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Architecture for Science: Space as an Incubator to Nurture Research

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**ARCHITECTURE FOR SCIENCE:
SPACE AS AN INCUBATOR TO NURTURE RESEARCH**

A Thesis Presented

by

MARYAM MOHAMMAD SHAFIEE

Submitted to the Graduate School of the
University of Massachusetts Amherst in partial fulfillment
of the requirements for the degree of

MASTER OF ARCHITECTURE

May 2014

Architecture + Design Program

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DEDICATION

To Emad,

I could not make it happen without you.

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I am deeply grateful for having amazing advisors, Professor Kathleen Lugosch, Professor Ajla Aksamija, and Pamela Rooney who have always been patiently my endless source of information and encouragement. Thanks to Thomas Huf and Jeffery Dalzell, my advisors in UMass Campus Planning who inspired me with such incredible support. Thanks to Betsy Blunt who taught me a new way of thinking.

Finally, thanks to all my friends who have always been there for me.

ABSTRACT

ARCHITECTURE FOR SCIENCE: SPACE AS AN INCUBATOR TO NURTURE RESEARCH
MAY 2014

MARYAM MOHAMMAD SHAFIEE, B.A., TEHRAN SHAHID RAJAEI UNIVERSITY
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Directed by: Ajla Aksamija

This thesis will study how scientific research environments should be designed, specifically addressing the issues beyond mere needs of research scientists. Assuming that the purpose of research is to create new knowledge and foster discoveries, as well as positively influence the community in its processes and results, this thesis will explore the potential of the influence of this building typology that has not been previously considered enough. The objectives of the thesis are on one hand, the changes in science disciplines and their reflections in the evolution among this building type, on the other hand, the impacts of research environment on scientific evolution. The question is, beyond support, can architecture promote and nurture science and enlighten scientists toward a new understanding of scientific activities? Based on this research, it is assumed that good science happens in spaces that are transparent and dynamically communicative. The methodologies, which will be used to address these objectives, include literature review, exploration of case studies, surveys and interviews with scientists about their use of the laboratory buildings, and the design of a prototype building for scientific research.

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CHAPTER 2

INTRODUCTION

A. The Argument

According to Suzanne Stephens¹, the lab building is not the most propitious place to look for architecture that transports us beyond the mundane. The demands of the program for various types of research too often make the manipulation of space, volume, and light seem beside the point. Then, too, clients often consider the inspiring potential of architecture the easiest value to be "value-engineered" out of the equation when budgets are squeezed.

The history of science buildings clearly shows that the role of architecture usually has been supporting and responding to the activities that take place in a science building. A successful project is assumed to be the one which could best meet the specified programmatic demands of the habitants.

Besides the fact that function rules in designing a science building, since the most important components of the space are laboratories and mechanical system in accordance to them, building codes and infinite regulations are another issue to confine the design.

Additionally, controversial research subjects demand certain types of security and safety and should not be constructed in particular areas.

¹Stephens, Suzanne. "Architecture's role." *Architectural Record* 195, no. 12 (December 2007): 121. Academic Search Premier, EBSCOhost (accessed October 23, 2013)

The question is, considering the very demanding limitations of the program, budget, regulations and codes, is there any room for moments of inspirational architecture in designing laboratories for the future? Can architects do anything beyond program, structure, budget, and regulation in the science building of the future? Can architects incorporate architectural poetry into this "function directed" building typology?

This thesis investigates the science building typology over history and the ways its architecture has evolved along with the changes in science and research methodologies. Science has developed from human's desire to answer questions about the world around them, which can affect society directly and/or indirectly. Therefore, this thesis explores the potentials of this building typology for influencing the future of scientific investigations and the importance of the role that architects are playing.

B. Goals, Objectives, and Methodologies

This thesis is targeting three main goals:

- Amplifying existing knowledge
- Identifying the meaning that is attached to this building type and present it as a collective value, along with introducing social activities to the building program.
- Integrate constructive communications between scientists and visitors.

- Generating new research disciplines into the building program

Incorporating a variety of disciplines within the same space will result in cross-pollinating between them. Building program amplifies this process by providing shared learning, testing, and support spaces.

- Catalyzing the translation of research into practice.

Conference rooms are located next to transparent workrooms and among office clusters along with regular meetings between producers, researchers, and community representatives in order to update each other about resources, needs, and demands. Accelerate the process of translating research into practical application by juxtapositioning test labs and working rooms with common spaces and conference rooms.

The design methodologies, which address the goals listed above, include:

- Developing permeability and connection between inside and outside along with accentuated entrances to an inviting, open provocative space that maximizes communication. Building position provides physical connection between all constituencies.
- Introducing disciplines such as art, humanity, and sociology rather than isolating science in order to raise the sense of consciousness as well as creating a pleasant, friendly atmosphere.
- Provide space for formal meetings between researchers and industry in order to update each other about the latest discoveries, needs, and demands.

- Provide space for informal gathering among researchers for a consistent flow of feedback and revisions; also among community and researchers to encourage and motivate next generation of scientists.
- Encourage casual conversational opportunities in open and pleasant spaces.
- Identify the occupants by clarifying that their reason for being in this complex is that they are willing to share and learn beyond their disciplinary boundaries. This identity distinguishes them without isolating or separating them from community.
- Provoke the sharing of knowledge by sharing facilities, equipment, resources, and space.
- Investigate the end user needs before design starts and reflect their thoughts and concerns into design.

C. How does Science work?

1. Structure of Revolution in Science

Science is a circle of continuous systematic inquiry that leads to acquiring knowledge. That systematic study is based on past attainments, which supply a base for future discoveries.

In research process, scientists use experimental methods to investigate a hypothesis, which can lead to anticipated and unanticipated discoveries within and beyond their discipline domain.

Figure 1 is a diagram that simply shows how scientific research works.

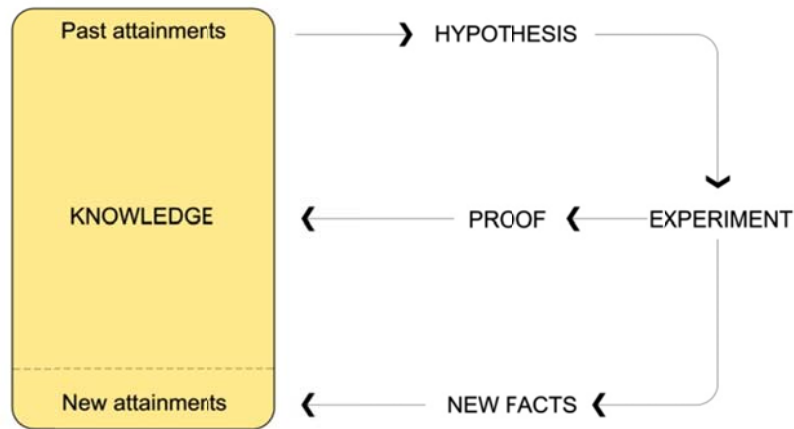


Figure 1- Science, Research, Knowledge

By this definition, the most important aim of science is to use hypothesis based on existing facts and theories to expand knowledge and, importantly, to open new avenues of research. Thomas Samuel Kuhn in his book, *The Structure of Scientific Revolutions*, calls this framework the Paradigm. He says that new novelties, which are inevitably produced by activities under particular set of rules, will lead to change the same rules and eventually the change of paradigm.

"....research under a paradigm must be a particular effective way of inducing paradigm change....after they have become parts of science, the enterprise, at least of those specialists in whose particular field the novelties lie, is never quite the same again."²

²Kuhn, Thomas S. "Anomaly and the Emergence of Scientific Discoveries" in *The Structure of Scientific Revolutions*. 2nd ed. Chicago: University of Chicago, 1970, pp....

2. How did Architecture Respond to the Scientific Revolution?

Scientific study goes way back in human history, but assigning a particular space that indicates the experimental and manipulative mode of science has taken place in modern, scientific society of 19th and 20th centuries. These spaces, laboratories, which are specifically designed for scientific investigation and their invention, are results of and emphasize a shift in the meaning of science itself.

Owen Hannaway refers to this shift and says that since then, science no longer was simply a kind of knowledge; it increasingly became a form of activity³. According to him, setting aside a place specifically for such activity and bearing a new name for it serves to measure the force of that shift.

Studying the structure of paradigms over the history helps to understand how science and research disciplines along with architecture for science have changed over time.

Kuhn says that scientific communities are inevitably practicing based on received beliefs from foundation of educational institutions.

Paradigms are in fact these pretty much fixed beliefs, which are always subject to change because in the scientific activities within them there will be novelties and discoveries that could lead to the shift in paradigm, Figure 2.

³Laboratory Design and the Aim of Science: Andreas Libavius versus Tycho Brahe Owen Hannaway Isis , Vol. 77, No. 4 (Dec., 1986), pp. 584-610

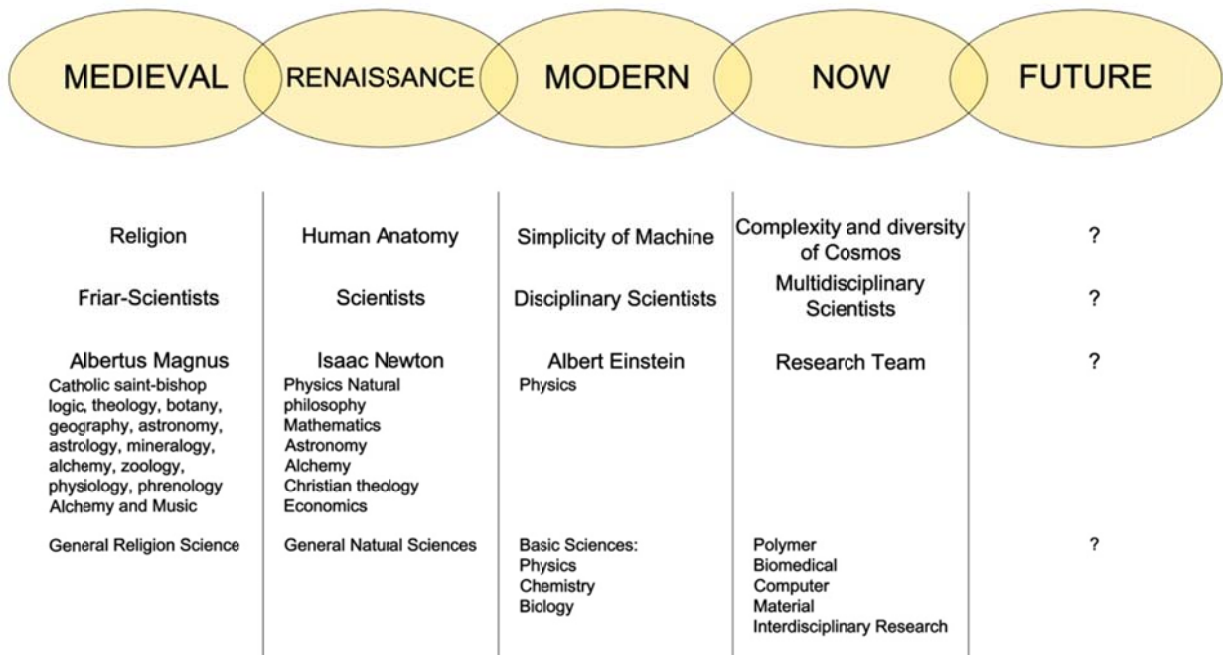


Figure 2 - Science History

These simplified diagrams in Figure 3 show different modes of research activities, clearly represent the spaces in which these activities have taken place.

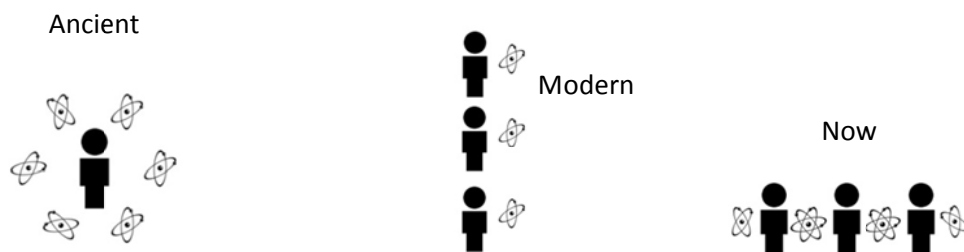


Figure 3 - Knowledge

When the first labs were designed in late 15th and early 16th centuries, the notion of scientific activities was to process it rather than operate it. In 18th and 19th centuries, as the realm of knowledge grew, basic sciences started to

take shape mostly because the content of knowledge was too vast for one person to take and divaricating it into basic branches established disciplines in which scientists were specifically researching and experimenting on specialized subjects.

"Only a free individual can make a discovery... Can you imagine an organization of scientists making the discoveries of Charles Darwin?"

--Albert Einstein

Accordingly, isolated laboratory buildings were designed and constructed in favor of this method of research. There are several examples that clearly show the disciplinary separation of modern scientists.

Buildings were categorized on a department basis such as physics, chemistry, astronomy, etc. and even within those buildings, spaces were completely arranged based on hierarchy of senior to junior researchers, each with its small, inflexible isolated lab next to it.

Some examples of disciplinary laboratory buildings now exist on University of Massachusetts Amherst campus, most of which have been repurposed for other kinds of uses, such as West Experiment Station showed in Figure 4. This building is going to be renovated and converted into an office building.

The most important problematic issue in such buildings is their resistance to change; it would be unreasonably expensive and difficult. Therefore, the only way would be using the space for a function other than laboratory.

West Experiment Station, Soil Testing Lab
Constructed: 1886-1887
Architects: Emory A. Ellsworth, Holyoke, Mass



Figure 4 - West Experiment Station (retrieved from <http://billbrea.wordpress.com/2009/12/12>)

The federal Hatch Act of 1887 allocated the \$15,000 necessary to build the West Experiment Station. West Experiment was the first of the two experiment stations on campus (along with East Experiment, constructed in 1889-1890).

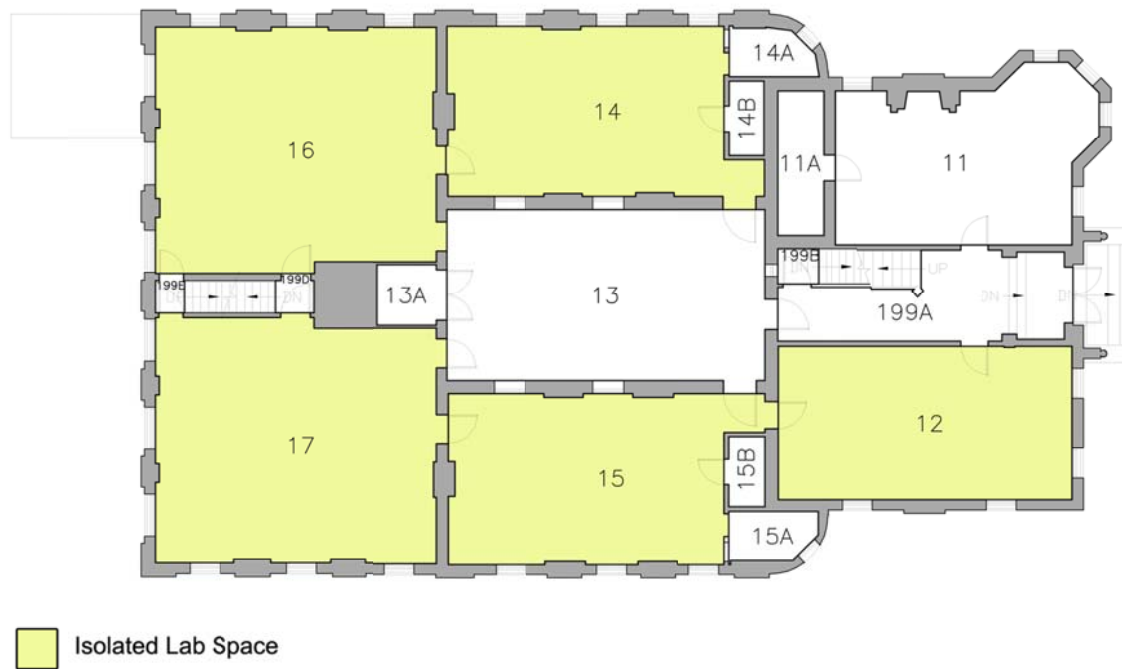


Figure 5 - West Exp. Station Floor Plan

The building resembles a Queen Anne style house, and it is currently serving the purpose that it was designed for (chemical, fertilizer, and plant and soil studies).

As a part of UMass New Physical Science Building project, the building will be moved, completely renovated, and repurposed as an office Building⁴.

⁴Norton, Paul F., Amherst: A Guide to Its Architecture (Amherst, 1975), Three Architectural Tours: Selected Buildings on the Campus of the University of Massachusetts Amherst (Amherst, 2000), The University Archives (RG 36/101)

Flint Laboratory, Dairy Building, Dairy Laboratory
Constructed: 1912
Architects: James H. Ritchie



Figure 6 - Flint Laboratory (retrieved from http://st-wiki.umasstransit.org/Flint_Lab)

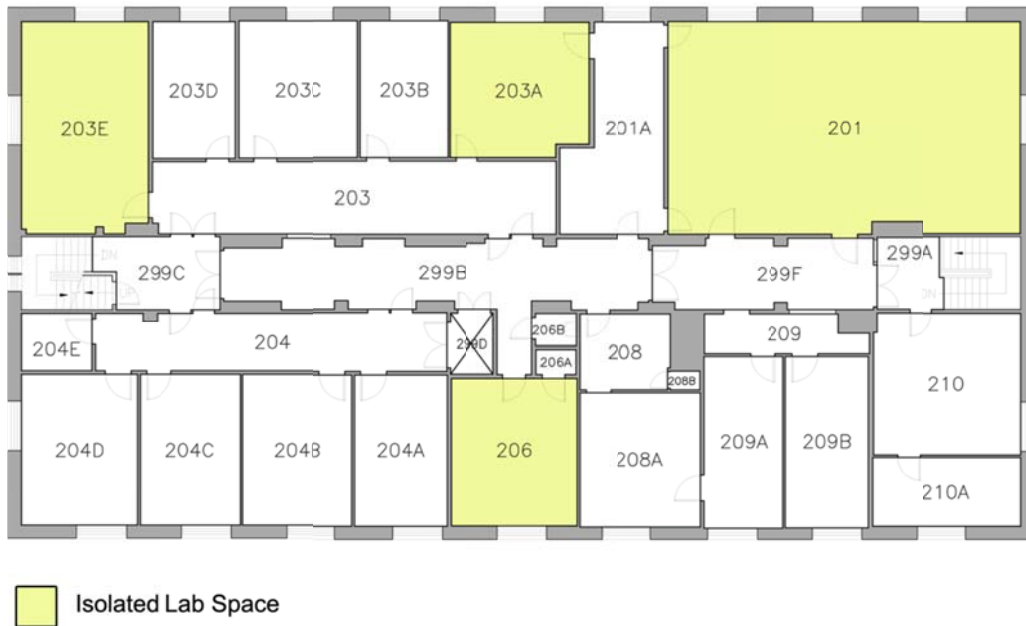


Figure 7 - Flint Lab Floor Plan

At the time of its completion, the laboratory was considered to be "one of the best equipped dairy buildings in the United States" and was described as "a model for the whole country" in one edition of the Works Progress Administration guidebook to Massachusetts⁵. Today the building has been almost entirely converted to an office space. The former "dairy bar" has been repurposed as a restaurant known as Fletcher's Café, which is run by students of the hospitality program.

⁵The Massachusetts Historical Commission, UMass Amherst Building Survey reports (2009).

A newspaper article on the construction of the building in the Meriden Morning Record- August 21st, 1911

Paige Laboratory
Constructed: 1950
Architects: Louis Warren Ross



Figure 8 - Paige Laboratory (photo by author)

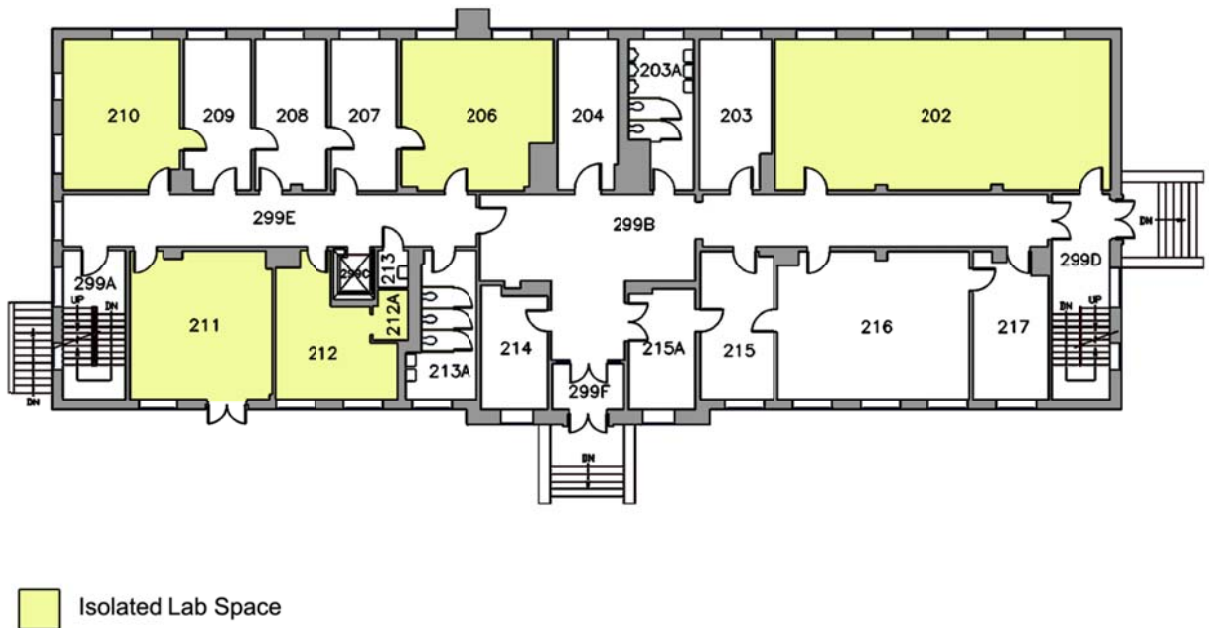


Figure 9 - Paige Laboratory Floor Plan

The building is a part of the northeastern quadrant of the campus, and it was devoted to the departments of engineering and the physical sciences. It was built following the early 20th-century construction of Stockbridge Hall.

Right now, the building is under excessive renovation process and lab spaces are under Capital Asset Board to be assigned to new functions⁶.

As science developed, researchers started to realize the connection between deep original aspects of different disciplines. Even when Einstein was searching for mathematical approach to general relativity, he collaborated with Marcel Grossmann, the mathematician who told him what was the appropriate geometrical tool to make progress toward the general theory.

In this regard, in late 20th until now, multidisciplinary lab buildings have been constructed to provide collaborative spaces. Unlike archaic arrangements in research environments based on discrete design to isolate senior and junior researchers in their small labs, new trend of interdisciplinarity is to encourage interaction among scientists and their research teams.

The idea is to trigger a contribution of two or more academic disciplines that could benefit all parties. Figure 10 shows the difference between single disciplinary lab and a multidisciplinary lab.

⁶ The Massachusetts Historical Commission, UMass Amherst Building Survey reports (2009)

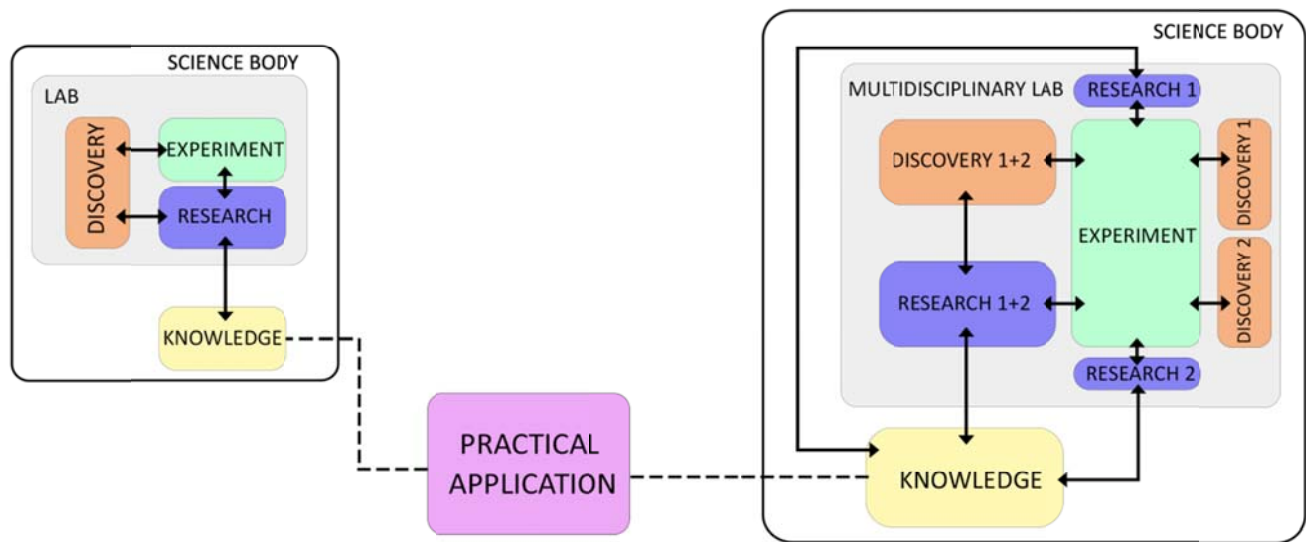


Figure 10 - Isolated Lab/Multidisciplinary Lab

The objective would be to involve members of different schools of thought in one movement to pursue a collective goal, by eliminating boundaries between students, teachers, and researchers within a particular discipline as well as an effort to "Cross-Pollinate"⁷ with those of other disciplines. Presuming that a positive influence on the society is the actual objective of scientific research, this goal will not be plausible if the produced knowledge does not go beyond the body of science and translate into practical applications. Translational research is to examine the last findings in research by a "fast track" test in practice and take advantage of feedback loop.

⁷Galison, Peter, and Emily Ann. Thompson. "The Design Process for the Human Workplace" in The Architecture of Science. Cambridge, MA: MIT, 1999.

Constructive communication among scientists and commercialization entities will make them aware of each other's findings and needs, and help this translation happen.

The recent Life Science Laboratory at UMass Amherst campus, designed by Wilson Architects and completed in 2013, is a good example of this typology.



Figure 11 - Life Science Laboratories (Image courtesy of Wilson Architects)

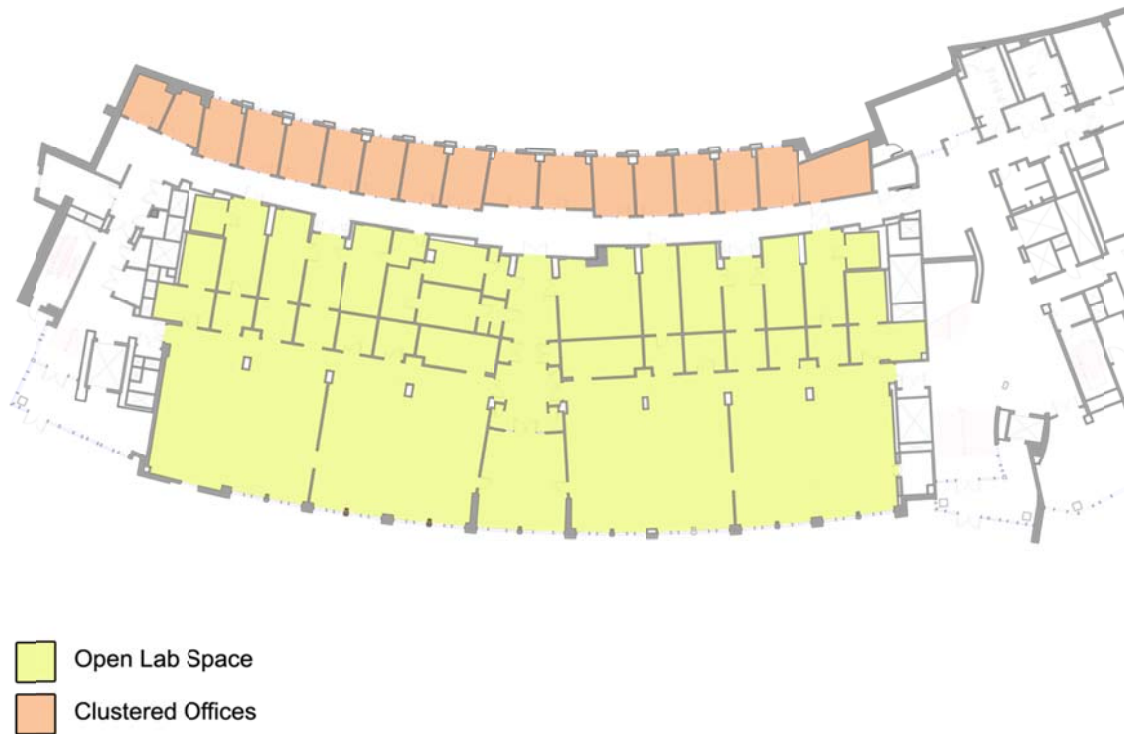


Figure 12- Life Science Laboratories Floor Plan

One of the main ideas in the Life Science Laboratories is to create large, flexible and adaptable spaces that can easily accommodate growth and change. However, creating large spaces does not necessarily guarantee the adoptability of space for different kinds of uses. This is discussed in more detail in later sections.

By looking at lab/science buildings over history, it is obvious that architects have always had to support scientists' needs and satisfy their demands.

Architects have always had to solve the puzzle of needs and uses within their design.

Michael J. Crosbie in *Architecture for Science*⁸ discusses the reason why lately world-renowned architects have received major commissions to design science buildings even if they are not experience in this field. Why would an owner select a signature architect who is not familiar with this building type to design a very expensive facility? He continues with arguing that the reason could be that the owner is interested in a building that has a distinct identity, or it may be the requirement of a donor or the owner may be searching for a new prototype to accommodate a new science.

Crosbie is right. There are examples that are not easy to be explained considering the usual approach toward architecture for science. Cases like these show that a new trend in designing science complexes has been started that understand the role of architects as more than mere puzzle solvers. Development of architectural spaces that can actually affect the users and the work they do within the space as the result.

Before studying the mentioned cases, few definitions need to be clarified.

3. Identity

According to Oxford English Dictionary, identity could be defined as the "absence of distinction between people of different ethnic groups." At the same time, it is the presence of sameness among individual existences. Either way, these definitions are pointing at the values that can bring a group of

⁸Crosbie, Michael J. *Architecture for Science*. Mulgrave, Vic., Australia: Images Pub. Group, 2004.

people together by the default meanings attached to them or attributed by others.

Considering that parts of these qualities can be subjected to change depending on time, situation and culture, also parts of them are constant, understanding the identity of a project's end users plays a role of importance in triggering their social interaction. In "The architecture of Science" Thomas Gieryn says, "strategic decoration of physical environment is crucial for identity formation"⁹.

4. Flexibility and Change

"It is not the strongest of the species that survives, nor the most intelligent that survives. It is the one that is the most adaptable to change."

-- Charles Darwin

As for "Discovery-Experiment-Knowledge" loop, one can say the nature of science is to change.

It is important to define "change" in science since the basic components of research activities remain pretty much the same and mostly gadgets are subjected to change. In other words, as we get closer to the surface the change intervals get shorter.

Relatively, a responsive design has to address different layers in various ways. In order to facilitate the changing nature of scientific activities, design

⁹Galison, Peter, and Emily Ann. Thompson. "Two Faces on Science: Building identities for Molecular Biology and Biotechnology" in The Architecture of Science. Cambridge, MA: MIT, 1999.

should be capable of being easily guided, modified, and adapted to diverse purposes.

D. Problems to be addressed

In this section, problematic issues around research will be discussed in different scales.

1. Human

Because of the isolated design of laboratories and offices in science buildings, researchers have become separated from community. Assuming that this seclusion has turned science into a personal gain and research into a job, in this project sharing and communication will be encouraged through design. Research is going to be considered as a lifestyle and science a public interest. Offices and laboratories are the spaces that researchers utilize extensively. Therefore, in this project their preferences will be considered to bring happiness and comfort into their workplace as much as possible.

2. Building

Science facilities are among the most energy consuming buildings because of their equipment. Safety concerns have led to complicated building systems as well as inconvertible specialized spaces that are considerably expensive to renovate or repurpose.

This project will investigate new methods and technologies in order to create open, transparent spaces without putting users and visitors' safety at risk.

Structural, infrastructural, and MEP systems will be designed as compatible as possible with future possible expansions and renovations.

3. Site

To better represent this complex as a symbol of campus' science community, this building will respond to its context by designed landscape corridors toward and adjacent to the building and visible entrances in all directions. Instead of a solid structure that divides the site into portions, this building will act as a gateway that forms a connection between the science core and student life, which is missing right now.

In addition to landscape design, project will address existing accessibility problems. The building form and skin will suit and to campus heritage.

The project site is next to an old existing laboratory building which has numerous problems. It is not up to code, in poor general condition, and lacks efficient MEP systems. By pairing a new structure with this existing building, existing building's most necessary needs will be met. In addition, parts of the new building's programmatic spaces will move to the existing building.

4. Science, Industry, Society

As mentioned before, traditionally designed separated laboratories have limited the collaborative interdepartmental conversations. Only recent interdisciplinary open laboratories have made it possible for scientists from different fields to integrate, but still there is boundary between laboratory

workstations and industry underlines the translational gap between research and practical application.

To use architecture to create opportunities for collaboration between academia and industry will help researchers to test their experimental products in a fast track process in connect with industry.

CHAPTER 2

PRECEDENT STUDY AND LITERATURE REVIEW

A. Precedents

Two types of precedent projects are going to be analyzed in this chapter.

First three examples are those that place architecture in a position to enable science to reach further into the unknown¹⁰. The next three are those that have prospered in this effort. Furthermore, their drawbacks and achievements will be considered.

1. **Stata Center for Computer, Information, and Intelligence sciences; A complicated building for complicated minds**

Architect	Gehry Partners, LLP
Associate Architect	Cannon Design
Location	Cambridge, Massachusetts, USA
Date Completed	2004
Construction System	Concrete, Clad in brick, Aluminum, Stainless steel
Scope	430,000 gsf plus 290,000 gsf underground garage



Figure 13 - Stata Center (Levine, Alan. 2005)

¹⁰Can architecture shape science? Seed Magazine. November 17, 2013. Available at: http://seedmagazine.com/content/article/can_architecture_shape_science/

When the building opened in 2004, Pulitzer Prize-winning critic Robert Campbell wrote in the Boston Globe that the building is "a work of architecture that embodies serious thinking about how people live and work and at the same time shouts the joy of invention."

It is sitting on the site of Building 20, MIT's legendary timber framed building, constructed during World War II and served as a playground for a great number of superb minds.

The building program is an interesting combination of "brain related" disciplines. Stata is home to two major departments, Computer Science and Artificial Intelligence Laboratory and the Laboratory for Information and Decision Systems, but it also includes Department of Linguistics and Philosophy.

In the maze of circulation, which does not seem to have any apparent order in this building, except for the ground floor "Student Street", it looks like that different types of intelligence are being challenged while they are wandering around and suddenly find themselves in a new scene of place.

Users of the building are continuously struggle with Stata's confusing floors. Surprisingly enough, they are delighted not just because they will never get bored but because of the identity of this building identifies them, as different than others; as occupants needing a different sort of space that matches their mind set.

Statawas best described in SEED Magazine¹¹, that it is the egghead playground and since it was built, many great projects have taken place there. After all, it is a complicated building for those who love complexity, scientists.

2. Perimeter Institute for Theoretical Physics; A monastery for those who look at the skies

Architect	Saucier + Perrotte Architects
Project Architect	André Perrotte
Location	Waterloo, Ontario, Canada
Date Completed	2006
Scope	64,583 sf



)

¹¹Can architecture shape science? Seed Magazine. November 17, 2013. Available at: http://seedmagazine.com/content/article/can_architecture_shape_science/

Designed and built "to discover and understand the fundamental laws of nature"¹², Perimeter Institute for Theoretical Physics is home for quantum gravity, string theory, quantum information theory, quantum mechanics, cosmology, and elementary particle physics.

At the middle of these two faces, bridges over the atrium along with the stairs climbing the glass walls connect between theoretical physics world and everyday life.

The form is translating these abstract theories into a square structure, which is a monastery for those who look at the skies.

North and south facades one facing the city other facing the park are responding to this difference in their appearance and program. Behind the anodized aluminum covered southern skin, laboratories and shared spaces, and in the north offices in 44 glass boxes are cantilevered over a reflection pool.

The striking features of this building, beside its monastic gesture are the successful translation of the program into the form along with responding to its context.

¹²Can architecture shape science? Seed Magazine. November 17, 2013. Available at: http://seedmagazine.com/content/article/can_architecture_shape_science/

3. Brain and Cognitive Sciences Complex at Cambridge, A place to bridge between thoughts and memories

Architect	Charles Correa Associates
Architect of Record	Goody Clancy
Location	Cambridge, Massachusetts, USA
Date Completed	2005
Cost	\$175 million (construction)
Scope	412,000 sf



Figure 15 - Bridge over the Rail Way (Haley & Aldrich, Inc. 2008)

After number of riotous projects on Cambridge campus such as Stata Center and Simmons Hall, the latest major new work is the Brain and Cognitive Sciences Complex (BCSC). Nancy Levinson states in Architectural Record that this is the least showy and arguably the most satisfying building of them all.¹³ The building houses three distinct departments, which at the same time have one thing in common, the brain. Departments are Brain and Cognitive

¹³ Levinson, Nancy. 2006. "MIT Brain and Cognitive Sciences Complex Cambridge, Massachusetts." Architectural Record 194, no. 7: 138-142. Academic Search Premier, EBSCOhost

Sciences, and two new, endowed centers, the McGovern Institute for Brain Research and the Picower Institute for Learning and Memory. This complexity in program in addition to laboratory spaces, and specialized equipment, call for common areas for collaborative activities. Design has taken advantage of the site characteristics, which is a triangular plot of land and is bisected by an active railroad. Despite this complexity, architects have come up with a brilliant idea of giving each department their own corner of the triangle and unifying them at the middle by a five story, glass roofed atrium bridged over the railroad.¹⁴

4. Jonas Salk Institute for Biological Studies

Architect	Louis Kahn
Location	La Jolla, California
Date Completed	1959-1965
Client	Jonas Salk
Scope	476,000sf



Figure16 - Salk Institute (Yusheng Liao, 2010)

¹⁴Levinson, Nancy. 2006. "MIT Brain and Cognitive Sciences Complex Cambridge, Massachusetts." Architectural Record 194, no. 7: 138-142. Academic Search Premier, EBSCOhost

The first laboratory that could also achieve architectural significance was Luis Kahn's Salk Institute in La Jolla, California built in 1965.

In this building, Kahn conceived the needs of function, utility, and flexibility as the performance principles¹⁵.

One of the main principles in this building is for researchers to have uninterrupted laboratory work. The notion of "servant/served" space is supposed to fulfill this goal. As Kahn stated, "the space above each laboratory is, in reality, a pipe laboratory."¹⁶ In his idea, what is happening in servant space is as important as what is happening in the space below.¹⁷

"Materials used are concrete, wood, marble and water. Concrete is left with exposed joints and formwork markings. Teak and glass infill in the office and common room walls...The laboratories may be characterized as the architecture of air cleanliness and area adjustability. The architecture of the oak table and the rug is that of the studies."¹⁸

Aside from the building's monastic solitude, thoughtful use of material, the wonderful view, and open, flexible lab spaces, there are two important other factors that make Salk Institute a successful building for science.

¹⁵ Crosbie, Michael J. *Architecture for Science*. Mulgrave, Vic., Australia: Images Pub. Group, 2004.

¹⁶ Alessandra Latour, ed., *Louis I. Kahn: Writings, Lectures, and Interviews* (New York: Rizzoli International, 1991), p. 207.

¹⁷ Moe, Kiel., 2008. Extraordinary Performances at the Salk Institute for Biological Studies. *Journal of Architectural Education*. 61 (4):17-24.

¹⁸ Louis I. Kahn. from Heinz Ronner, with Sharad Jhaveri and Alessandro Vasella *Louis I. Kahn: Complete Works 1935-74*. p164.165

First is an engaged and well-informed client who was able to clearly articulate his vision for the institute and his constructive collaboration with architect in design process.

Second is Kahn's ability to go back, study his previous work performances, and actually use the lessons learned rather than ignoring them. He has always been celebrated for the Salk institute, but at the same time derided for Richards medical center by the researchers housed in his designs of the 60s. The vertical shafts and large windows at Richards medical center did not perform as they were expected. Jonas Salk argued that architecture and landscape provide the stimulating setting required for the brain to make scientific discoveries.

Although, even after Kahn's success in Salk, most designs for science laboratories mostly focus on equipment support rather than architectural inspirations. There are examples in recent decades where architects have been called to devise new buildings in which scientists will perform research.

5. Studies Ray and Dagmar Dolby Regeneration Medicine Building

Architect	Rafael Viñoly Architects
Location	San Francisco, CA, USA
Date Completed	2010
Landscape Architect	Carducci & Associates, Inc
Civil Engineer	Sandis Cahd Browning
Scope	68,501sf



Figure 17 - Stepped Ribbon (courtesy of Rafael Viñoly Architects, Copyright Bruce Damonte)

The new center for stem-cell research at the University of California, San Francisco is home to nearly three hundred scientists. The ribbon-like building is sited on an impossible steep mountainside site. Cantilevered steel columns resting in concrete piers support the structure. This structural system minimizes site excavation and creates a seismic isolation to absorb earthquake forces.

What is striking about this building is that considering the controversial research program, site restrictions and limited time, architect has designed a building that not only is responsive to everything that bounds it, but also he has used all those apparently negative constants in favor of the program and the project.

Because of the steep site situation, it was impossible to make an ordinary entrance to the building. This fact has worked in assistance of the program, which needed additional security.

The ribbon is climbing the site along the contour lines of the ridge with its four steps that are connected with stairs. Next to each interior stair, there are common lounge spaces that act as filters between each laboratory, as well as individual entrance from the lower step green roof. The common spaces function as collaborative spaces in between flexible laboratories. As mentioned, each roof is the garden of the next step module and all gardens are connected by a set of stair that runs parallel to the building skin.

6. Collaborative Research Center, The Rockefeller University

Architect	Mitchell Giurgola Architects
Location	New York, NY
Date Completed	2010
Scope	250,000sf



Figure 18 - Collaborative link (retrieved from Google Earth)

The Rockefeller University has recently built a glass atrium between two existing laboratory buildings, which is a good example of translation of

intuitive intention into architectural elements that satisfy its functional-social-psychological purposes. Of these the most important is providing collaboration scientists from different disciplines and developing the base for cross-pollination among them¹⁹.

This aim becomes possible with a link filled with lounges, conference rooms, and places to eat. This addendum is a voluptuous glass link, seven stories high, which they call it Collaborative Research center.

In this complex, no one can reach any of the labs without going through the common space first. The notion of this collaborative space is to bridge between an institution academic history and the future of scientific accomplishments.

The two old facilities are entirely renovated into open, flexible laboratory spaces and equipped with the latest technology but it is not enough just to support the current flow of research, architects have taken on step future to link between two disciplinary old buildings along with the scientists habitants. This is a very stunning example of how architecture can affect science and its flow.

¹⁹Goldberger, Paul. "Laboratory conditions" New Yorker 87, no. 28 (September 19, 2011): 88-89. Academic Search Premier, EBSCOhost (accessed October 23, 2013).

B. Literature Review

1. *Architecture For Science* edited by Michael J. Crosbie²⁰

In *Architecture for Science*, the author discusses the nature of science, its rate and reasons of change and role of architects. He mentions that laboratories are a relatively new invention and says one of the characteristics of laboratory buildings is their dependence on technology, equipment and those technologies, which are woven through the building to make scientific work possible. He continues, "reliance on high-powered mechanical systems and energy makes laboratories tough candidates for sustainable design."

The book demonstrates that this is changing, but how? Crosbie suggests that reuse of existing facilities preserves materials and energy embodied in old structures.

"The design should mend past planning mistakes on the campus, reuse some existing structures, and help to create a new quadrangle to reinforce campus identity and sociability. It should also provide a dynamic center for the sciences, which encourages researches to cross-pollinate disciplines."

Constants are not merely required design codes, but answering "the deepest and most ancient needs of those inside who need light, air and social interaction to produce their best work."

In such highly designed environments where first consideration often seems given to the work at hand rather than the comfort to the staff, it is important

²⁰Crosbie, Michael J. *Architecture for Science*. Mulgrave, Vic., Australia: Images Pub. Group, 2004

to reduce the stress associated with intensive research by answering the deepest and most ancient needs of those inside to produce their best work. He mentions the new movement toward collaboration in scientific activities. "A new phenomenon is gaining momentum-the research park-where universities, corporations, and governments become partners on a variety of research projects by bringing together the talent and resources. ... In laboratories, we strive for ideas that define new and innovative ways for people to work collaboratively, efficiently, and safely in a highly technical environment. ... There is an expanding need for shared core facilities such as analytical instrumentation and animals."

On how the building should respond to changes, the author believes that one measure of success is how building can adapt to changes in use, occupants, and technology over time within reasonable initial budget constraints.

"Key to a successful building is the designer's knowledge of how the components of each category are designed and how they are assembled to best meet the needs of users."

"Why do science buildings need to accommodate change? If the average duration of its research program is three years, it is conceivable that up to 30 percent of the building can be undergoing some level of intervention at any time."

"A building designed with flexibility to accommodate change will minimize intervention costs but it will also incur higher first costs."

2. The Structure of Scientific Revolutions by Thomas S.Kuhn on architectural style by David Wang²¹

Wang refers to The Structure of Scientific Revolution by Thomas Kuhn and says, "perhaps because of this interdisciplinary inclusiveness of his philosophy, Kuhn's insights have informed theory in many disciplines."

He suggests that Kuhn's theory can also inform evaluations of architectural style. His methodology is case-based reasoning, what he calls CBR. He demonstrates seven similarities between architectural styles and Kuhn's paradigms. I have used four of them to demonstrate the process in which architecture for science has evolved along with the paradigms."

I) A style in architecture resembles a paradigm. Researchers affirm key principles, researchers make connections between theory and nature, and researchers apply their principles to new domains.

II) The establishment of a style is preceded and followed by competing points of view. These parallels for activity in research paradigms and architectural styles show that participation in a paradigm is not mere cognitive agreement on things. Rather, it is immersion in a way of seeing that transcends particular acts of decision-making by rooting those decisions in a pre-cognitive, and hence phenomenological, commonality of being. Common

²¹Wang, David. 2009. "Kuhn on architectural style." Arq: Architectural Research Quarterly 13, no. 1: 49-57. Avery Index to Architectural Periodicals, EBSCO host.

traits between an aesthetic style and research under a scientific paradigm arise out of this commonality of being.

III) Designing in a style does not require following rules. This suggests that research, like design, is essentially a creative activity, or at least rooted in a pre-cognitive way of knowing that defies propositional definitions.

IV) Normal science and design activity both emerge out of cultural-aesthetic percolations. For science as well as style, neither a paradigm nor a style can attain hegemony unless and until a community agrees to it, and then promotes it. Significantly, in the case of paradigms, Kuhn appeals to aesthetic considerations to explain how a sanctioning community emerges:

"Something must make at least a few scientists feel that the new proposal is on the right track, and sometimes it is only personal and inarticulate aesthetic considerations that can do that. Men have been converted by them at times when most of the articulate technical arguments pointed the other way. When first introduced, neither Copernicus' astronomical theory nor De Broglie's theory of matter had many other significant grounds of appeal. Even today, Einstein's general theory attracts men principally on aesthetic grounds [...]."²²

By aesthetic, Kuhn does not mean anything overtly art-related, but the generally inarticulate manner in which group consensus usually forms.

²²Kuhn, Thomas S. *The Structure of Scientific Revolutions*. 2nd ed. Chicago: University of Chicago, 1970.

3. Laboratory Conditions, Architects Reimagine the Science Building- Paul Goldberger²³

Using number of examples, Paul Goldberger demonstrates the role of architects in designing spaces that enlighten researchers by allowing them to meet, interact, and collaborate. He says, "architecture increasingly reflects the view that important breakthroughs come about not necessarily from the glorious isolation of hermit geniuses but often from collaboration and unexpected moments of cross-pollination."

This means that architects should look into science buildings as an artwork but not one that is mere aesthetically attractive, "whereas art can look great in unusual spaces, an architect cannot decide that he is going to make a wedge-shaped laboratory just because wedge shapes are his trademark. Scientists have very clear specifications for what they need: laboratory benches have to be a certain size and laid out in certain ways; equipment has to be accessible to everyone; some labs need powerful vents, while others need absolute protection from the tremors that rattle almost every building from time to time. It is not easy to make a building exciting amid so many constraints."

He continues with raising an argument that, "there is perhaps a lurking irony in the fact that scientists, with all their love of hard data and sure proofs, are eager to let architects--as unempirical a bunch as one could hope to meet--

²³Goldberger, Paul. "Laboratory conditions" New Yorker 87, no. 28 (September 19, 2011): 88-89. Academic Search Premier, EBSCOhost.

shape a new kind of work environment for them. You cannot test architectural ideas the way you can test scientific ones, but it still seems a safe bet that the arrangement of a space helps shape the activities that take place in it."

After few examples of such laboratories, Goldberger says, "so many lab buildings are now designed with the goal of promoting collaboration that I have begun to think that scientists have become the architecture profession's most optimistic clients. They believe that well-designed buildings can help them."

4. Laboratory Design and the Aim of Science²⁴

In this article, early modern science and laboratory etymology are discussed. Owen Hannaway writes about the shift in the meaning of science itself and the way it has affected the science buildings. "The appearance of the laboratory is indicative of a new mode of scientific inquiry, one that involves the observation and manipulation of nature by means of specialized instruments, techniques, and apparatuses that require manual skills as well as conceptual knowledge for their construction and deployment.

With this emphasis there came a shift in the meaning of science itself: science no longer was simply a kind of knowledge (one possessed scientia); it increasingly became a form of activity (one did science). That there should

²⁴Hannaway, Owen. ". Laboratory Design and the Aim of Science: Andreas Libavius versus Tycho Brahe." The University of Chicago Press, Dec. 1986. pp. 584-610. Web. 24 Oct. 2013.

have arisen in this period a place specially set aside for such activity and bearing a new name serves to measure the force of that shift."

5. *The Architecture of Happiness*²⁵

The Architecture of Happiness mostly discusses the impacts of architecture as a physical environment on its habitants and visitors.

According to Alain de Botton, "what we find beautiful in architecture is something deep and mysterious in ourselves." It depends on what we are most likely to observe and what we are looking for.

He looks into different factors that can change the impact of the physical environment on a person, one of which is "time". The instant impact of a place on a visitor could be different from its slow impact on a habitant.

Architects play the most important role in generating "happiness" by triggering comfort in space.

Although, the physical shape of the building could be designed based on a certain idea of the architect, but it goes only half way to absorb the concept, the other half is the absorber.

A good architecture has to be designed in a way that can develop a positive effect on the habitants as well as a fairly good first impression on the visitors.

²⁵De, Botton Alain. *The Architecture of Happiness*. London: Penguin, 2007.

C. Design Principles

How can Architecture promote science and amplify the scientific revolution?

To promote science through space, first, architects have to have a comprehensive understanding of what will come next. Since the nature of science is to change, it is necessary to perceive the future changes. The next step is to design in a way that could guide researchers toward that future. That understanding makes the construction of a facility that works now and is flexible to subsequent changes, become feasible.

Architects, just like researchers, are working within a paradigm. Common sense says that they should not tend to conflict with it. Any evidence, which is conflicting with this commonality of seeing things, is seen as an anomaly. However, in the end, as David Wang in "Kuhn on Architectural Style"²⁶ says, more and more anomalies crop up such that, after a transitory period of crisis, a new paradigm emerges. This thesis is one of those anomalies, which, tends to see the future of scientific activities as it is shown in Figure 19.

²⁶Wang, David. 2009. "Kuhn on architectural style." Arq: Architectural Research Quarterly 13, no. 1: 49-57.

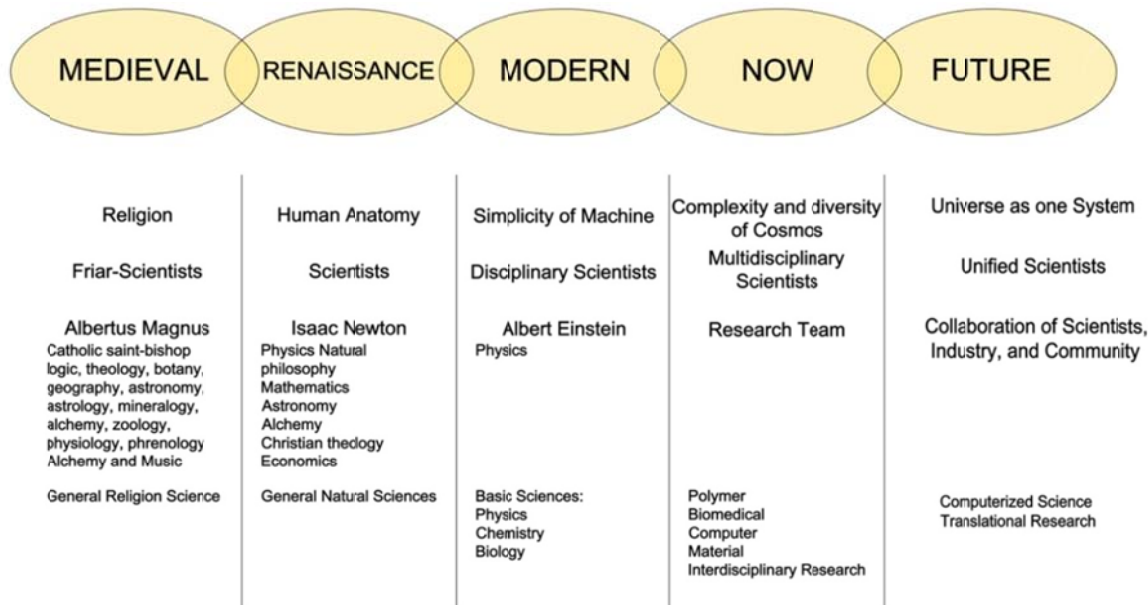


Figure 19 - Science over Time

Practical research methods are based on multidisciplinary teamwork and basic sciences are getting more and more dissolved into each other.

It seems like future computers excavate material properties and simulate bench experiments. There might be no more need to massive mechanical spaces for ventilation.

Finally, collaboration in science will not be limited to the researchers. The knowledge body will be fed from the collaboration of academia, industry, and community (Figure 20). The link, which connects between demand and offer, will be stronger.

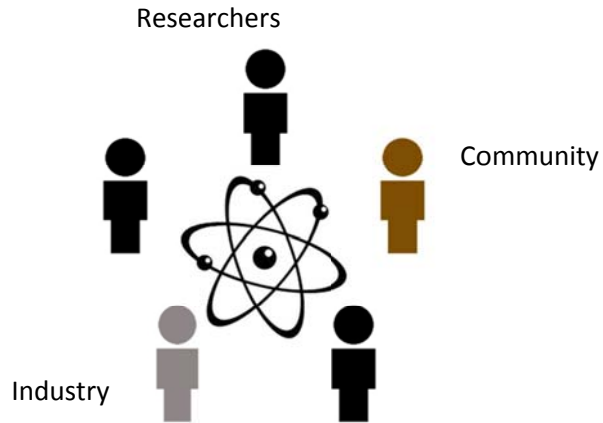


Figure 20 - The Collaborative Research

Considering the speed with which information and knowledge increases, designing for next decade is a challenging task. There are several examples that demonstrate designers' wrong perception of future. Not far from one of this thesis site, LGRC low-rise is the perfect example. At the time of its construction there was no doubt that computers were going to be stronger and "bigger", therefore the design was to be able to adopt with future equipment. The only problem was the difference between designers' imagination of a big computer then, and what really happened to computers (Figure 21).



computers

CHAPTER 3

SURVEY

As an architect, the most important mission is to consider and satisfy the end-users of the building. It is vital to investigate how existing similar faculties are serving the users to know what needs to be alternated or expanded.

Therefore, a survey was conducted focusing on faculty members, graduate students, and their preferences within laboratory spaces. The results were useful to develop guidelines for the design of laboratory space.

The Questionnaire Design and Analysis

The survey was carried out mostly spatial qualities of the learning and research environment. Two first questions were to acknowledge if the respondent is an undergraduate or a graduate student, also the amount of time they spend in laboratories on a weekly basis. (Figure 22)

The survey takes approximately three minutes to complete. The questionnaire was composed of six questions in total, in two of which respondent has to choose between two laboratory layout options presented as simplified picture. The survey was sent to 200 students and 25% responded to it.

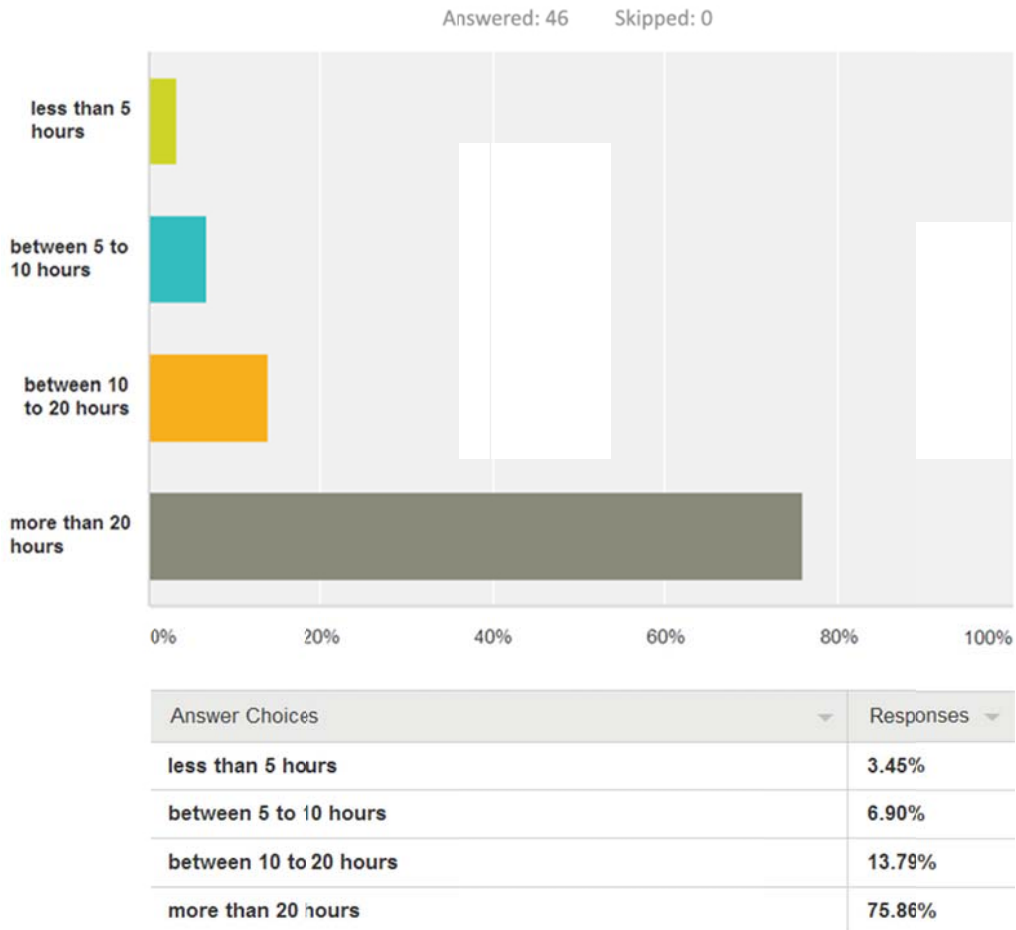


Figure 22- Time spent in lab

Next question was asking researchers to score each spatial quality they think is of more importance in a laboratory environment.

Among all options, natural light has received the highest score. Even though, as number of researchers have mentioned in their comments, some experiments require dark environment, a naturally lit work environment is desired.

Followed by natural light, the next demanded quality is a view to outside. It makes it clear how important is to connect with the everyday life, which is going on outside of the laboratory.

Lab work is usually repetitive and there are time gaps in between experiment to be filled by productive activities. Many believe the most important things happen in these gaps when researchers have some time to share their progress with their colleagues and get some feedback as well as a fresh look to what they are doing. To make this progress happen, there is a need to incorporate common lounges equipped with kitchenettes and informal gathering areas to exchange ideas. Interestingly enough, common lounges and informal group workspaces close to labs are equally demanded (Figure 23)

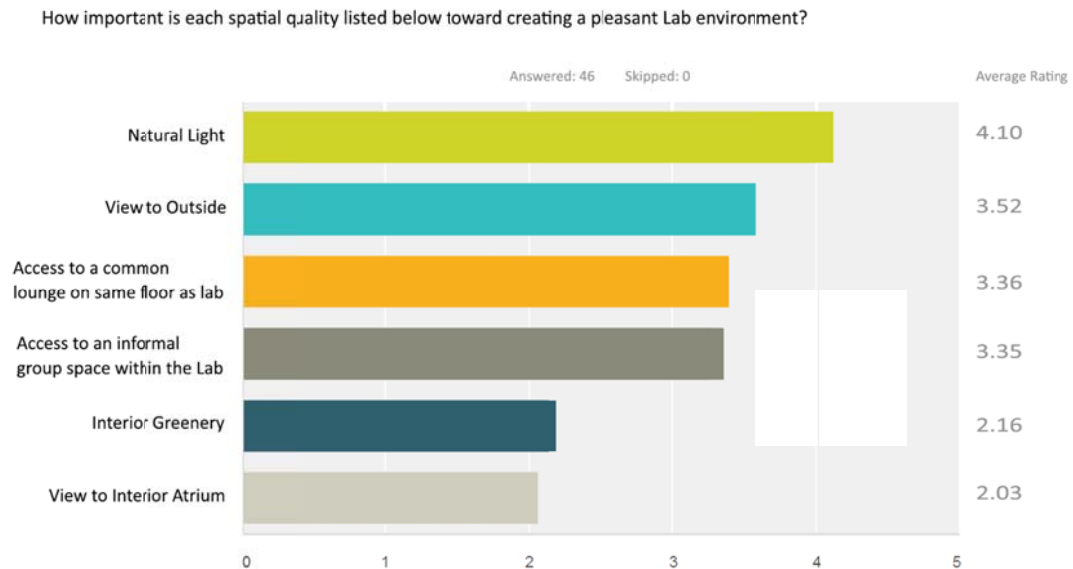
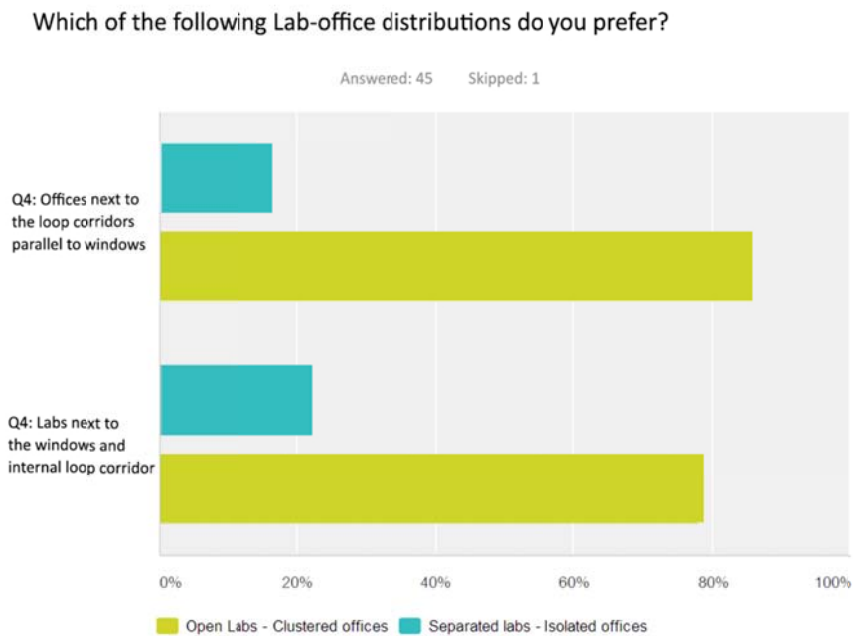


Figure 23 - Spatial Quality

Two pairs of simplified floor plan layouts comprised the next two questions. Researchers had to choose between "labs next to windows" and "labs next to interior corridors", then between "open lab" and "isolated lab" layout options. As it is shown in Table 3, about 75% of either those who prefer labs next to windows or interior corridor, wanted to have the open laboratory layout.



	Open Labs - Clustered offices	Separated labs - Isolated offices	Total
Q4: Offices next to the loop corridors parallel to windows	76.19% 14	23.81% 5	14
Q4: Labs next to the windows and internal loop corridor	74.18% 19	25.82% 7	26
Total Respondents	33	12	45

Figure 24 - Open/Close laboratory

In the end, researchers were asked to choose between existing facilities on campus. Thinking about a real space helps them to have a clear imagination of what they want to convey (Figure 25).

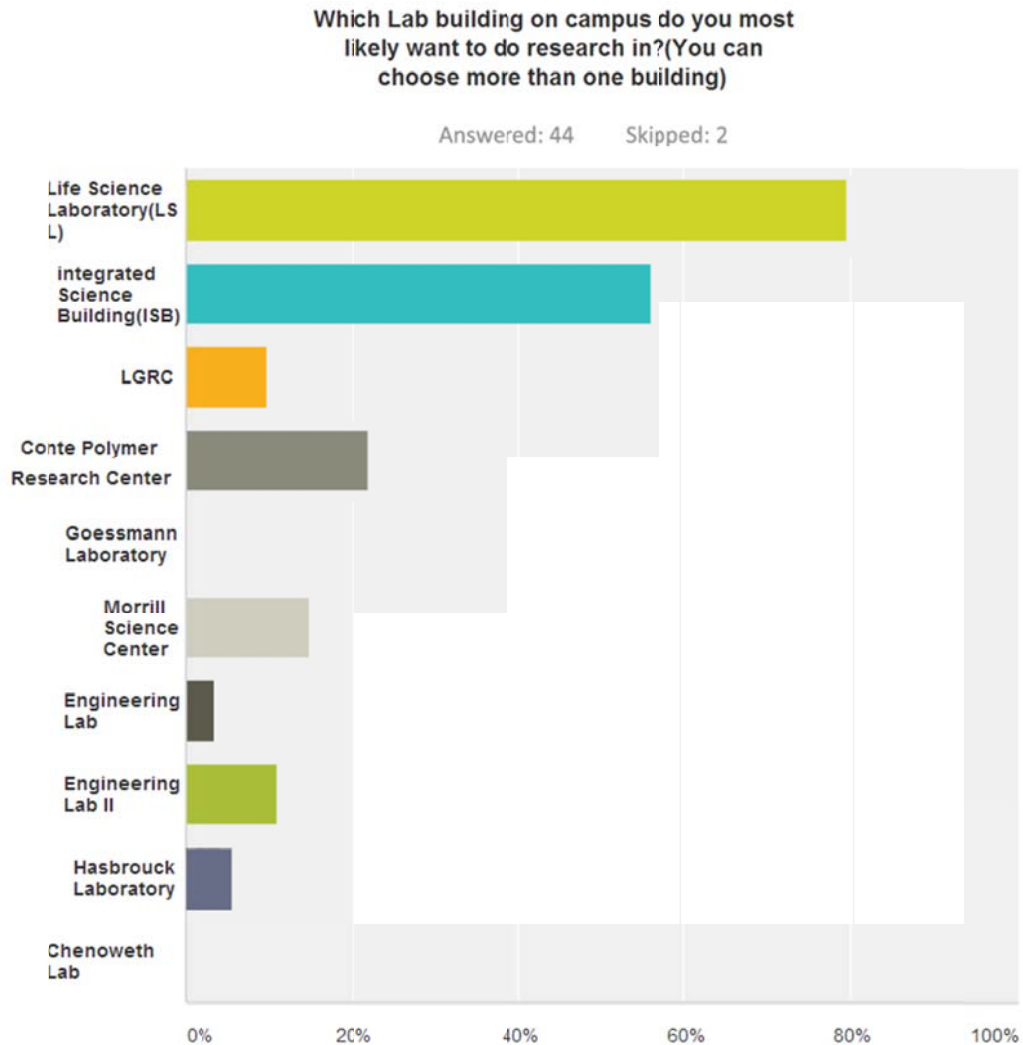


Figure 25 - On Campus Labs Popularity

Following notes are comments provided by researches who took the survey.

- ISB- excellent new facilities but not my favored design.
- LSL, ISB, Conte- Newest
- LSL, ISB, Conte, E-Lab II- The tools in these lab buildings are far better and newer than the other buildings.
- It is also a matter of convenience walking to lab every day.
- Anything but Morrill!
- LGRC and Hasbrouck- near bus stop
- LSL and ISB- natural light
- LSL and ISB- Large windows to outside. CLEAN. Generally hospitable.
- ISB and Hasbrouck- I have not been to a lot of the new buildings, but I really like the open design of the
- ISB. The labs in Hasbrouck are just fine though. Shared offices without traditional cubicles are important though, because all those extra walls make collaborative discussions very frustrating.
- LSL- It's a new building the space is a little smaller than what we used to have but the good thing is almost everything is within your reach. I do not have to walk long distances to get what I want. Also, we are mixed with other groups so if there are things that I need and our group don't have it, I just borrow them from the other groups.
- LGRC and Hasbrouck- Physics
- I sadly have not had a chance to see most of these facilities. While I personally feel that natural light and views are important, my research field unfortunately requires darkness and therefore permits neither of these.

As it shows, in addition to natural light, it is very promising that researchers and students themselves demand the new approach in collaborative and open scientific activities.

CHAPTER 4

DESIGN

As it was mentioned before, the goals of this thesis are to amplify existing knowledge, and develop a building type that would generate new research disciplines, and catalyze the translation of research into practice.

Those goals are being attained by different project components including project location, program, building systems, and its form and materials.

A. Umass Campus History/Guidelines

In 60s and 70s, the buildings were designed without affiliation to the architecture of the past or to other campus buildings constructed in the same period.

The result is a campus with collage of disparate architectural styles that reflect the rich history of the institution, but that lack a certain visual unity.

Furthermore, there is little cohesion between campus buildings and surrounding open space²⁷.

According to University of Massachusetts Amherst Design Guidelines, new buildings should be effective at all levels, contributing to a sense of community and cohesiveness, as well as being an individually strong work of

²⁷University of Massachusetts Amherst Design Guidelines.UMA Campus Landscape Design Standards. March 2007.

architecture. Respect for context implies sensitivity to scale, materials, patterns and form without dictating strict adherence to any particular style.

When considering siting options for a new building project, the following priority order should be generally followed:

- Seek to identify an underutilized and/or decaying existing building – suitable in size, location and structure – that could be renovated to meet the needs of the new program.
- If no renovation possibility exists, consider an addition to an existing facility, possibly linked with renovation work to the existing structure.
- If neither renovation nor addition is feasible, consider an infill site on campus. This includes open space within the campus core (whether green or paved) as well as the possibility of removing obsolete facilities in order to make space available for the new project. Preference should be given to infill sites that have already been developed over virgin sites.
- If no other possibility exists and if land is available, consider adding a new structure at the periphery of the campus²⁸.

In order to maintain a homogenous context and respect campus' historical heritages, following preferences will be considered in the design:

²⁸University of Massachusetts Amherst Design Guidelines.UMA Campus Landscape Design Standards. March 2007.

- Materials complimentary to brick such as natural stone can also be used successfully.
- The intent is not to restrict creativity but to improve the visual unity of the campus as a whole.
- Where buildings front on public streets, the design should include public entrances and attractive, open streetscape facing the street. The use of highly reflective or deeply tinted glass should be avoided.
- All new construction must comply with the Massachusetts Architectural Access Board Regulations (521 CMR) and Americans with Disabilities Act (ADA) guidelines. Renovations of historic buildings should seek to improve access for the disabled in a manner compatible with their historic integrity.
- Rooftop mechanical equipment should be enclosed in structures that are integrated into building design.

B. Location

The town of Amherst is located in Hampshire County, Pioneer Valley of Western Massachusetts. The town is host to Amherst College, Hampshire College, and the University of Massachusetts at Amherst. As of the 2010 census, population in 2010 was 37,819.

The project is located on UMass Campus and it lies exactly at the intersection

of campus science life and its student life. There is an existing physical sciences building on the site, Hasbrouck Hall, which was constructed in 1947 by Kilham, Hopkins, Greeley, and Brodie with additions by Desmond and Lord in 1964.

Hasbrouck is logistically very important. There are several pedestrian paths directed and adjacent to it. It is located next to North Pleasant Street and there are two bus stops few steps away from it. These qualities results in two focal nodes (Figures 26 & 27).

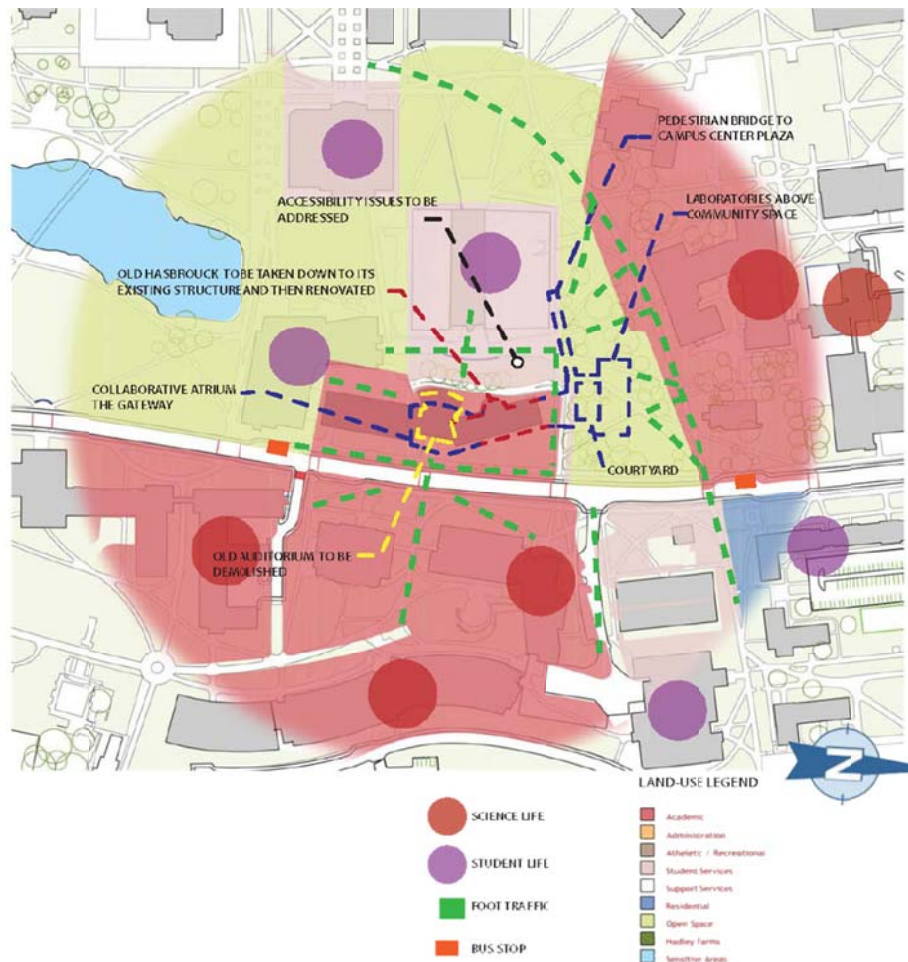


Figure 26 - Land use/Overview

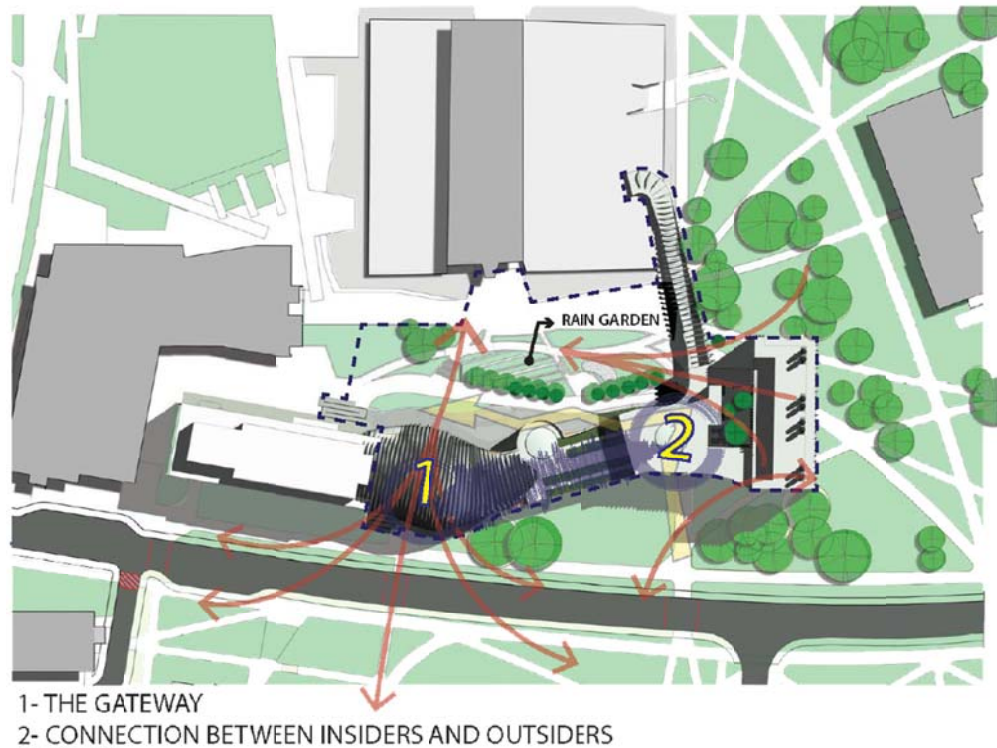


Figure 27 - Focal nodes

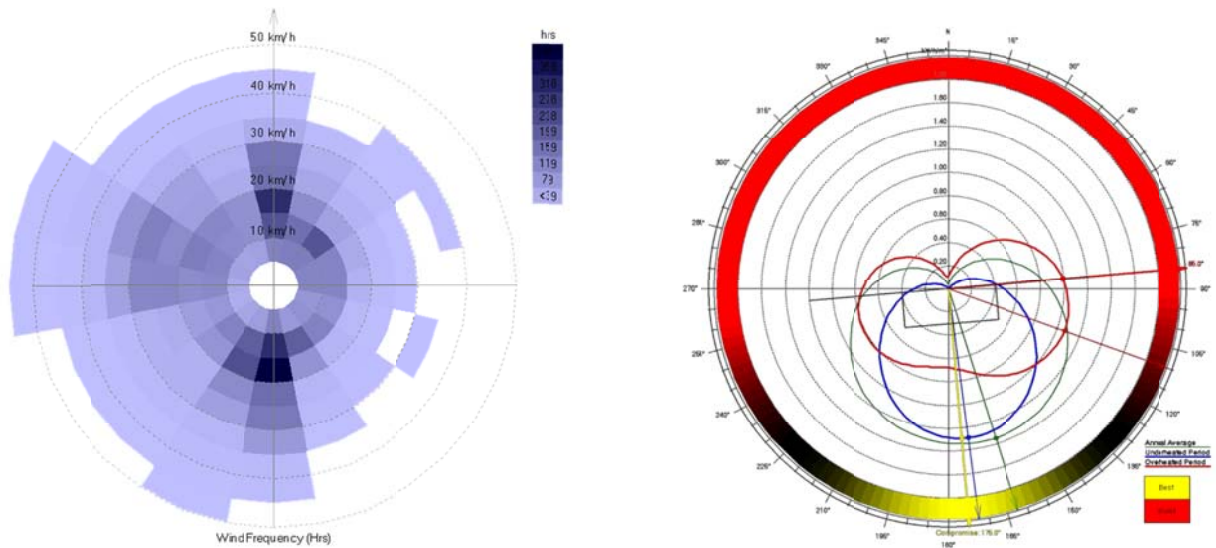
Node number one, where Hasbrouck and its addition meet has the potential of celebrating the space as a gateway that forms a connection between two entrances, one in the ground floor from west and another in the first floor from east side of the building.

This quality will serve the notion of thesis by blending a vast variety of students, faculty members, and visitors through a single space. New construction is extended out of the northern wing of Hasbrouck following the street curve and going over the existing service road.

Accessibility issues are addressed on the west side of the site, between Hasbrouck and Lincoln Campus Center by adding two ramps. The space

between two buildings is embraced and celebrated as a courtyard in campus scale. A pedestrian bridge is connecting the first floor to Campus Center plaza completing the circulation loop around the courtyard. A rain garden along with exterior seats is provided to activate the landscape.

There were few other concerns about the site such as infrastructure, existing trees as a part of the Waugh arboretum, solar radiation, and because there are Laboratories included, wind direction (Figure 28).



Building orientation was designed responsive to the topography, wind frequency, and the best orientation suggested by Ecotect performance Analysis software.

An interior courtyard is embedded to provide sunlight and to preserve the trees.

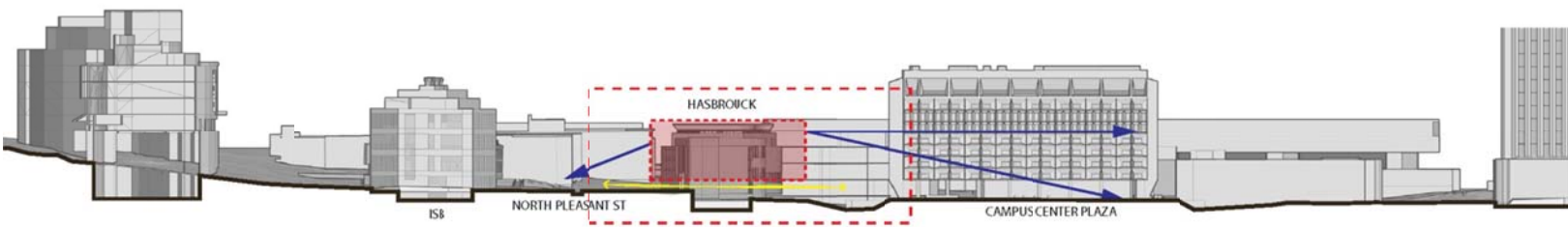


Figure 29 - Profile

C. Program

The program represents three stages of new science; it starts with research getting into application and ends with prototyping. The notion is that these three stages are on a progressive feedback loop.

These processes happen in collaborative spaces that are shared between multidisciplinary research teams, external users that could be from other academic centers and/or industry.

Research teams' principal investigators (PI) and laboratory equipment are composed of substantial research types, which can be utilized by all departments including Cyber-Technology, Biotechnology, Nano-Technology, and Engineering. In order to incorporate community in the program, collaborative instructional spaces are accessed and used by humanity departments such as Art and Communication.

Figure 31 shows the primary programmatic diagrams of how the spaces are arranged around the circulation system.

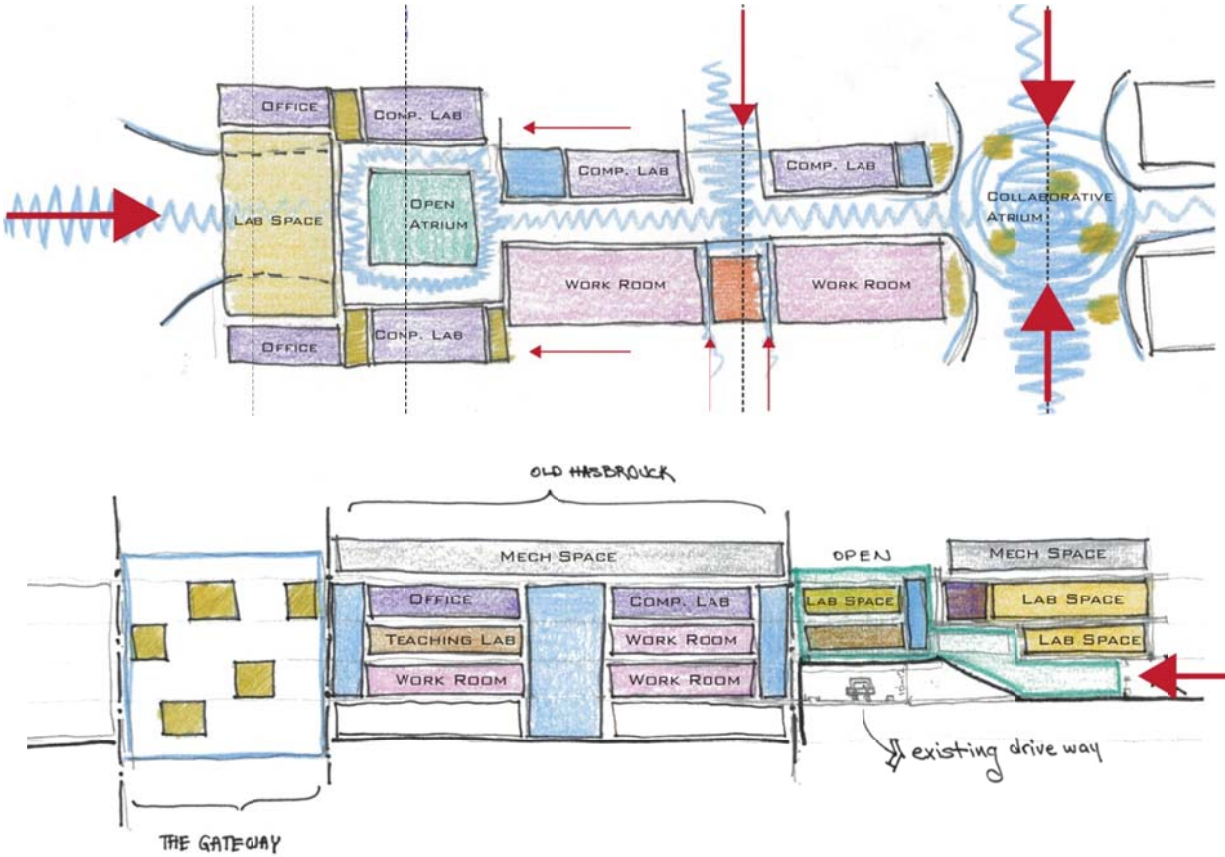


Figure 30 - Program Diagram

A large part of the program is to use existing structure of northern wing of Hasbrouck. Old labs cannot support new research methods and they are significantly expensive to renovate into up to dated laboratories. Therefore, existing structure is completely repurposed.

The space is used as offices, conference rooms, team based classrooms, and transparent multipurpose workrooms. Figure 29 shows renovation phases in Hasbrouck hall.

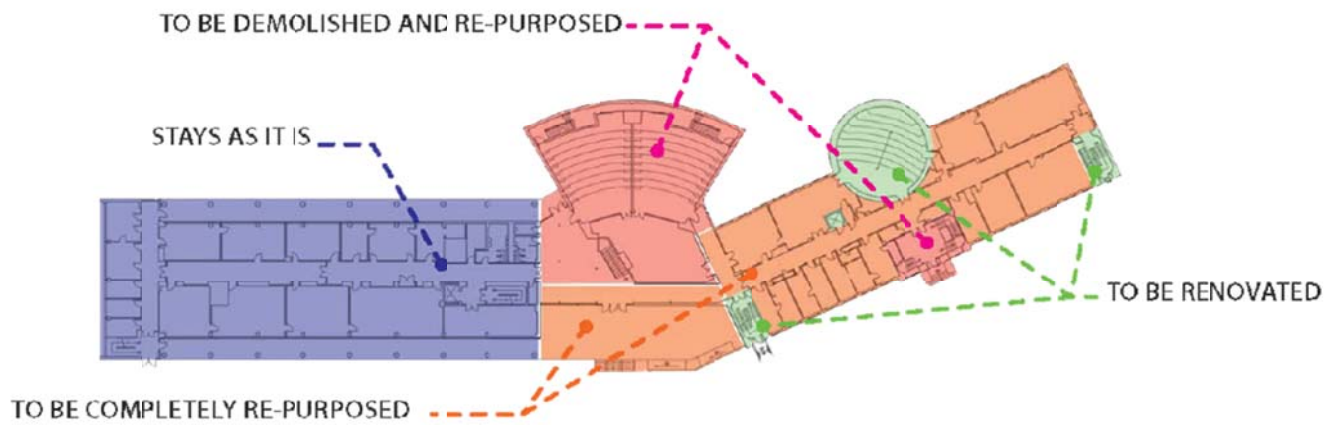


Figure 31 - Renovation phase

Workrooms can be used as testing labs for engineering departments.

Providing conference rooms next to workrooms makes it possible for different parties such as faculties, community representatives, and industry headquarters to observe the activities in them (Figure 30)

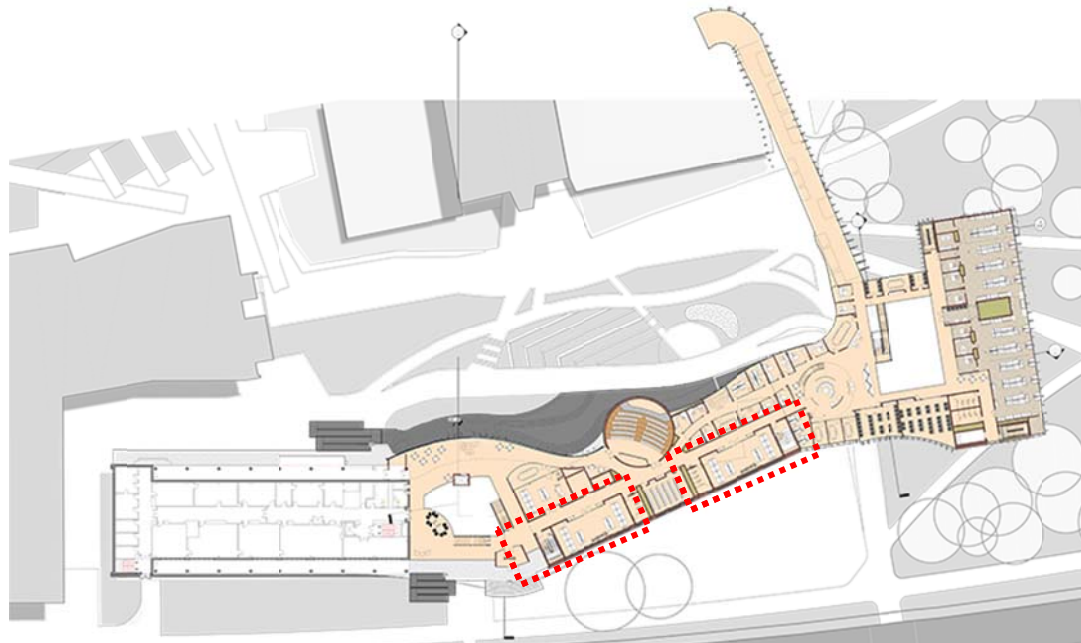


Figure 32 - First Floor Plan



Figure 33 - Workroom

There are open and warm enjoyable spaces incorporated in the program to make it suitable for long hours of working. Researchers can use these spaces to communicate and talk about their work. Lounges, group study rooms, and conference rooms for each research group are preferably on the same floor of their Lab and within their offices (Figure 31).



Figure 34 - Lounge

These collaborative spaces are visible to everyone and can be used by everyone.

The pedestrian ramped bridge houses a variety of activities, and it activates the Lincoln Campus Center plaza (Figure 32).



Figure 35 - Pedestrian Bridge

Combined teaching and research facilities in one building brings in and blends different kinds of activities. Coffee shop and community space in the ground floor is located where several pathways lead. Occasions such as exhibitions, live music, or simply "fresh cookies at 3:00 pm" can bring down researchers from their labs and offices, brings in other students from all over the campus and provide chances for communication, interaction and cross-pollination (Figure 33).



Figure 36 - Fresh cookies at 3:00 pm



Figure 37 - Collaborative Link

D. Building Systems

The project is designed to be structurally and mechanically flexible to future changes. Lab area's layout can easily be rearranged to correspond other types of use (Figure 35).

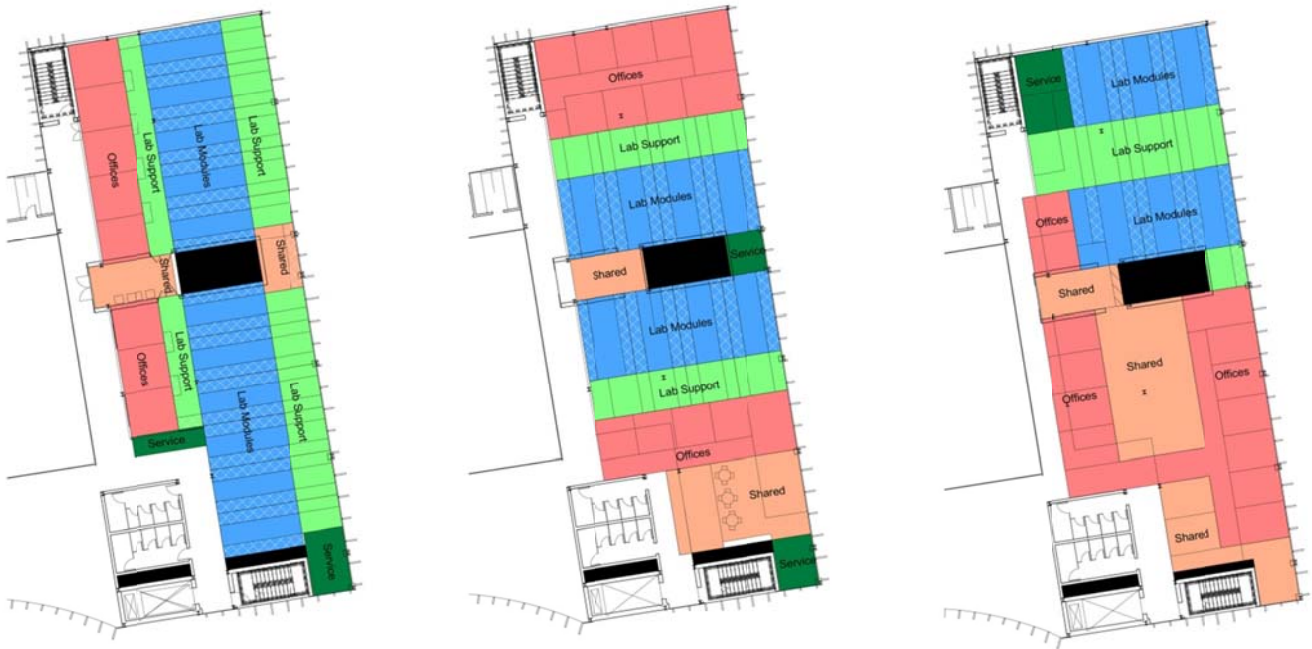


Figure 38 - Alternative layouts

Interstitial mechanical spaces between double volume labs can be accessed by a corridor from second floor. Stairs align with existing structure's floor slabs and it makes it possible to divide double volume lab spaces into two normal floors (Figure 36).

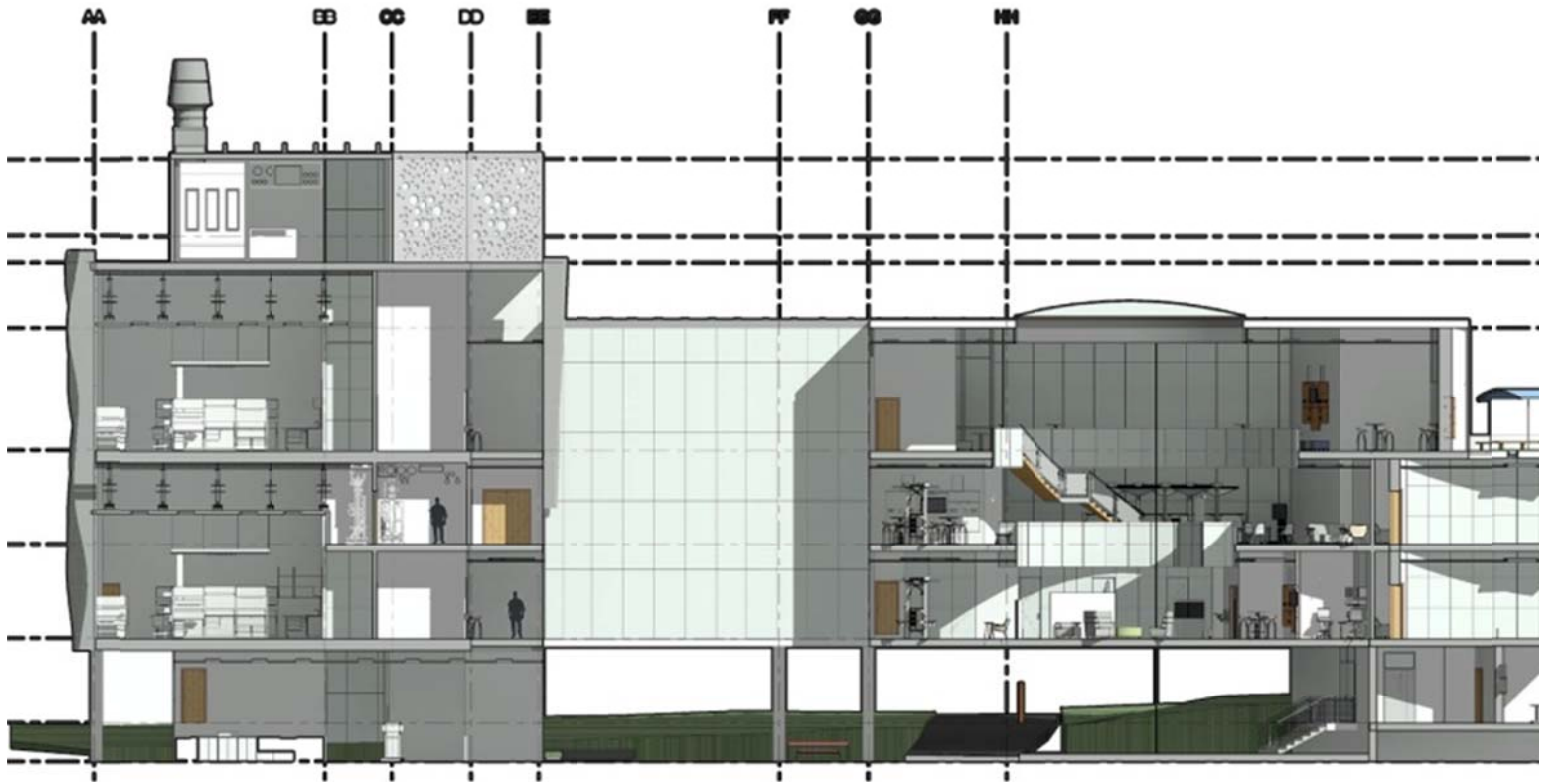
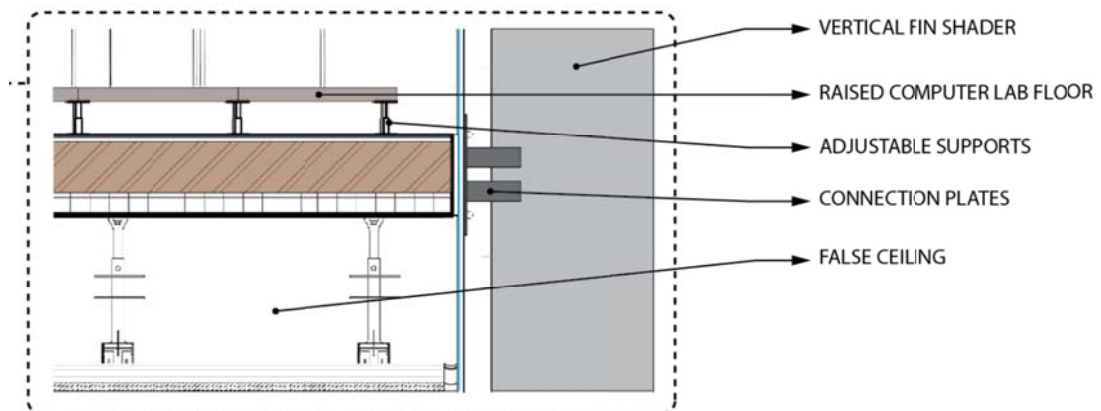


Figure 39 - Flexible Building Systems

Computer labs floor is raised by adjustable supports, which are independent from the structure and can be relocated (Figure 37).



E. Forms and Materials

The shape of this project is a combination of a curves that are opposing the rectangular parts. A translucent curvy roof is covering the collaborative link and it fades into Hasbrouck's north wing, as we continue toward the new construction, same material used in collaborative link start to be used again as exterior glazing and vertical shading fins.

Hasbrouck north wing façade is replaced by wooden double skin façade and it has more openings, material used in the café is a combination of wood and glass.

In fact, wood and glass are representing community and warmth, in contrast, curvy steel and glass are representatives of science and future. The whole form is emphasizing this contrast. The notion is to show how a new paradigm could be different from the past one yet, it has emerged out of it (Figure 38).

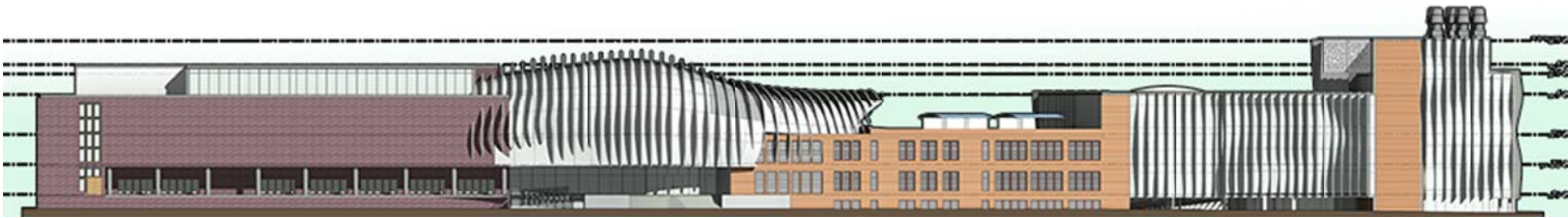


Figure 41 - East Elevation

Following figures show details of building façade. The curved roof translucence shell material is ETFE, Ethylene tetra fluoro ethylene, which is designed to have high corrosion resistance. This fluorine based material is

very strong against wide temperature range, It is light, easy to install, and easily adapted to variety of forms²⁹ (Figure 39).

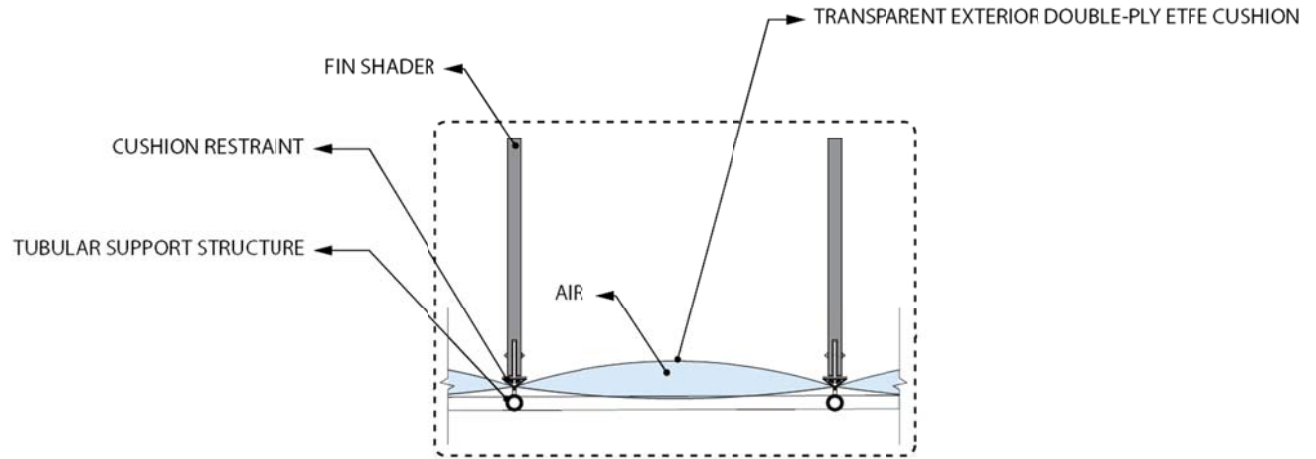


Figure 42 - ETFE Detail

²⁹ Aksamija, Ajla. Sustainable Facades: Design Methods for High-performance Building Envelopes. New Jersey: Wiley, 2013.

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