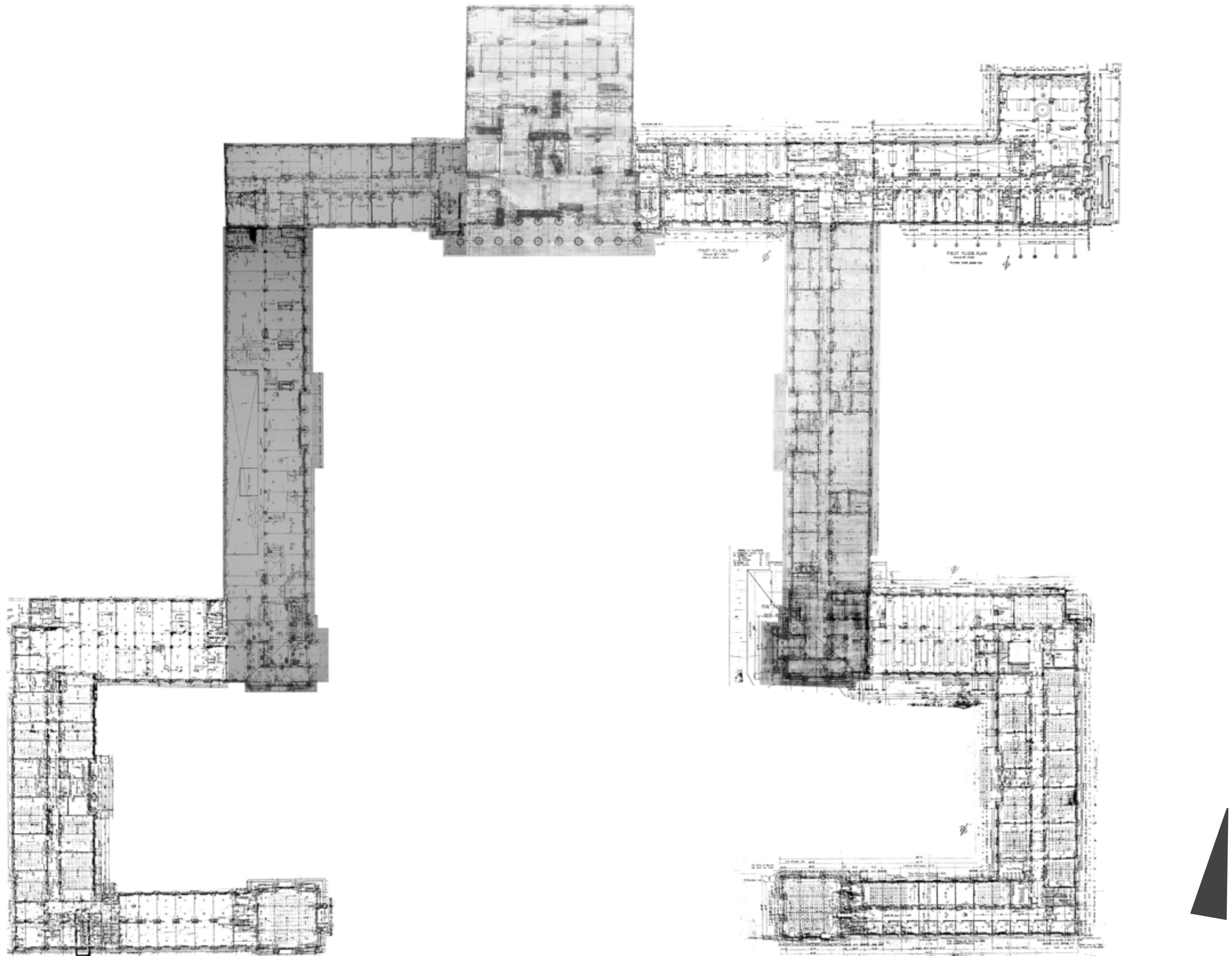


Fig. 16: Floor Plan- First Floor (Collage of separate drawings).

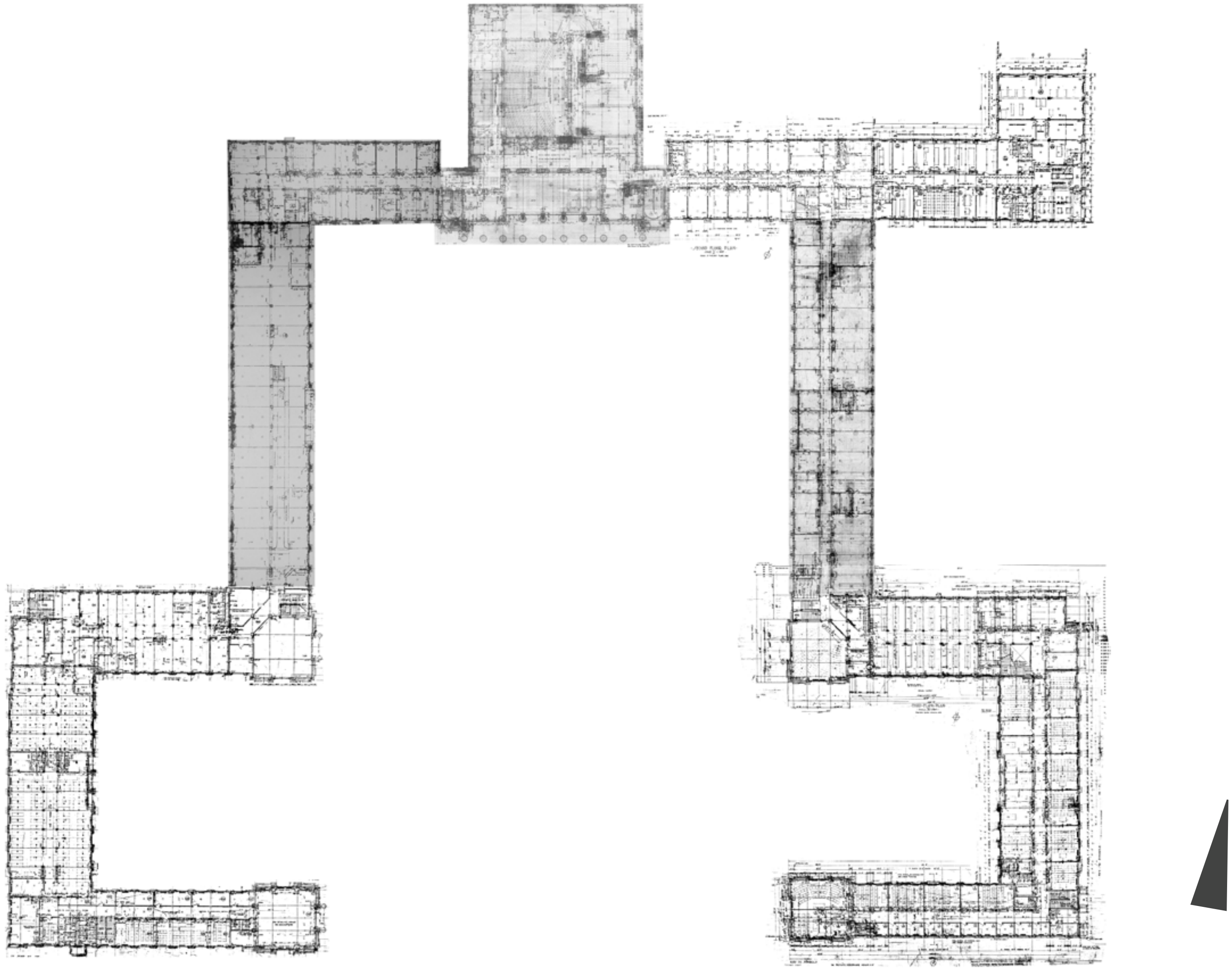


Fig. 17: Floor Plan- Second Floor (Collage of separate drawings).

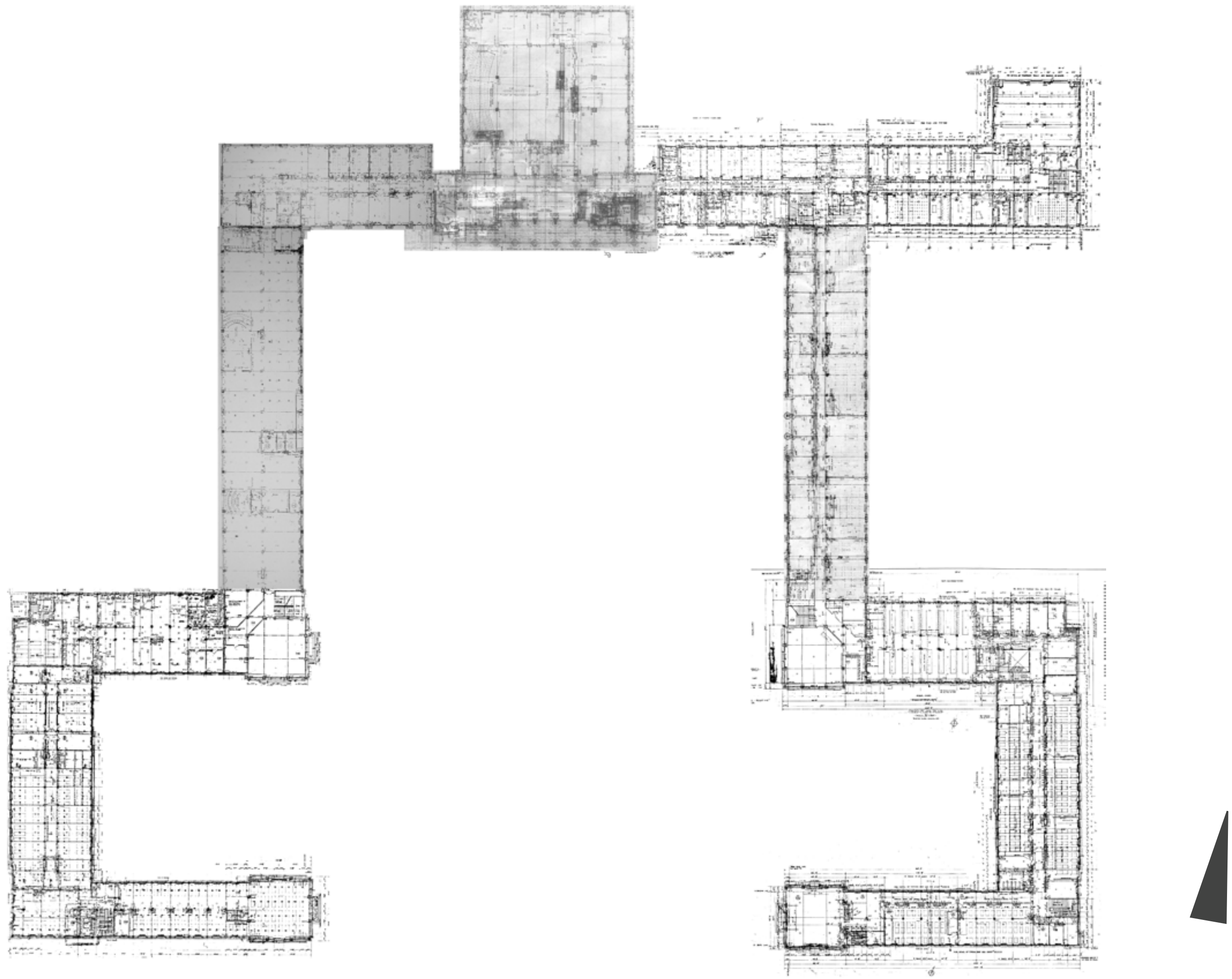


Fig. 18: Floor Plan- Third Floor (Collage of separate drawings).

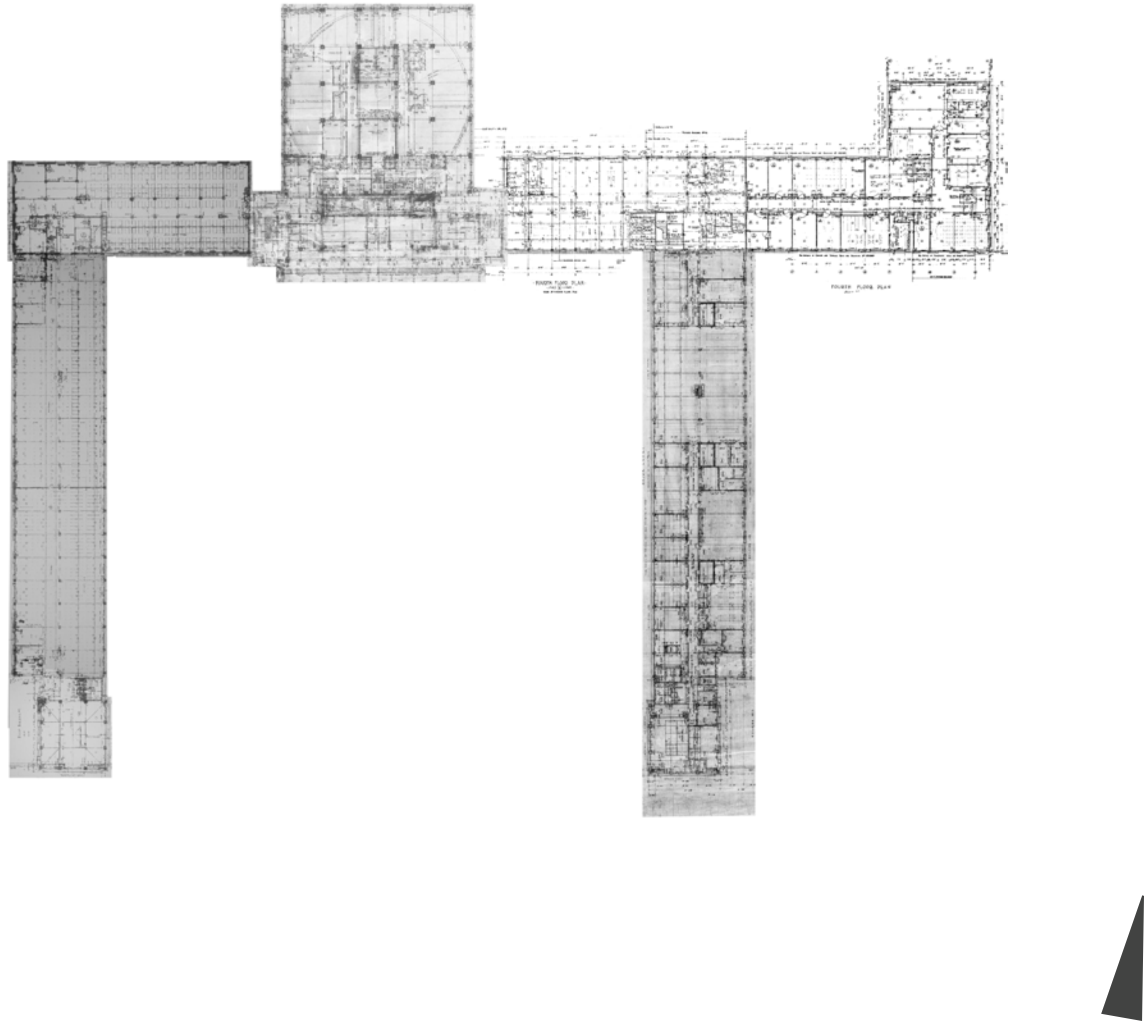


Fig. 19: Floor Plan- Fourth Floor (Collage of separate drawings).

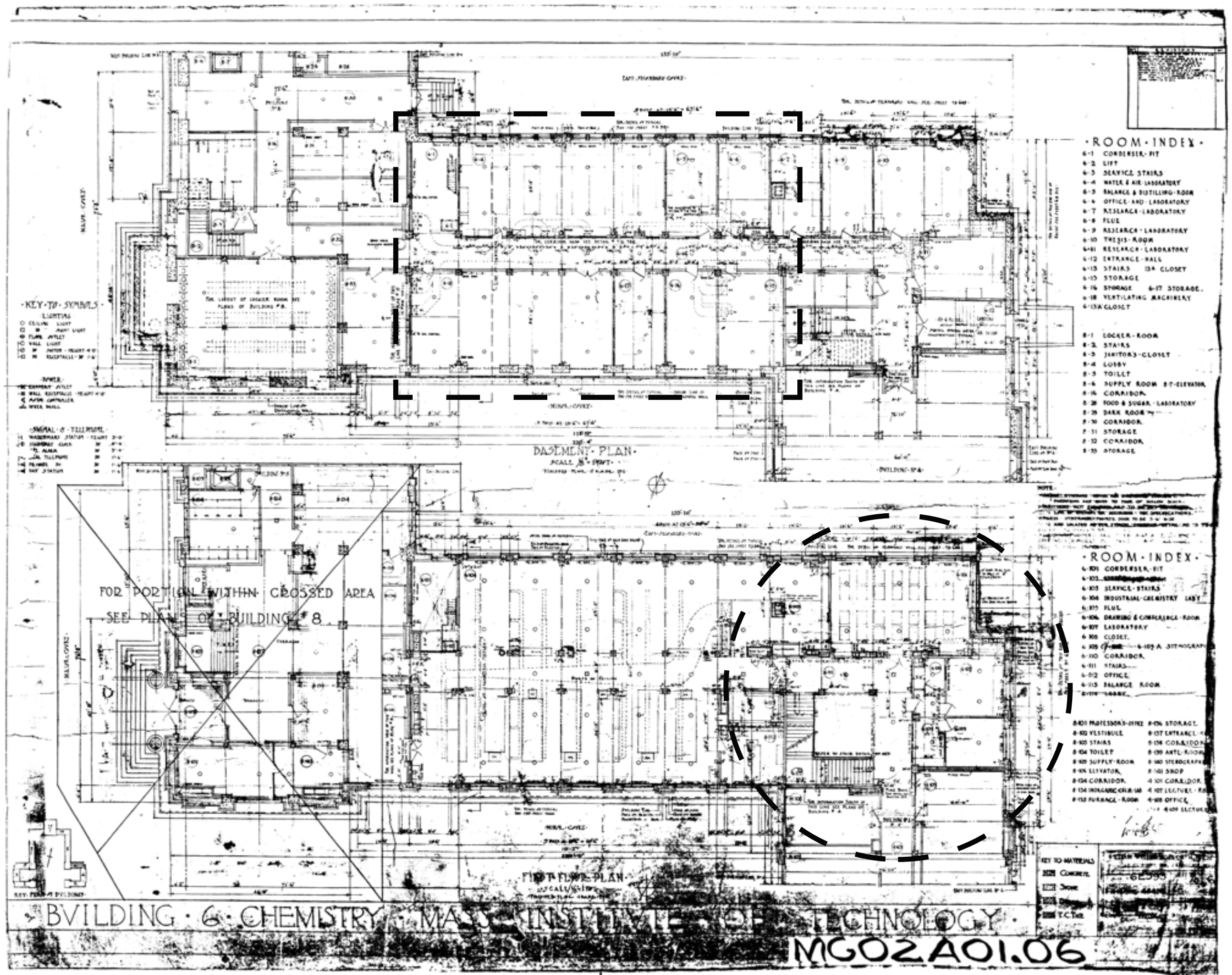


Fig. 20: Basement and First Floor plan of former Building 6 .

Although the new MIT was a unified mega- structure, the buildings were designed separately **[20]**. Each building had its own number, this enumeration being different than it is today, and the overall number of the buildings without the wings that got built was 12. At the points where these buildings met, namely on the vertices of the invisible grid of the initial scheme, the staircases and elevators were located. The only exceptions were an elevator in Building 8 and a staircase in Building 1. This created a system of spaces that concentrated vertical movement, namely **joints or knuckles**, and of spaces that were void of any permanent structure of such nature, namely **stems [21- 22] [Quote 3]**. The types of stems that finally got built were 3, less that in the initial scheme.

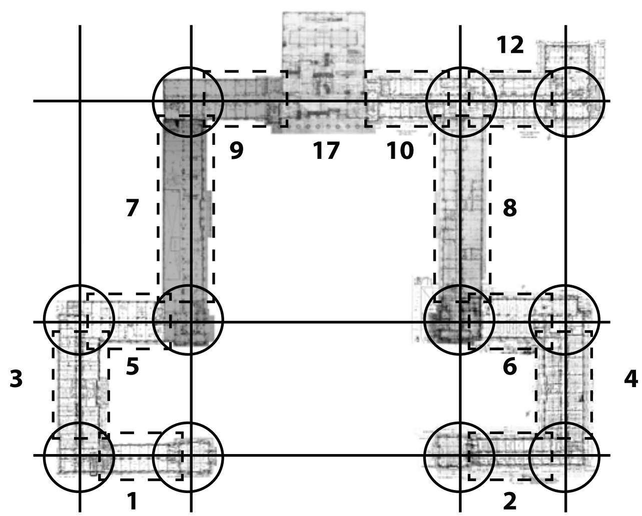


Fig. 21: Knuckles and Stems along the invisible grid.

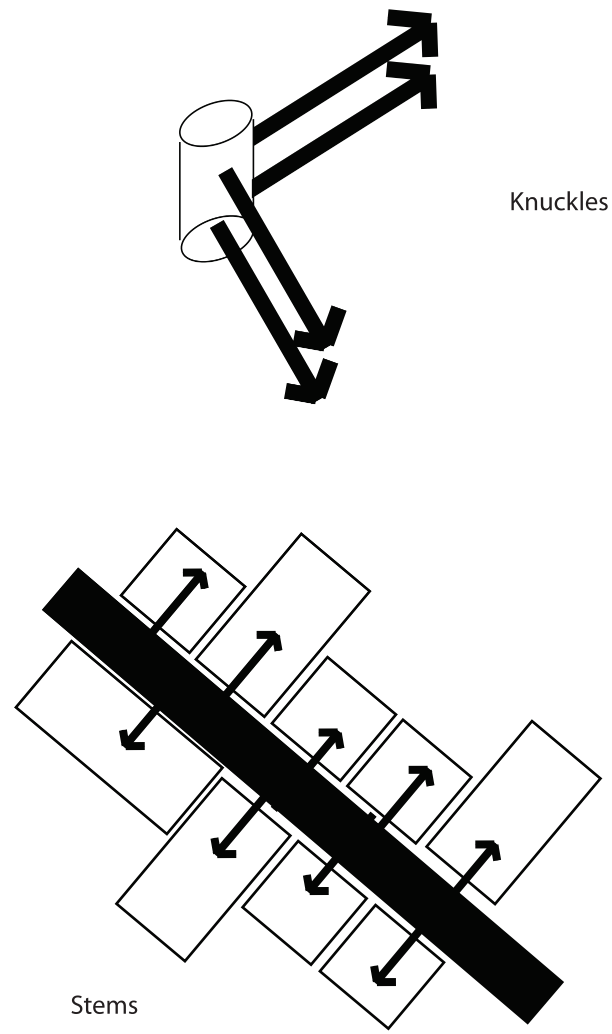
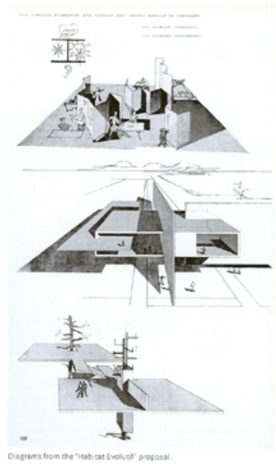
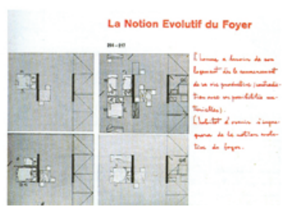


Fig. 22: Diagrams

[3] ["*Determinate and Indeterminate Elements*."
Bagnols- sur- Céze by Candilis, Josic, Woods.
Dirk van den Heuvel and Max Risselada, eds., *Team 10: In Search of a Utopia of the Present* (Rotterdam: NAi Publishers, 2005): 18- 79.





"*A third and commonly advocated measure is to reduce the interference between parts, so that a change to any one part will not force change on another.*"
Kevin Lynch, *Good City Form* (Cambridge: The MIT Press, 1984): 179.]

The first type of **stem** featured a 60' span with two supporting columns in the middle.[3] The distance between the columns was 8' 1 1/2" and in most of the cases defined the circulation corridor. The second type of stem was again a 60' span but this time with only one supporting column in the middle. In this case, a corridor of the previous width ran along the supporting columns. Finally, the third one was identical with the last one in terms of structure but only thinner, namely 40', and allowed for the corridor to run along both the supporting and the edge columns **[23]**. There is not anywhere any written explanation regarding the criteria by which each type of stem was used. My own feeling is that the first type was generally more preferable as it provided for a very stable framework for a circulation corridor. This could be true, since it was used in most of the stems, namely the ones in buildings 2, 3, 4, 5, 9, 10, 12 and 14. Also its use in buildings 9, 10 and 12 was probably related to the fact that that corridor was one of the basic circulation elements, almost a spine, as we will see later, and thus had to remain unchanged. On the contrary, it seems that the second type was used in the cases where less constriction was desired. The absence of a second series of columns resulted in a maximum width of approximately 31' 9" without the interference of columns. This was very convenient in the cases where big machinery had to be used. Thus in buildings 7 and 8 where Mechanical and Chemistry laboratories were located, this type seemed more appropriate. Finally, I believe that the span of 40' was

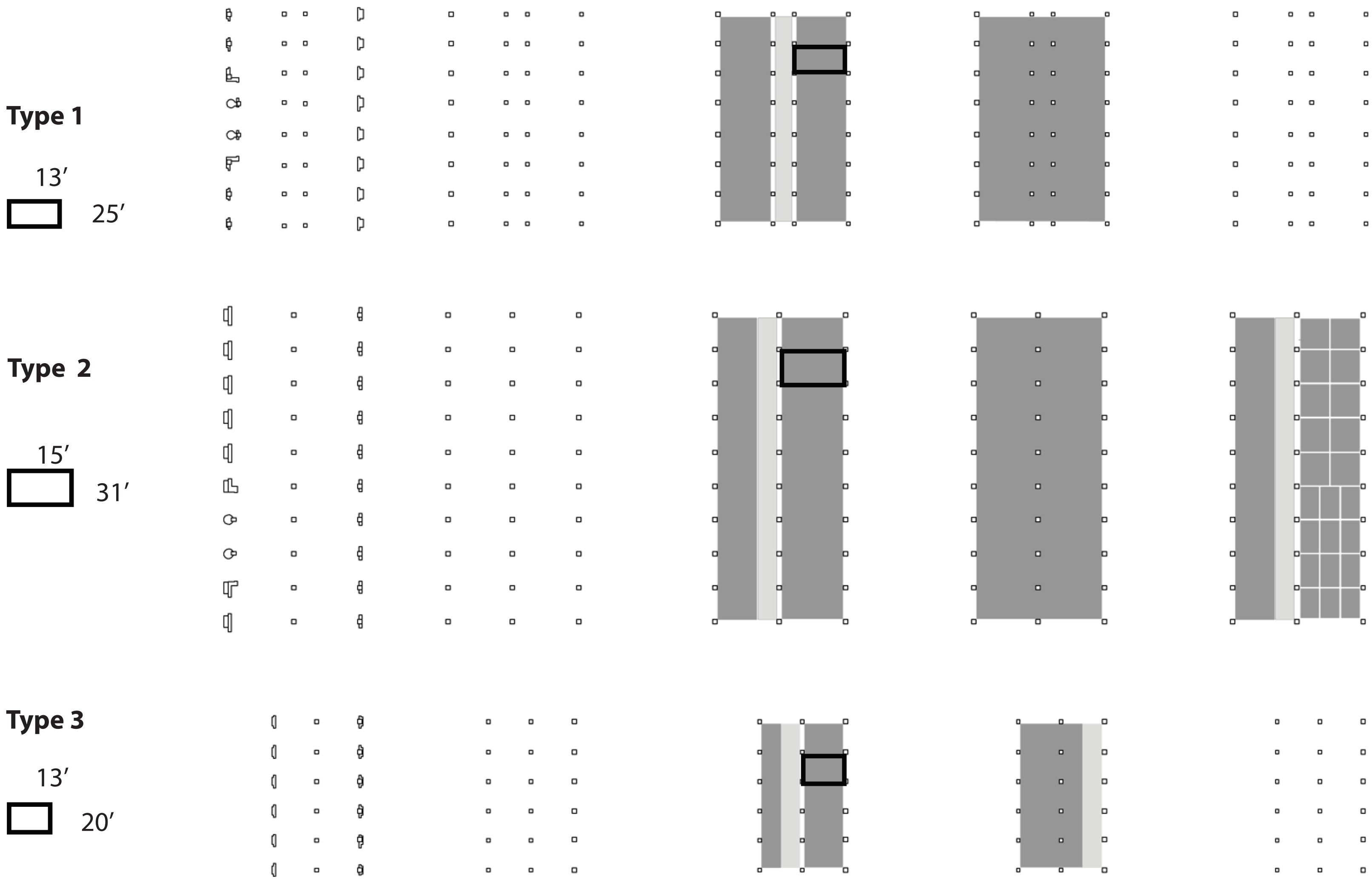
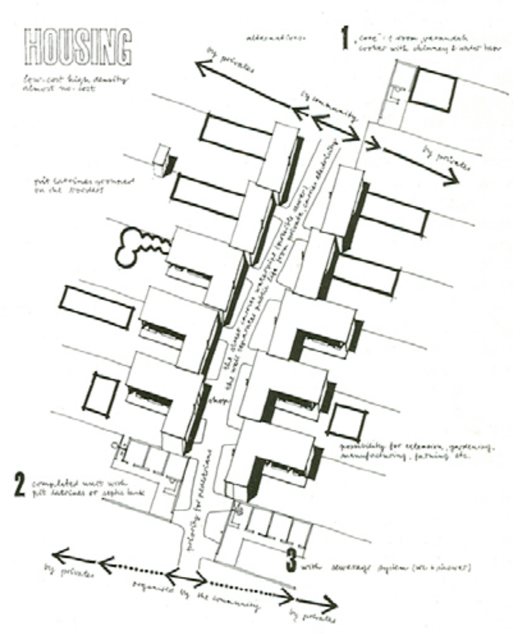


Fig. 23: Types of Stems.

used at the ends of the unified structure in order to lighten it up. In this case a double series of supporting columns would be impractical as it would fragment space. In all types, however, a general guide for the definition or the potential of a double- loaded corridor existed, a characteristic deriving from Freeman's plan **[Quote 4]**.



[4] ["Gana, Housing, Pologni"
Alison Smithson, ed., *Team 10 Primer* (Cambridge, Massachusetts: MIT Press, 1968): 15.]

The second interesting attribute of the stems was the bay, which brings us to the aforementioned **unit- section [24]**. Bosworth also adopted a system of uniform bays creating in this way his own- unit sections, which considering the different types of stems, were 3 in number; thus, despite the approximately 15' by 31' unit similar to the one of Freeman, the scheme featured 2 smaller ones too, 13' by 25' and, 13' by 20', approximately. Although the widths and lengths differed from the dimensions that Freeman gave, I cannot imagine that Bosworth did not give an equally thorough consideration in defining them. This is evident in the various uses that were housed in the combinations and subdivisions of these units. For example, the 13' by 20' unit was used; single, as a periodical room (2- 104) or as an office (2- 105); subdivided, as part of corridor and as one person office (2- 114); combined in two, as a lecture room of thirty people (2- 107); or combined in three, as an Economics lab of 48 people (2- 103) **[25]**. The adoption of this system by Bosworth reveals what was mentioned earlier in relation to the way that MIT was designed. Thus, first the "bookcase system" and the unit- sections were designed, secondly these were subdivided or combined accordingly to each department's needs and finally finishing alterations were done in collaboration with the representatives of the Departments. **[Quote 5]**

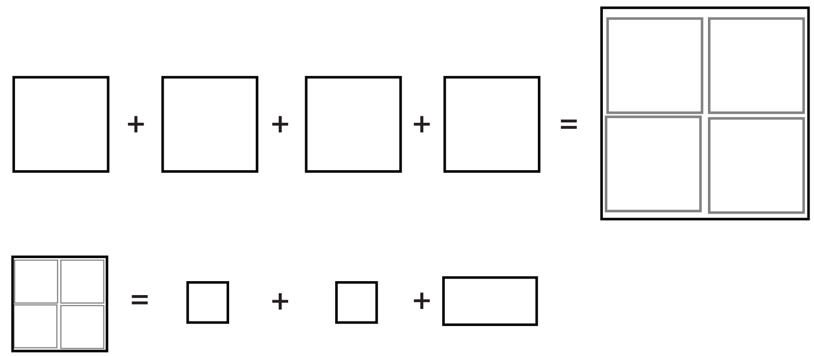
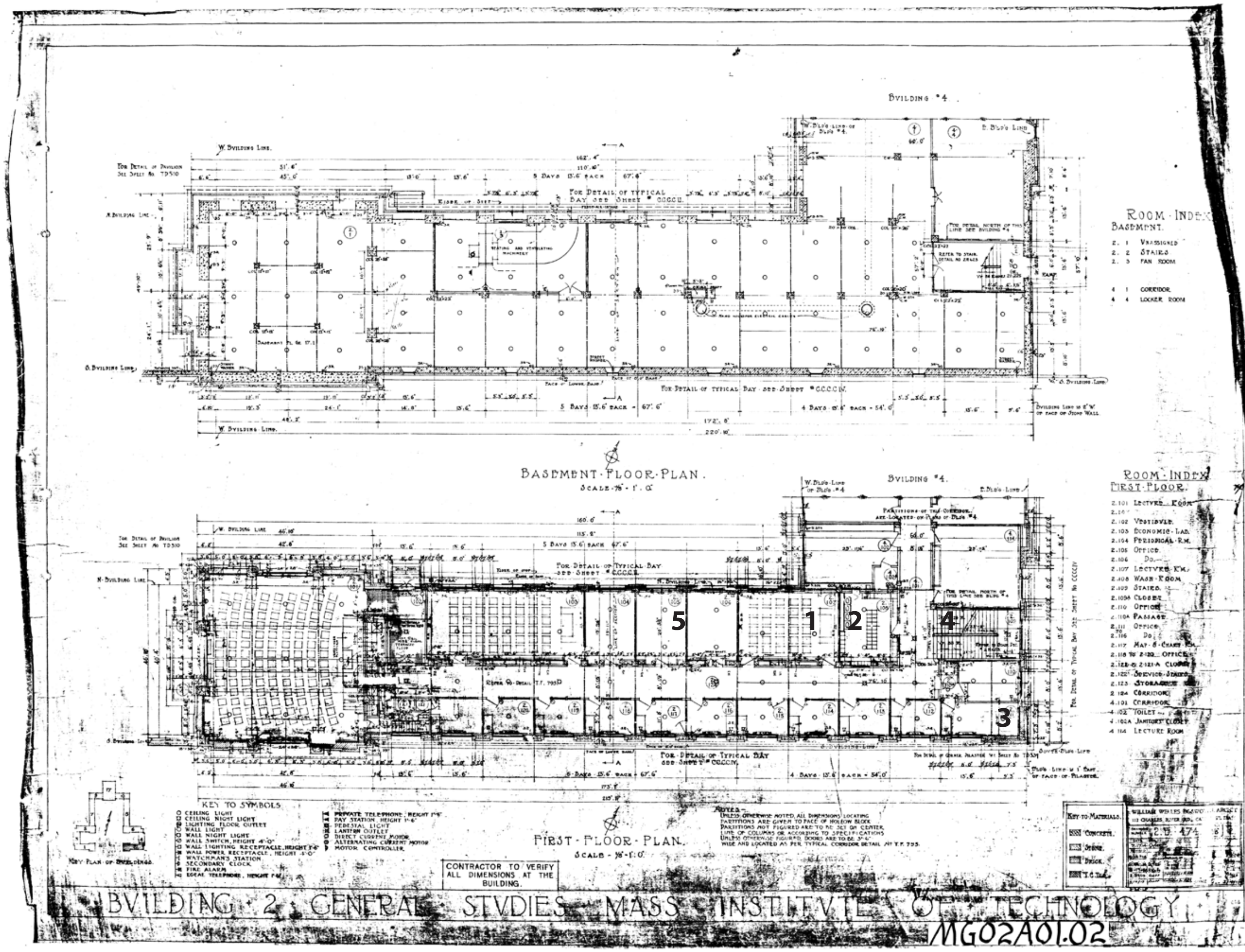


Fig. 24: Unit- section diagram.



1: periodical room
2: office
3: one prs office
4: lecture rm for 30 prs
5: lab for 48 prs

Fig. 25: Basement and First Floor plan of former Building 2.

The unit- section of Bosworth differed from the one of Freeman also in terms of services. The emplacement of the ventilation ducts along the four columns of each unit section was not followed. However, it appears that some kind of service or services ran along the supportive columns of the building. For reasons of time, I have not looked at the mechanical plans. In the architectural plans though, little cupboards are discerned next to many of the supporting columns. A part of these are wire shafts, while others carry the title "therm" **[26]**. The number of these cupboards is much higher in the cases of the first type of stem than in the other two. Photos taken during the construction reveal that no beams were put along the supportive columns, probably thanks to the small bays, and thus explain how such provision of service could be possible. In any case, although the unit- section of Bosworth wasn't as serviced as the one of Freeman, it still had a window which provided it with natural air and natural light, which are the basic services. Thus we could still consider it as a fully serviced unit and to a very high degree autonomous.

[5] ["*One of the first studies therefore was to work out a standard unit section, somewhat on the same idea as the modern sectional bookcases, so that we would have a shell made up of windows, piers, columns and roofs, within which curtain walls of light weight could be put up in any convenient position so as to take into a room either one, two or three windows, as might be required for a particular use, or so that these partitions could be readily shifted during the next hundred years as new developments come. Flexibility for change and extension of departments must be a controlling feature in the type and arrangement of buildings to be constructed forthwith, and no man can today tell at just what part of the organization the greatest change will come.*

John R. Freeman, "NOTES ON "STUDY NO. 7" FOR NEW TECHNOLOGY (and on Various Studies made during the year 1912)," p. 17 [Freeman, Box #41, MIT Archives]

"*In this way a support will be something entirely different from a skeleton of a big building, although, looked at superficially it may suggest some resemblances. The skeleton of a building is entirely determined by a single project of which it is a part. It can only be properly realized if we know in every detail what the whole building, with everything pertaining to it, will be like. A support however, is built while one is fully aware of the fact that no-one can imagine what exactly is going to happen to it. The freer the form of housing, which is possible in the support, the better.*"

John Habraken, The Supports and the People: the End of the Housing Project (Amsterdam: Scheltema & Holkema, 1961):36.

"In order to design the building quickly, no less than build it quickly, Paxton used system design techniques in which a relatively few design decisions for the spanning and junctural (sic) situations could be repeated often enough to enclose the required area…Its design did not condition the arrangement of the exhibition spaces since the only services provided by the building- natural ventilation and natural light- were available for use over its entire area."

John Weeks, "Indeterminate Architecture," *Transactions of the Bartlett Society* vol.2 (London: Bartlett School of Architecture; School of Environmental Studies, 1963- 1964): 88-89.

"*A fourth general strategy is the "modular" one, in which standard units are used repetitively, either because experience has shown that those units are peculiarly apt for diverse functions or because such standardization will permit easy connections between parts and thus easy repatterning*"

Kevin Lynch, *Good City Form* (Cambridge: The MIT Press, 1984): 180.]

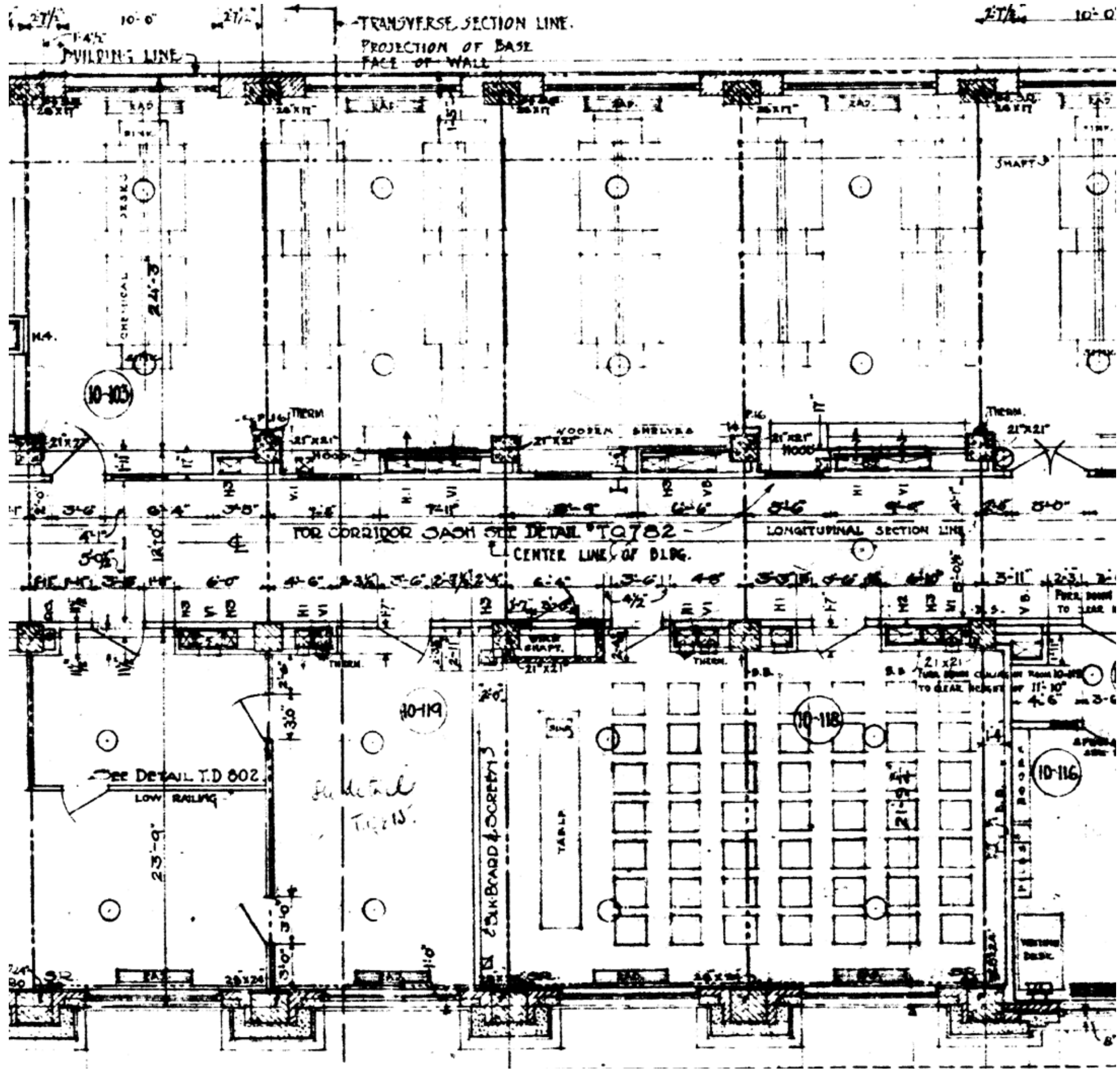


Fig. 26: Part of First Floor plan of former Building 10.

The **joints or knuckles** of the system provide as much interest as the stems. I would argue, that, with the exception of the joints between Buildings 3 and 5, and 3 and 1, the configuration of the rest, reveals the intentions for providing different degrees for growth **[27- 32]**. Thus the joints between Buildings 7 and 9, and 10 and 8, which in the initial plan would connect four buildings, had a very regular and clear configuration, as stairs and elevators were located out of the circulation system and furthermore on the dark quadrangle of the circulation cross that was shaped, or in other words at that part of the knuckle that was already adjoined by buildings. Light in these cases came from the light wells on the top of the stairs. The same configuration of the knuckle occurs between Buildings 4 and 6 that was expecting the growth of the building that would enclose the east secondary court. In all these knuckles the end of the unified building was left open. In contrast, the knuckles between Buildings 12 and 14, 8 and 6, 4 and 2, 5 and 7, and 3 and 1, placed the stairs at one of the free sides of the knuckle. Furthermore, in the case of the knuckle between Buildings 12 and 14, stairs were put on the circulation corridor, while in the case of the knuckles under the pavilions, movement was diverted from the free sides with the placement of big lecture rooms. I do not know what the reasons for this design were exactly as in an education building one would assume that the naturally lit spaces would be saved for instructional purposes. One could speculate though, that this was a way of controlling growth and not permitting it, at any cost, to take place towards the court or the east where the dormitories would be put. Finally, the configuration of the knuckle between Buildings 3 and 5 is a true mystery for me. But I will come back to this matter when growth with the Pratt School will be discussed.**[Quote 6]**

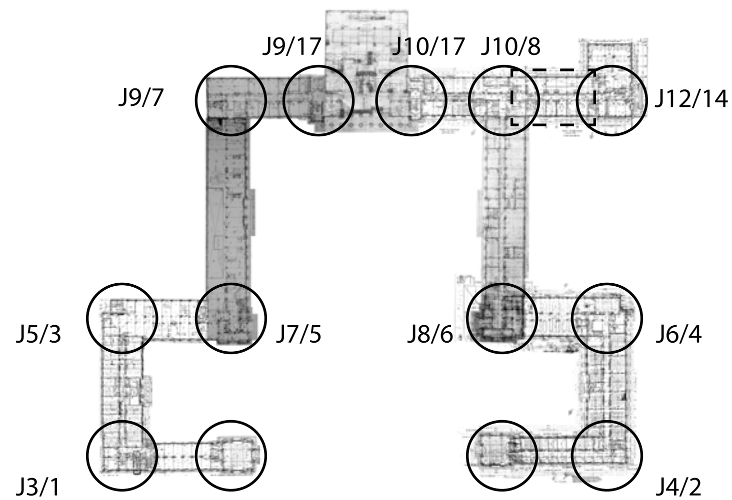
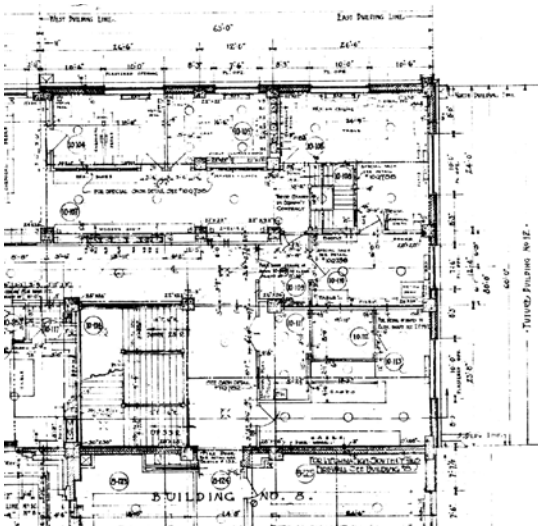
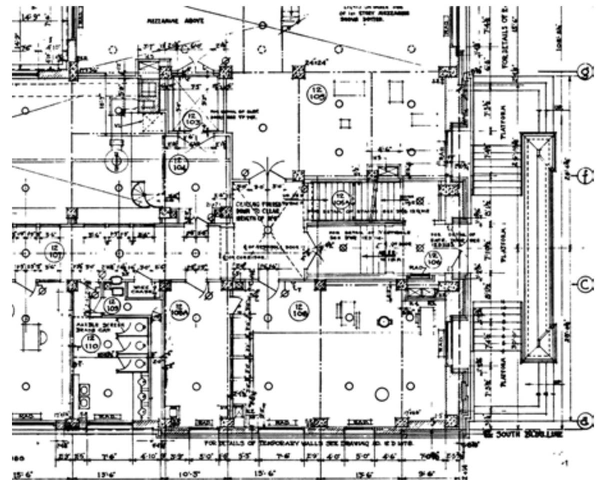


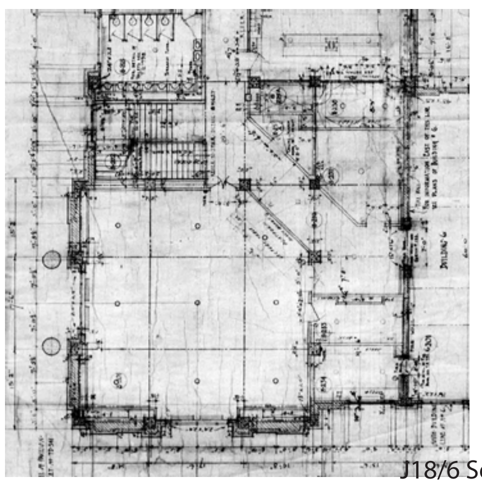
Fig. 27: Knuckles or joints.



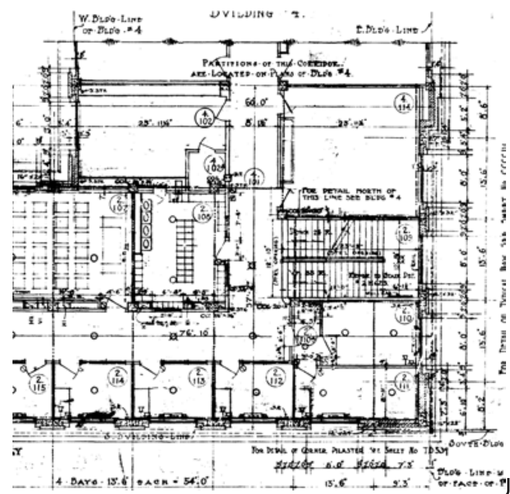
J10/8 First Floor



J12/14 First Floor



J18/6 Second Floor



J4/2 First Floor

Fig. 28: Knuckles or joints.

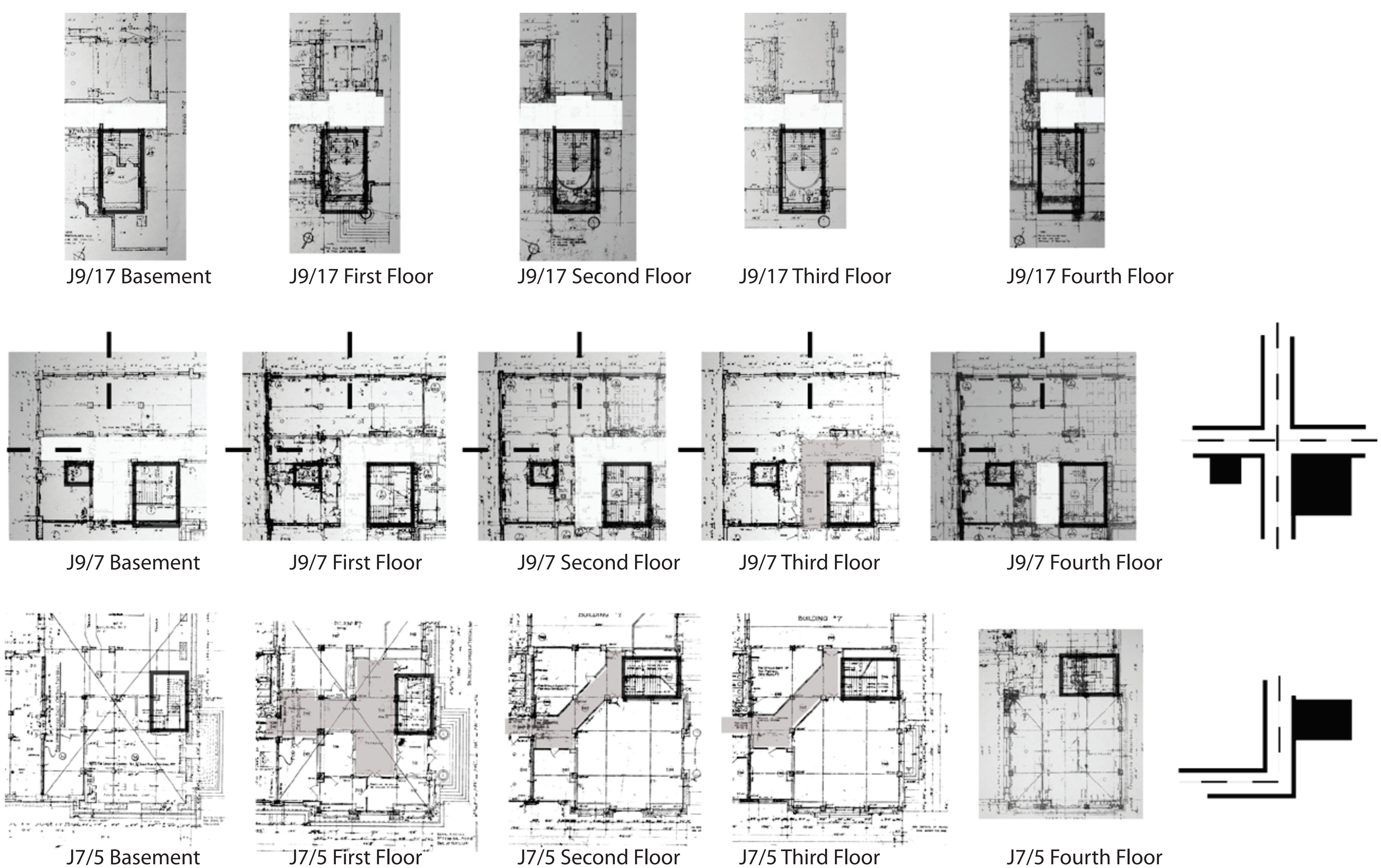


Fig. 29: Transparent grey and white outline circulation areas. Black frames show staircases and elevators. Diagrams at the end show possibilities for future expansion.

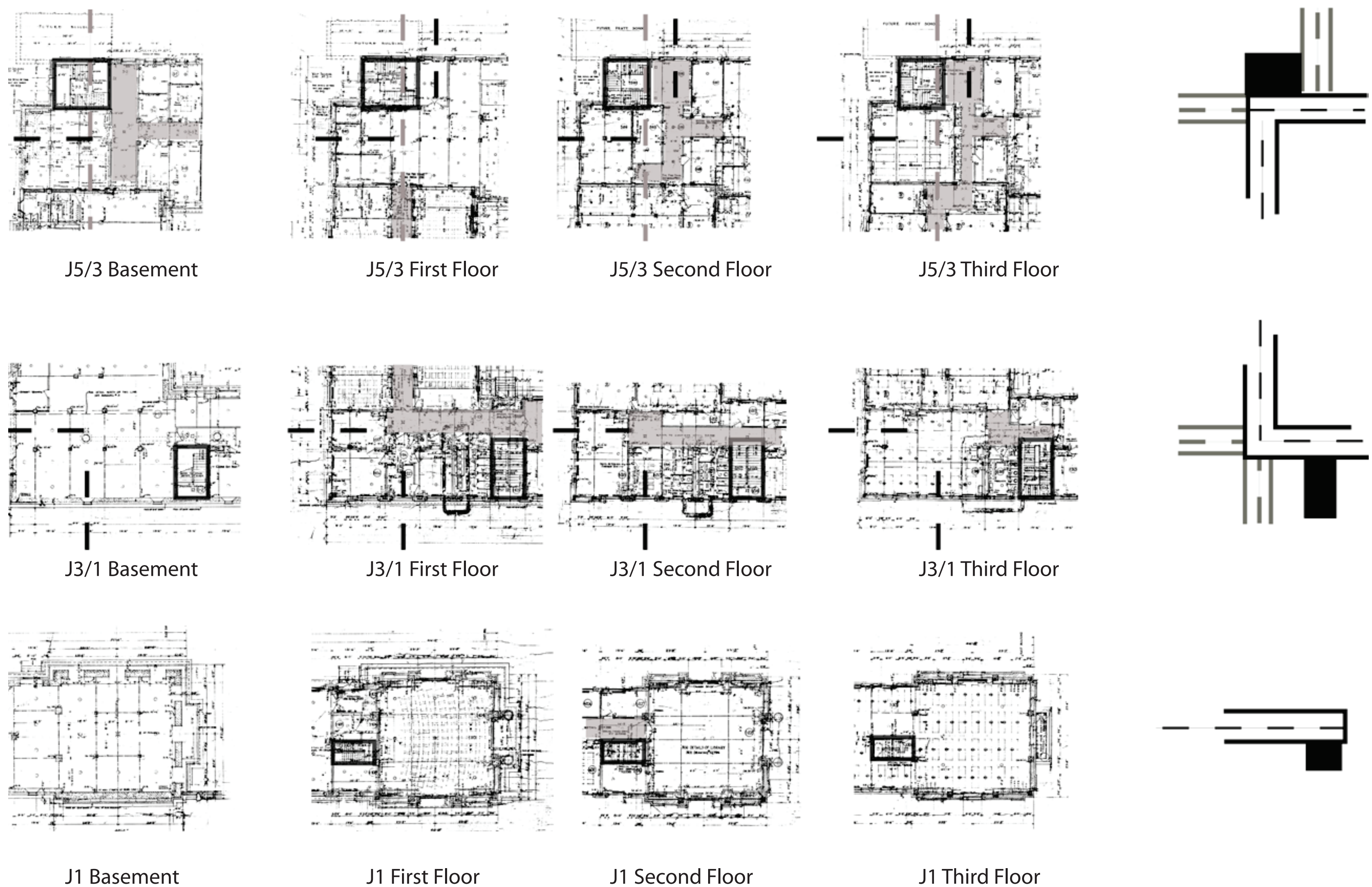
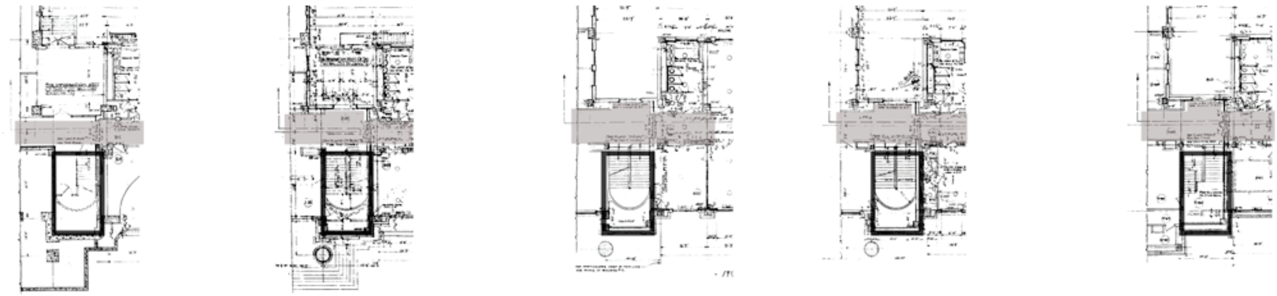
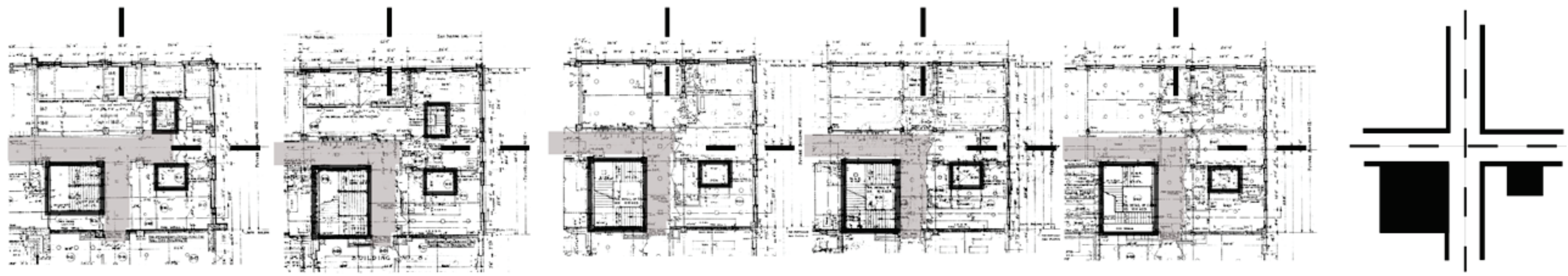


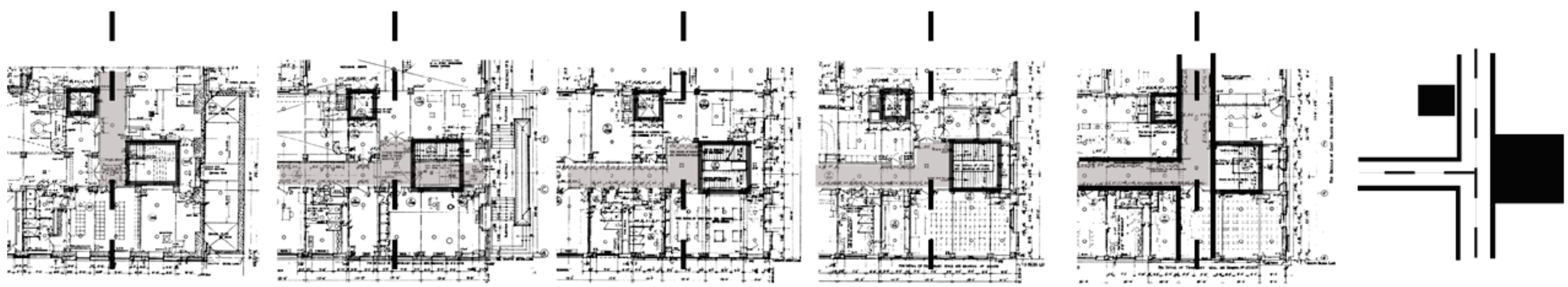
Fig. 30: Transparent grey and white outline circulation areas. Black frames show staircases and elevators. Diagrams at the end show possibilities for future expansion.



J10/17 Basement J10/17 First Floor J10/17 Second Floor J10/17 Third Floor J10/17 Fourth Floor



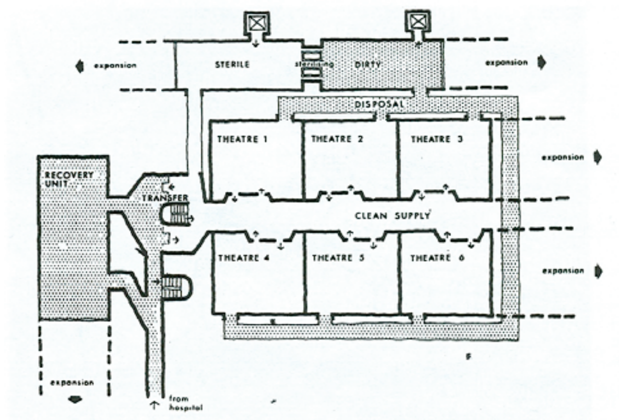
J10/8 Basement J10/8 First Floor J10/8 Second Floor J10/8 Third Floor J10/8 Fourth Floor



J12/14 Basement J12/14 First Floor J12/14 Second Floor J12/14 Third Floor J12/14 Fourth Floor

Fig. 31: Transparent grey and white outline circulation areas. Black frames show staircases and elevators. Diagrams at the end show possibilities for future expansion.

Fig. 32: Transparent grey and white outline circulation areas. Black frames show staircases and elevators. Diagrams at the end show possibilities for future expansion.



[6] ["*Disposition of its plan elements, the method of servicing and the structural organization, would all be ordered by recognition of the growth potential in the building, and since buildings do not, like living organisms, grow by proportional enlargement of their parts, different growth rates and characteristics, including no growth and no change, will also be visible*."
John Weeks, "Indeterminate Architecture," *Transactions of the Bartlett Society* vol.2 (London: Bartlett School of Architecture; School of Environmental Studies, 1963- 1964): 98.]

The supporting columns of the stems and the knuckles, that defined direction of movement and ensured the vertical communication, provided for the formation of a very clear **circulation system**, that was based on the grid of the initial plan **[33]**. I use the word "provided" and not "defined" because this circulation system was not continuous. For example, on the first floor, although on the east side of the Institute the corridor was kept throughout the whole length of the stems, on the west side it was interrupted by the Hydraulic Laboratory in Building 7, the Testing Materials Laboratory in Building 5 and the Museum in Building 1**[34]** . This interruption revealed one of the basic deficiencies of the system: the constant width that resulted from the use of the unit- section did not permit for the simultaneous existence of large laboratories, or big lecture halls and a corridor. This was probably the reason why the very big lecture rooms were located in Building 17 and under the pavilions, where circulation could easily be diverted or terminated. Nevertheless, as the east part of the Institute reveals, there were the seeds for a very efficient corridor system. Furthermore, considering that the entrance of the Institute was on the south façade of Building 17, we could say that a very efficient spine was formed, by the double- loaded corridors of buildings 9, 10 and 12, which could feed the north and south wings attached to it. This potential efficiency was further enhanced by the fact that the number of floors of the buildings was kept to five maximum, including the basement. Although that was one floor more

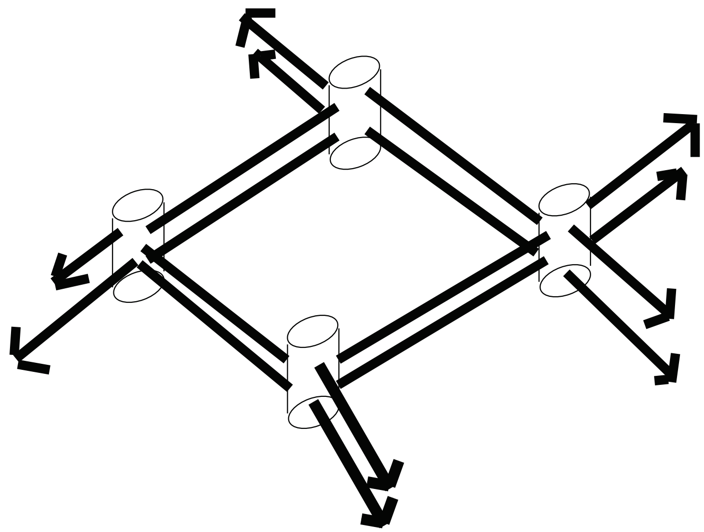


Fig. 33: Circulation System Diagram

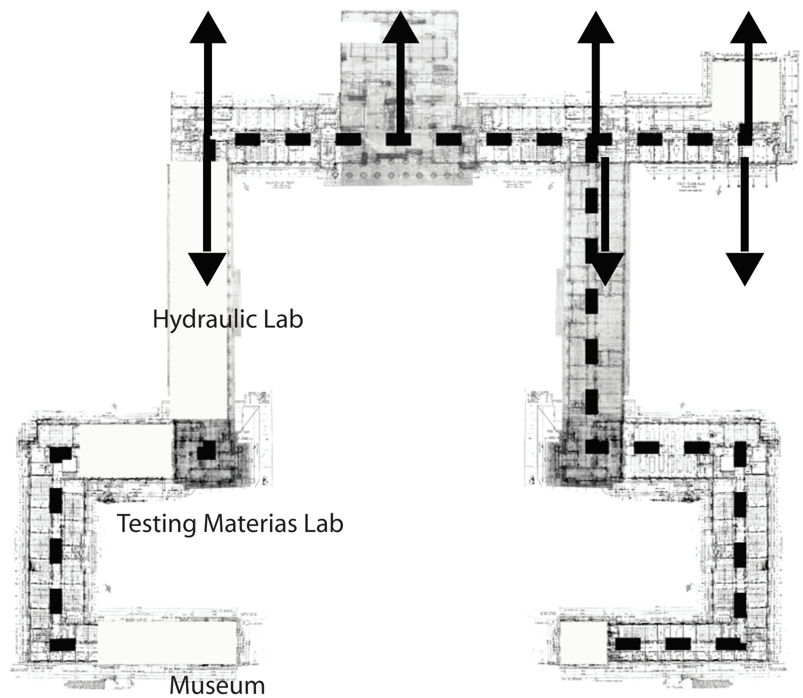
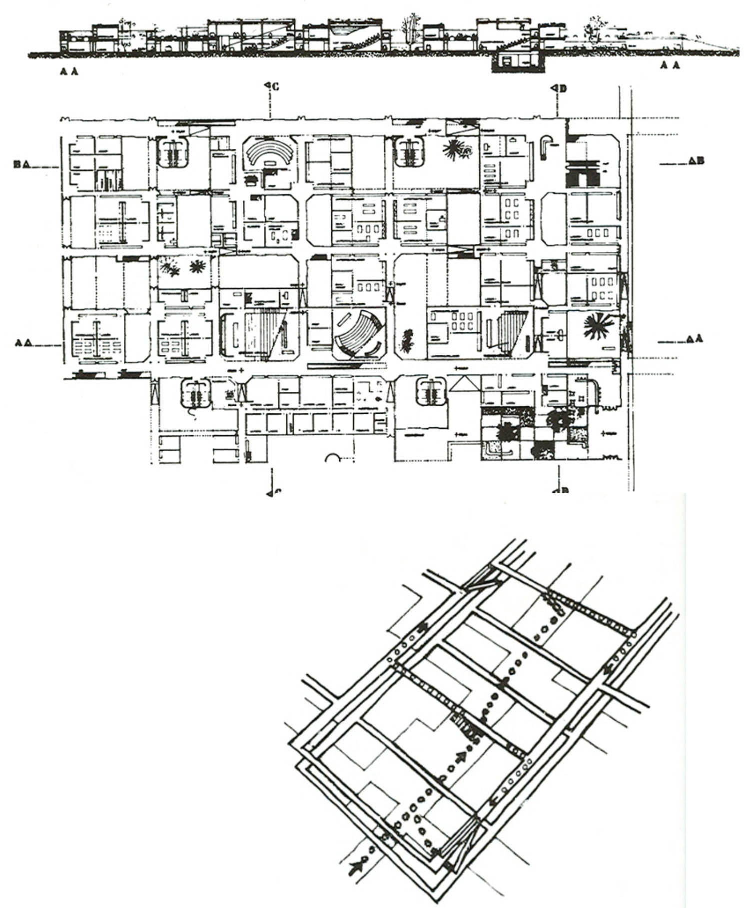


Fig. 34: Circulation System on the First Floor.

than in the study of Freeman, the same advantages occurred. It is necessary to comment at this point that the elevators in the knuckles between buildings 7 and 9, 8 and 10, as well as the one in building 8, should have been destined mainly for the movement of equipment and supplies as they were very big and separated from the circulation system by a service space. These are the elevators that today are used for such purposes. In any case, one of the system's elements was an underlying open- ended, at the points were it mattered, circulation system. **[Quote 7]**



[7] ["Berlin Free University" of Candilis, Josic, Woods and Schiedhelm Alison Smithson, ed., *Team 10 Primer* (Cambridge, Massachusetts: MIT Press, 1968): 62- 64.]

The **courtyards** comprised the fifth element of the system **[35-36]**. Although this is presumably the result of the grid-ed mega-structure, I would argue that some kind of application was conceived in relation to the courtyards right from the beginning. This is evident in the initial general plan where a large auditorium is attached to the Pratt School in the secondary east court. Thus it appears that the courts would provide the necessary free space for additional growth. Furthermore, even if this growth diverted from the constant width and as such disturbed the stylistic unity of the scheme, it could be conveniently concealed. I believe that the courts were what Lynch calls "excess capacity" **[37]**.[4] Later on, studying growth, we will see how the courts were used in this way. Furthermore, the secondary courtyards provided the inwards unit- sections with light and air.

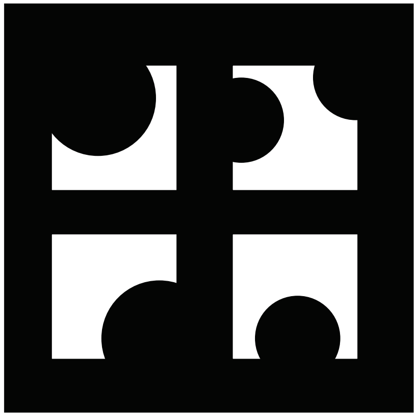


Fig. 35: Court or "backyard diagram."

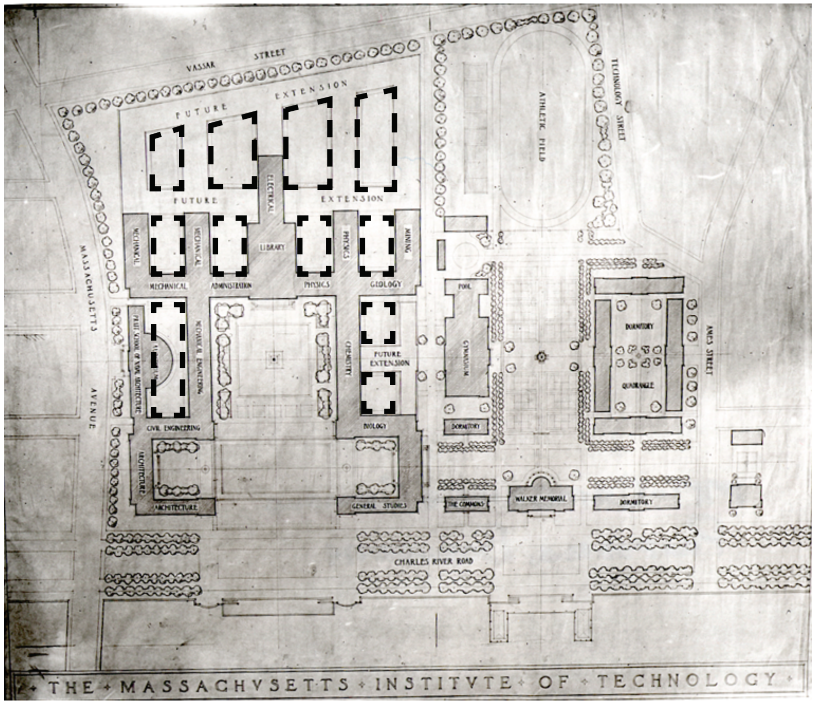


Fig. 36: The large Auditorium is conveniently hidden in the courts.

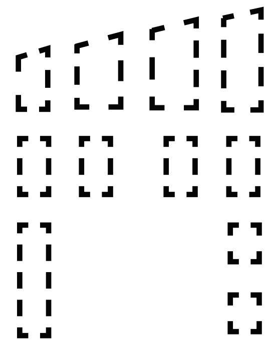


Fig. 37: "Excess capacity" of Lynch.

Finally, the sixth element of the scheme was what I would call **“add- on” facades [38]**. In other words, the concrete structural system permitted for an independent design of the elevations and as a result these were formed in a process of dressing up the buildings. This allowed for different degrees of elaboration according to the importance of the façade. Thus, the facades of the pavilions and the south one of Building 17 were very ornate with inscriptions and porticos, while the rest of the conspicuous ones were dressed up with a series of pilasters and a frieze **[39- 40]**. For all these elevations the materials used were granite and Indiana limestone. On the contrary, on the facades that were to be less public, like for example the ones along the secondary courts or the ones at the north side of the buildings, there was no outstanding frieze, only thinner ones made out of concrete, and the pilasters were made out of yellow brick. Furthermore, at the points where new buildings would be added, the exterior walls were merely plastered while openings were left at the points where corridor connections would be made **[41- 42]**. Thus the façade system expressed, like the knuckles did, different potentials for growth **[43]**.

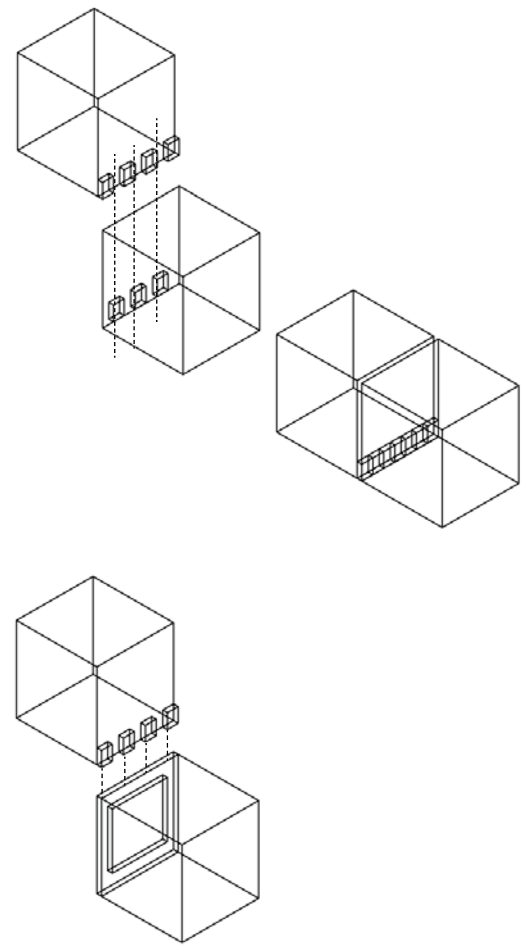


Fig. 38: “Add- on facades” diagram. Different degrees of elaboration permit for different degrees of growth

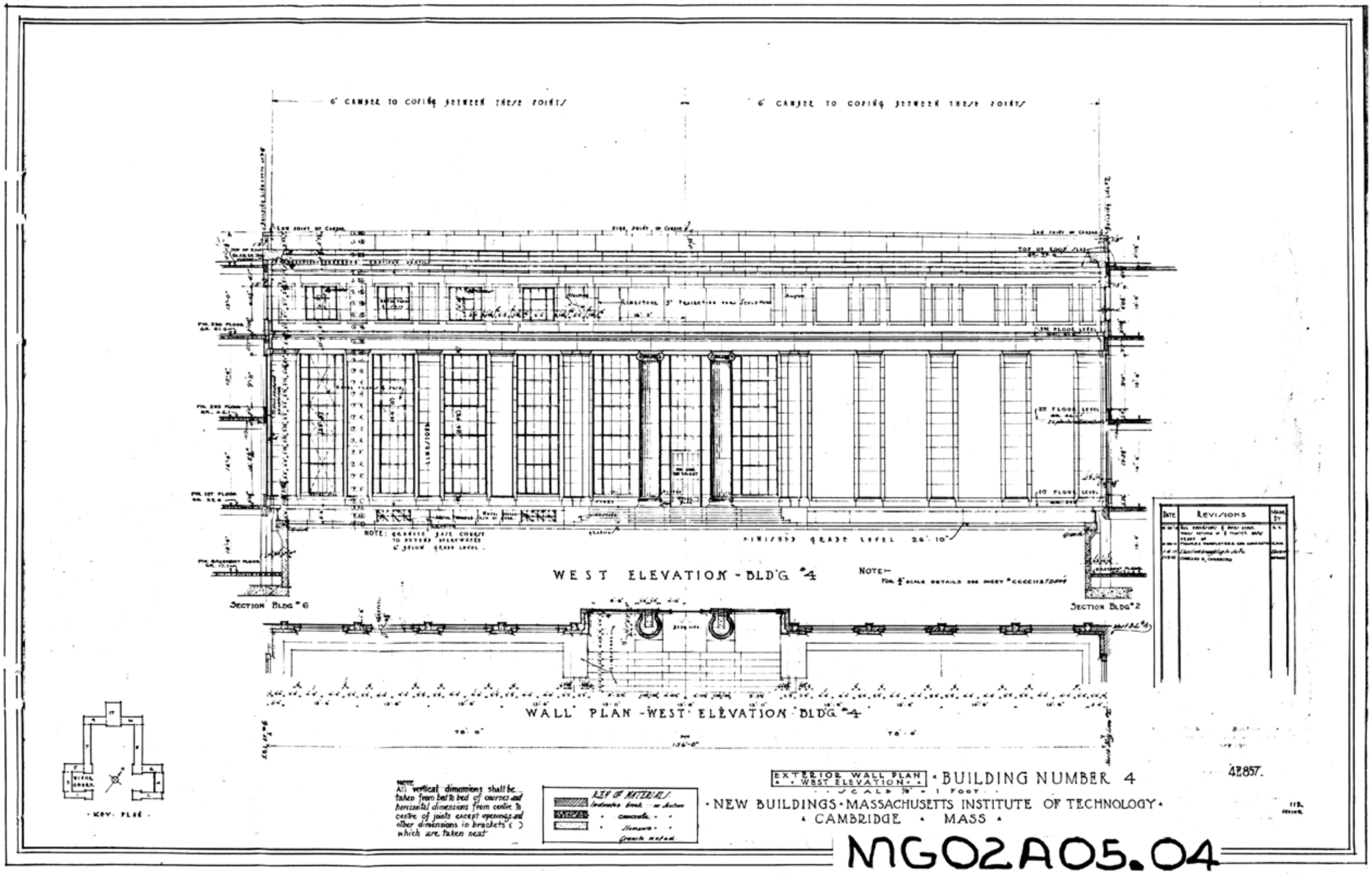


Fig. 39: Facade modeled out with columns and pilasters facing the big Court.

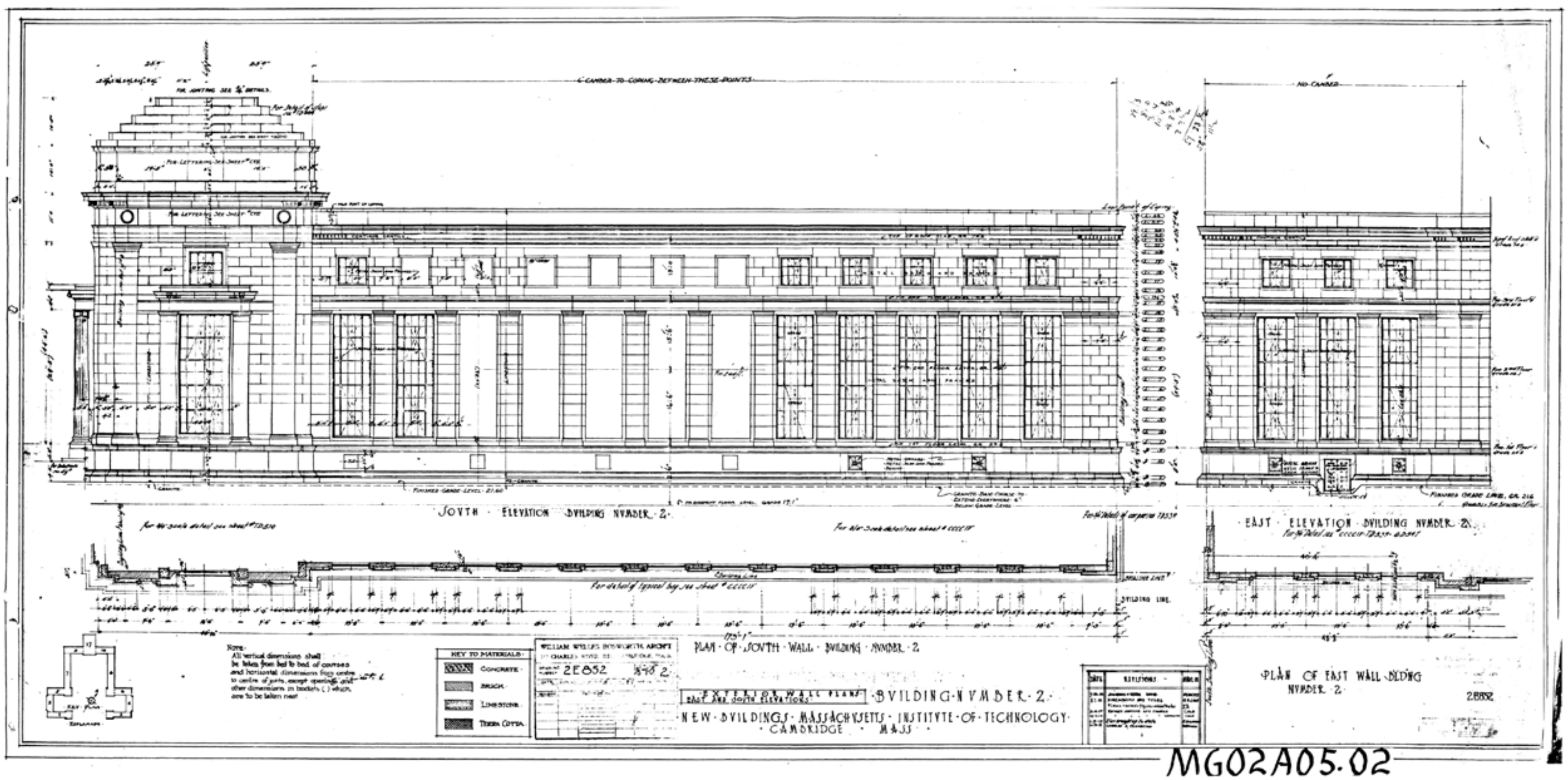


Fig. 40: Facade with pavilion facing the Charles River.

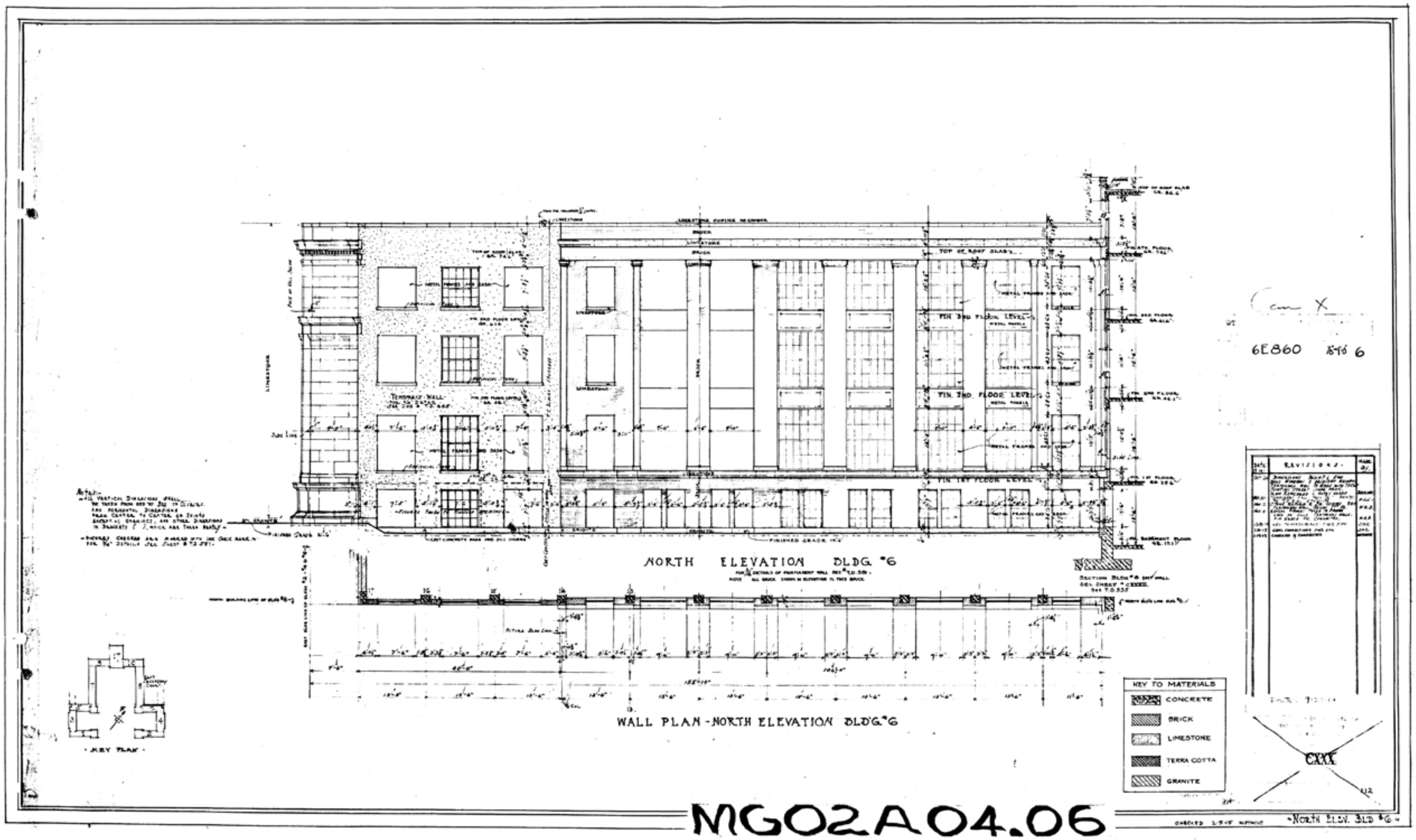


Fig. 41: Facade facing a secondary court. The dotted area is plastered.

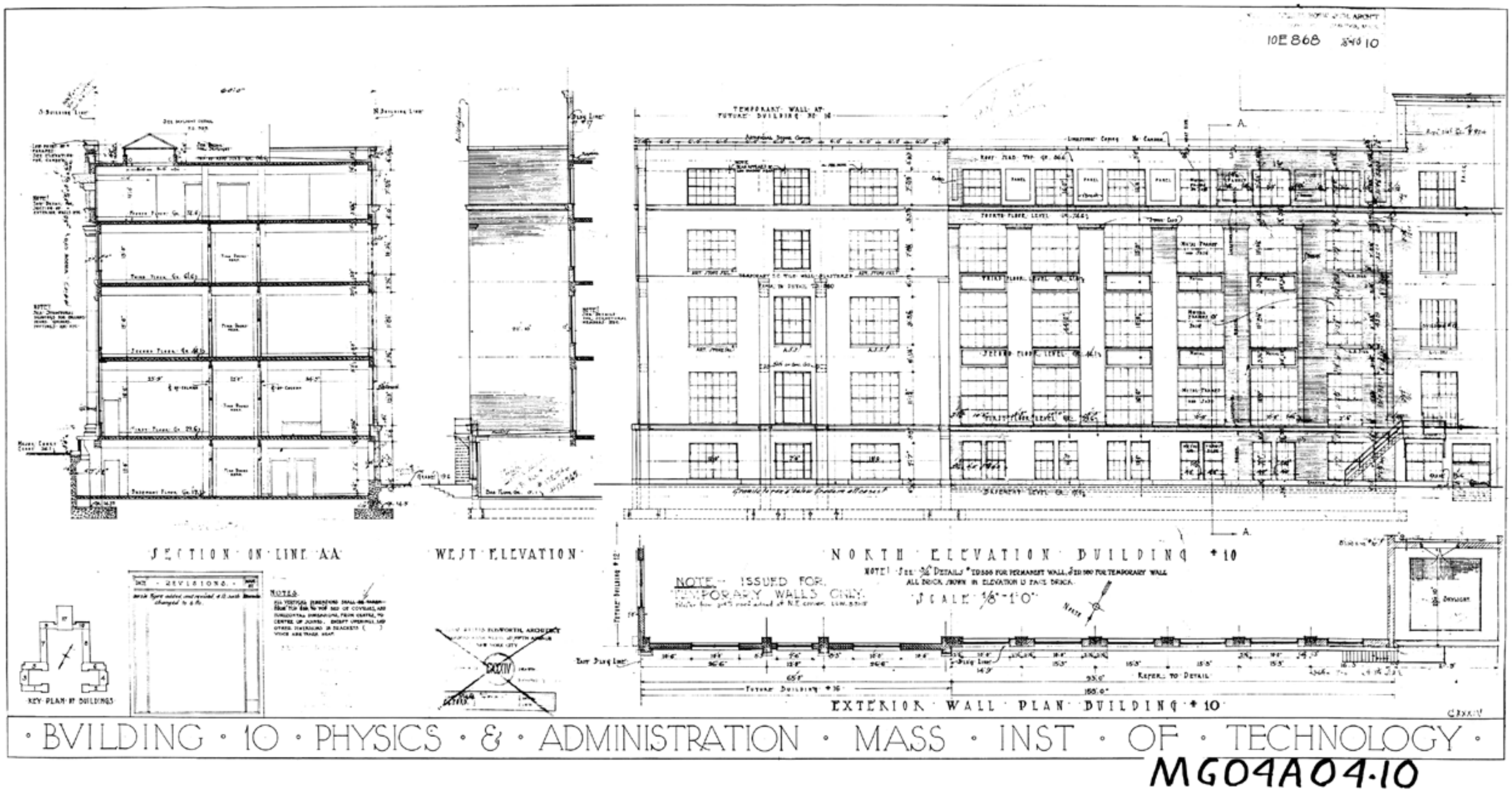


Fig. 42: Facade facing the North backyard. The hatched area is dressed with brick.

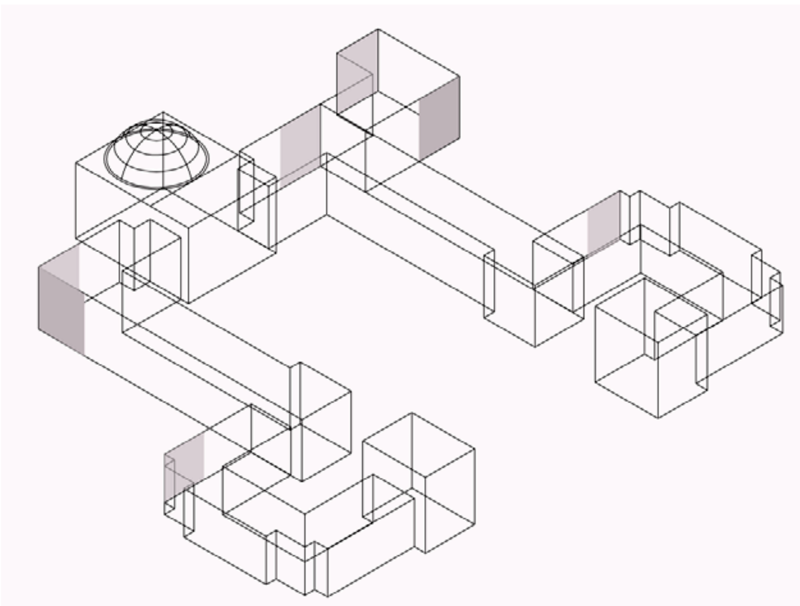


Fig. 43: Plastered facades indicating directions for future growth.

As aerial photos of the time reveal, together with this main educational building system, a number of others, probably auxiliary, smaller edifices were built **[44- 45]**. As these have been demolished it was difficult to find any information regarding their form and use, and for this reason they are not examined here. Furthermore, more buildings were designed by Bosworth and were built on the north side of Vassar Street. Admittedly, the study of all these buildings would give good information on what the system that was adopted could accommodate and what not, or in other words, how adaptable in terms of use the unified system was. Nevertheless, the central aim of this thesis is to study how a built form can grow and change. As a result, only the buildings that later on comprised the one mega-structure of MIT are studied. Finally, as with the case of the dormitories, the buildings in question, which were most probably service buildings, were not firmly connected with the educational activities. Keeping this in mind, I believe that we can draw safe conclusions about correlation of need changes and space transformations.

Fig. 44: Aerial Photo, 1916.

Fig. 45: Aerial Photo, 1917.

(Endnotes)

[1] "Interesting History of Institute Buildings recently Completed," *The Tech* (Cambridge Mass., Tuesday, December 27, 1921): 1.

[2] Letter of President Maclaurin to Arthur Winslow, October 5, 1916, p. 2- 3 [Office of the President AC 13, Box #22, Folder 624, MIT Archives].

[3] 60' was the width that was also mentioned in verbal descriptions of the buildings and it refers to the distance of building line to building line. The rest of the dimensions in this text are based on dimensions of the drawings which other times are measured axially, and other times taken by the edges of the columns. The condition of the drawings didn't permit for a 100% consistent measurement. However, a difference of such scale, namely of the width of a column, doesn't play any important role to the discussion introduced here.

[4] Lynch (1984): 176.

(Inhabitation) First Signs of Performance

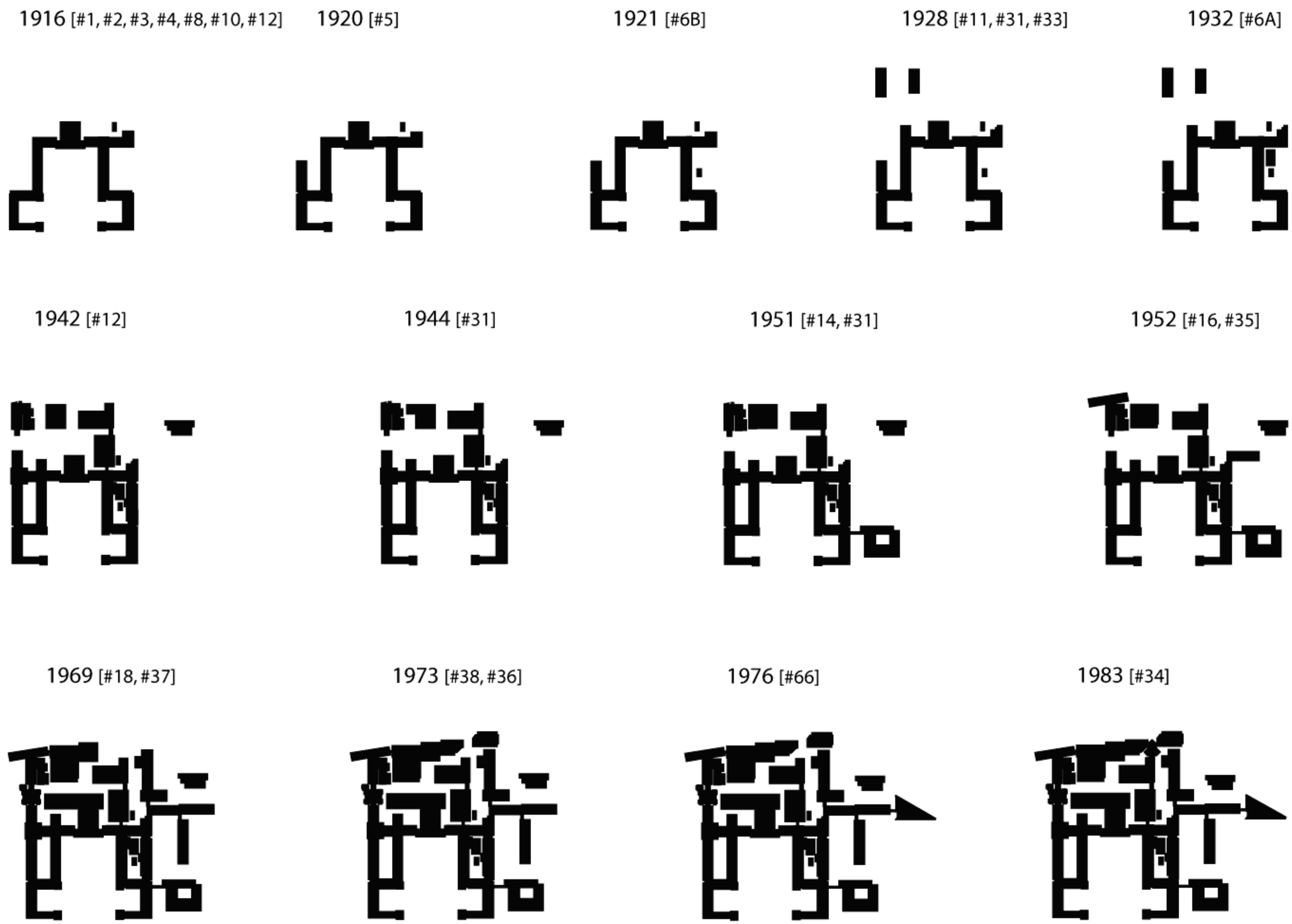
The first acquaintance whether among people, or between people and objects, or between people and spaces, is always exploratory. As a result, as well designed as a place might be, instances of ‘misfit’ may always occur during the first days of inhabitation. It appears that in the case of MIT such misfits were few and they appeared mainly because other parts of the plan had not yet been completed. During the first months of the new buildings, when the construction of the dormitories had not been finished, a large number of students stayed at the Museum, in Building 1. According to the *President’s Reports*, the spatial arrangement was adequate but also a great amount of adaptation from the part of the students was exhibited.[1] Other than that, the various departments were very well settled in their new headquarters. Comments about the new buildings included that research would be accomplished more adequately, that the spatial arrangement was very well adapted to the program and to the way that teaching was conducted, that instruction spaces were commodious, well lit and ventilated, and interconnected as needed, and that a great deal of “enthusiasm accompanied by greater productiveness should result.”[2] Only in the report of the Department of Mathematics did some complaints appear, regarding the lack of individually owned headquarters, as well as the lack of sufficient blackboard surface. Overall, however, it seemed that the new buildings performed very well.

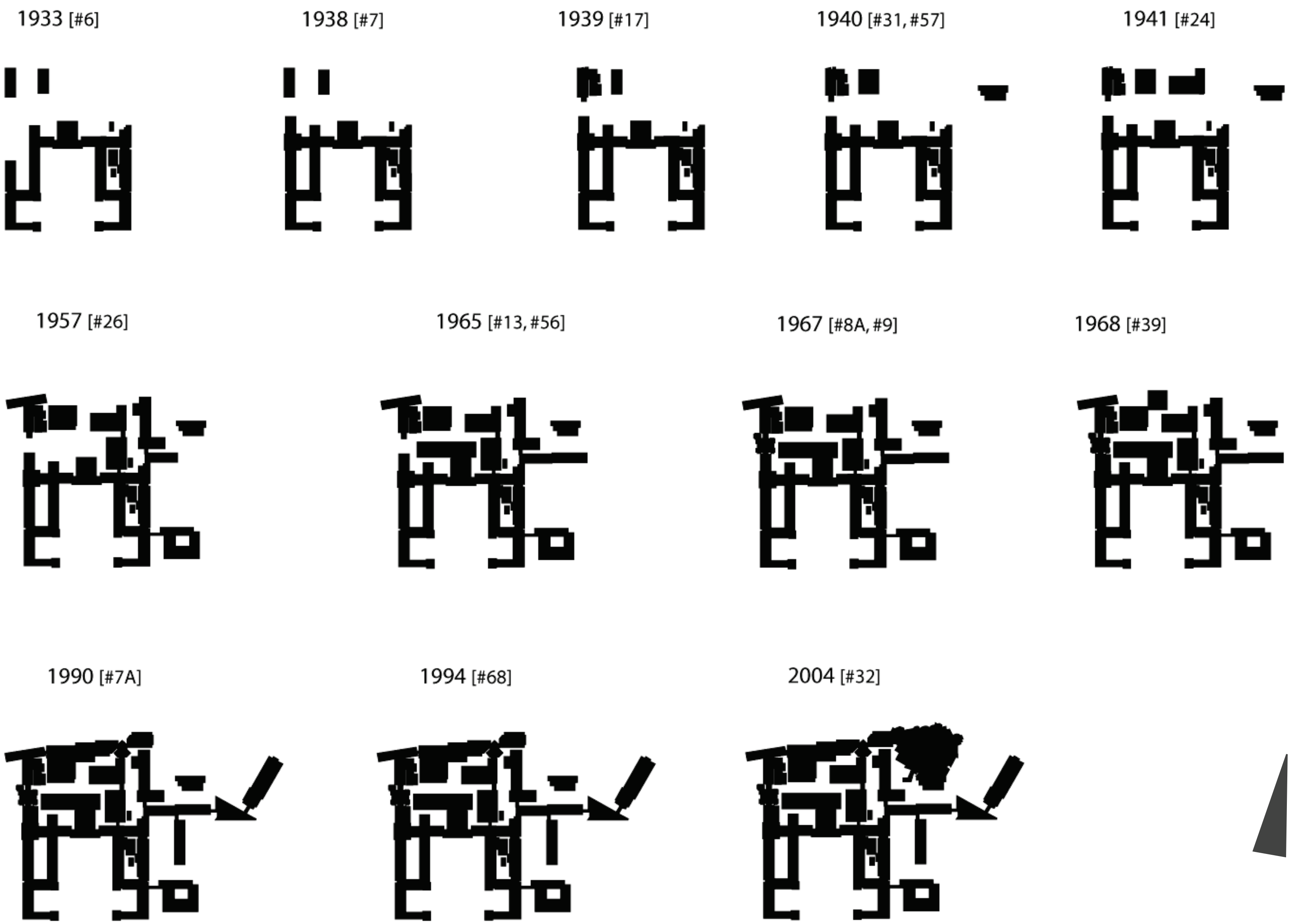
This was very important at the time, as the university, with the opportunity of a new start, was redefining and renewing its goals. MIT had already established its graduates’ position in industry, and research in applied science had often been funded by companies such as the American Telephone & Telegraph Company and the Stone & Webster Company. However, it was eager to promote research in these fields even more. Whatever spatial needs were, the buildings were providing everything that was needed in order to make such research possible. The new buildings featured a number of the best equipped laboratories in the country like the “steam and compressed air laboratory, the power measurement laboratory, the gas engine laboratory, the refrigeration laboratory, the laboratory for the testing of materials, and the hydraulic laboratory,” as well as the metallographical laboratory, the ore dressing laboratory and others.[3] But besides applied science, MIT was also recognizing the importance of fundamental sciences, as it considered these two to be inseparable and that research in one presented the same principles as research in the other. Spatial arrangements satisfied the need for explorations in these fields too. The Department of Chemistry had been given approximately two acres of space in the new campus while the Department of Biology had been placed as mentioned before in a position where it could easily acquire more space in the future.[4] Thus, in terms of buildings MIT, in the era to come, was making a true headway. However, science, either applied or fundamental, would change rapidly and the new buildings of MIT would have to be transformed.

(Endnotes)

[1] *Massachusetts Institute of Technology President's Report* (Cambridge Massachusetts, 1917): 13.
[2] *Massachusetts Institute of Technology President's Report* (Cambridge Massachusetts, 1917): 83. See also pages 61, 64, 88, 95, 96 and 114 for the Department of Mathematics.
[3] *Massachusetts Institute of Technology President's Report* (Cambridge Massachusetts, 1917): 17-22.
[4] *Massachusetts Institute of Technology President's Report* (Cambridge Massachusetts, 1916): 21.

[NEXT PAGE] Fig. 46: Diagram illustrating the physical evolution of the Main MIT Campus. Only the buildings that comprise the present mega-structure appear. Dates refer to first occupation date except for the first stage of 1916; Building 1 was occupied in 1917. Dates are based on the "Building Data: Academic Facilities," see References.


1916 [#1, #2, #3, #4, #8, #10, #12]
1920 [#5]
1921 [#6B]
1928 [#11, #31, #33]
1932 [#6A]
1942 [#12]
1944 [#31]
1951 [#14, #31]
1952 [#16, #35]
1969 [#18, #37]
1973 [#38, #36]
1976 [#66]
1983 [#34]


1933 [#6]
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1968 [#39]
1990 [#7A]
1994 [#68]
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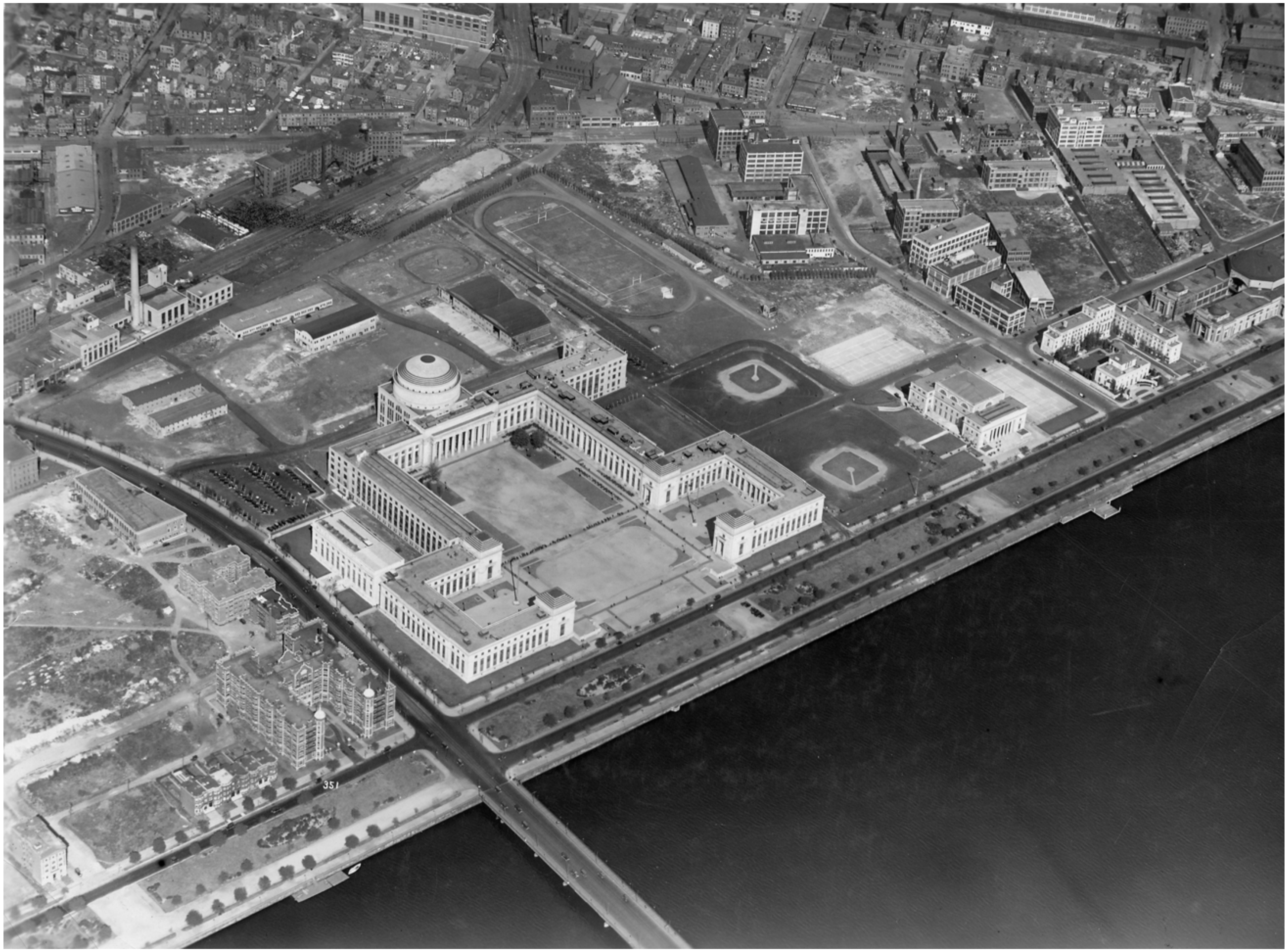


1920 [#5]

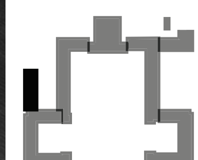


Fig. 47: Aerial view of the Campus, 1921. The Pratt School of Naval Architecture has already been added on the free end of former Building 3.

(4th step of tuning) Growth one_ Pratt School of Naval Architecture (1920-1921)

"*The latest reports of the progress of the construction of the Pratt School of Naval Architecture indicate that the building will be completed and ready for occupancy by the second term of the next fiscal year… The new building will be connected with Building 1 through the corridors*."[1]

The first growth occurred with the construction of the Pratt School of Naval Architecture **[47]**. The Department had a long history in the Institute as subjects on ship construction and basic principles had been taught since 1888 by Everett Burgess and Professor Peabody respectively, after the instigation of President Walker. In 1893 the Department was officially established and since then it had held a respectful position in naval affairs both in the USA and foreign countries. Since 1901 all Annapolis graduates had to continue their studies for two whole years in the Institute while the school had been attracting graduates from Japan since 1906. The accomplishments of the Department impressed Charles Herbert Pratt who founded a trust and bequeathed its holdings to the Institute for the erection of a separate edifice for Naval Architecture, provided that these holdings would first reach the amount of $750,000.[2] The will was executed in 1913 and, although the Institute could not get the funds until the death of Mrs Pratt, plans for the separate edifice were made and were included in the general plan for the new buildings in Cambridge. The Pratt School, however, although designed right from the beginning in 1913, would be pending for around seven years.[3]

The plans of 1913 were reassessed and refined in 1916 in order for construction to proceed, following the initial principles. Two main academic branches comprised Naval Architecture at the time, namely the design of the body of a ship and the design of its machinery. As the second one was conducted within the framework of the courses of Mechanical, Electrical and Civil Engineers, the necessary equipment had already been acquired and installed in the respective buildings of these disciplines, and as a result it was deemed wise that the Pratt School should provide facilities only for the first branch. Thus the new building would include mainly drafting and lecture rooms, and the necessary accompanying offices, while it would also include a museum. The building would be narrower than the other buildings of the group, namely 42', for reasons of lighting, and it would be 282' long. It would be attached to Building 5, so that it would retain the necessary proximity with the engineers and it would run along Massachusetts Avenue in order to give the desired exposure to the memorial of Charles Herbert Pratt. As mentioned above, attached to the Pratt School in the secondary west court would be the big lecture hall.[4]

This initial design sheds some light on the “mystery” of the knuckle between Buildings 3 and 5. I have not found any of the drawings made in 1916 but since these followed the basic idea of the ones of 1913, we can get information from the general plan assembled back then. In this scheme a single-loaded corridor ran along the east side of the building, servicing this way not only the spaces of the Pratt School but also the big amphitheatre in the court. Considering the width of the building and the layout of the knuckle in question one could assume that the corridor of the new building would meet the knuckle at the edge of the staircase and not on it as the double- loaded corridor of a 60’ wide building would do **[48]**. However, even this explanation is not adequate as on the basement floor and on the first floor the staircases protrude on the circulation axis This persistence of mine on the design of this knuckle may seem unnecessary. However, it is very strange how Bosworth, who has shown such a great mastery in the design of the rest of the knuckles that would enable growth, designed this particular this way.

The construction of the building, however, was postponed for the following reasons. On the one hand, with the erection of the other buildings, no considerable funds were left to be contributed the Institute to add to those that were going to be given by the Pratt foundation. On the other hand, the war had already started and this fact had its own twofold effect. First, the building materials and labor

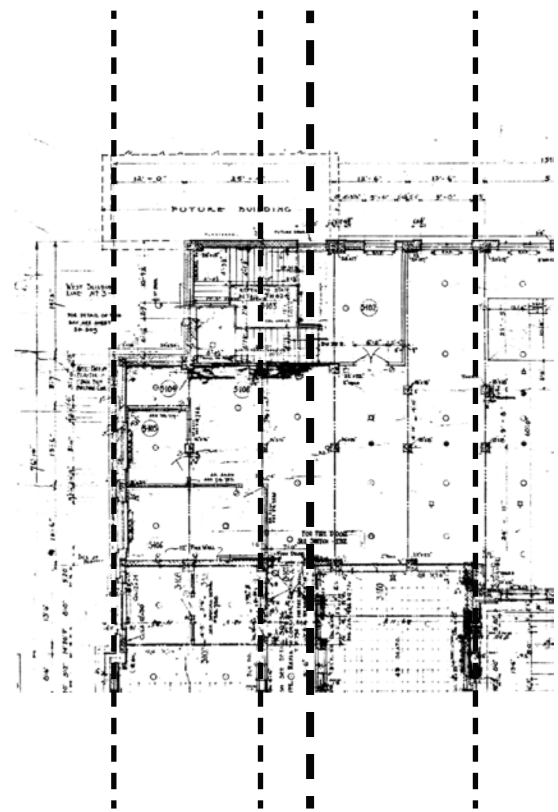


Fig. 48: Knuckle between former Buildings 3 and 5.

became extremely expensive and no construction unrelated to the war was encouraged by the State, and secondly, Naval Architecture acquired a different position in the currency of events.[5] As soon as the United States entered the war, the graduates, current students, and a number of professors of the Department were scattered away in the country in the various navy yards in order to offer their knowledge. In the Institute itself, an intensive course in naval drafting was created, as well as a Governmental School of marine engineering.[6] As a result the plans for the new school had to be re-evaluated and the corresponding Committee started to attend a number of conferences in order to acquire a better knowledge about the spatial needs of the department. This situation created a kind of paradox where on the one hand the construction of the building had to be delayed in order to be successful and efficient, while on the other, it had to be expedited in order to better supply trained men during these demanding times.

The main change to the plans that the Committee brought to the table was the consideration of the construction of a towing tank. It appears that up until then relevant experiments had been conducted in the Charles River. In Froude and Foulton, both "floating laboratories," measurements had been made regarding every attribute of a boat.[7] However, the study of the only two experimenting towing tanks that existed at the time in the country, as well as of the results of the studies that had been conducted in them, revealed the potential value of a man- made tank. The first one considered was that at the Navy Department in Washington, which measured 500' by 50' and was destined for 20' models, and the second was the one at the University of Michigan, which measured 300' by 20' and was destined for 10' models. The last one was deemed as the most suitable for the needs of the Institute and, with an increase in the width, it was used as a model in the designs of the new building which was now to be wider and have a smaller number of floors.[8]

However, this building was not constructed either due to the same reasons mentioned above, and this allowed for a big discussion to begin on its final form. Many people were interviewed in relation to the tower tank and even people from abroad, like James R. Jack, manager of the Denny Brothers shipyards in Scotland and former professor of Naval Architecture in the Glasgow Royal Technical College, who was invited as a Visiting Professor to the Institute in order to give his valuable insights on the matter.[9] The alternatives that were considered most were four; a three or four storey building with or without a towing tank and great consideration was given to the cost of the construction at the time, and to the cost of the construction had it taken place in 1914. It is not clear which were the reasons that led to the final decision, but finally what was built was a five storey edifice, including the basement, 175' long and 60' wide, without a tank. The building included an Instruments' Room, a Power Measurement Lab, a Museum and a Library, a Model room and a Shop, a large Lecture Hall, Drafting Rooms, Classrooms and Offices. The big amphitheatre at the east side of the building did not finally get built. Finally, the Pratt School had an entrance of its own. Construction begun in December of 1919 and the building was occupied in the winter of 1920 to 1921 **[49]**.[10]

The new building carried some of the characteristics of the existing system to which it was attached **[50-57]**. The single loaded corridor was abandoned and the layout was based on the first type of stem described above, with the difference that it featured a typical bay of 15' which shrank to 14'9" in the middle of the building on the two sides of the entrance, and expanded to 20'6" at the edges. Thus, considering that the width of the double- loaded corridor was approximately 8'to 9' the unit- section used in this case was approximately 15' by 25'. The circulation system of the building, however, was autonomous and did not depend on shared knuckles like those of the stems of the existing buildings. A staircase was put right next to the entrance while another, temporary one, was put on the exterior on the north side in order for the building to comply with fire protection restrictions. The double- loaded corridors of the basement, first and second floor were connected to the knuckle of buildings 3 and 5, while on the third and fourth floor this communication was interrupted by the large lecture hall, a fact that revealed once more the disadvantage of the constant width used in the system. The new building, however, still left an open end, at all levels, on its north side waiting for future growth. Extension at that point was also enabled by the adoption of the same add-on façade system. While the façade on Massachusetts Avenue introduced a highly decorated entrance, with a ship model, and pilasters made out of the same Indiana limestone, the east façade of the building was again made of brick and the north was devoid of any exceptional material. Thus, if not all, a considerable part of the DNA of the system had survived during the process of the transformation.

Fig. 49: Front of the Pratt School of Naval Architecture

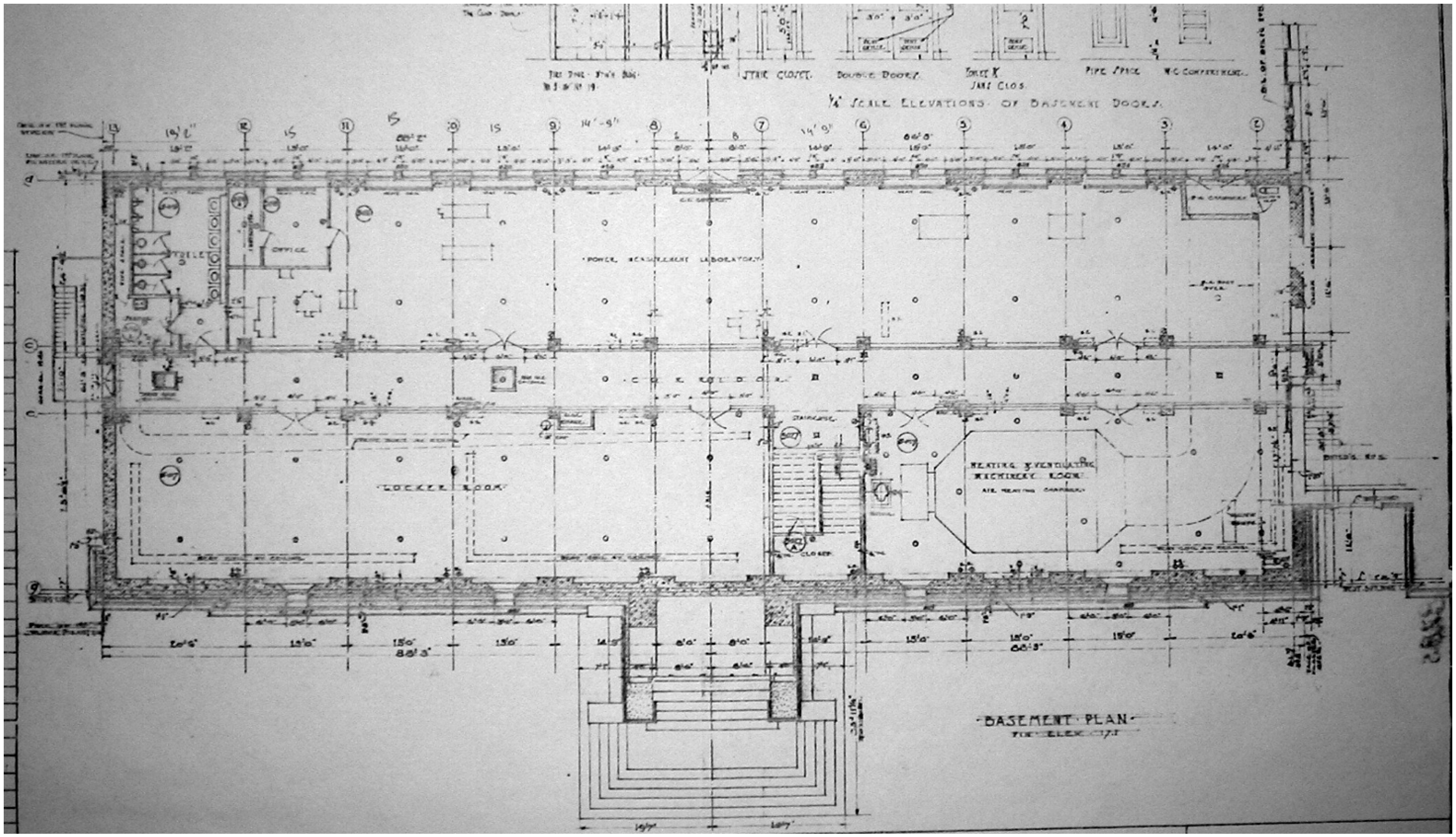


Fig. 50: Photo of the Basement Plan of the Pratt School of Naval Architecture.

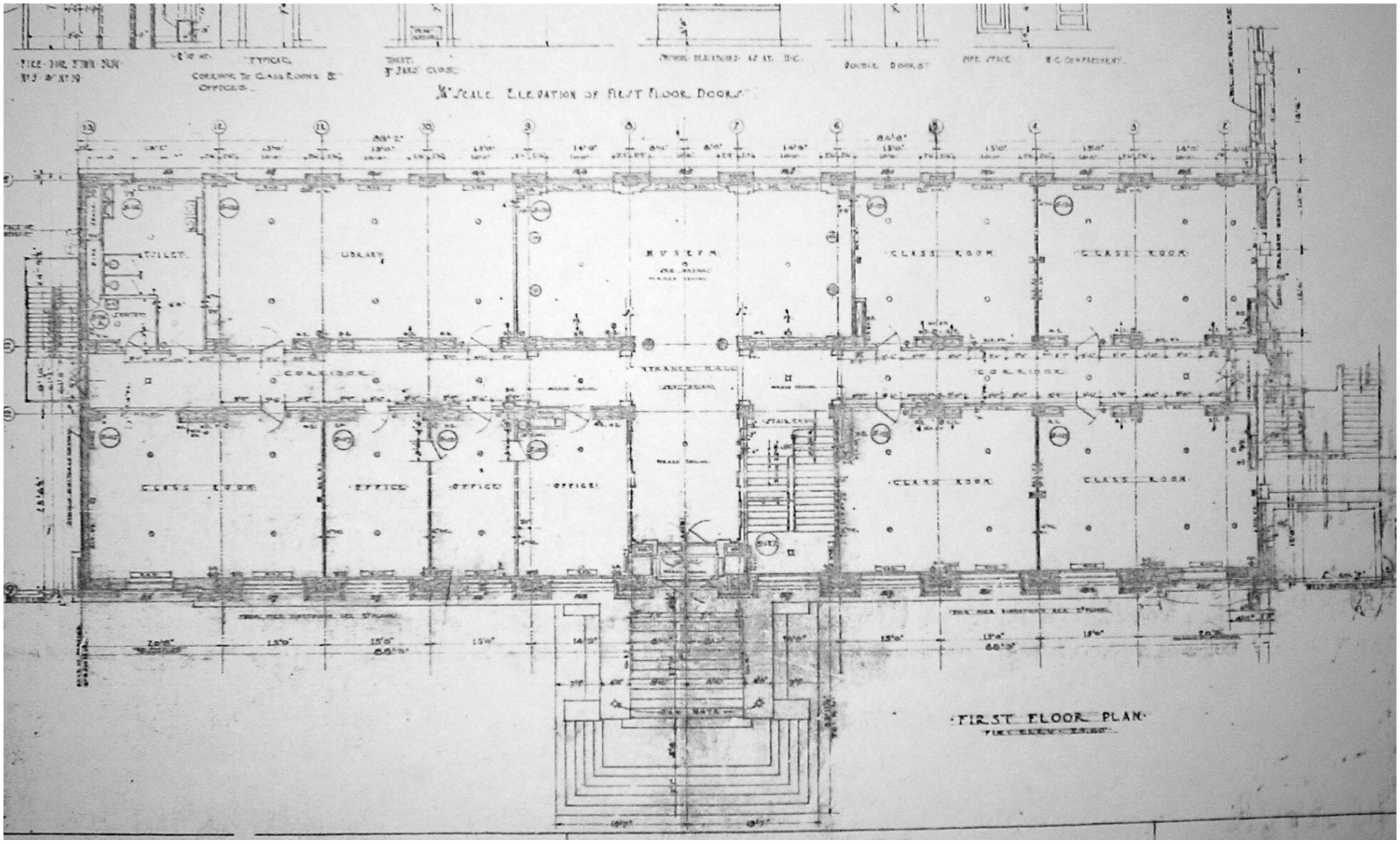


Fig. 51: Photo of the First Floor Plan of the Pratt School of Naval Architecture.

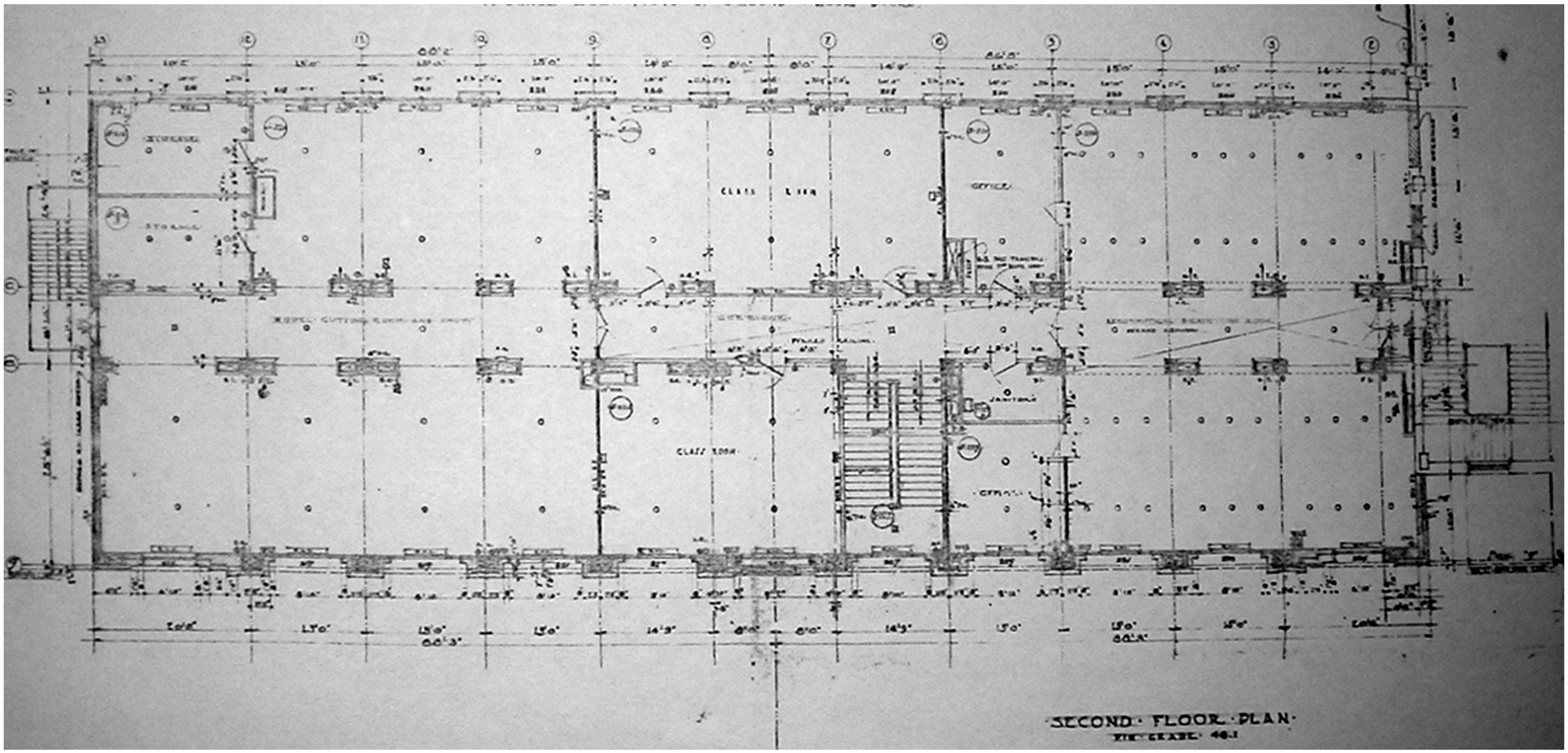


Fig. 52: Photo of the Second Floor Plan of the Pratt School of Naval Architecture.

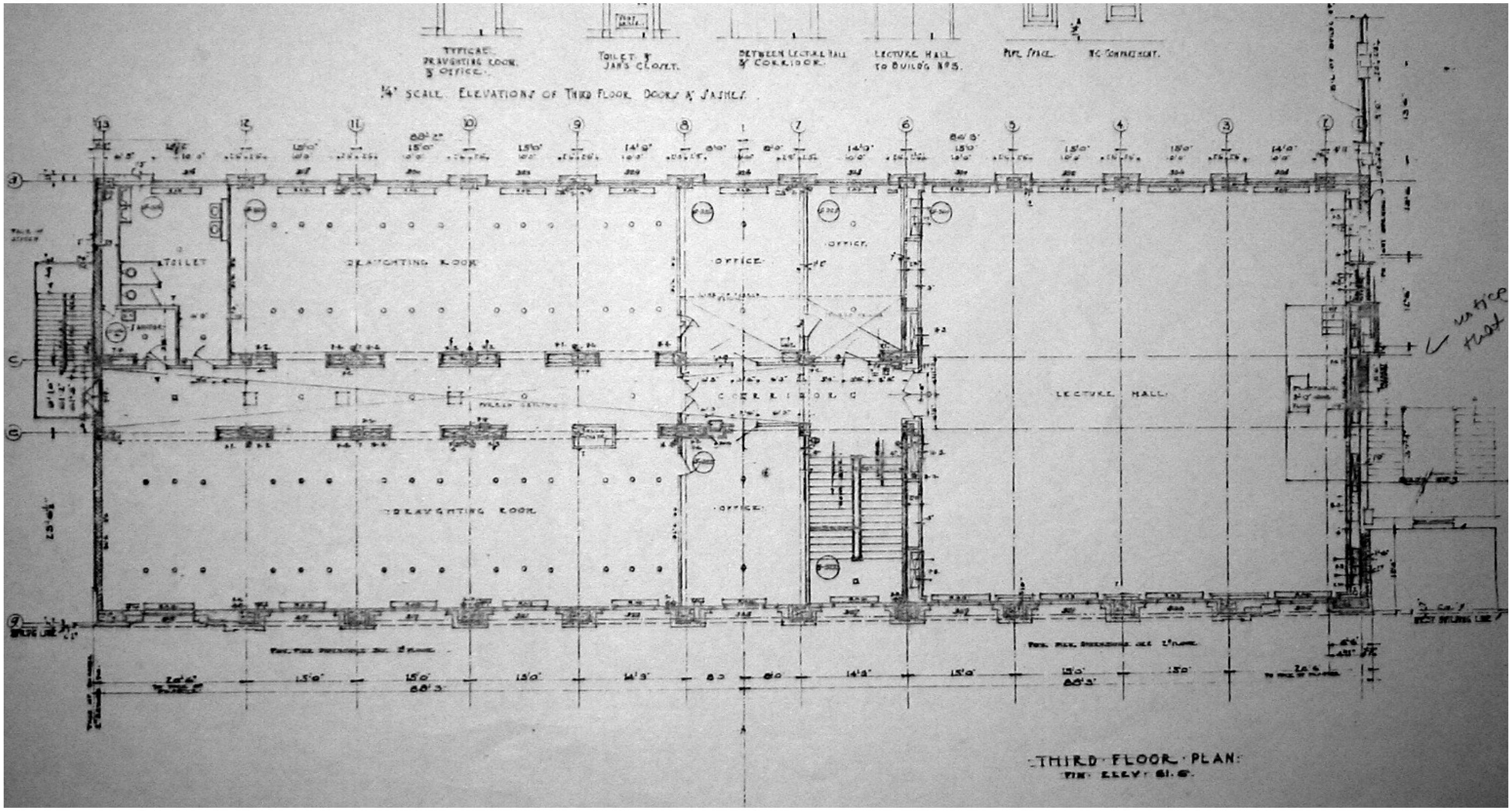


Fig. 53: Photo of the Third Floor Plan of the Pratt School of Naval Architecture.

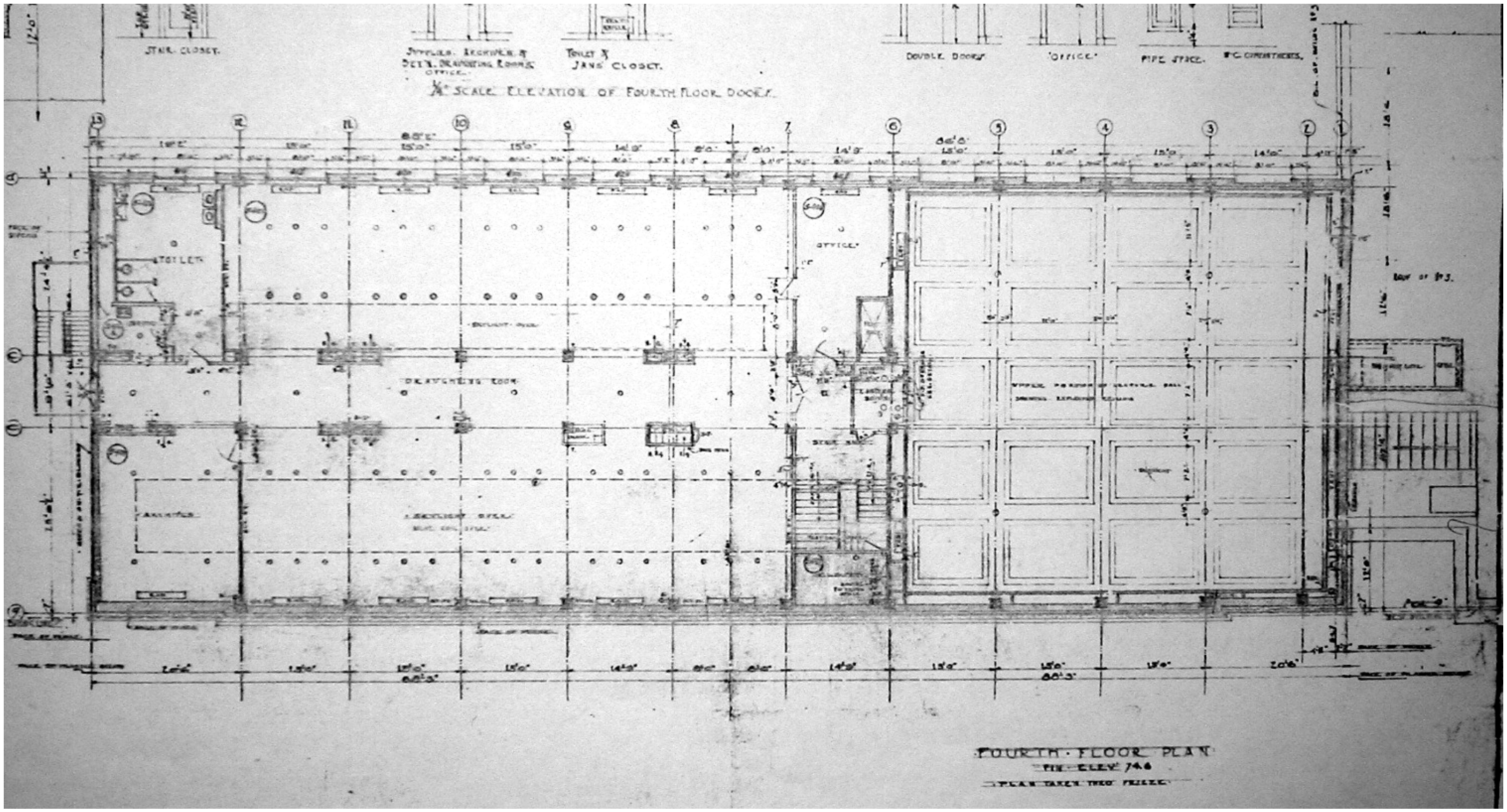


Fig. 54: Photo of the Fourth Floor Plan of the Pratt School of Naval Architecture.

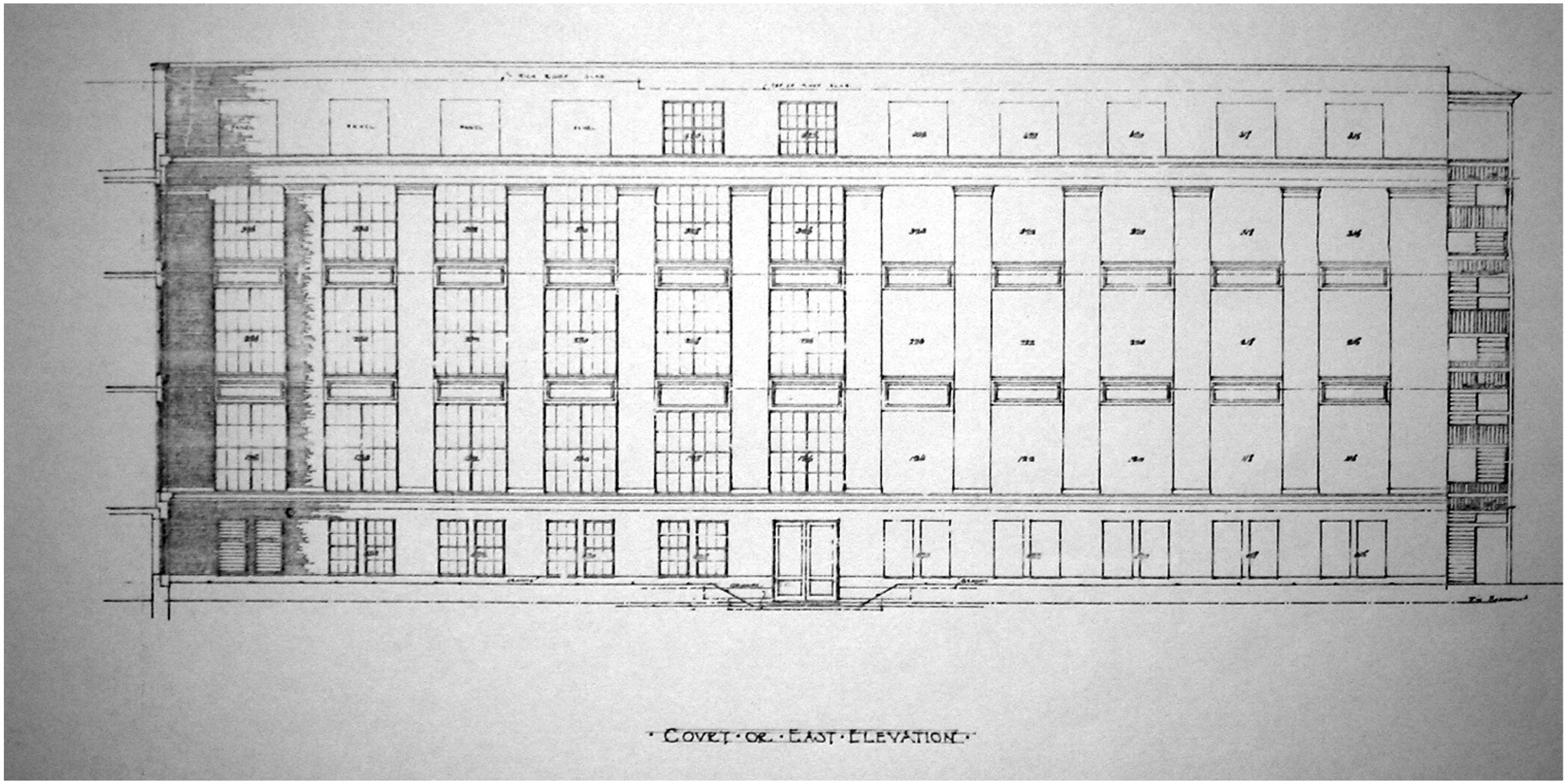


Fig. 55: Photo of the East Elevation of the Pratt School of Naval Architecture.

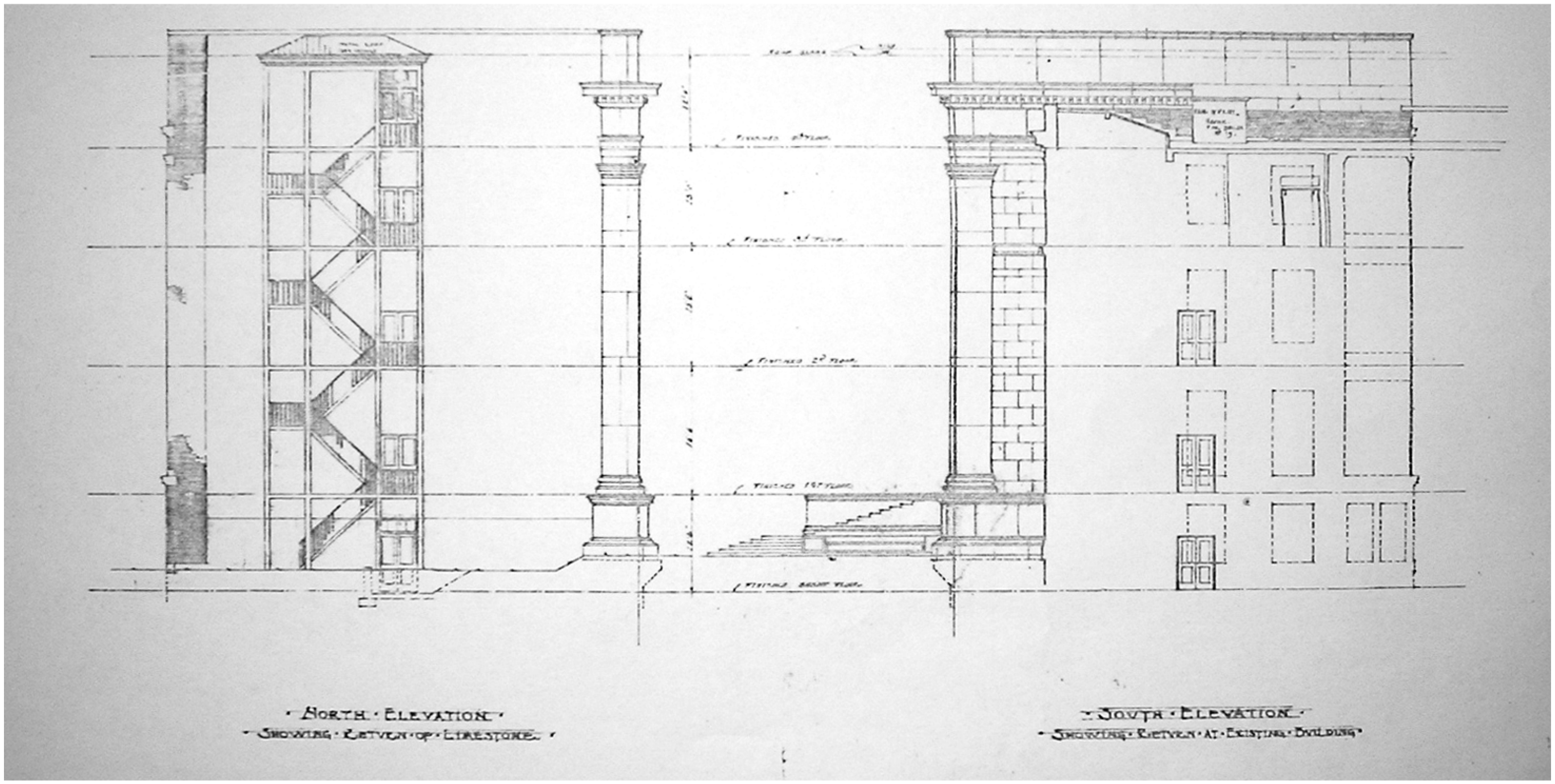


Fig. 56: Photo of the temporary elevation of the Pratt School of Naval Architecture.

Fig. 57: Photo taken during the construction of the Homberg Memorial Infirmary 8 years later where the temporary facade of the Pratt School of Naval Architecture is visible.

(Endnotes)

[1] "Pratt School Ready January First: New School of Naval Architecture Progressing Rapidly," *Technology Review* vol. 22 (July 1920): 456.

[2] See "Memorandum Re Pratt School of Naval Architecture," p. 1 (undated) [Office of the President AC 13, Box #26, Folder 256l, MIT Archives] and John Ritchie, "The Pratt School: The Promised School for Naval Architects to be Speedily a Reality" *Technology Review* vol. 20 (January 1918): 15.

[3] "Tech to get Pratt money" *Technology Review* vol. 15 (May 1913): 15.

[4] "Memorandum Re Pratt School of Naval Architecture," p. 1- 2 (undated) [Office of the President AC 13, Box #26, Folder 256l, MIT Archives]

[5] Memorandum Re Pratt School of Naval Architecture," p. 2- 3 (undated) [Office of the President AC 13, Box #26, Folder 256l, MIT Archives]

[6] John Ritchie, "The Pratt School: The Promised School for Naval Architects to be Speedily a Reality" *Technology Review* vol. 20 (January 1918): 12.

[7] John Ritchie, "The Pratt School: The Promised School for Naval Architects to be Speedily a Reality" *Technology Review* vol. 20 (January 1918): 16.

[8] Memorandum Re Pratt School of Naval Architecture," p. 4- 5 (undated) [Office of the President AC 13, Box #26, Folder 256l, MIT Archives]

[9] "Scotch Expert for Naval Architecture" *Technology Review* vol. 21 (November 1919): 535- 536.

[10] See "Pratt School Ready January First: New School of Naval Architecture Progressing Rapidly," *Technology Review* vol. 22 (July 1920): 456, and *Building Data: Academic Facilities*
MIT Office of Facilities Management System (February 1987) [T 171.M423P712 ,MIT Archives].

1928 [#33]

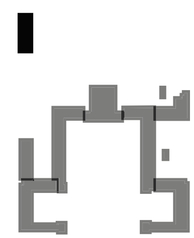


Fig. 58: Aerial view of the Campus, 1928. The Daniel Guggenheim Aeronautical Laboratory has been added to the north west corner of the campus.

(5th step of tuning) Growth two_ The Daniel Guggenheim Aeronautical Laboratory (1928)

"*This plan shows the location, relative to the other Institute buildings, of the Guggenheim Aëronautical Building soon to be erected. While it is to be isolated at first, it will be later connected to the main group by other buildings.*"[1]

The erection of the Pratt School had, for the time being, relieved the burden on the educational buildings caused by the number of students which in the academic year of 1918- 1919 had reached the 3000, and it was deemed that after its completion no new buildings would be required in the near future.[2] Indeed it seems that in that part of the Campus, with the exception of the Solvent Storage House, which was located in the secondary east court and the construction of which finished in 1921, no other building was built until 1927 when the construction of the Daniel Guggenheim Aeronautical Laboratory began.[3] The new laboratory came as a new relief to the Institute as from the academic year of 1925- 1926 urgent appeals from all the departments were made for more laboratory space **[58]**.[4]

Aeronautical studies in the Institute originated in the experiments in aerodynamics conducted in a small wind tunnel of 4' diameter in 1909 by Professor Gaetano Lanza, Head of the Department of Mechanical Engineering at the time and a number of his students. The results were obviously encouraging, as after this initiation, it was considered necessary for a Committee to be organized to study the possibility of the provision of classes and the way that these should be taught. Henry Howard, Henry A. Morss and Butler Ames, all MIT alumni, visited universities in France, Germany and England and prepared a report which resulted in the creation of a Graduate course in 1913 under the supervision of Lieutenant Jerome C. Hunsaker. At that time a second wind tunnel with a 7' foot diameter was constructed which was able to generate a velocity of 70 miles/ hour and provided better grounds for experiments.
The Graduate course quickly acquired an important position in the educational and military life of the country. During the war a school of aviation directed by the Government was created on the grounds of the Institute while the alumni of the course, reaching 200 by 1926, were to hold important positions in the Army Air Service, in the "Bureau of Aëronautics" and in industry. In March 1926 "Aëronautical" Engineering became a separate undergraduate course, Course XVI, under the direction of Professor Edward P. Warner, whose excellent accomplishments and contribution to the Department earned him that year the position of the Assistant Secretary in the "Aëronautics" Navy. The new department flourished like the preexisting Graduate course and by 1928, 46% of the "Aëronautics" students in USA were studying in MIT.[5]

It is possible that the establishment of the new Course in March 1926 was forwarded by an opportunity that had appeared to the Institute some months ago. In December of 1925, President Stratton received a letter from Admiral Cone, the representative of Daniel and Harry F. Guggenheim. The letter stated the interest of the Guggenheim family in Aeronautics and by referring to an endowment made for the New York University, it expressed the potentiality of a similar contribution to MIT. President Stratton was aware of the endowment in question, which had consisted of $500,000 and called for the founding of a School of Aeronautics; he immediately replied to the letter and expressed his wish for the construction of a separate edifice to house the Institute's activities. He proposed for a meeting with Admiral Cone either in New York or in MIT where a better sense of the school's accomplishments in the field could be seen. Things moved pretty fast and sometime by January of 1927 the "Daniel Guggenheim Fund for the Promotion of Aeronautics" was created. In that month an endowment of $230,000 was given to the Institute for the construction of a separate building.[6] Whether the foundation of Course XVI was a prerequisite of the endowment, or not, the result was that MIT would have to offer a well equipped and suitably designed environment to the new students, and with the Guggenheims' support it could. Coolidge and Carlson, architects, were called to forward implementation, while Bosworth would still be welcome to serve as an advisor to the project.[7]

Great consideration was given to the design of the building which finally complied with the point of view of how Aeronautics should be taught at the Institute at the time. As stated above, theory and application held an equal position in the curriculum of MIT. This was also the case for Aeronautical Engineering where it was believed that this relationship, between the knowledge of the "natural law" and its application, was "more vitally important" than to any other profession.[8] According to the Head of the Department at the time, the Aeronautics student should be able to not only translate theory into a competent design, but to also materialize this design in a real scale model. Furthermore, the student should have the chance to test the model in the air, to personally fly the airplane and to get a first hand experience not only of its performance but also of the needs of the passengers and pilot. In other words, the education of the Aero Engineer had to rely on a progressive method of study. Apart from the last stage in this progression which could not easily be accomplished in the framework of the Institute, provision could be made for the rest. The fundamental "aerodynamic and structural theory" needed a wind tunnel, design required well lighted drafting rooms, modeling needed shops, while for the next stage there should be "provision for the setting up, rigging, and subsequent testing to destruction of airplanes."[9] Indeed, the program that was figured out for the building provided these spaces and could be outlined as following: two tunnel rooms, instrument rooms, drafting rooms, a library, a museum, research laboratories, a rigging room, a flight test and instrument research laboratory, and a material research and testing laboratory, accompanied by the necessary offices and services. Only an Engine Laboratory was not put under the same roof and, as we will see later, was built as a separate building.

Consequently the new building would have to comply with certain specifications due to the inflexible, because of its size, wind tunnel. The two wind tunnels that the Institute was using at the time were housed in a temporary building behind building 17. This was probably an indication of the inability of the main system to house every educational activity. Indeed, it appears that the dimensions of the big tunnel did not permit it to fit in any of the three stems that have been described above. Thus the new building's structure at the first three levels, namely a very high basement and a first and second floor which occupied only part of their level's area, was based on the dimensions of the two tunnel rooms. At the perimeter of the building, however, which measured 150' in length by 60' in depth, a regular bay of 13'6" was kept **[59-61]**. Furthermore, a fact that is quite impressive considering that in a skeleton a vertical continuity in the columns is desired, at the next two levels the building's structure reverted to the layout of the first type of stem, namely to the inclusion of a double series of supportive columns **[62- 65]**. This becomes even odder, if one takes into account that in none of the two last levels the spatial configuration was based on the unit- section that was formed. In any case, the final result was a sort of fragment of the system, a building which while accommodating two wind tunnels, carried, like the Pratt School, a number of the system's DNA.

It appears, however, that the building was supposed to be only a fragment **[66]**. Placed along the invisible grid of the Institute's system it would be connected in the future with the Pratt School through the addition of more buildings. Considering that a connection was desired, it is difficult to understand why it was not immediately

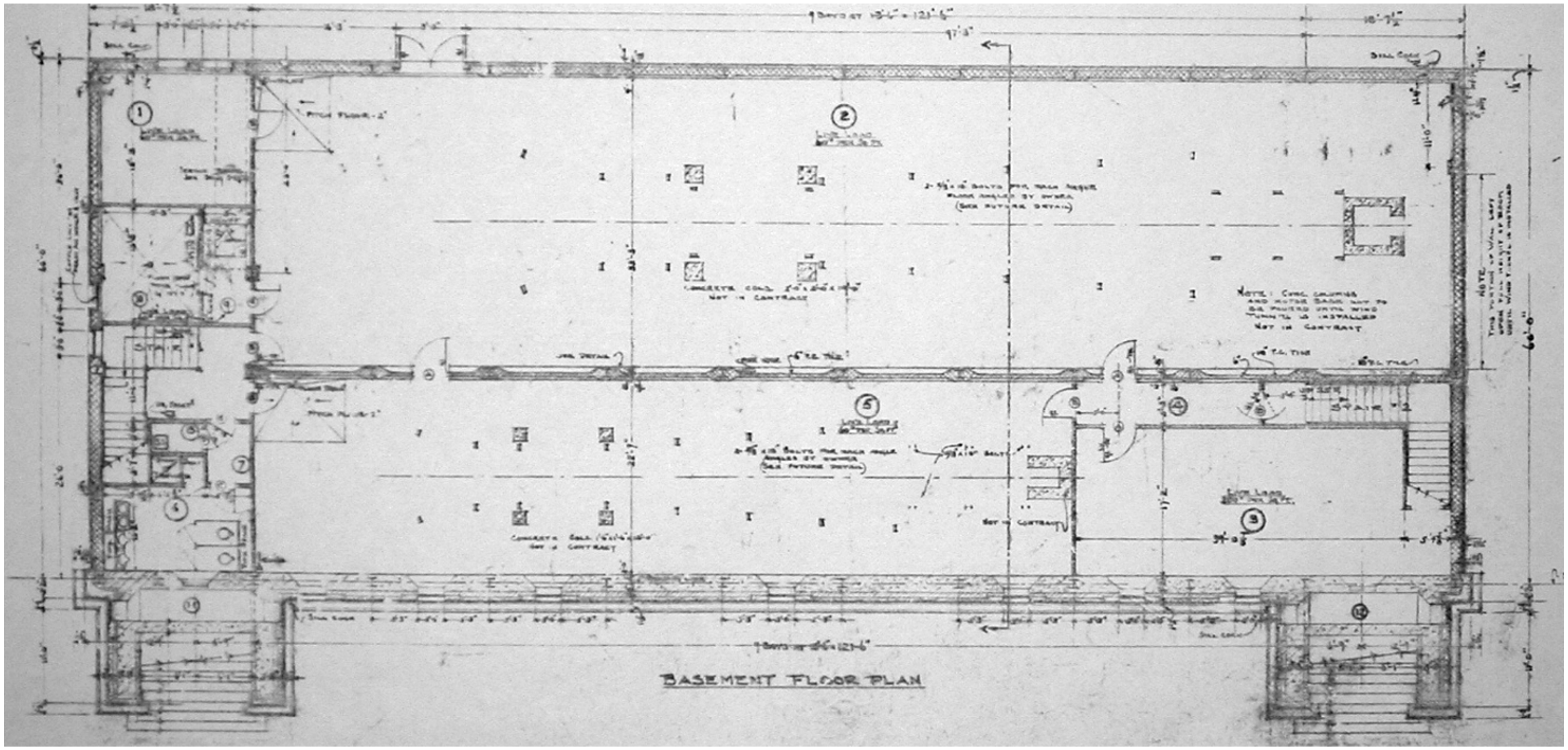


Fig. 59: Photo of the Basement Plan of the Guggenheim Laboratories.

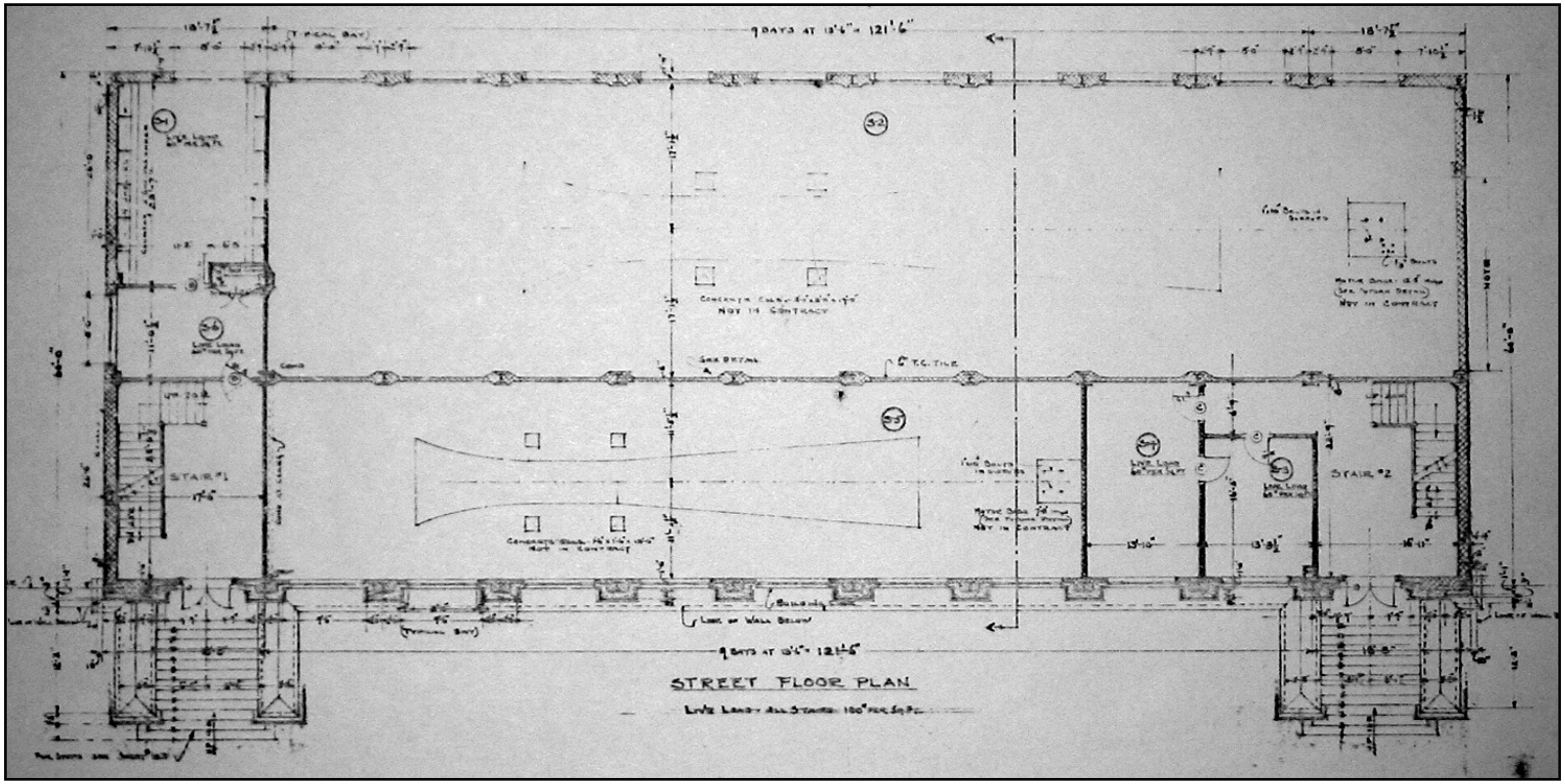


Fig. 60: Photo of the Street Floor Plan of the Guggenheim Laboratories.

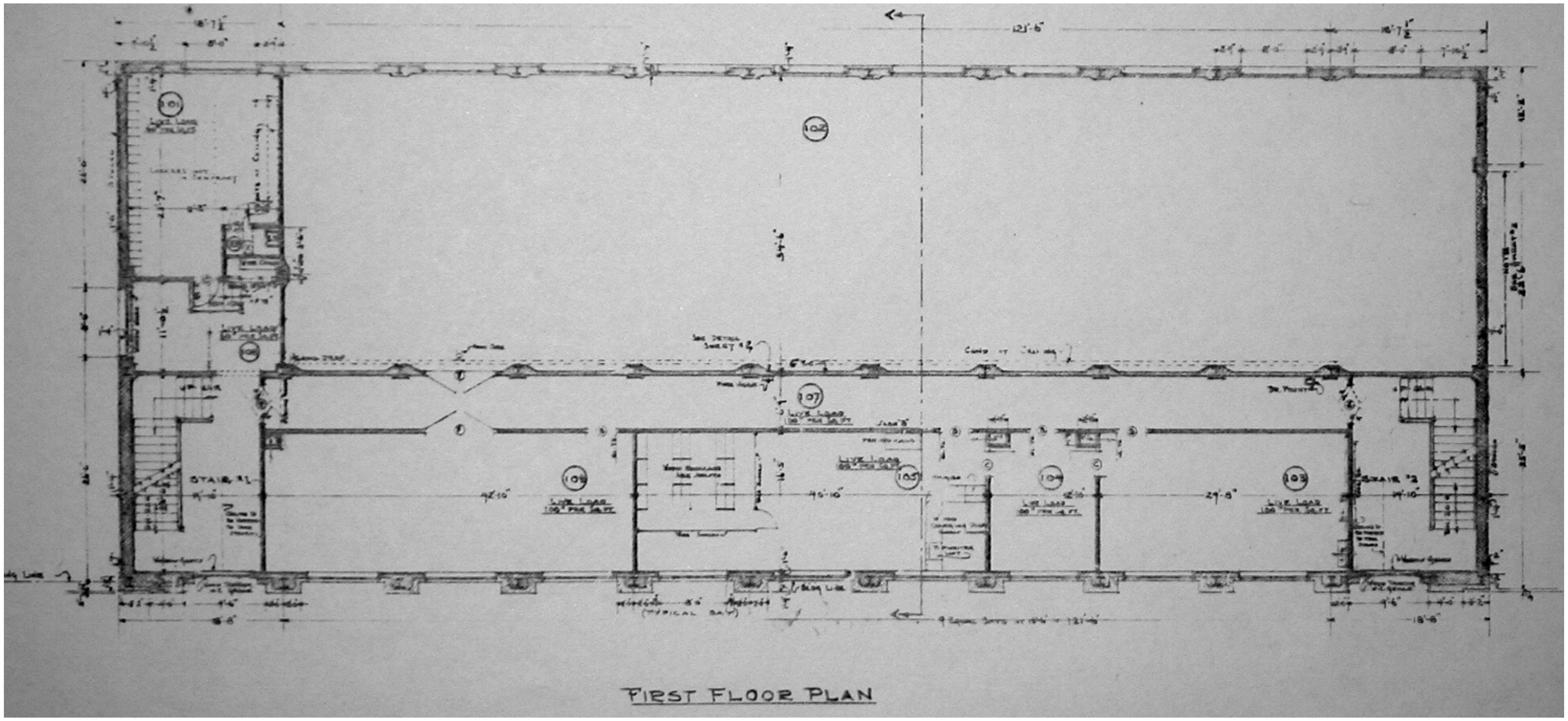


Fig. 61: Photo of the First Floor Plan of the Guggenheim Laboratories.

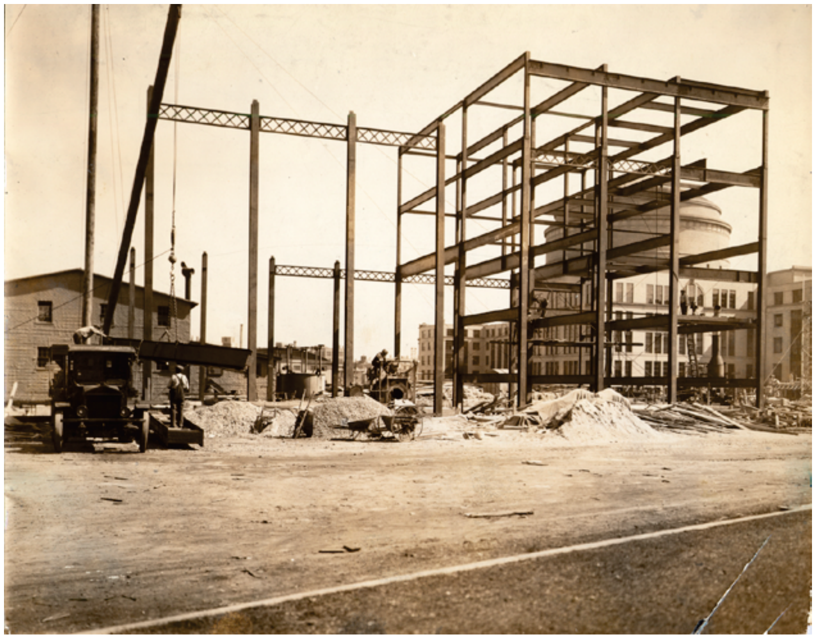


Fig. 62: Photo taken during the construction of the Laboratories. The metallic structure probably facilitated the conversion of the structural system on the upper floors. At the background, the construction of the Homberg Memorial Infirmary, taking place at the same time, can be discerned.

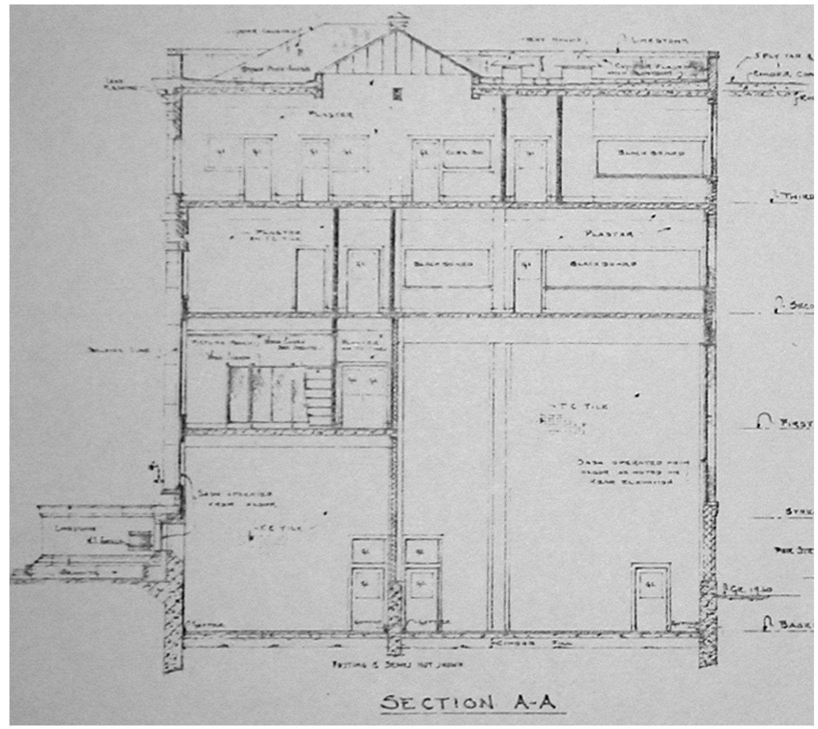


Fig. 63: Section A-A showing the conversion of the system.

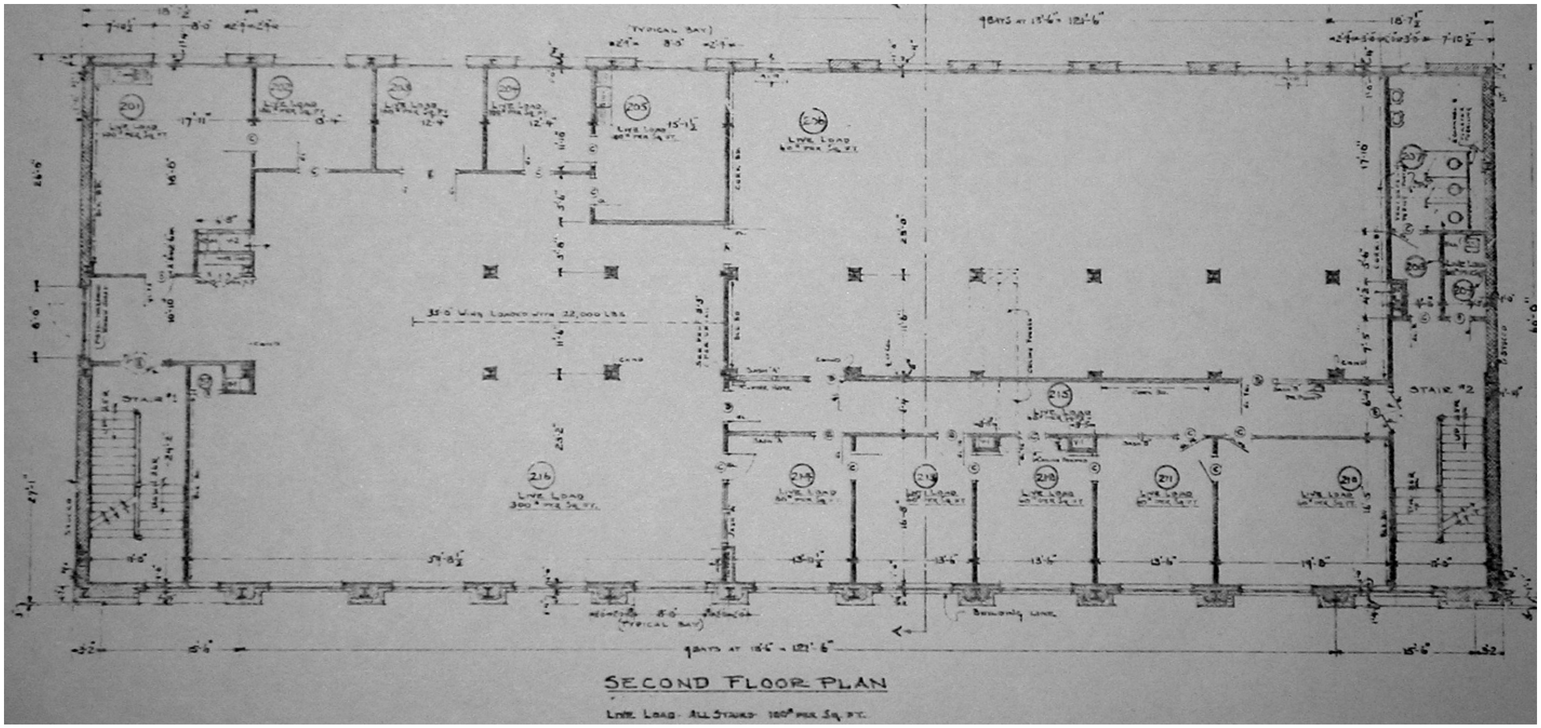


Fig. 64: Photo of the Second Floor Plan of the Guggenheim Laboratories.

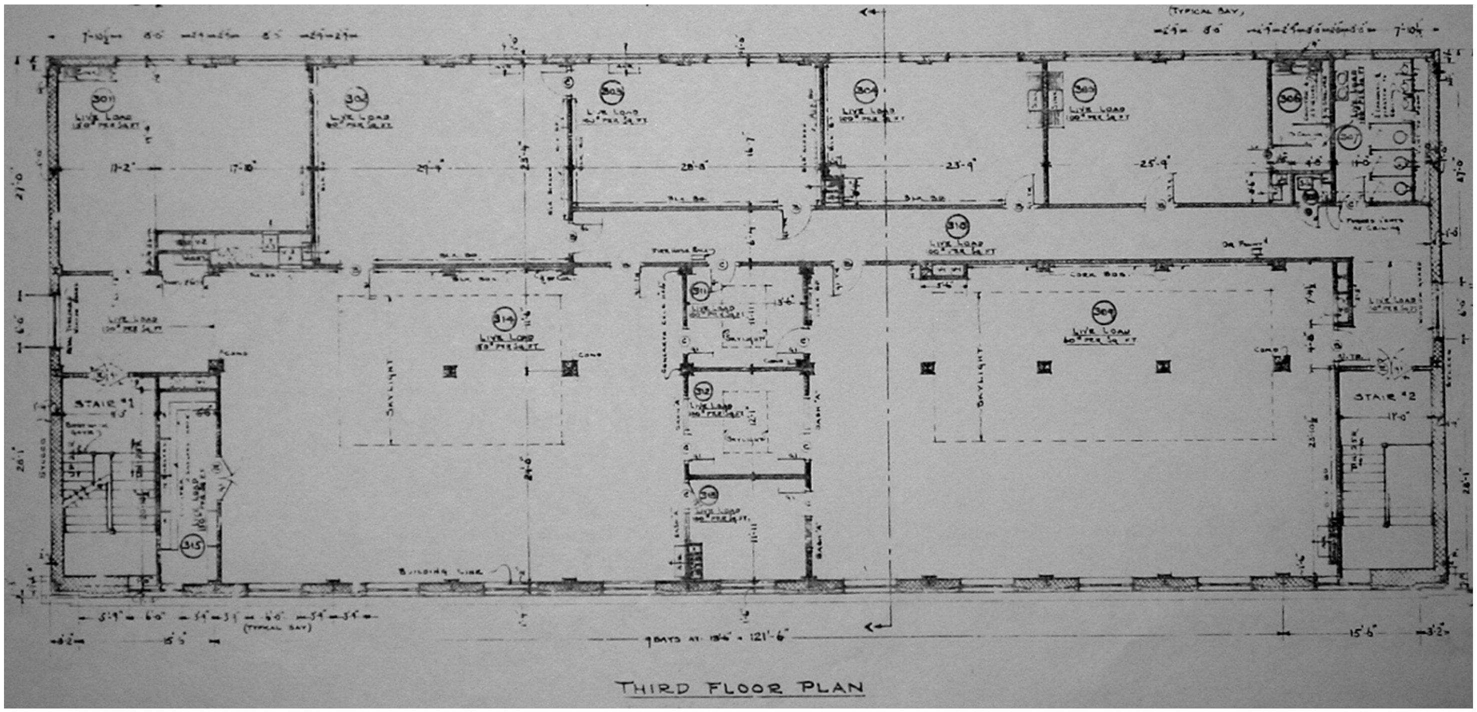


Fig. 65: Photo of the Third Floor Plan of the Guggenheim Laboratories.

connected to any of the open ends of the system. Furthermore, two of the service buildings had to be demolished in order for the new building to be placed at that spot. A possible answer is the following. On the one hand the building would interrupt the circulation at the ground level if placed at the middle parts of the invisible grid. Of course the circulation system of the Institute was already interrupted, as mentioned above, by the various laboratories in buildings 7 and 5. However, movement through these labs was discouraged by a number of closed doors. A wind tunnel, on the contrary, was a "capricious monster" which had to be "carefully housed and tenderly sheltered" as it could "suck a gale through" its "innards."[10] As a result, one could assume that movement across the wind tunnel rooms would be forbidden during operation. On the other hand, the open ends that had been left were not particularly satisfying for a dedicated and funded building. Apart from the open end of the Pratt School, for which, however a grandiose entrance was envisioned, probably since then all the other open ends were out of conspicuous public sight.[11] As a result, placing the building near the corner of the site along Massachusetts seemed the best choice. This had a positive effect that was recognized at the time: the Guggenheim building would offer the necessary privacy to the back yard of the Institute.[12]

Since the connection of the Guggenheim Laboratory with the rest of the Institute was desired the facades were worked out in a compatible way. Not only were the same materials used but each façade was treated in a different manner. Thus the west façade featured the same pilasters and frieze as the other buildings, made

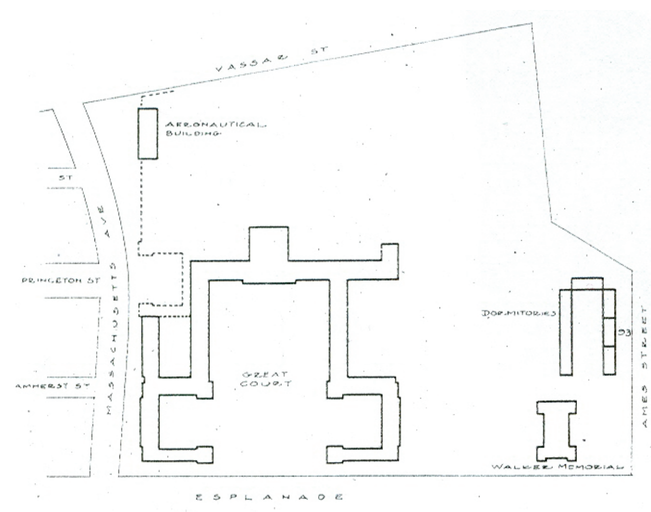


Fig. 66: Diagram showing the relation of the new labs with the existing buildings.

out of granite and Indiana limestone, as well as an inscription, the east façade featured brick, and the two narrow ones stucco; the north facade was treated also like a temporary one since provision for extension had been made for this side too **[67-69]**. Hence, during this growth too, an important part of the system's DNA was transferred.

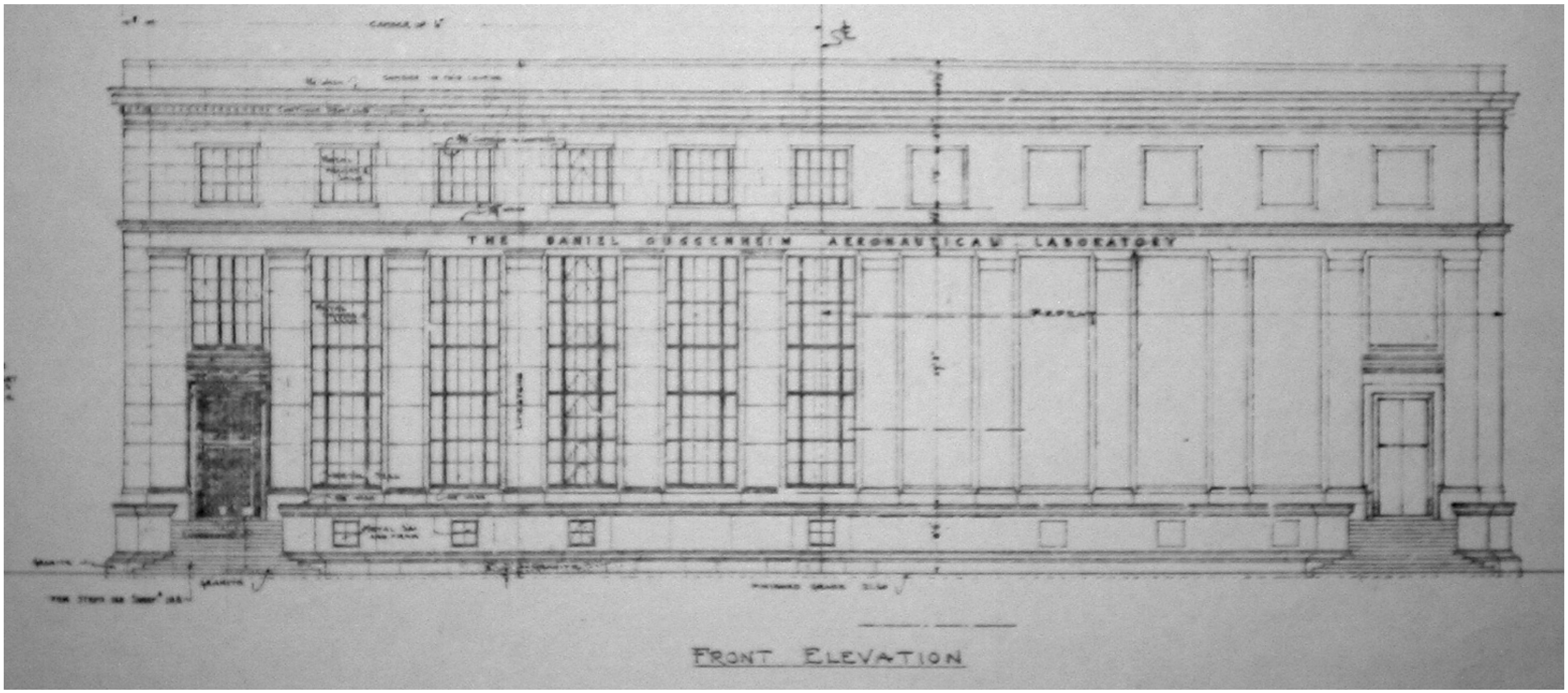


Fig. 67: Front elevation of the new labs.

Fig. 68: The East and North temporary facade of the new labs.

Fig. 69: The East and South temporary facade of the new labs.

(Endnotes)

[1] *Technology Review* vol. 29 (March 1927): 273.

[2] See *Massachusetts Institute of Technology President's Report* (Cambridge Massachusetts, 1920): 9, and *Massachusetts Institute of Technology President's Report* (Cambridge Massachusetts, 1922): 12.

[3] In the meantime, part of the dormitories was constructed and an auxiliary building for the Department of Mechanical Engineers was built on the North side of Vassar Street, where equipment from the Main Group was transferred and hazardous experimentation would take place. However, as mentioned before only the buildings which are now parts of the continuous system are examined in detail. For the Mechanical Engineers Building see *Massachusetts Institute of Technology President's Report* (Cambridge Massachusetts, 1920): 9, and *Massachusetts Institute of Technology President's Report* (Cambridge Massachusetts, 1923): 57.

[4] *Massachusetts Institute of Technology President's Report* (Cambridge Massachusetts, 1926): 42-43.

[5] See a) "The Past Month" *Technology Review* vol. 28 (April 1926): 309- 310, b) "The Trend of Affairs: An Aëronautical Building " *Technology Review* vol. 29 (February 1927): 213, c) "The Trend of Affairs: Aëronautical Secretary " *Technology Review* vol. 29 (November 1926): 5, d) "The Trend of Affairs" *Technology Review* vol. 30 (May 1928): 399, e) John Ritchie, "The Pratt School: The Promised School for Naval Architects to be Speedily a Reality" *Technology Review* vol. 20 (January 1918): 12, f) "For Use in the Morning Editions, Monday, January 17, 1927" (Cambridge, Mass.: Massachusetts Institute of Technology): 1 [Office of the President AC 13, Box #26, Folder 270l, MIT Archives]

[6] "For Use in the Morning Editions, Monday, January 17, 1927" (Cambridge, Mass.: Massachusetts Institute of Technology): 1- 4 [Office of the President AC 13, Box #26, Folder 270l, MIT Archives]. See also Letter of Admiral Cone to President Stratton, December 28, 1925, p. 1 [Office of the President AC 13, Box #26, Folder 270l, MIT Archives] and Letter of President Stratton to Admiral Cone, January 4, 1926, p. 1-2 [Office of the President AC 13, Box #26, Folder 270l, MIT Archives]

[7] At the time Bosworth was still providing criticism and advice for any important project that was undergoing in the Institute. For the Guggenheim building see Copy Mr. Hart of Letter of William W. Bosworth to Everett Morss, 21st December, 1928, p. 1[Office of the President AC 13, Box #2, Folder 56, MIT Archives]

[8] Edward P. Warner, "Aeronautics in Technical Schools and Universities: the Standards influencing the best in Aeronautical Study and Instruction," *The Tech Engineering News*, vol. IX/4 (May, 1928): 135.

[9] Edward P. Warner, "Aeronautics in Technical Schools and Universities: the Standards influencing the best in Aeronautical Study and Instruction," *The Tech Engineering News*, vol. IX/4 (May, 1928): 136.

[10] "Hence the Pyramids," *Technology Review* vol. 30 (March 1928): 275.

[11] Mark Jarzombek in his book refers to the Massachusetts Avenue entrance. Although its construction was agreed in 1939 plans for that part of the campus had started being studied since the late 20s. So we could assume that an entrance was envisioned since 1927. See Jarzombek (2004): 113.

[12] "Shifting Skyline," *Technology Review* vol. 30 (November 1927): 17.

1928 [#11]

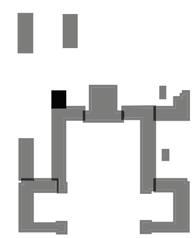


Fig. 70: Aerial view of the campus, 1928. The Homberg Memorial Infirmary has been added to the free end of former Building 7.

(6th step of tuning) Growth three_ Homberg Memorial Infirmary (1928)

"*Close by and directly connected with the main educational group at its northwest corner is the Richard Homberg Memorial Infirmary, which also is due to be completed in the spring*."[1]

At the same time of the construction of the Guggenheim Laboratory, another growth was taking place in the academic part of the campus, namely the building of the Homberg Memorial Infirmary **[70]**. Medical care had for a long time been provided to the Institute students. From the days of the Boston campus, consultation hours had been held regularly each week in a small office, while talks were given each year to the Freshman class regarding personal hygiene, training, nutrition, sleep, eye care, ordinary illnesses, first aid, alcohol use, smoking, and sexual diseases. Furthermore, in the framework of the first year Gymnasium course, a physical examination of the students participating in the class was taking place twice a year, once at the beginning and once at the end of the course. Statistics of illnesses were held and particular interest was shown in the prevention of contaminations, which in the case of the Institute, however, were not very frequent as students did not live often in dormitories.[2]

When the plans for the new Institute were being worked out, Arnold Rockwell, the Medical Adviser of the school, introduced a list with the minimum specifications for any space that would be provided for medical purposes. Furthermore, he pointed out the need for an infirmary based on the one hand on the occurring incidents during which the lack of proper facilities had put serious obstacles to the care of the students, and on the other, on the general opinion coming from other universities' advisers that such spaces should be included in a campus. In one of his last attempts, he mentioned the example of Radcliffe College where an infirmary had been built and where the services of a full-time nurse were provided.[3] However, as imperative as the requests of Dr. Rockwell had been, an infirmary was not provided in the new campus. On the contrary, the Medical Department proved to be quite nomadic as from its temporary headquarters in 3- 329, in 1917 it moved to 8- 101, while during the academic year of 1920- 1921 it moved to 3- 019.[4]

Nevertheless, in the late 1920's two things happened that made that initial request of Dr. Rockwell a reality. First, a progressive turn in the view of medical care in schools seemed to have finally taken place, and the ideas that Dr. Rockwell and his fellow advisers in other schools had supported before, seemed to acquire a more substantial and widely accepted position in the academic circles. From a few occasional visits in a gymnasium office and a number of talks that was the case in 1900 when medical advice had first appeared in schools, the system had evolved in order to offer a general examination prior to the beginning of classes for "detection of defects," and training and "surgery or medical treatment" later on, for the "correction" of these defects.[5] In other words, at some point prevention was introduced. Furthermore, the system was turning its attention from the education of the masses to the education of the individual. Until then the lectures to a wide audience had not turned out any satisfactory results, as the reference to a number of general diseases from which most of the students did not suffer, left them with the impression that they were absolutely healthy and in no need of medical attention. Individual consultancy on the contrary, would be able to detect the variety of health problems among students and prevent more unexpected incidents. It appears that this view was part of a general turn in public health policy: from the institutionalization of sanitation and the effort to combat massive diseases, which were the first two eras of public health, the government was now passing to a period where the relationship of each citizen with a personal doctor would have to be established and grow. This was, in reality, an effort to battle the various superstitions that still characterized the behavior of ordinary people in cases of sickness. The infirmary would act as a vehicle in this preventive campaign, establishing check ups as an inextricable part of the students' future lives. In this light, it was deemed that such a space should include both in patient facilities, for first aid, convalescence, and isolation and out-patient, for consultation, facilities.[6]

The second stimulus was an endowment especially for the construction of an infirmary. The gift came from the family of Richard Meyer Homberg, a former MIT student who had died of pneumonia in 1923 while studying at MIT. The endowment called for the construction of a Memorial and posed restrictions among which was that the donors would provide their own architects, Charles Butler and E. A. Grunsfeld, the latter being a member of the donors' family.[7] It seems like this stipulation, depriving full control of the planning and of the drawings from MIT, proved a particular impediment in the procedure which was also slowed down by a dispute about the position of the Infirmary taking place between the school and the family. The latter wanted, of course, a very prominent position for the Memorial while MIT wanted the new building to be connected to the main group of educational buildings, probably for practical reasons. It seems that the construction of the Guggenheim Laboratory, which was planned at the same time, must have made things even more complicated as MIT waited to see how the Massachusetts Avenue front would be treated in order to take a final stand on the matter. Negotiations lasted for about three years and finally it was agreed that the Infirmary would be plugged in to the present Building 3 at the point where Bosworth's wing 15 would be.[8] In order to stress the fact that the whole building was a Memorial, its entrance, which was on the knuckle between former buildings 9 and 7, was modeled with two Doric columns which are still present today in the Infinite Corridor.

Unfortunately, except for a detail for the entrance, the elevations and one section, there are no other drawings of the Memorial saved in the Archive of the Department of Facilities. However, one can get an accurate view of the structural system from the first alteration drawings, and a pretty good idea of the spatial arrangement, both from two plans that had been published before the agreement was made and from photos after the completion **[71-76]**. It is not exactly clear from the correspondence that has been saved what final control MIT had over the final plans, but the Infirmary was based on the initial plan of Bosworth for building 15. In other words the building had a width of 65' which was divided in three equal sections of approximately 21' by a double series of supportive columns. Furthermore, a regular bay of 15'6" was kept along the length which measured 77'. From the two published plans, we can see that the specific structure allowed for two spatial configurations. The first floor plan featured a double loaded corridor with a width of 9'6" which ran through the building to its other end. The second floor plan featured a central nucleus with a corridor around it and a ring of spaces running along the perimeter of the building. The building had a basement, three floors and a solarium on a fifth level. On its exterior it obeyed the vocabulary of the main group featuring the yellow brick on its long sides and plaster on its north elevation.

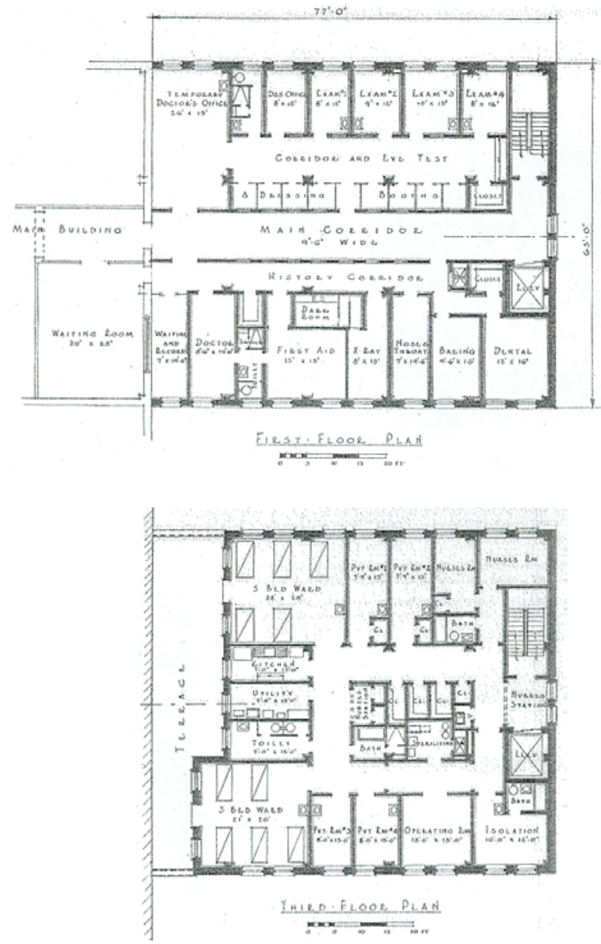


Fig. 71: Plans of the Homberg Memorial as published in *Technology Review* in May, 1927.

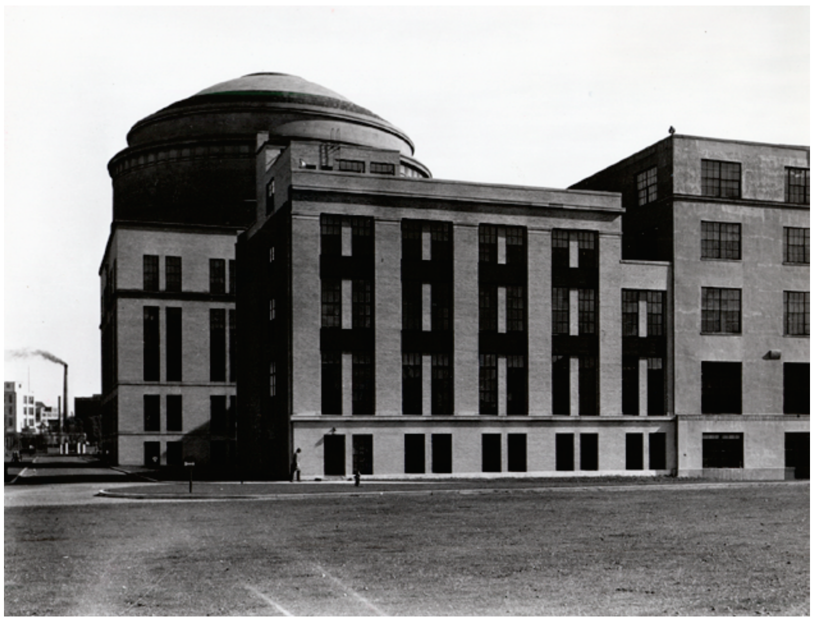


Fig. 72: Homberg Memorial Infirmary, present building11, before the construction of the Massachusetts Av. entrance.

Fig. 73: Entrance to the Infirmary from the Infinite Corridor.

Fig. 74: The windowless waiting room as shown at the first floor plan.

Fig. 75: Examination room with Building 10 at the background.

Fig. 76 : Solarium at the terrace of the building..

It is noteworthy that during this growth the initial plan of Bosworth was followed. In both the Pratt and Guggenheim buildings, a preference was shown towards the first type of stems, even though in the case of the Pratt building another layout had been planned. A possible explanation for this is the fact that in this case, the layout might actually turn out to be more economical for the specific use. In the case of an infirmary not all spaces had to be well lit as in the case of classrooms or laboratories. As a result more spaces could fit in a shorter wing, as these could be arrayed along the width and not along the length. If the first or second type of stem were followed, most probably a plan similar to the one of the first floor would result if spaces were arrayed along the width. In this case, however, a lot of space would be lost in intermediary corridors. On the contrary, the structural layout that was used allowed for the creation of a space between the two central series of columns and furthermore for the inclusion in this width of a circulation space, with less interference of columns. In other words, it seems to me that this system allowed for more efficient communication and interrelation of spaces in a little wider, but considerably shorter building, and thus cheaper than those that the other three types of stem would allow in a longer and thus more expensive building. Although the layout of the first floor goes against this explanation, I would argue that a double- loaded corridor was preserved at this level in order to provide for efficient connection to the existing buildings and for efficient circulation and communication in case of future growth, an idea which is enforced by the plastered north façade. But of course, all these remain speculations, especially since we do not know what the spatial configuration in the other levels was. As a matter of fact, for these, namely basement and second floor, we can assume that they remained "open spaces" as a letter prior to the final agreement on drawings indicated.[9] However, the persistence of the first type of stem is an important part of the conclusions of this thesis, and I therefore wanted to provide a detailed discussion about the choice of this type of stem, in this case.

(Endnotes)

1 "Shifting Skyline," *Technology Review* vol. 30 (November 1927): 17.

2 *Massachusetts Institute of Technology President's Report* (Cambridge Massachusetts, 1911): 33- 35.

3 *Massachusetts Institute of Technology President's Report* (Cambridge Massachusetts, 1914): 30, *Massachusetts Institute of Technology President's Report* (Cambridge Massachusetts, 1916): 31.

4 *Massachusetts Institute of Technology President's Report* (Cambridge Massachusetts, 1917): 26, and *Massachusetts Institute of Technology President's Report* (Cambridge Massachusetts, 1922): 43.

5 Haven Emerson, "Why an Infirmary," *Technology Review* vol. 31 (December 1928): 82.

6 For the ideas on medical treatment and education see Haven Emerson, "Why an Infirmary," *Technology Review* vol. 31 (December 1928): 81- 84.

7 See "Agreement Between the Subscribers to Richard M. Homberg Memorial Infirmary and Massachusetts Institute of Technology," [Office of the President AC 13, Box #23, Folder 77l, MIT Archives]. The agreement is not dated and not signed. However, from the result, we can infer that the specific condition remained until the end.

8 See "The Trend of Affairs: Infirmary," Technology Review vol.29 (May 1927): 405, and Letter to Mr. Rosenwald, unsigned, May 14, 1925, [Office of the President AC 13, Box #23, Folder 77l, MIT Archives] and Letter of Everett Morss to Dr. Stratton, March 3, 1926 [Office of the President AC 13, Box #23, Folder 77l, MIT Archives].

9 Letter of Carlson to Dr. Stratton, March, 23rd, 1927 [Office of the President AC 13, Box #23, Folder 77l, MIT Archives]

1928 [#31]

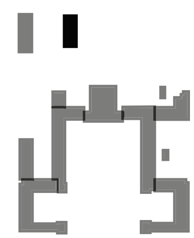


Fig. 77 : Aerial view of the campus, 1929. The Engine Testing Laboratories, a one storey Building have been added adjacent to the Guggenheim lab.

(7th step of tuning) Growth four_ Engine Testing Laboratory (1928)

"*In the field of aeronautical power plants, the year was marked by the completion of a building to house the laboratory equipment for aeronautical power plant, donated through the generosity of Messrs. H. M. Crane and A.P. Sloan, Jr. This is a one- story building approximately 60 feet by 150 feet, located to the east of the Guggenheim Laboratory*."[1]

As mentioned above, the Guggenheim Laboratory came as a relief to the need for more space the Institute. However, space was still not enough and in 1928 the construction of a second building for this purpose began. The building was partly funded by A.P. Sloan Jr., President of the General Motors Corporation at the time, a fact related to its use since the edifice would gather under its roof all the equipment, of all the departments, related to the research on "internal combustion engines."[2] The design was by Coolidge and Carlson and it was of a very sophisticated and technical nature since provision had to be made for sliding bars in order to fasten the engines on them, for "outlets for fuel, water and electric current," and for exits for gases produced.[3] The building was finally a one- storey structure, approximately 82' by 157', while according to the drawings, future buildings would be put, or at least considered on its east and west side.[4] The structural system was based on an almost regular grid of approximately 20' by 20'. Thus, the building introduced a completely new structural and spatial organization to the existing system, one that did not even exist in Bosworth's initial plan, probably because of its very special use **[78-81, 83]**.

Fig. 78 : View of the building with the Guggenheim labs at the back-ground.

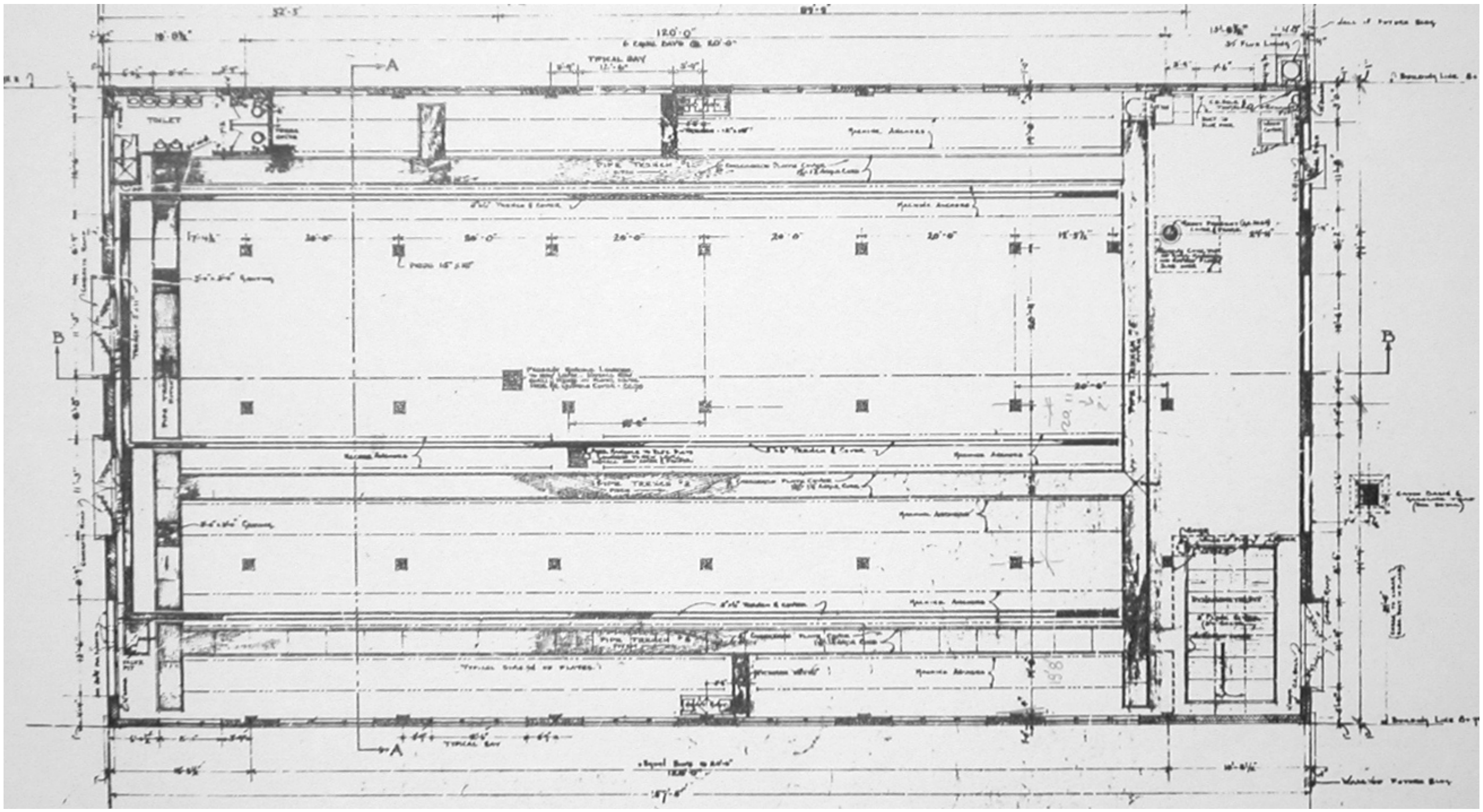


Fig. 79 : Plan of the new labs.

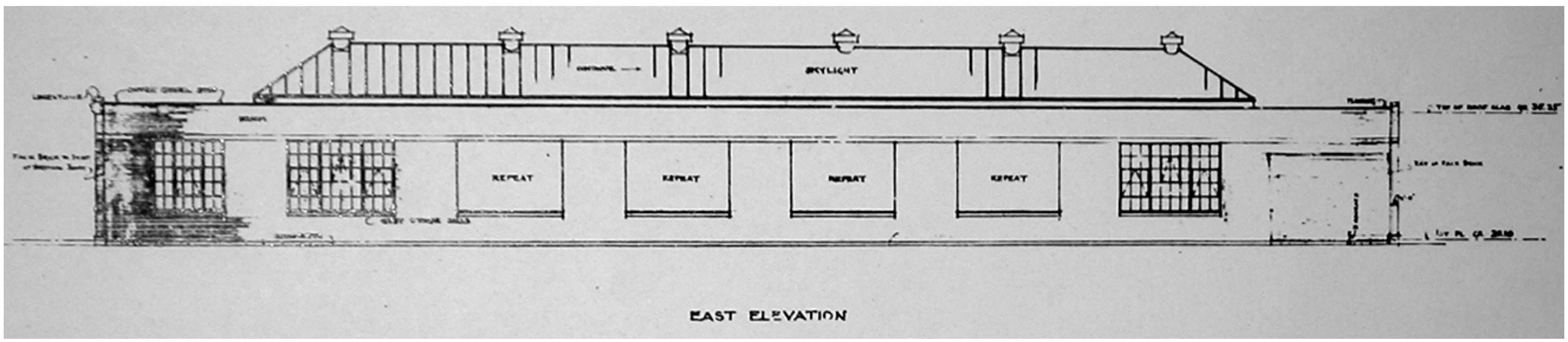


Fig. 80 : East Elevation.

Fig. 81 : Interior of the building. The picture is undated but we can get a fair view of the structure.

But the skeleton of the building was not the only novelty introduced. Strangely enough, although this had not been the case in any of the other growths, the building was located in a position that was not in accordance with the extension plan of Bosworth. More specifically, it was not an extension of the stems. My initial reaction to this was that the building was supposed to be a temporary structure. This idea was reinforced by a letter of Bosworth to Everett Morss, written at the time the building was being constructed. Bosworth congratulated MIT for enlarging the physical space of the Institute in accordance with what he called the "Phantom Plan." Furthermore, he said that building permanent structures on the perimeter of site and putting temporary and costless buildings in the interior was the right way in order to "accomplish the orderly disposal of the expansion on the Courts."[5] The first impression was that the terms "temporary" and "cheap" referred to the Engine Laboratory. Considering, however, the equipment and facilities of the building I realized that Bosworth was most probably referring to the existing temporary buildings like the ones that were demolished in order for the Guggenheim Laboratory to be located. This led to another thought according to which the Engine Laboratory did respect the "Phantom Plan." It seems to me that the building was located in one of the "phantom" secondary courts, in such a way that it could be immediately connected to a future building that would occupy the position of the stems. In other words, it seems that it was deemed that the building, although important, wasn't high enough, and as a result spacious enough to occupy a part of the future stems. More of an auxiliary nature, it was located in a void of the courts. This idea is enforced by the fact that "future buildings" were envisioned adjoining the east and west facades of the Engine Laboratory.

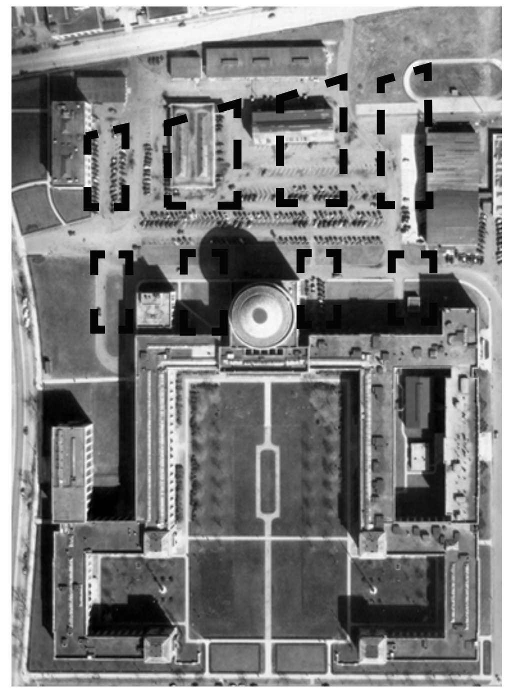


Fig. 82 : Secondary courts superimposed on an aerial view of the Campus.

Fig. 83 : Pratt School, Homberg Memorial and Testing Engines Lab before the construction of Building 7.

(Endnotes)

[1] *Massachusetts Institute of Technology President's Report* (Cambridge Massachusetts, 1929): 32- 33.

[2] *Massachusetts Institute of Technology President's Report* (Cambridge Massachusetts, 1929): 33.

[3] *Massachusetts Institute of Technology President's Report* (Cambridge Massachusetts, 1929): 33.

[4] Dimensions are based on the drawings of the building as found in the Archive of the Department of Facilities, See drawing MG 31 A01.01.

[5] Letter of William Welles Bosworth to Everett Morss, 26th January, 1929, p. 1 [Office of the President AC 13, Box #2, Folder 56, MIT Archives].

1932-33 [#6A, #6]

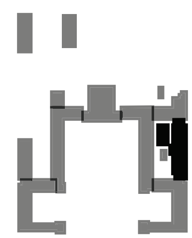


Fig. 84 : Aerial view of the Campus, 1933. The George Eastman Laboratories have enclosed the east secondary court.

(8th step of tuning) Growth five_ The George Eastman Research Laboratories (1933)

"*Last July The Review recorded President Compton's hope for a new physics and chemistry building at an early date… Funds for starting the building, which will join two wings of the present buildings on the east side of the main Technology educational group, are available from the gift of $2,500,000 donated by Mr. George Eastman in 1916, as a supplementary fund for additional educational buildings, when needed.*"[1]

As mentioned at the beginning of this chapter, Physics and Chemistry were part of the original curriculum of MIT when it was still called the School of Industrial Science. Physics were first taught by President Rogers who soon passed the torch to Professor Pickering. The latter, drawing from the principles that had been established by the former, founded the Physical Laboratory, the future "Rogers Laboratory of Physics," in order not only to enrich, but to base students' education on experimentation. The laboratory flourished and when the Institute moved to Cambridge it was comprised of about sixteen different branches, the "Laboratory of Mechanics, Optics and Heat," the "Laboratory of Applied Electrochemistry" and the "Laboratories allotted to Optics, Photography, Photometry, Spectroscopy, Radiation," just to name a few. The Department soon grew even more in terms of fields of study while the creation of the Division of Industrial Co- operation and Research in March of 1921, which channeled many of the Department's graduates into key professional positions, revealed the measure of the importance that Physics and men trained in it held in industry.[2] Overall, it appears that Physics, at the time, played an important role in the academic life of the Institute.

The same robust research environment existed in the Department of Chemistry. Instruction in Chemistry had also been based right from the start on experiments conducted in the framework of a laboratory. This Department also grew and until 1932 almost half of the Doctor Degrees of the Institute had been granted to Chemistry graduates. Its importance became quite evident during the war years when Europe could not provide the necessary trained men. In the framework of this Department, the Course in Chemical Engineering, which later on became a Department on its own, and the Research Laboratories of Applied Chemistry, of Physical Chemistry, and of Organic and Inorganic Chemistry were created.[3]

When the Institute moved to Cambridge, Buildings 6 and 8 were devoted to the study of Physics and Chemistry, a fact that denotes their importance. However, from as early as 1920 the two growing departments started to invade space in the Institute which was formerly allocated to other departments, like room on the 4th floor of the Mining Buildings or in the barracks that had been built during the war. Pretty soon appeals for more space from both departments became particularly intense. Additional space was needed for offices, for research, for more flexible labs, as well as for a big lecture room similar to the one in 10-250. Congestion became such a big issue, that in the Department of Chemistry, although the number of applicants was very high due to the importance of the field, the number of accepted students had to be restricted. Furthermore in the late 20s, competition from other schools and insufficient space and equipment in the department made it difficult to retain capable instructors. Although, in 1925 a mention was made that the most "economical" solution to the problem would be a new wing between Buildings 2 and 8, no implementation steps were taken at the time in order to remedy the situation.[4]

This new wing became, finally, a reality with the presidency of Karl Taylor Compton, who, being a physicist, spent a lot of time, along with many members of the instructing staff, and the architects Coolidge and Carlson, on the program and the design of the new building. What was finally decided was that it should include ample facilities and excellent equipment for shop work, labs, a new library, a big lecture room that would feature equipment for film projection, a spectroscopy laboratory, as well as a room especially designed for social and extracurricular activities. The most important conditions that were set were that the labs should be designed in such a way in order to allow for future flexibility, while the whole building should be free from vibrations due to the delicacy of the experimental measurements in physics and chemistry. Furthermore, the spectroscopic laboratory posed a whole set of restrictions on its own: to begin with, the corresponding equipment called for a room with at least one side of 40' and free of any interfering columns. In addition, the laboratory would be much more sensitive to vibrations than any other part of the building while it would be absolutely necessary that the temperature in it be kept at a stable degree.[5]

What was proposed and finally built in order to satisfy the aforementioned needs was a 60' wide and approximately 300' long, four storey building with a basement **[85]**. The structure featuring in most of its parts a regular bay of 14'6" and a double loaded corridor, 8'1" wide, was based on the first type of stem of Bosworth, including also the wire shafts on each part of most of the columns. Connection with the two existing buildings, namely present Buildings 2 and 8 was retained at all levels, while a separate entrance and staircase were put at the middle part of the building. The shops were concentrated at the basement, the library was located at a mezzanine over the lecture room and on the third floor, while a big assembly space, the "Forris Jewett Moore Room," was found on the third floor opposite the book stacks.[6] Labs, research rooms, classrooms and offices fit in the rest of the unit- sections. Not everything, however, was included in this structural and organizational framework. First the big lecture room located on the first floor and also occupying the height of the second floor, protruded towards the secondary court from the constant width **[87- 90]**. This was still another indication of the inability of the stem system to house large spaces and still retain continuity in circulation. Secondly, the spectroscopy lab, not being able to fit in the skeleton of this building was finally housed in a separate edifice, approximately 52' wide and 92' long, which was put in the secondary east court **[90]**. Connection with the main group was achieved through a corridor that led to the basement of the new wing **[86, 91]**. In order to deal with vibrations, both buildings were laid on very sophisticated types of foundations; for example, for the new wing, approximately "3,000 piles of reinforced concrete" were used, while the spectroscopy's foundation was "more than three feet thick, and composed of alternate layers of sand, felt, transite board, ground cork, and reinforced concrete."[7]

Fig. 85: Rendering of the George Eastman Laboratories.

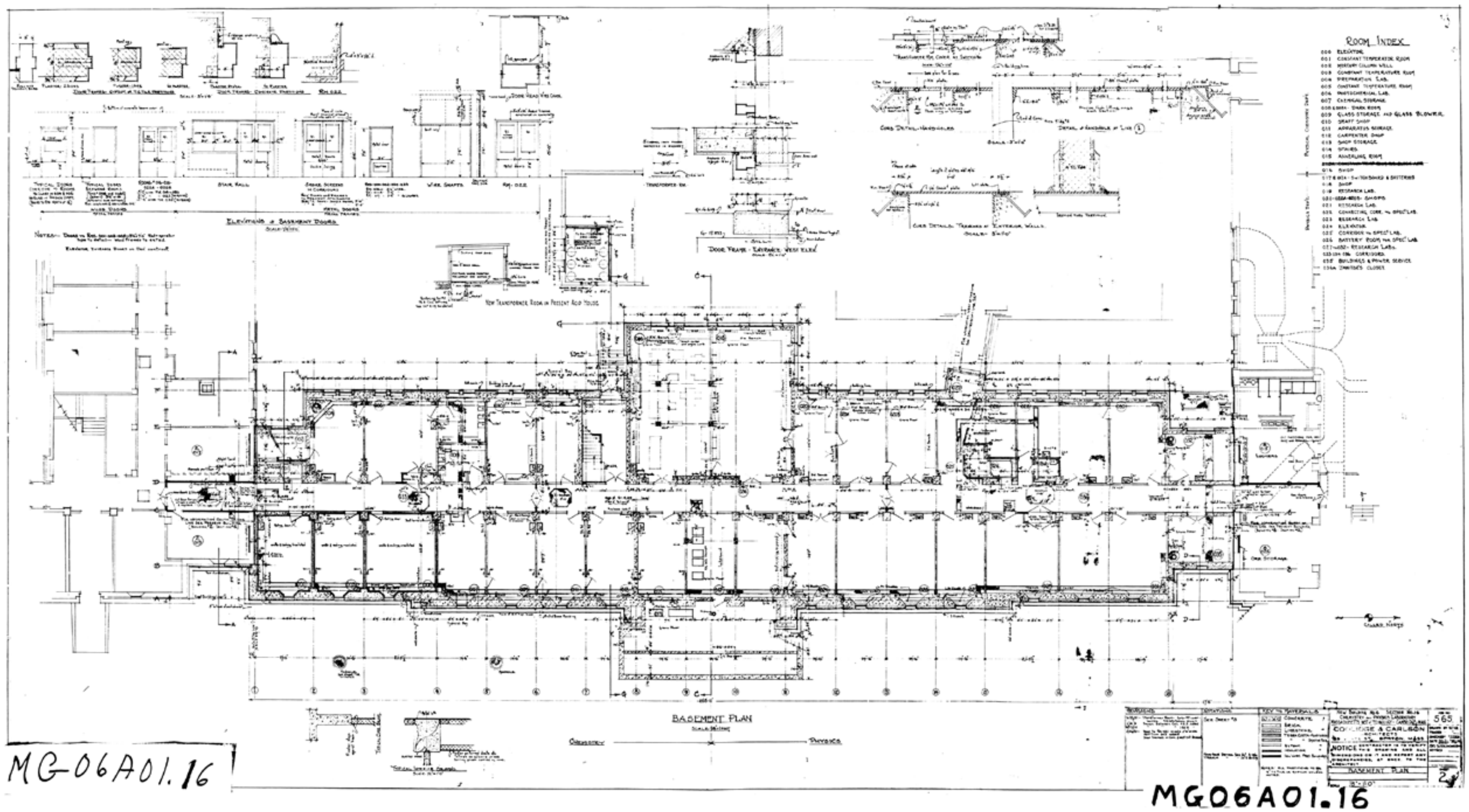


Fig. 86: Basement Plan. The connection with the Spectroscopy Laboratory at the top right corner is discerned.

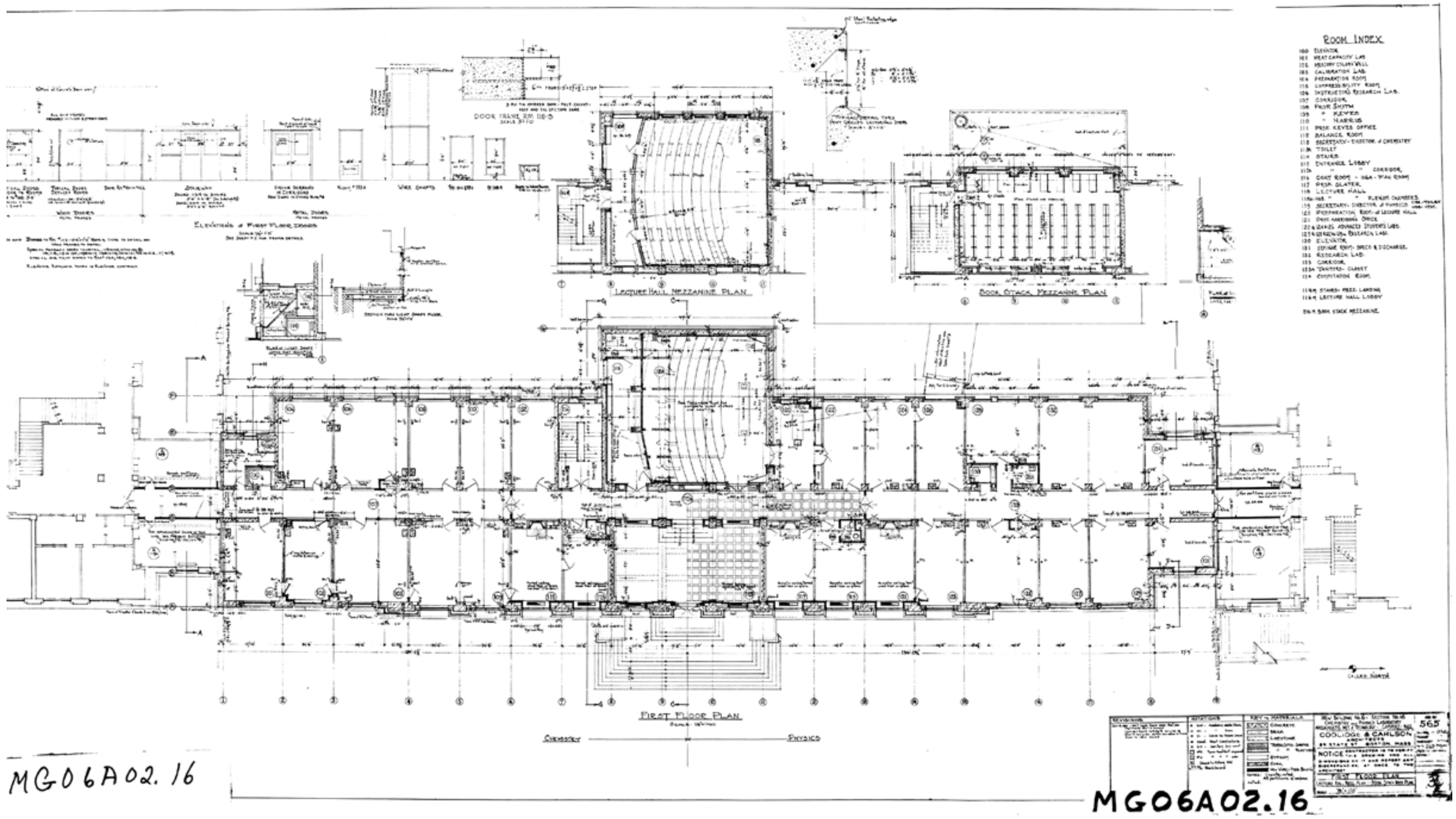


Fig. 87: First Floor Plan. The large lecture hall protrudes from the constant width of the building.

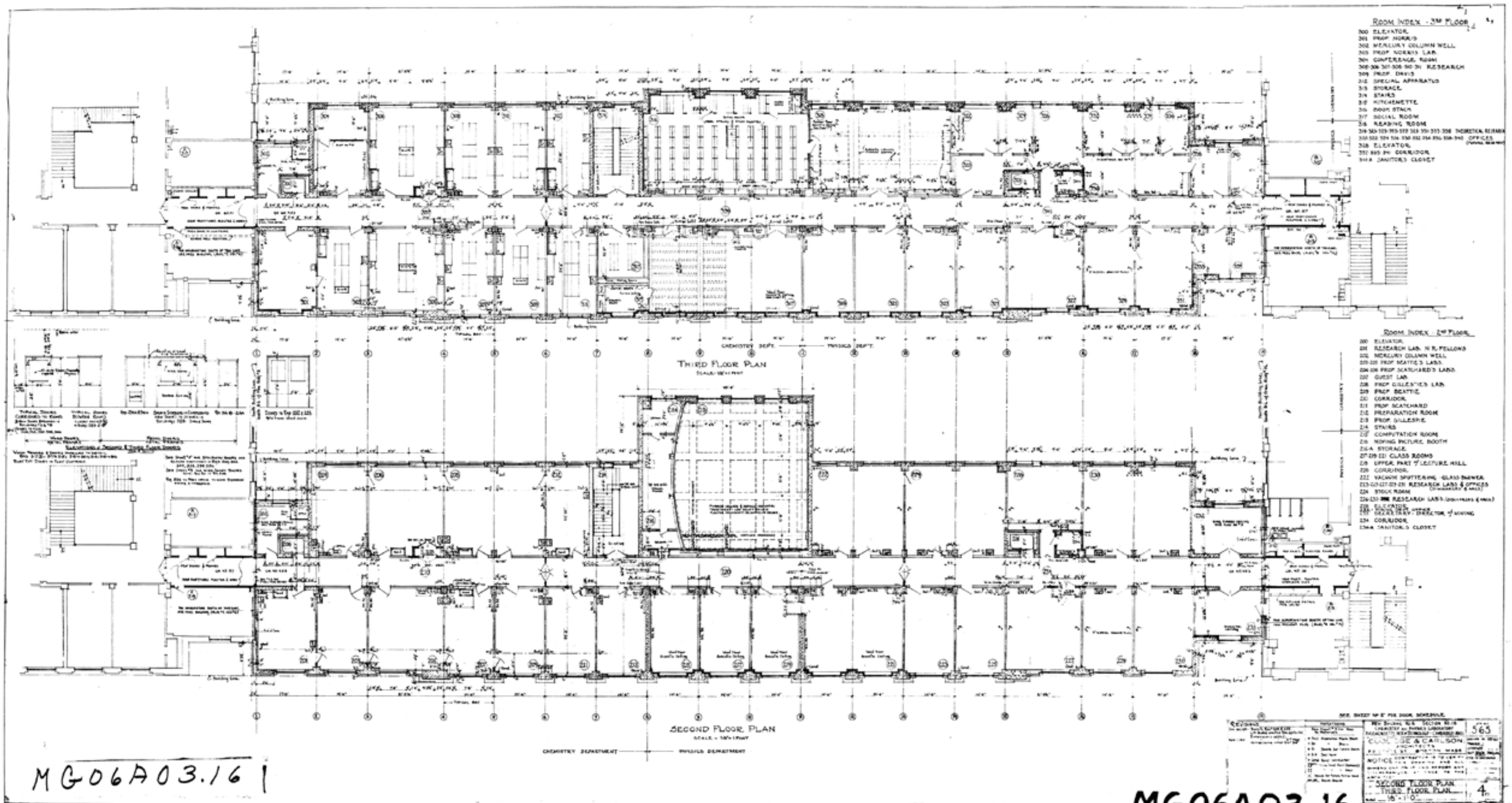


Fig. 88: Second and Third Floor Plan.

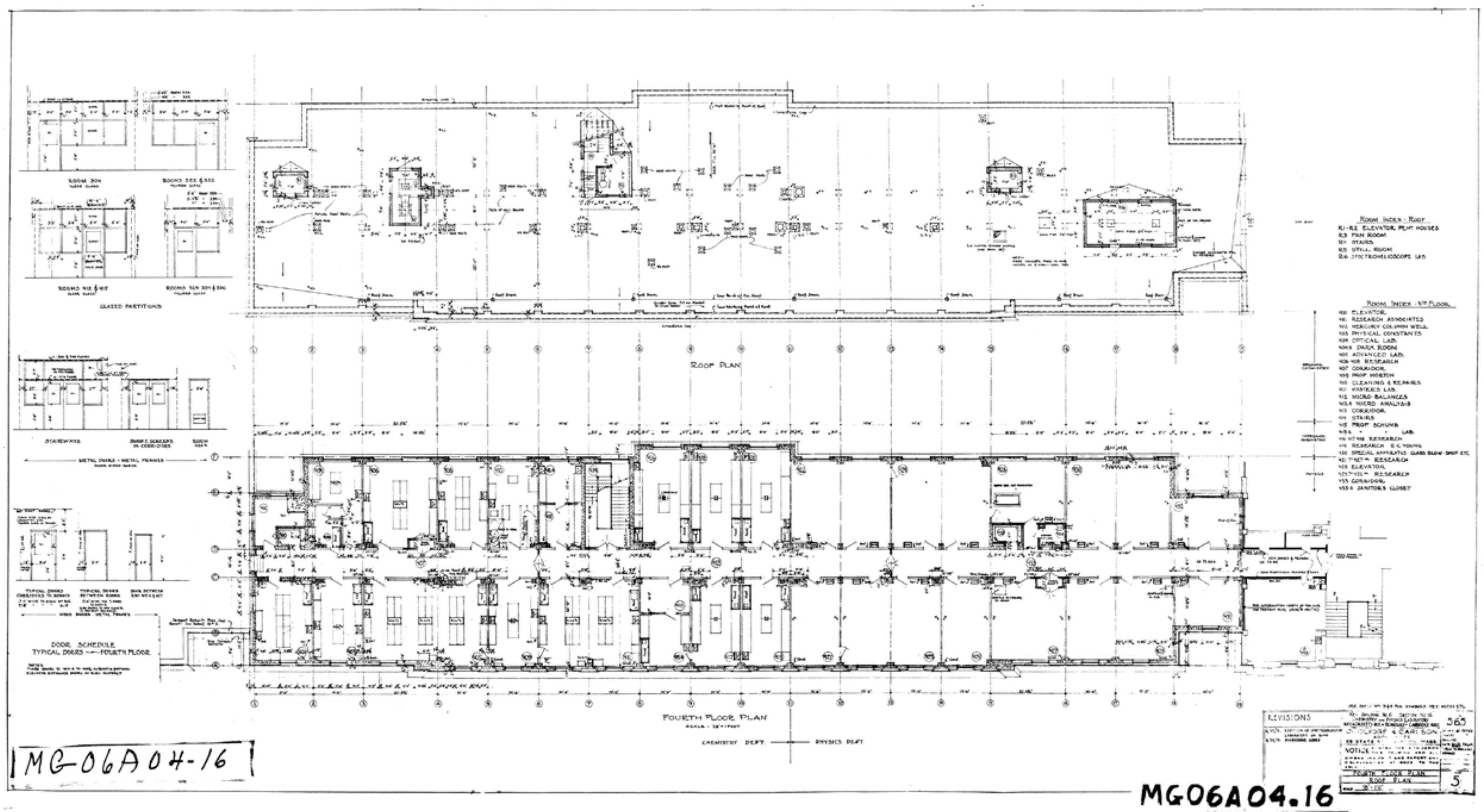


Fig. 89: Fourth Floor Plan.

Fig. 90: Photo taken during construction. The Spectroscopy Laboratory is the roofed edifice at the north side of the court.

Fig. 91: Construction of the connection of the Spectroscopy Laboratory to the new wing.

(Endnotes)

[1] "The Institute Gazette: Physics and Chemistry Building," *Technology Review* vol. 33 (December 1930): 145.

[2] See H. M. Goodwin, "Physics at M.I.T.: A History of the Department form 1865-1933," *Technology Review* vol. 35 (December 1930): 287, and *Massachusetts Institute of Technology President's Report* (Cambridge Massachusetts, 1921): 18..

[3] Tenney L. Davis, "Chemistry at M.I.T.: A History of the Department from 1865- 1933," *Technology Review* vol. 35 (April 1933): 250- 266,268,270- 272, and *Massachusetts Institute of Technology President's Report* (Cambridge Massachusetts, 1916): 18- 23.

[4] See Reports of the corresponding departments in *Massachusetts Institute of Technology President's Report* (Cambridge Massachusetts) for the years 1920-1929. For the proposition made in 1926 see *Massachusetts Institute of Technology President's Report* (Cambridge Massachusetts, 1925): 34.

[5] See "Karl Taylor Compton- the Scientist," *Technology Review* vol. 60 (November 1957): 27, and "The Institute Gazette: Physics and Chemistry Building," *Technology Review* vol. 33 (December 1930): 145.

[6] Tenney L. Davis, "Chemistry at M.I.T.: A History of the Department from 1865-1933," *Technology Review* vol. 35 (April 1933): 272.

[7] Caroline Shillaber, "Architecture of MIT Buildings: Part I," *Technology Review* vol. 56 (April 1954): 324, and "The Institute Gazette: Physics and Chemistry Building," *Technology Review* vol. 33 (December 1930): 145

It is with the construction of the Eastman Laboratories that the study of growth in MIT concludes in this thesis. The reasons, as mentioned in the introduction, are mainly practical. Although I would have liked very much to include what now comprises the single and unified mega-structure of the main MIT Campus, time did not allow me to do so. However, I believe that even with these five steps of tuning, in terms of growth, we can form valuable conclusions about adaptable forms. Furthermore, the mega- structure is there and even if we cannot know at a micro-scale, evident in old drawings, how exactly the growth occurred, we know that it did. Thus, up to a point we can re-confirm secondary hypotheses and assertions. But before wrapping-up, it is necessary to go through the second type of fine tuning examined in this thesis the more tentative one. During the growth of MIT's building system, another type of transformation was taking place in the interior in order to respond to changing needs and releasing of space or exchange of it among departments.

Internal Change as an Attempt of Tuning_ The Case of Building 3.

"*The old ship "Copernicus" as it was known to the Technology "gobs," is having old walls torn down and new ones erected in order to house the Mechanical Engineering Department properly. The former Civil Engineering Museum is being subdivided into offices and a laboratory. Other rooms are either being enlarged or made smaller according to the wishes of the department.*"[1]

It would be interesting to observe how often the intention of a designer is actually discerned or implemented by the users of the designer's physical product. Although a complete obedience would be a dreadful situation to imagine, a simple understanding of the potentialities of the physical form would be, in my mind, a rewarding experience for both actors. I could argue that in the case of MIT this understanding has been more than clear, and Bosworth's, or Freeman's, intention for a 'manipulatable' form has been fully realized. In the case of Building 3, from the early 50s until the mid 90s, *at least* 39 projects, including multiple additions, eliminations and movements of partitions, doors or other interior openings, have taken place leading to a constant renewal of the spatial configuration. I say "*at least*" because, as mentioned in the introduction, not all of these projects have been documented in drawings, or at least drawings of every change are not saved. But still, what is reproduced here is enough for lessons to be learned. In the case of the fourth floor in particular, it seems like we can have an accurate view of the changes that have occurred. Furthermore, the presentation to follow is more of a qualitative nature trying to describe internal change, and as a result numbers do not matter as much.

A study of change at this scale brings to the surface again the issue of language, and the difference between form and activity. If one wanted to include every *type of change* that can occur to the interior of a building, undeniably one would have to study the following; first, change in space configuration, or *internal change* as this has been defined in this thesis; secondly, *change in use*; and finally, an *update of equipment* or furniture. In this thesis, however, I chose to work mainly with the drawings that documented the first type of change, as it is the only one that is closely related with the formal attributes of a building. The last two usually can occur either as a building permits it or not, according to the degree to which the user will have to compromise with the appropriateness of the space for a different use. Furthermore, most of the documented changes in use, at least in the case of Building 3 in MIT, were accompanied by a change in spatial configuration. Thus, the study of the first type of change will allow for a fair view of the second as well. This way, one can have a general view of the degree of the robustness of a building as a shell, according to the complexity of the changes it allowed. The changes in use are noted in the presentation that follows for another reason; I have not been able to find many stories relating to the reasons that caused these internal changes. The changes in use compliment this deficiency as they provide a rough indicator of the changes in the needs of the Institute.

The two stories that I have found however, provide an indication of how changes in the curriculum of a school can cause physical transformations. It is important to mention at this point that throughout the years most of the south wing of Building 3 has been occupied by the Department of Mechanical Engineering. The north wing has been used partly by Engineers and partly for administrative purposes, while after a point it has also housed the Department of Architecture. The stories regard the parts that were used by the engineers and explain the changes of the '60s. When the Institute moved to Cambridge, the education of the Engineer was based to a considerable degree on the study of the function of machines and on their design. As a result, a substantial amount of the area corresponding to the Department was occupied by the Steam Laboratory, the equipment of which demanded the space volume of a three-storey crane well, and by Drafting Rooms. However, as time went by, the machines of the Steam Laboratory were rendered ineffective and of no use in regard to the experiments that had to take place. Research was moving to other fields such as "heat transfer" and "gas turbines."[2] As a result, the big machines were finally taken away, the crane was filled- in and in the place of the Steam Laboratory the "Engineering Projects Laboratory" was built. Furthermore, design stopped being a part of the curriculum and the fourth floor, where the drafting rooms had been located, was subdivided into smaller rooms.[3]

Regardless of similar stories, one could outline the following from the observation of the internal changes that have been documented [see diagrams at the following pages]. First, the *framework* provided from the original plan has been followed in the transformations. In other words, users have in most cases put the partitions on the lines of the invisible grid formed by the columns of the stem; one by one the "bookcases" of Freeman have been filled in. Exceptions are some small, partial transformations in which the partitions have been put against the sill of a window, and the transformations that have occurred in the basement of the building. Furthermore, although the south wing of the building is of the second type of stem, where a corridor is not defined as clearly as in the first, a straightforward corridor has been kept during most transformations. Exceptions have occurred, like on the first floor, as well as on the fourth towards the end of the time period. This last change indicates that as time went by, internal change became more complicated and involved more spatial layouts than the ones included in the original plan. In general terms however, Building 3, while being transformed, tended to present the image of the original first floor of Building 4, or in other words, the image of a “fulfilled” stem.

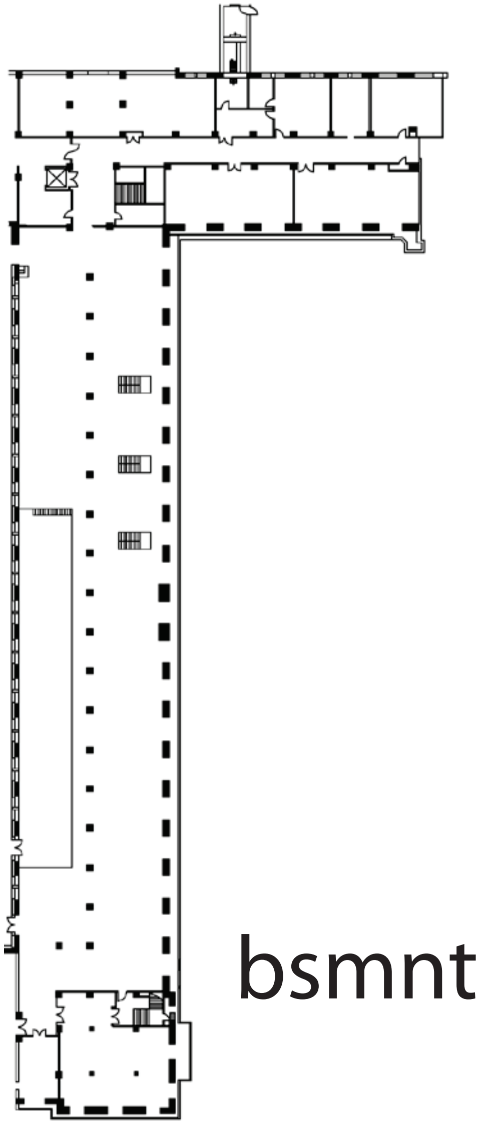
The second remark regards the *distribution of room sizes* across time. Throughout the floors, what took place was a continuous clipping and subdivision of spaces. This, as explained above, is due to the fact that as time went by, the heavy machinery and big sized equipment necessary for the instruction of mechanical engineers moved out of the building and teaching started to take place in small labs and classrooms. From a size of about 14,400 square feet (30 unit- sections) that was the case in the early years of the Institute, we see towards the end that the majority of rooms are of the sizes of 960 square feet (2 unit sections), 480 square feet (1 unit- section) and 300 square feet (part of unit- section). This *distribution of room sizes* across time indicates another factor especially useful for describing transformations, namely the *grain of change*; regardless of the size of the area that is being filled in during each transformation, there is each time an average room size which most of the time ranges between 960 square feet and 300 square feet. The *distribution of uses* across room size does not seem to present any regularity except for the fact that classrooms are usually of the size of 960 square feet, while the smaller rooms range from labs to offices or research rooms.

I would like at this point to make another remark related to use, although this might be a little rushed and not completely substantiated. I have not studied any heating, plumbing, or electric drawings, due to lack of time and as a result I am not in a position to know what kind of alterations in services accompanied these internal changes. However, it seems to me that spaces in Building 3 that were more equipped than the ordinary classrooms or offices didn’t get transformed at all. I am referring to the three lecture rooms, 3- 270 and 3-370, at the south knuckle, and 3-133. Since their construction these spaces have only undergone renovations and updates of equipment, in contrast to spaces around them that have been transformed and changed in terms of use. This might suggest that the initial provision of the basic services only renders a space more adaptable, as no consideration would have to be given to the cost of demounting any expensive equipment.

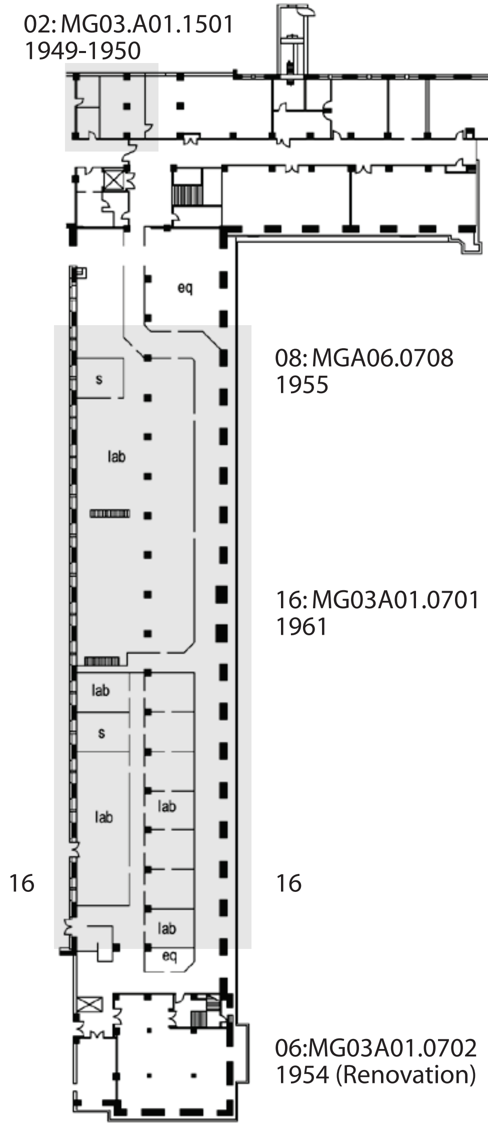
The final remark regards the *medium* by which this internal change took place. Users have been perfectly conscious of the fact that the possibility for future adaptability needed to be preserved. As a result the materials that were used for the construction of the internal partitions were light ones, which could be easily dismantled and removed. At the beginning cinder blocks were used and after a while gypsum boards mounted on metal stand. Furthermore, standardization was kept throughout time in terms of opening sizes. As a result, many doors have been relocated and reused.

[PAGES 158- 170] Internal Change Diagrams: The diagrams are based on the MIT floorplans as found in the site of the MIT Department of Facilities. The floorplans have been brought in their original condition and then changes have been added one by one according to the drawings found in the Facilities Archive. The final stage is the present one as drawn by the Department of Facilities. As mentioned in the Introduction, changes should be considered indicative and not fully descriptive. Furthermore many of them correspond to the existing condition of the another change, which very often differs from the final condition of a previous change. A number is assigned to each change according to the time that it has occured. The codes noted next to each number are the codes of the corresponding drawings.

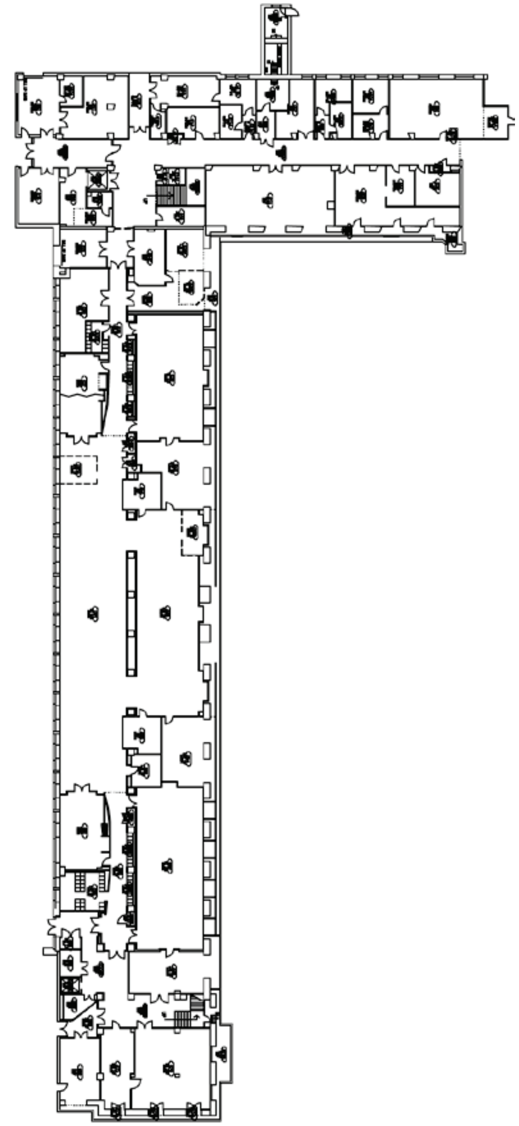
USES
clsr: classroom
lct: lecture hall
of: office
s: services:
eq: equipment
lab: laboratory



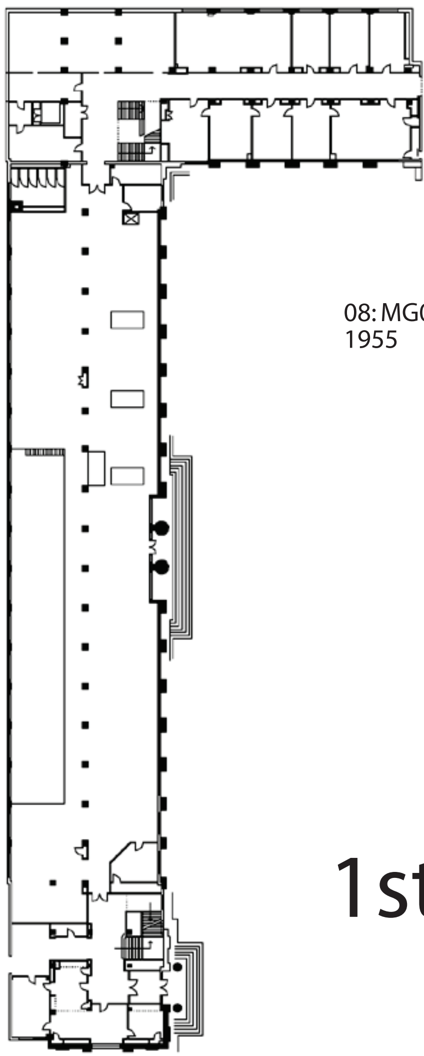
Basement [1]



Basement [2]

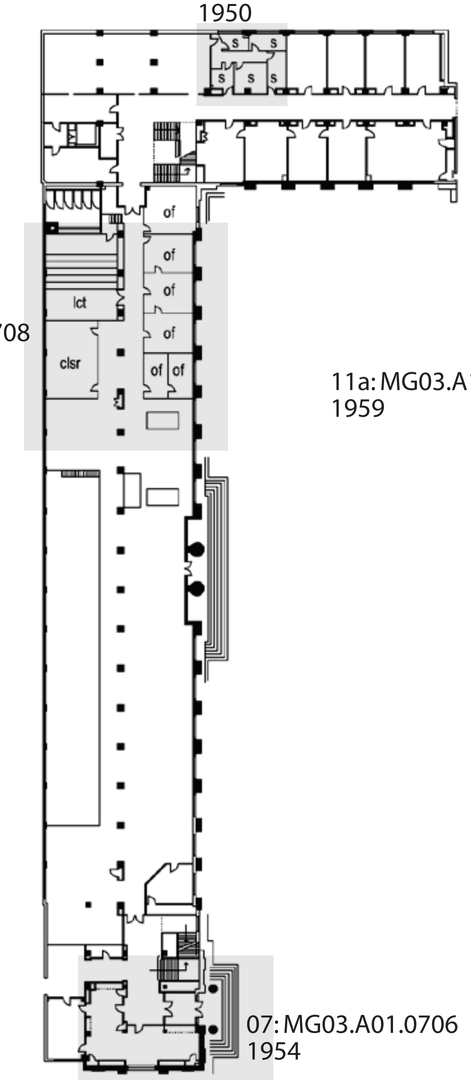


Basement [3]

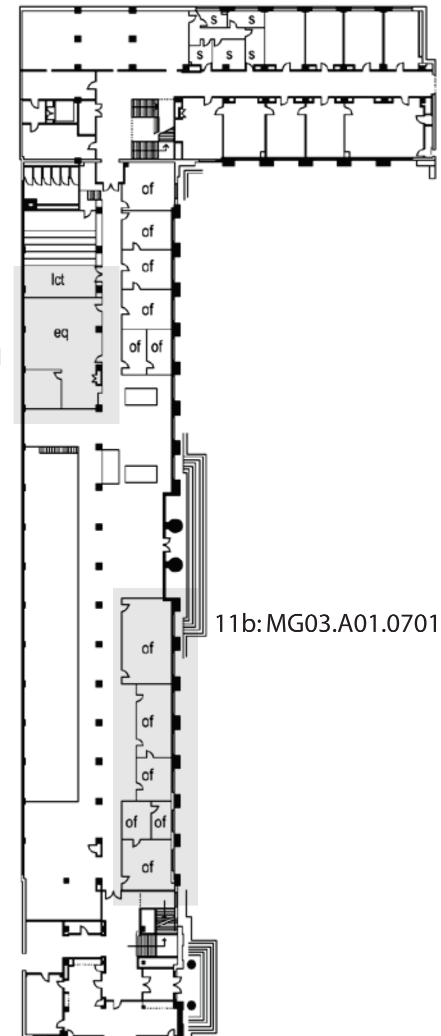


First Floor [1]

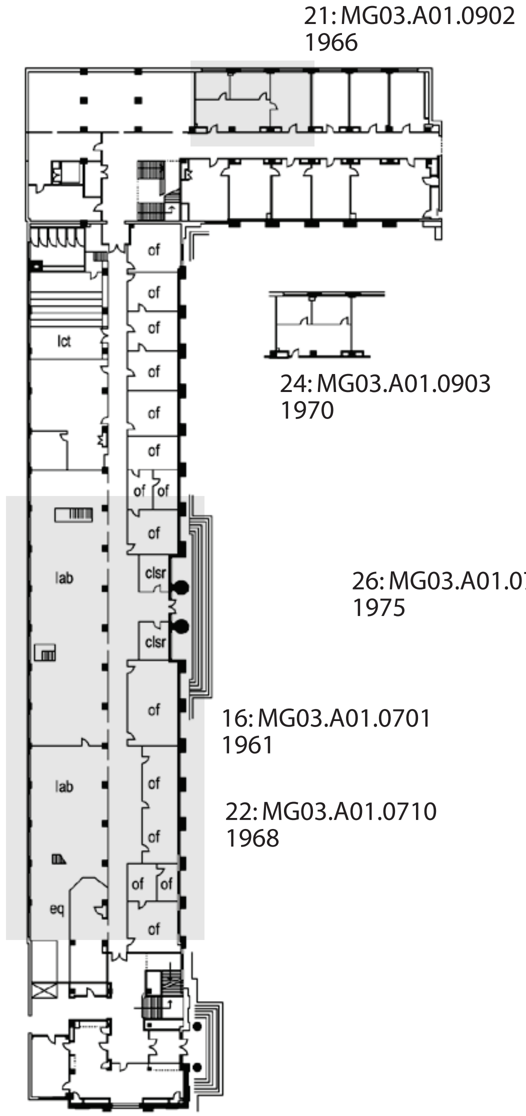
1st



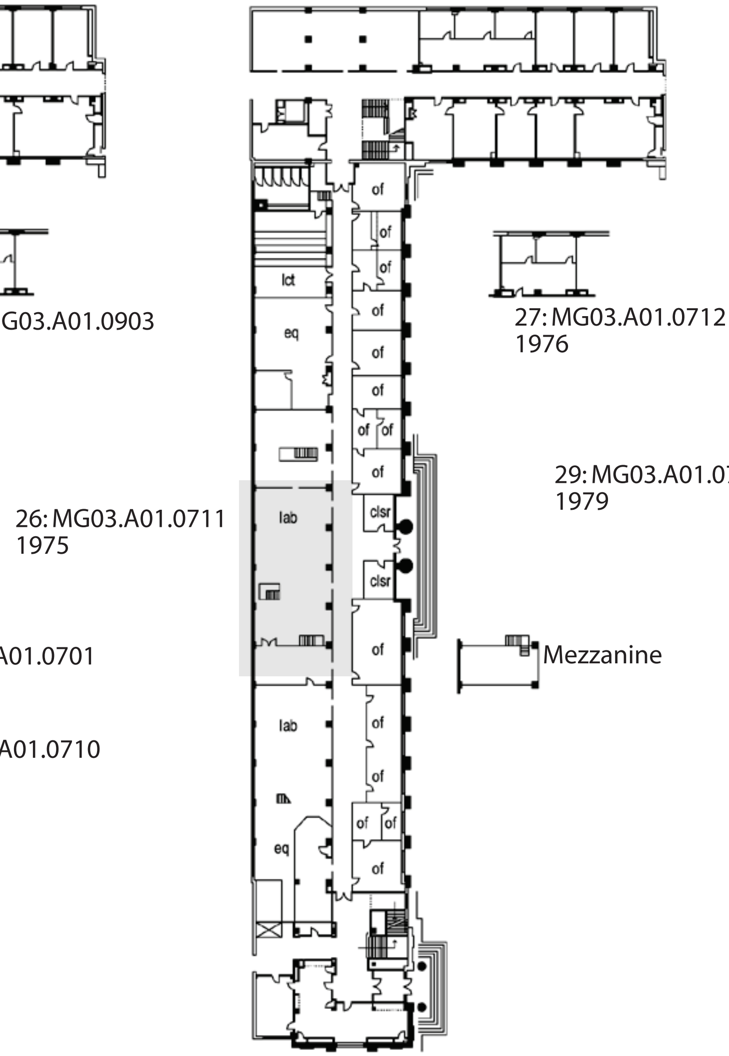
First Floor [2]



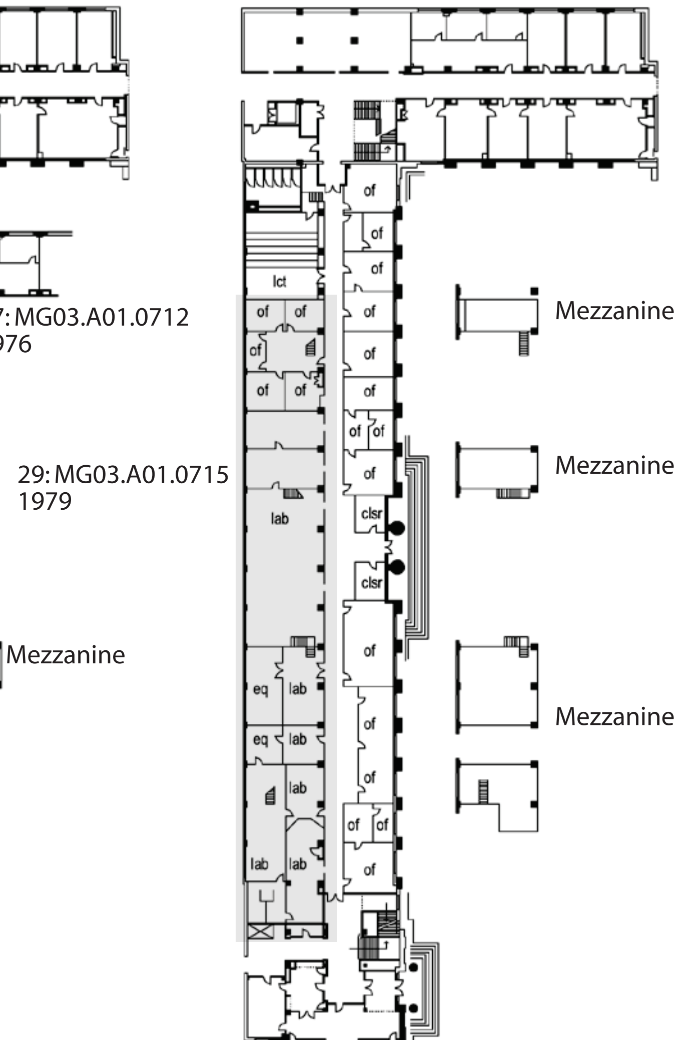
First Floor [3]



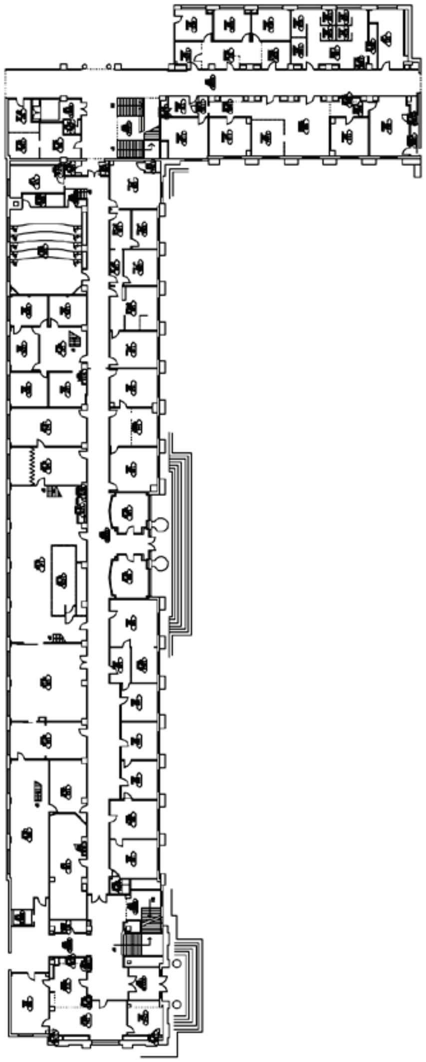
First Floor [4]



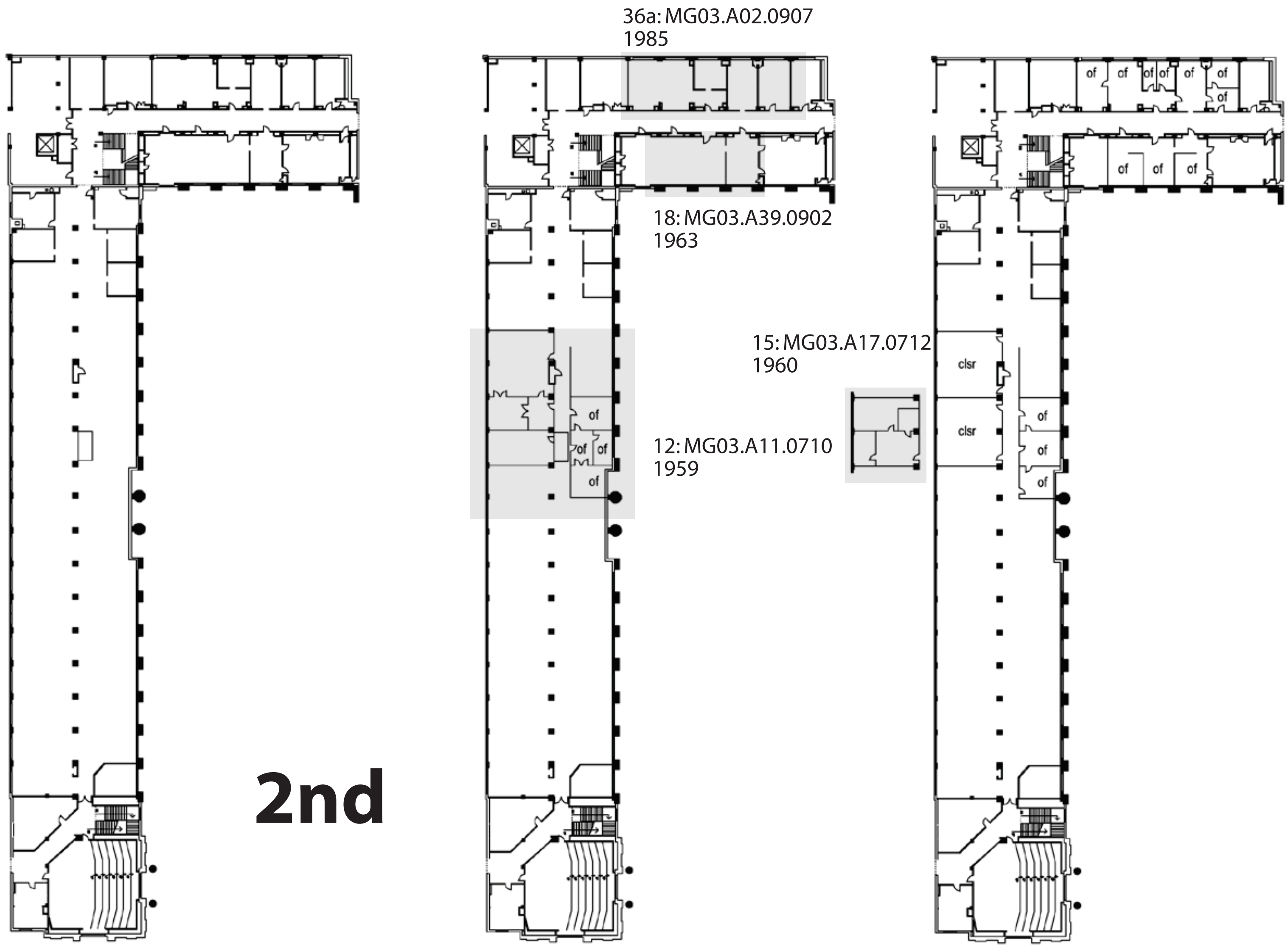
First Floor [5]



First Floor [6]



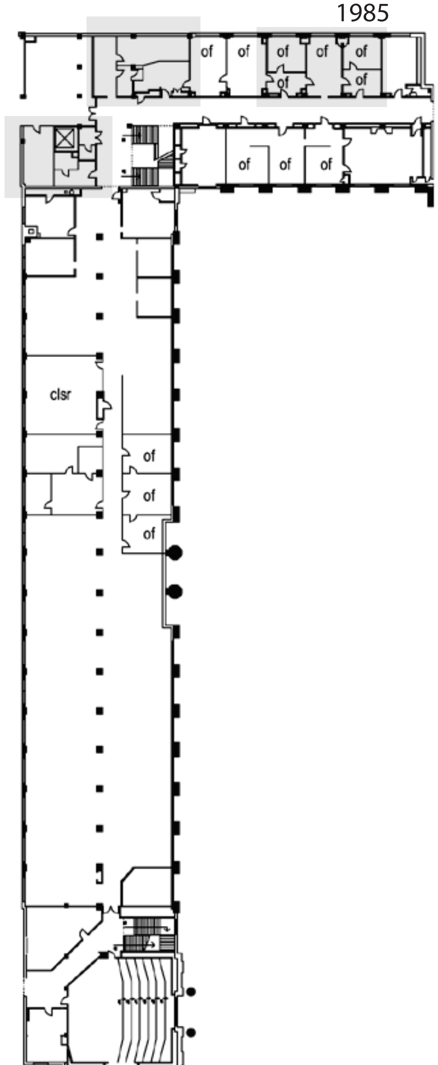
First Floor [7]



Second Floor [1] **Second Floor [2]** **Second Floor [3]**

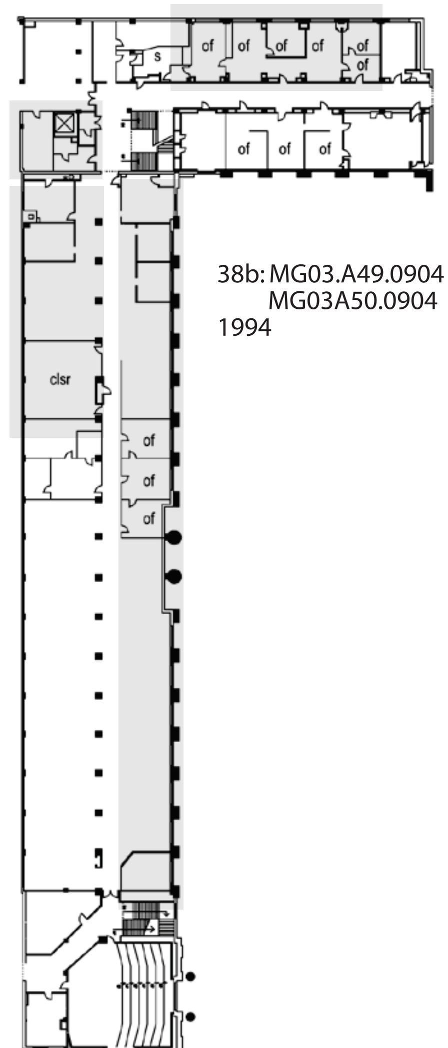
38a: MG03.A49.0904

36b: MG03.A02.0907
1985

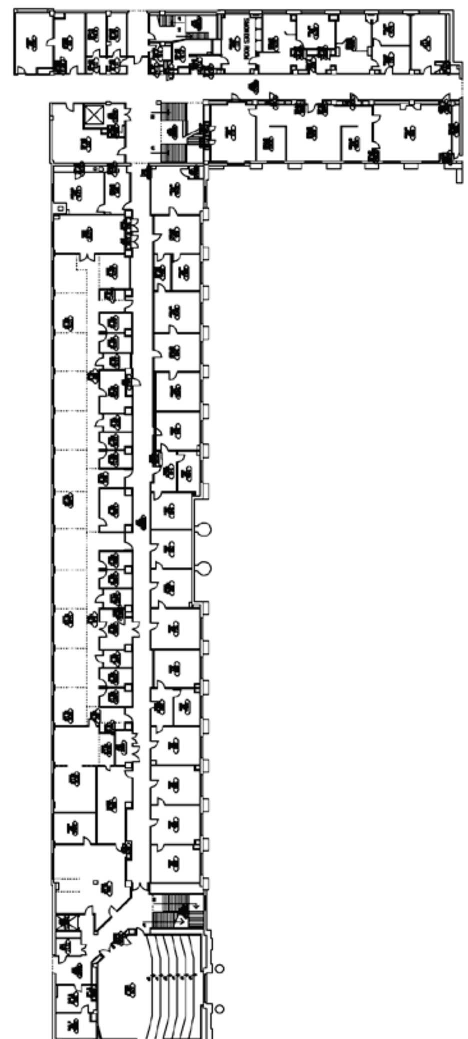


Second Floor[4]

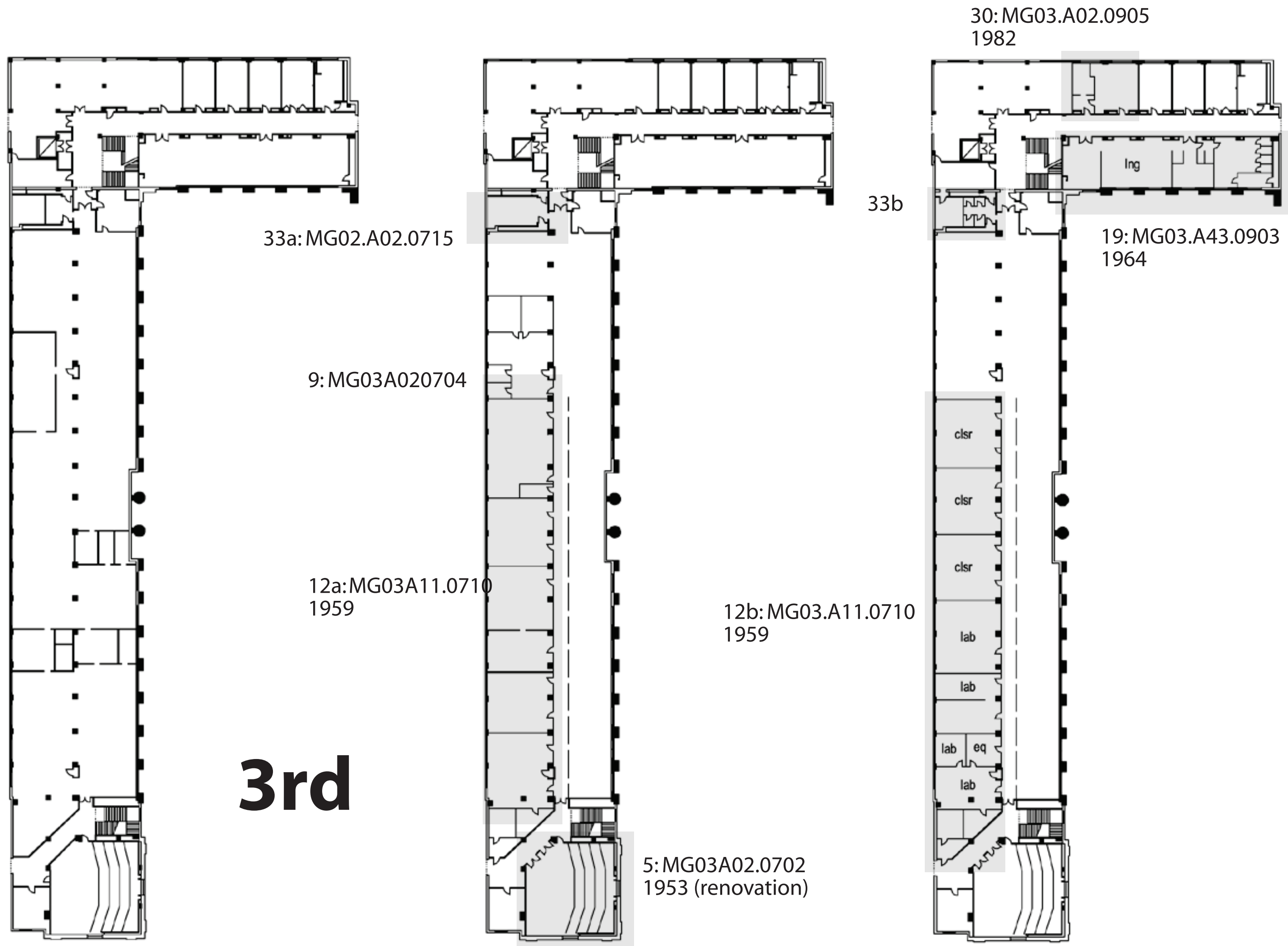
38b: MG03.A49.0904
MG03A50.0904
1994



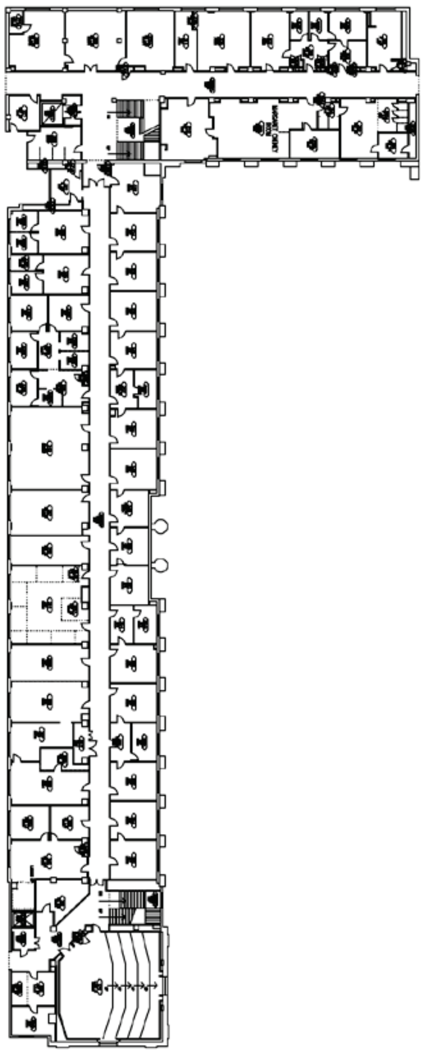
Second Floor [5]



Second Floor [6]



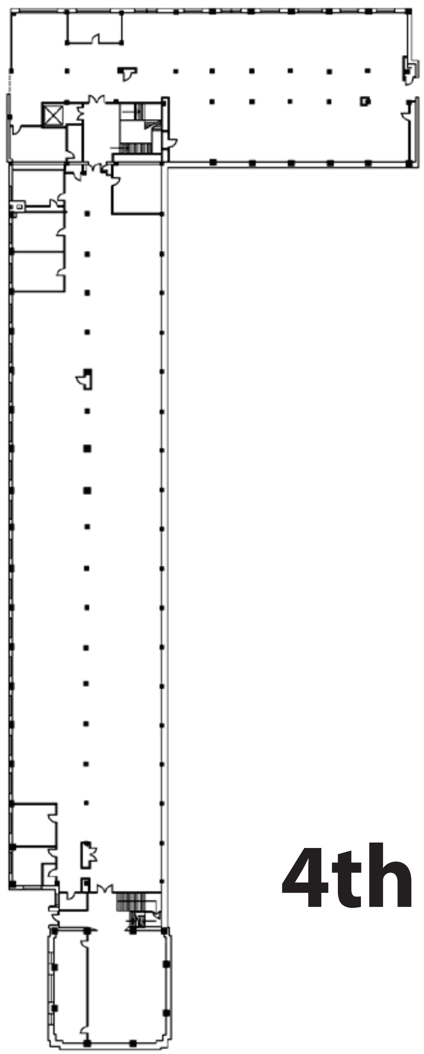
Third Floor [1] **Third Floor [2]** **Third Floor [3]**



Third Floor [4]

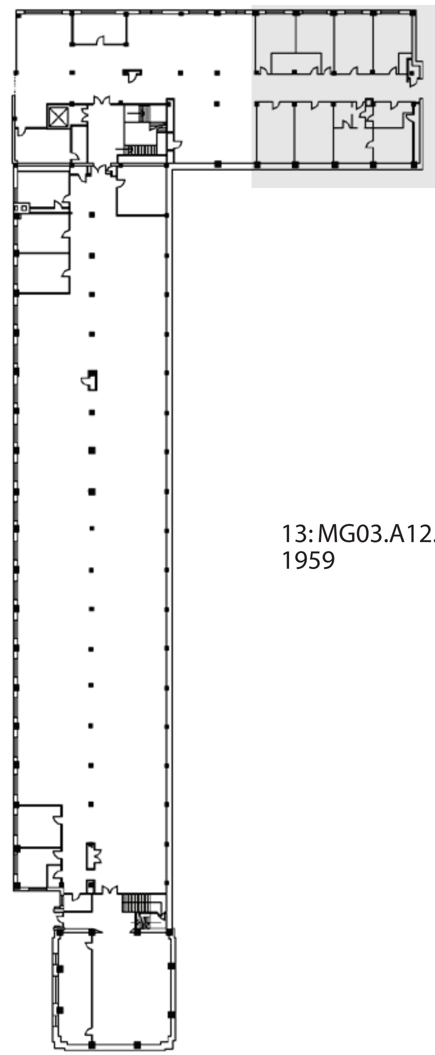
3a: MG03.A03.0901
1952

3b



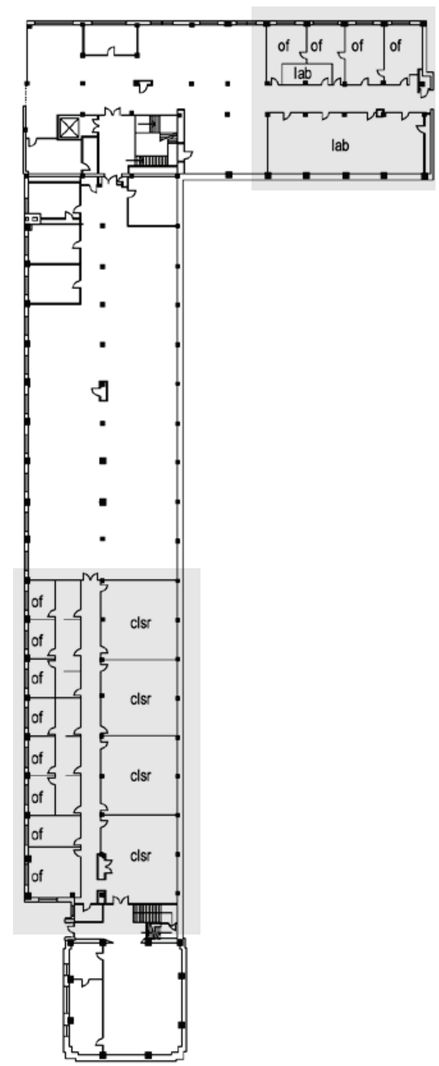
4th

Fourth Floor [1]



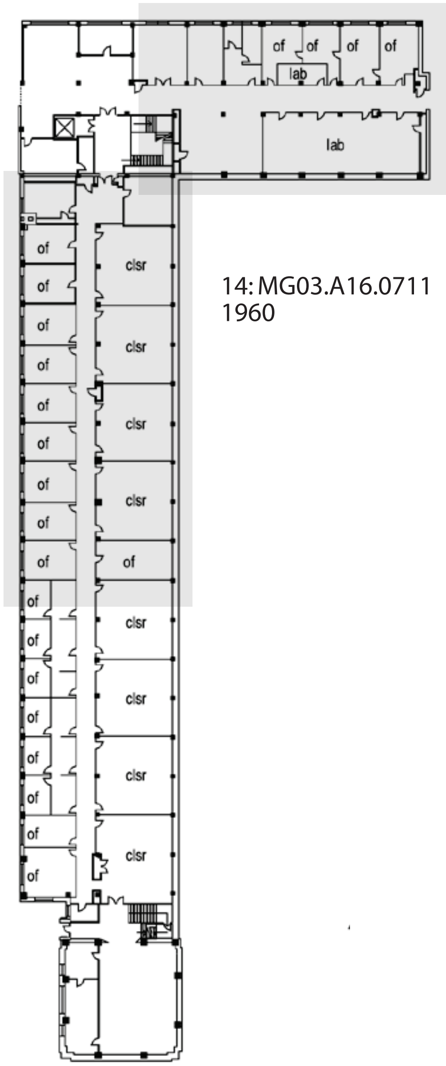
Fourth Floor [2]

13: MG03.A12.0710
1959



Fourth Floor [3]

31a:

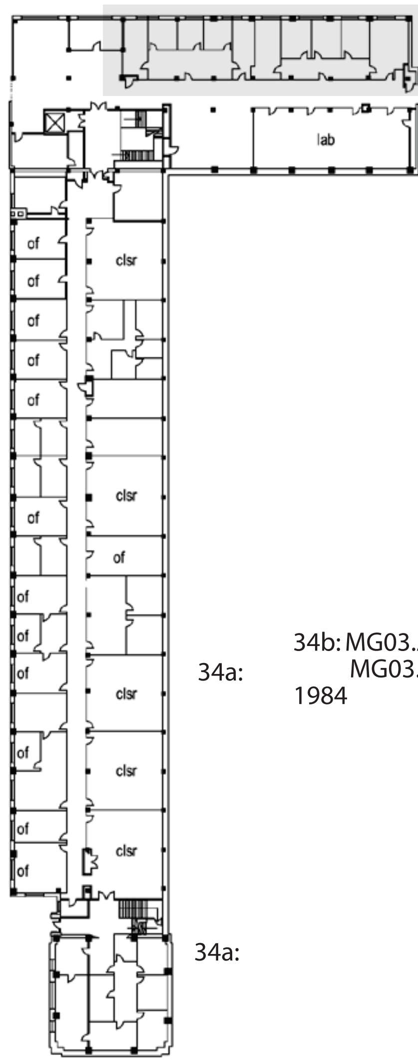


14: MG03.A16.0711
1960

34a:

Fourth Floor [4]

31b: MG03.A03.0903
1982

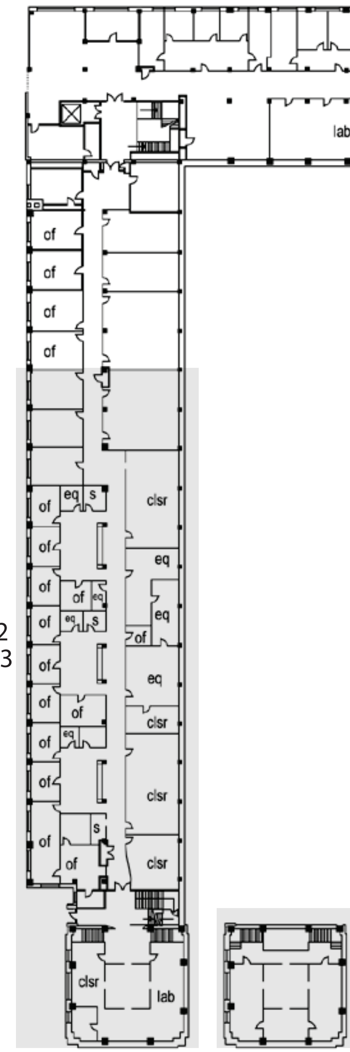


34a:

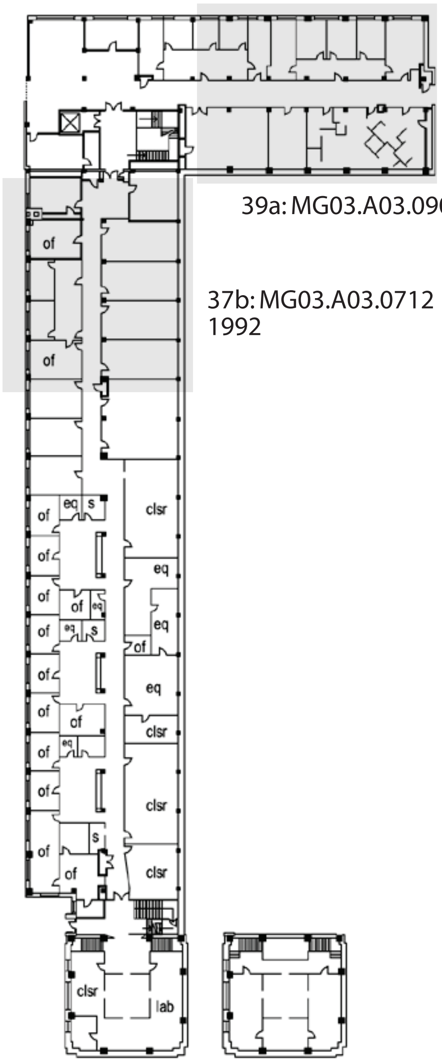
34a:

Fourth Floor [5]

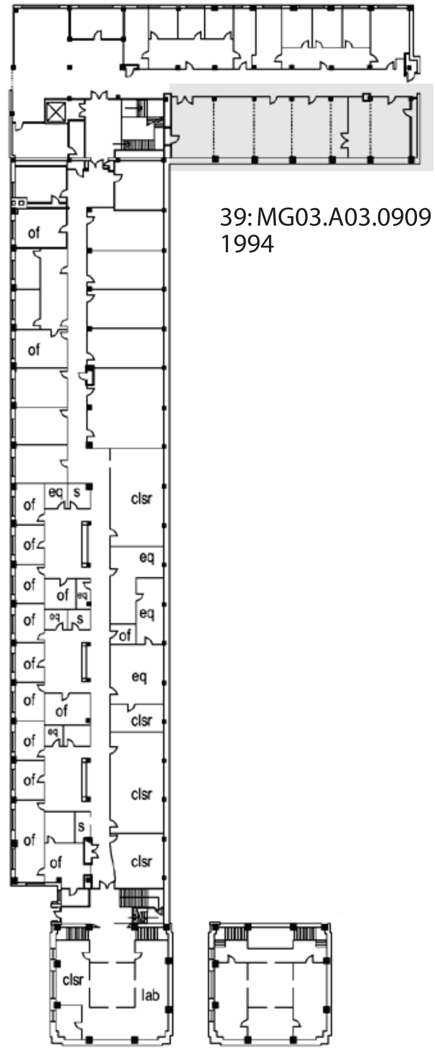
34b: MG03.A03.0702
MG03.A03.0703
1984



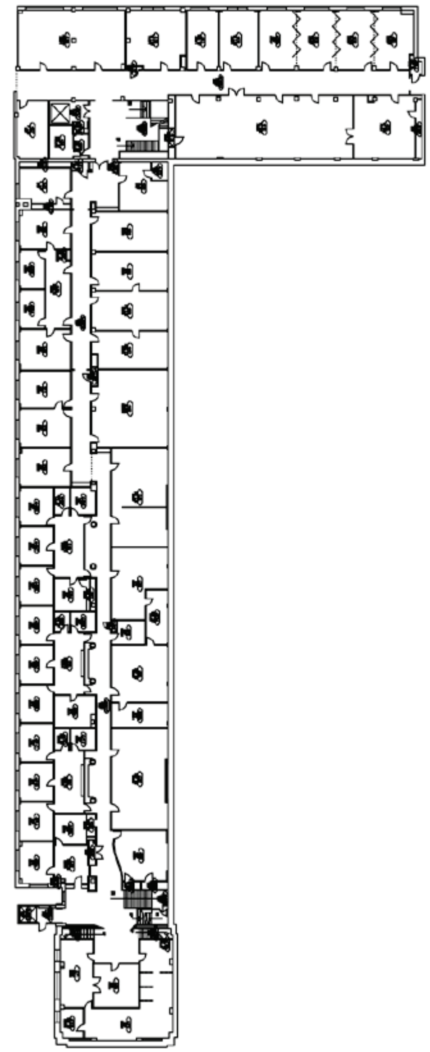
Fourth Floor [6]



Fourth Floor [7]



Fourth Floor [8]



Fourth Floor [9]

(Endnotes)

[1] "Building Changes for the Coming Year," *Technology Review* vol. 21 (November 1919): 540.

[2] Francis E. Wylie, *M.I.T. in Perspective: A Pictorial History of the Massachusetts Institute of Technology* (Boston, Toronto: Little, Brown and Company, 1975): 20.

[3] Francis E. Wylie, *M.I.T. in Perspective: A Pictorial History of the Massachusetts Institute of Technology* (Boston, Toronto: Little, Brown and Company, 1975): 21.

CHAPTER 3: SYNOPSIS AND CONCLUSIONS

CHAPTER 3: SYNOPSIS AND CONCLUSIONS

"These were the buildings that we all disliked in the thirties and forties because of their pseudo- classical sterility. But let us not dismiss them so easily just because we once disliked them. One can see that they form a unity: they create an environment. They have also proven quite useful. They were built in parts and X- number of units was added. They were built on the principle of continuous space. Fortunately Welles Bosworth chose a bay which has proven very workable despite hundreds of shifts and alterations within. It is possible that had the buildings been done on a complete modular system with movable partitions they would have proven less flexible. Parenthetically, the Bosworth M.I.T. buildings have been called dull and monotonous, but I have come to a point where I welcome more dullness and more monotony in our cityscapes instead of all the visual clashes typical of our time…. Specialized space (auditoriums, etc.) is different; but it seems to me that for the academic instruction, space such as that in the old M.I.T. buildings provides an excellent example of what in the long run proves to be economical space."[1]
Eero Saarinen

At this point, enough evidence has been presented in order to account for what Saarinen has said. Enough "shifts and alterations within," as well as stages of growth, have been studied in order to regard MIT as a paradigm not only of an "economical space," but also of a controllable and manipulable environment, void to a large degree of any designer's idiosyncrasy. It is an environment that has managed to adapt more than adequately to the multiple changes in the academic life of the Institute, either due to an expansion of or change of its curriculum, or to an increase of the number of students. But this remark is not the only outcome of this thesis. I believe that the study of the MIT transformations has left us with some valuable lessons regarding on the one hand, a number of more or less specific formal means, and, on the other, some general measures to achieve adaptability in architecture.

At the beginning of this thesis the following hypothesis was proposed: that MIT must have contained right from the start a kind of DNA that permitted it to transform easily and effectively. Indeed, the original buildings were designed according to a system, the elements of which: an underlying circulation system, stems, fully equipped "unit- sections," knuckles, courts and add-on facades, were conceived with future adaptability as a guide. Each of these elements played a different role during each transformation, impeding the disturbance of the existing system in different ways, and contributing to the continuity and efficient function of it after the transformation in question had taken place. In other words, each part of the DNA had a different result in terms of ease of growth, ease of internal change, accommodation of different uses, and maintenance of efficiency and clarity of movement, before and after the transformation, the latter being the performance measure. These different roles will be more clearly outlined in the synopsis that follows. To this hypothesis we can now add another idea: that most of this DNA survived the form's growth and internal change, and played a further analogous role in subsequent transformations. This last remark could be, I would argue, a positive response to the question stated at the first chapter of this thesis through the words of Cowan; "*Does the city evolve selectively*?" It is at this point that we will need to jump in time in order to substantiate this: a selective heredity of DNA that at times reached the limits of an unrelenting persistence.

During the first growth the indeterminate façade of the existing system, on the knuckle between former Buildings 3 and 5, permitted for a less costly growth. The new wing was also organized along a double loaded corridor which led to an open end and to an indeterminate façade as well. Furthermore, it was based on the same modular system of unit sections. All these indicate a preference towards specific formal characteristics, which in the four years of the new Institute's life must had been tried out. The DNA that passed on played its own role on the further development of the grown building. In 1938, with the construction of the Massachusetts Avenue entrance, a new wing was attached to the Pratt School to connect what would be present Building 7 with it **[92]**. We do not know what exactly all these buildings looked like at the time but we do know what we experience now. A continuous corridor, with a diversion at the "notorious" knuckle, defines a more than efficient circulation system, at all levels except the fourth floor.

During the second wave of growth, which took place eight years later, this persistence re- appeared. The Guggenheim Laboratory, despite the limitations set, insistently carried on the same modular system and the unfinished facades. Indeed, in 1952, the Laboratory's north façade was hidden by a new building which was connected to the laboratory, while the same thing happened with the south façade in 1967. In this case, I do not know whether the use of the modular system on the upper floors was in any way effective as neither the original, nor the present spatial layout of Building 33 are based on it. Furthermore, the connection with the Bosworth buildings was not that successful, but only because the intermediate building, namely Building 9, was not organized along a corridor system.[2] However, the layout of the stem was used at the time Building 33 was designed, 12 years after its first use in the preexisting buildings, a fact that reveals that its potentials were already fully recognized.

The third growth, Homberg Memorial Infirmary, must have taken

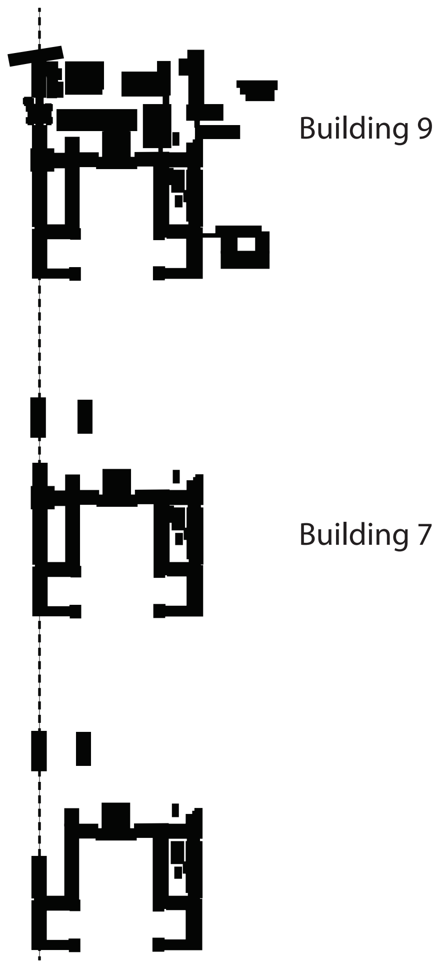


Fig. 92: Addition of a new wing to the Pratt School and connection of the Guggenheim Laboratories with the Main Buildings.

place in an equally easy way as with the first. Photos taken during the construction reveal that the existing system remained undisturbed while present Building 11 was just "glued" on to the plain façade **[93]**. A quick demolition and opening of doors must have followed the completion. The results of the regular knuckle at that point were immediately revealed; the joint became a real urban crossroads introducing an elaborate entrance at its open end. The new building's façade was also modeled out simply. The fact that another growth did not occur there might be simply due to the construction of Building 13, which went against this south- north expansion **[94]**. Although in the case of this third growth, as well as in the case of the Engine Testing Laboratories which nevertheless did not seem to be a part of the "phantom" stems but a part of the "phantom" courts, the first type of stem did not appear, during the last growth studied, the double loaded corridor and the unit- sections emerged again.

Fig. 93: Photo taken during construction of the Homberg Memorial .

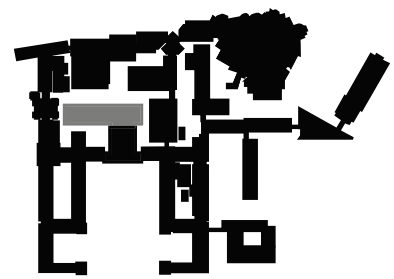


Fig. 94: Building 13 going against the north- south expansion.

The re-appearance of this DNA 16 years after the completion of the first buildings and especially in a case where “flexibility” was sought, confirms its value and a preference towards already tried techniques. Although one could argue that aesthetics factors and a wish for continuity in the facades of the existing buildings must have played an important role in the choice of the regular bay, and thus of the unit- section, I would answer the following: first, MIT right from the start sought practicality and efficiency in design. As a result it would not be easily “disillusioned” by a “good- looking” design. Secondly, 16 years of experience are enough in order to reject a non- working layout. Finally, “flexibility” was an imperative constraint on the design of this new building, while the experience from the existing congestion and dysfunction called for a sort of compensation to the Departments of Chemistry and Physics. As a result, this was not the place to design “irresponsibly.” In the example of the Eastman Laboratories, I would argue that the efficiency of the DNA of the original system was revealed in the most emblematic way: the building was connected to two knuckles that had left the corresponding end completely free. The easiness of this connection is revealed in the drawings themselves, where it is indicated that only a couple of walls should be demolished on each floor of the existing buildings in order for this to happen **[95]**. The same easiness is revealed in photos [see previous Chapter, Fig. **90**] of the facades of these knuckles where all that had to be done was to strip off the

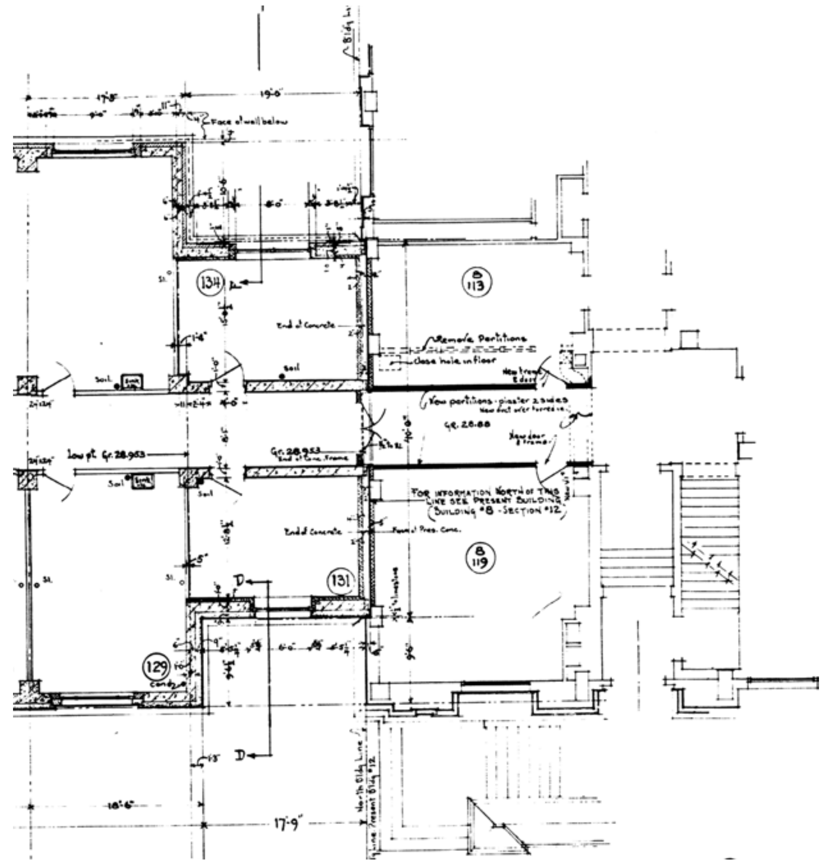


Fig. 95: First Floor north knuckle of present building 6.

layer of plaster. Furthermore, whatever did not fit in the system was conveniently hidden in the secondary court. Finally, the double-loaded corridor of the new building was connected with the existing corridors completing the underlying circulation system and revealing another side of this DNA's capability to respond to change, namely the choice of route **[96- 97]**. Although at the time this might not have been clear, right now as this thesis is written, internal change is taking place in Building 6. People wanting to reach Building 2 can simply follow the "detour" of Building 4, if they prefer to stay indoors. This specific detail reveals still another side of the adaptability of the circulation system. Retaining the number of floors to five led to a horizontal extension and not to a vertical one. Had expansion of the Chemistry and Physics Department taken place on a vertical axis, above Building 4 and were construction works taking place on that building, the possibility of reaching Building 6 would be seriously

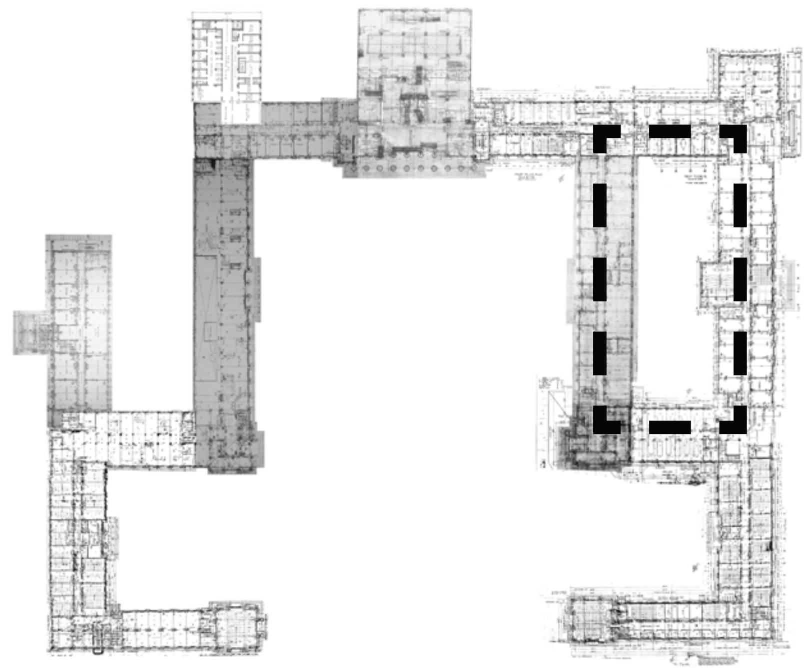


Fig. 96: Completed circulation system in the case of present Building 6. The collage of drawings is indicative as the plans of the existing buildings are the original ones and do not reflect the spatial articulation of the time.

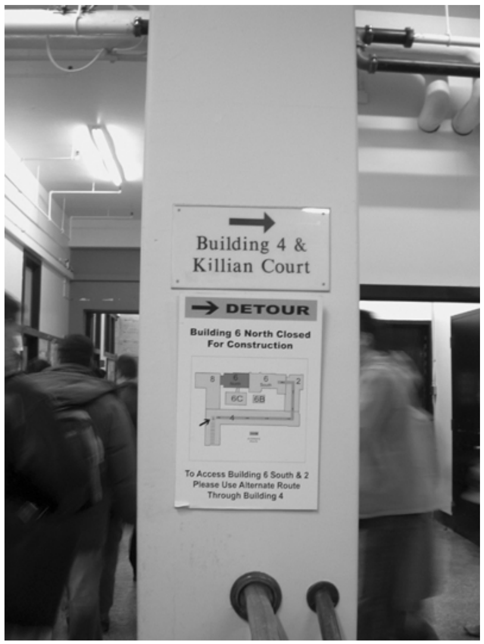


Fig. 97: Detour of Building 4, Infinite Corridor .

Fig. 98: Detour of Building 4, knuckle between former Buildings 6 and 4 .

impeded.

I believe that in the above synopsis, the persistence of certain “benign” spatial attributes, this idea of buildings evolving “selectively,” has been substantiated. In the presentation of internal change in Building 3, the same thing has happened in relation to the preservation of a circulation corridor and the obedience of the spatial configuration to the preexisting framework of the unit- sections. At the same time, a sort of evaluation of the role of each part of the DNA during the adaptation of the initial buildings has been delineated; first, standardized knuckles leaving completely free ends enable growth in different directions and regulate circulation; second, stems free of permanent structures, such as staircases, can change internally, while when organized along a corridor and unit sections clarify circulation and allow for many different uses; third, an underlying circulation system, grid-ed at an horizontal level, provides for efficient movement which gives a choice of route; fourth, indeterminate facades save unnecessary costs of materials that will be later disposed and of dismantling; and finally, courts, or “backyards”, give a way out when the system proves inefficient and when interventions might disturb the aesthetic unity of a building. This is a list of rather specific formal means that can provide adaptability.

However, more general measures can be derived, measures which could be proposed as general guidelines. To begin with, many of the suggestions of the architects and scholars mentioned in the first chapter are reflected; modularity in the unit sections; “open-endedness” in the knuckles and to some extend in the facades; “grids” in the corridor system; “supports” in the structural framework and the stems; autonomy of parts in the structural framework; “backbones” in the stems; “clusters” in the unified structure; “determinate and indeterminate elements” in the knuckles, stems and the facades; and “excess capacity” in the courts. The importance and effectiveness of these suggestions has been outlined through the effectiveness of their mirrored idols. From these more or less specific suggestions, I will keep “open- endedness” and “excess capacity” as general measures generated by the MIT transformations and add another one, namely a comprehensible outline combined with the right dimensions.

The importance of a clear general outline re- introduces the issue of “understatement” and “over-design”. I believe that although many things should be left un-designed, in order for users to decide what their proper form would be, general guidelines or propositions about how this implementation could take place should be obvious. This is what is suggested in the internal changes of Building 3. The central series of the supporting columns, the existence of windows in each bay of the external walls, as well as the constant width, making the invisible grid more noticeable, indicated a comprehensible

Fig. 99: Photo taken during construction of former Building 7, and revealing the legibility of the structural system of the second type of stem.

Fig. 100: Photo taken during construction of former Building 3, and revealing the legibility of the structural system of the first type of stem.

structural framework, the existence of which led to the formation of a clear pattern of spaces and of a straightforward corridor during the incremental transformations **[99- 100]**. With the formation of spaces along the framework, their ability to be transformed was preserved, or in other words the building remained "manipulable." Had the structural system not been so clear, it is possible that the subsequent transformations might have caused anarchy in circulation and access, and confusion regarding what could be, or could be not, further transformed. At a larger scale or in the case of growth, the existence of an underlying circulation system also played an important role. All buildings might have not acquired the exact form of the initial plan but finally a very clear circulation system, comprised of the spine of the Infinite Corridor and the way-outs towards north and south, is preserved, ensuring the continuity of the building system; "*They were built on the principle of continuous space.*"[3] The need for such a framework is obvious in the case of Building 13, which going against it, cut through the extension of Building 11 and the communication of Building 10 with the buildings of Vassar Street as well. As a result, it appears that a "determinate" and evidently suggestive framework seems essential in order for "manipulability" and orientation clarity to be achieved. In other words, it appears that the imposition of certain control by the designer from the beginning will ensure control for more users and incremental change or tentative "fine tuning" for a longer period.

The dimensions suggested by this framework appear to be equally important. One could ask whether the dimensions of the bays chosen by Bosworth played any role in the transformations of the buildings. Saarinen characterizes the bay "*very workable*" and, based on the internal change of Building 3, I would have to agree with him, and add that the span proved quite workable too. The grain of change observed in the previous chapter shows that the Freeman-Bosworth logic was right. The rooms that were formed each time were a small multiple, approximately two, or a big subdivision, approximately half, of the unit- section. This asserts that even if big spaces are needed in the beginning, a framework should provide for an orderly subdivision of a medium sized space. This medium sized space would of course be defined by the general use- activity in a building. If in a school it corresponded to the size of a small classroom or a recitation room, in a hospital it might correspond to the size of a 3- person ward. In a framework where bigger minimum units would be defined, it is possible that the subdivision of them might not lead to an evenly clear and manipulable pattern of spaces, since in multiple subdivisions it is difficult to preserve a clear access. Overall, a comprehensible framework, dimensioned properly, protects from the danger of confusion that incremental transformations can cause in the function of the building as a whole and in its parts: in this case, in the function of the corridor and in the patterns of spaces feeding from it.[4]

The primary concern of this thesis has been adaptability and how this can be achieved. A number of answers have been given to questions in relation to this issue, as these were generated by the case study of MIT and as these had been posed by designers previously preoccupied with adaptability. Adaptability can be attained by the following formal strategies; the provision of extra space for the absorption of unexpected diversions, the provision of open- endedness and the delineation of a framework along which transformations can take place. I consider these answers valuable, as they are based on the study of concrete data, namely on drawings and photos of a built and evolving system, and not only on propositions outlined in manifestos or abstract diagrams. Although this close scrutiny might have seemed unnecessary at some points, it was this that gave the valuable insights regarding the adaptability of the MIT system, both at a small and a larger scale, concerning internal change and growth respectively. This thesis has also empowered my trust in the study of built form itself, in such a degree of detail, as a basic source of knowledge about architecture at any scale. Finally, through this work a physical history of MIT has been delineated; the Cambridge Campus has been studied from the moment of the purchase of the site until the completion of the George Eastman Research Laboratories, while Building 3 has been monitored through time until the late 90s. Although partial, I believe that this history has presented us an understating of the particular reasons that granted MIT its present form; the survival of a certain DNA, as found in its original knuckles, stems, add- on facades, unit- sections, courts and circulation system.

(Endnotes)

[1] Eero Saarinen as quoted in Francis E. Wylie, *M.I.T. in Perspective: A Pictorial History of the Massachusetts Institute of Technology* (Boston, Toronto: Little, Brown and Company, 1975): 51.

[2] O. Robert Simha, *MIT Campus Planning: An Annotated Chronology 1960- 2000* (Cambridge Massachusetts: The MIT Press, 2001): 60, and Mark Jarzombek, *Designing MIT: Bosworth's New Tech* (Boston: Northeastern University Press, 2004): 95.

[3] Eero Saarinen as quoted in Wylie (1975): 51.

[4] It is interesting to mention at this point that similar conclusions about a "simple, straightforward, and easily legible urban framework" with "small lots," are reached in the study of Vernez- Moudon mentioned in the introduction, which is a study contacted at a much larger scale. In that case, the small lot is more related to property rights than to issues of access as it is here. However, as similarities they seem important for anyone who might want to transfer any of the means or principles suggested here, at a larger scale. See Anne Vernez Moudon, *Built for Change: Neighborhood Architecture in San Francisco* (Cambridge Massachusetts: The MIT Press, 1986): 188.

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[1] Primary Sources

[1a] Archives
MIT Archive
Archive of the MIT Department of Facilities
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[1c] Reports
Massachusetts Institute of Technology President's Report

[1b] Newspapers/ Journals
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Technology Review

[2] Secondary Sources

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ILLUSTRATION CREDITS

Figure 01: By author

Figures 02- 04: Courtesy of the MIT Museum

Figures 05- 09: MIT Archives

Figures 10: *Architectural Review* 2/9 New Series (September, 1913), PLATE LXIII

FigureS 11- 13:Courtesy of the MIT Museum

Figure 14: By author. Parts are from drawings from the MIT Department of Facilities Archive. See TIFFS: 4_08D4, 4_08D-, 8_0FTS, with order of appearance

Figures 15-19: By author. Collages made from drawings from the MIT Department of Facilities Archive. For the plans of each building please see Index of Original Drawings Used.

Figure 20: By author. Base drawing MIT Department of Facilities, please see Index of Original Drawings Used.

Figure 21: By author. Base collage made of First Floor Plans, please see Index of Original Drawings Used.

Figure 22: By author

Figure 23: By author

Figure 24: By author. Base drawing MIT Department of Facilities, please see Index of Original Drawings Used

Figure 25: By author. Base drawing MIT Department of Facilities, please see Index of Original Drawings Used.

Figure 26: By author. Part of drawing 4_08D3, MIT Department of Facilities

Figure 27: By author. Base collage made of First Floor Plans, please see Index of Original Drawings Used. based on the collage of Figure 16.

Figure 28: By author, parts of drawings 4_08D3 (J10/8), 8_0FTU (J12/14), 4_08D6 (J8/6), 2_03NF (J4/2).

Figures 29- 32: By author, parts of drawings from the MIT Department of Facilities Archive. See Building 9 (J9/17), Building 7 (J9/7), Building 5 (J7/5) and Building 7 (J7/5 Fourth Floor), Building 5 (5/3), Building 3 (J3/1), Building 1 (J1), Building 10 (J10/17) and (J10/8), Building 12/14 (J12/14), Building 8 (J8/6), Building 6 (J6/4), Building 2 (J4/2). Please see Index of Original Drawings Used for details on the drawings.

Figure 33: By author

Figure 34: By author. Base collage made of First Floor Plans, please see Index of Original Drawings Used.

Figure 35: By author

Figure 36: By author. Base plan Courtesy of MIT Museum.

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Figures 39- 42: MIT Department of Facilities. Please see Index of Original Drawings Used

Figure 43: By author

Figures 44- 45: Courtesy of the MIT Museum

Figure 46: By author

Figure 47: Courtesy of the MIT Museum

Figure 48: By author. Based on part of drawing 1_02Z$.TIF, MIT Department of Facilities

Figure 49: Courtesy of the MIT Museum.

Figure 50: By author, part of MG05A05.19, MIT Department of Facilities

Figure 51: By author, part of MG05A06.19, MIT Department of Facilities

Figure 52: By author, part of MG05A07.19, MIT Department of Facilities

Figure 53: By author, part of MG05A08.19, MIT Department of Facilities

Figure 54: By author, part of MG05A09.19, MIT Department of Facilities

Figure 55: By author, part of MG05A03.19, MIT Department of Facilities

Figure 56: By author, part of MG05A04.19, MIT Department of Facilities

Figures 57- 58: Courtesy of the MIT Museum

Figures 59- 60: By author, part of MG33A01.00, MIT Department of Facilities

Figure 61: By author, part of MG33A02.00, MIT Department of Facilities

Figure 62: Courtesy of the MIT Museum

Figure 63: By author, part of MG33A04.00, MIT Department of Facilities

Figure 64: By author, part of MG33A02.00, MIT Department of

Facilities

Figure 65: By author, part of MG33A03.00, MIT Department of Facilities

Figure 66: *Technology Review* vol. 29 (March 1927): 273.

Figure 65: By author, part of MG33A04.00, MIT Department of Facilities

Figures 68- 70: Courtesy of the MIT Museum

Figure 71: *Technology Review* vol. 29 (May 1927): 417.

Figures 72- 78: Courtesy of the MIT Museum

Figure 79: By author, part of MG31A01.01, MIT Department of Facilities

Figure 80: By author, part of MG31A03.01, MIT Department of Facilities

Figure 81: Courtesy of the MIT Museum

Figure 82: By author, part of aerial photo, Courtesy of the MIT Museum

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Figure 93: Courtesy of the MIT Museum

Figure 94: By author

Figure 79: By author, part of 6_0597, MIT Department of Facilities

Figure 36: By author. Base collage made of First Floor Plans, please see Index of Original Drawings Used and *Technology Review* vol. 29 (May 1927): 417.

Figure 98: By author

Figures 99- 100: Courtesy of the MIT Museum

Internal Change base-drawings and final stages, namely Basement [3], First Floor [7], Second Floor [6], Third Floor [4], Fourth Floor [9] can be found at http://web.mit.edu/facilities/maps/floorplans.html. See 3_0, 3_1, 3_2, 3_3, 3_4, respectively.

INDEX OF ORIGINAL DRAWINGS USED

(For alteration drawings in Internal Change please see relative diagrams. Former building names are used. Names such as 2_03NF are digital files; names such as MG03A03.09 are microfiche drawings)

Building 1
Basement and 1st floor plans: **1_02Z-.TIF**
2nd floor and 3rd floor plans: **1_02ZZ.TIF**

Building 2
Basement and 1st floor plans: **2_03NF.TIF**
2nd floor and 3rd floor plans: **2_03NI.TIF**
South Elevation: **2_03NR.TIF**

Building 3
Basement and 1st floor plans: **1_02Z_.TIF**
2nd floor and 3rd floor plans: **1_02ZY.TIF**

Building 4
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West Elevation: **2_03NS.TIF**

Building 5
Basement and 1st floor plans: **1_02Z$.TIF**
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Building 6
Basement and 1st floor plans: **2_03NH.TIF**
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North Elevation: **2_03NQ.TIF**

Building 7
Basement and 1st floor plans**: MG03.A01.07a, MG03.A01.07b**
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4th floor plan: **MG03.A03.07a, MG03.A03.07b**

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Basement and 1st floor plans: **4_08D1.JPG and 4_08D2.jpg**
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4th floor plan: **4_08D9.JPG**

Building 9
Basement and 1st floor plans: **MG03A01.09**
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Building 10
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4th floor plan: 8_0FT$.TIF

Building 17
Basement and 1st floor plans: **10_06PY.JPG** and **10_06PY.JPG** respectively
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4th floor plan: **10_06L-.JPG**

Pratt School of Naval Architecture
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East elevation: **MG05A03.19**
North and South: **MG05A04.19**

Guggenheim Laboratories of Aeronautics
Basement and street-floor, and 1st floor plans: **MG33A01.00** and **MG33A02.00** respectively
2nd floor and 3rd floor plans: **MG33A02.00** and **MG33A03.00** respectively
Section: **MG33A04.00**
Front elevation: **MG33A04.00**

Engine Testing Laboratory
First floor plan: **MG31A01.01**
East elevation: **MG31A03.01**

George Eastman Laboratories
Basement and 1st floor plans: **6_058Z.TIF** and **6_0598.TIF** respectively
2nd floor and 3rd floor plans: **6_059P.TIF** and **6_05A2.TIF** respectively
4th floor plan**: 6_05A2.TIF**