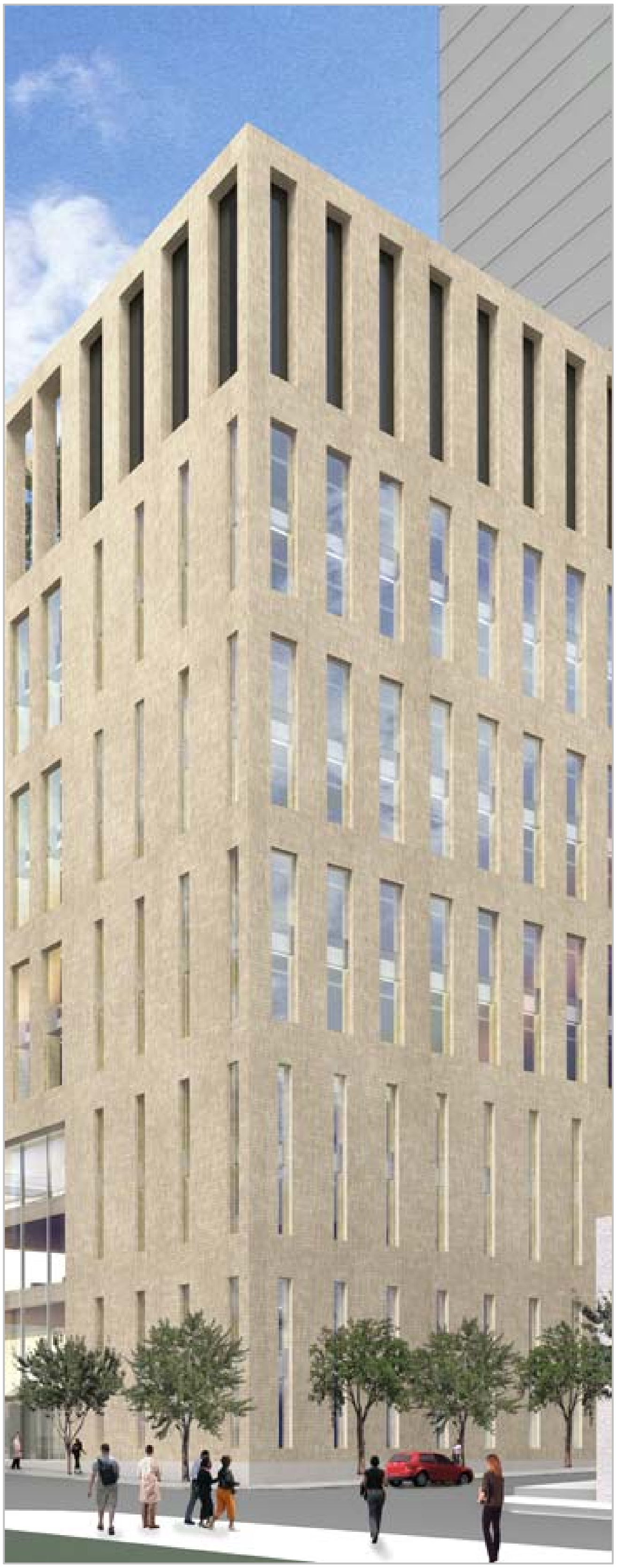
# center for science & medicine

## new york, ny



## Thesis Proposal

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# Executive Summary

## Building Description

The Center for Science & Medicine is an 11-story research laboratory located in New York City's Upper Manhattan. Situated within the building are a spacious lobby area, 6 floors of wet lab research space, 1½ floors of clinical space, a clinical trial area, and space for research imaging. The building stands a total of 184'-0" above grade, with a typical floor to floor height of 15'-0." It is a steel structure designed with a core of braced frames in the center of the building and moment frames around the perimeter. The footprint of CSM is approximately 172 feet by 200 feet.

## Depth Study: Lateral System Re-Design

At its current phase of design, the Center for Science and Medicine has been planned to utilize a combination of perimeter moment frames and core braced frames to resist lateral loads. After careful study of this system, it has been determined that moment frames are not significantly stiff, due to their double-heighted configuration, and braced frames pose coordination headaches as well as constructability issues. Therefore, two alternative systems will be proposed to in an attempt to eliminate these issues.

> Alternative 1: The first option for a lateral system re-design is a core-only system of shear walls. These shear walls will be designed to resist 100% of the lateral load in both directions, therefore eliminating the need for perimeter moment frames. Such a system is expected to provide more stiffness than the current braced frame design, provide added resistance to uplift, and possibly speed erection time while cutting costs in the elimination of expensive moment frames.
>
> Alternative 2: The second system considered will use a combination of shear walls at the core and moment frames at the perimeter to resist lateral loads. Shear walls around the building core will be thinner in this configuration since they will be aided by moment frames in resisting load. Moment frames will be located one bay length inside of the perimeter and will be designed with moment connections at every level. With this configuration, frames will be stiffer, they will not need to run the whole length of the building, and the exterior cladding system will become a non-issue. This system should be lighter than Alternative 1 while still reducing the number of moment connections needed to resist lateral loads.

## Breadth Study 1: Sustainability

The Center for Science and Medicine has been designed with the goal of attaining a LEED Gold rating. Such a classification requires the building and its systems to fulfill at least 39 out of a possible 69 LEED points. Since the project is still in the design development phase, only a pre-certification estimate has been performed to determine which points can be earned. The estimate indicates that 33 points are planned or have already been incorporated into the design of the building. This leaves a minimum of 6 points to still be fulfilled in order to attain LEED Gold. This breadth study will investigate various sustainable solutions that will earn the needed LEED credits to obtain a Gold rating. Cost analysis of these systems, as well as schedule impacts, will be considered as well.

### Breadth Study 2: Construction Management & Building Information Modeling (BIM)

One of the unique aspects of the Center for Science & Medicine is that it is being designed in 4-D, utilizing BIM (building information modeling) technology. Since this is a relatively new design tool in an industry based on historically-rooted standards and practices, it is a question as to whether this cutting-edge design method will truly pay off. This breadth study will consider the positive and negative effects BIM has had on the design process of CSM thus far. Additional research will be done to investigate other design / construction processes done using BIM, and data collected from such case studies will be used to compare to CSM's specific case. From here, conclusions can be drawn regarding the effectiveness of building information modeling, and recommendations can be made to CSM's design team as well as the rest of the AEC community.

# Introduction

The Center for Science & Medicine is a research laboratory designed for scientific investigation, discovery, and treatment. Located in New York City's Upper Manhattan, the building is organized and shaped by its architectural program. On the north and south edges of the site, two linear lab bars encompass a core of support spaces. The building's east edge links the inside to the outside with a window-covered, multi-story atrium. Situated within the building are 6 additional floors of wet lab research space, 1½ floors of clinical space, a clinical trial area, and space for research imaging. The building is 11 stories above grade with a typical floor to floor height of 15'-0", giving a total building height of 184'-0." A 40-story residential tower will also rise on the site adjacent to the lab, but the buildings are clearly defined as two separate entities. Below is a site plan showing the CSM research center, the adjacent residential tower, outdoor service areas, and surrounding buildings.

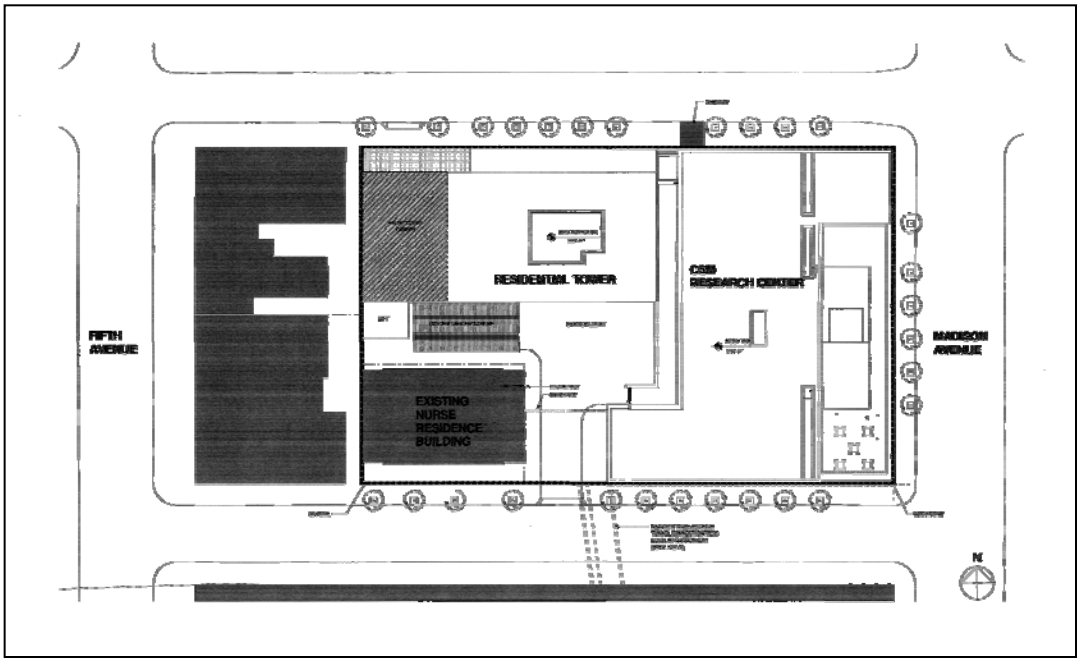


Figure 1: Site Plan

It is important to note that the Center for Science & Medicine, or CSM, is only at the 50% design development phase. Thus, the existing structural design and calculated quantities are not absolute or finalized.

# Existing Structural System

## Foundation

The foundation consists of reinforced concrete spread footings ranging from 4'x4'x2' to 8'x8'x4' (l x w x h) in size, with a concrete compressive strength of $f'_c = 5000$ psi. Maximum footing depth is 49'-0" below grade, and all footings bear on sound bedrock (Class 2-65 rock with bearing capacity 40TSF or Class 1-65 rock with bearing capacity 60TSF, according to New York City Building Code). Seven (7) of the total forty-three (43) footings have been designed to support columns from both the research center and the residential tower, as dictated by their location at the CSM / tower interface. Foundation loads vary from 400 to 3200 kips.

Below grade perimeter walls consist of cast-in-place, reinforced concrete ($f'_c = 5000$ psi) braced by the below-grade floor slabs. The walls stand 48 ft in height (equivalent to 4 basement levels). These walls have been designed to resist lateral loads from soil and surcharge in addition to the vertical loads transferred from perimeter columns above. On the north and south perimeter walls, reinforced concrete pilasters support perimeter columns above. A continuous grade beam ($f'_c = 5000$ psi) supports these perimeter basement walls.

The lowest level basement floor is an 8" concrete slab on grade with a compressive strength of $f'_c = 4000$ psi, typically reinforced with #5 bars@12" each way. At typical columns, additional slab reinforcement is provided with (4)#4 bars oriented diagonally in the horizontal plane around the column base. At lateral columns located around the building core, the slab is reinforced with (12)#5 bars oriented diagonally with additional longitudinal bars arranged in a grid pattern around the column base.

## Floor Framing System

CSM's existing floor system uses composite metal deck. The floor slabs typically consist of 3" metal deck with 4 ¾" normal-weight concrete topping, giving a total slab depth of 7 ¾". Thicker, normal-weight concrete slabs will be provided in spaces such as mechanical floors to meet acoustic and vibration criteria. These thickened slabs will be designed with 3" metal deck and 8" NWT concrete topping with reinforcement, giving a total slab depth of 11". Full composite action is created by 6" long, ¾" diameter shear studs, and concrete compressive strength is to be $f'_c = 4000$ psi. The composite metal deck is supported by wide flange steel beams ranging from W12x14 to W36x150 in size and spaced approximately 10'-6" on center.

There are two typical bay sizes used throughout the building, 21'-0"x 21'-0" and 43'-8" x 21'-0." Square bays typically occur within the building core, and rectangular, longer span bays typically occur around the building perimeter where research labs and clinical spaces are located. All floor framing has been designed to meet stringent vibration limits, due to the sensitivity of laboratory equipment located throughout the building, and these requirements are outlined further into the body of this report.

## Lateral System

Lateral resistance to wind and seismic loads is provided by a combination of braced and moment resisting steel frames. Refer to the plan on the right for the location of each lateral element and its label. Braced frames are shown in red, and moment frames are shown in blue.

**Braced Frames.** In both the North-South and East-West directions, lateral loads are resisted by diagonally-braced frames located around the building core. The majority of the braced frames are braced concentrically, but some of the frames are eccentrically braced due to architectural needs (space for doors, etc.). The core is made up of (6) column bays spaced at approximately 20'x20' and using W14 column sections. Heavy double tee sections serve as diagonal braces at the core and vary from WT6x39.5 to WT6x68 in size.

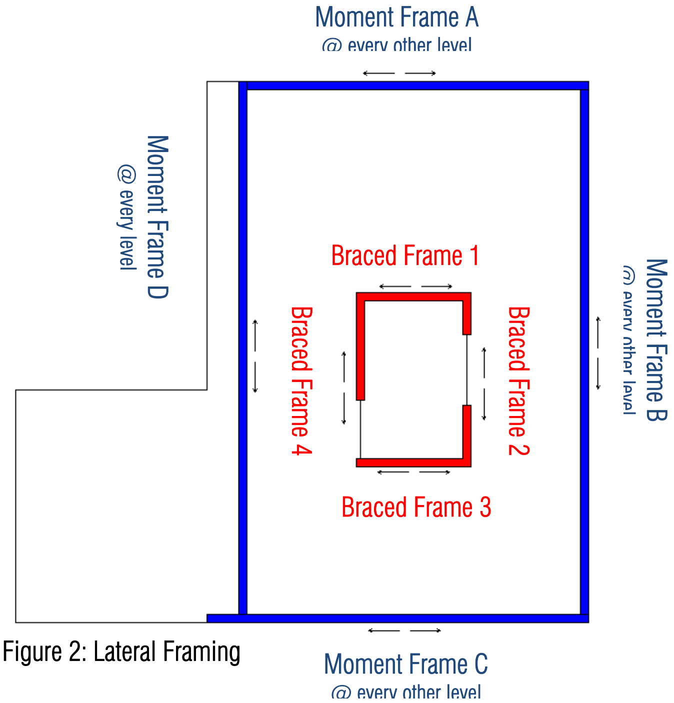


Figure 2: Lateral Framing

North-South Direction

Braced Frame 2

Braced Frame 4

East-West Direction

Braced Frame 1

Braced Frame 3

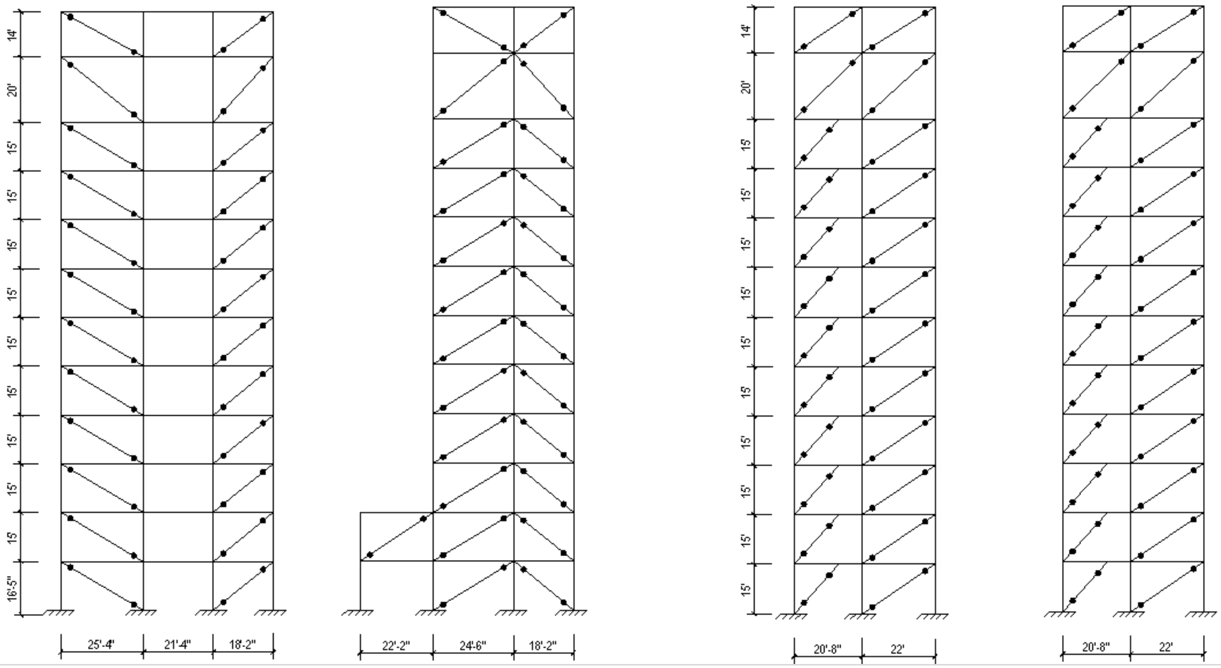
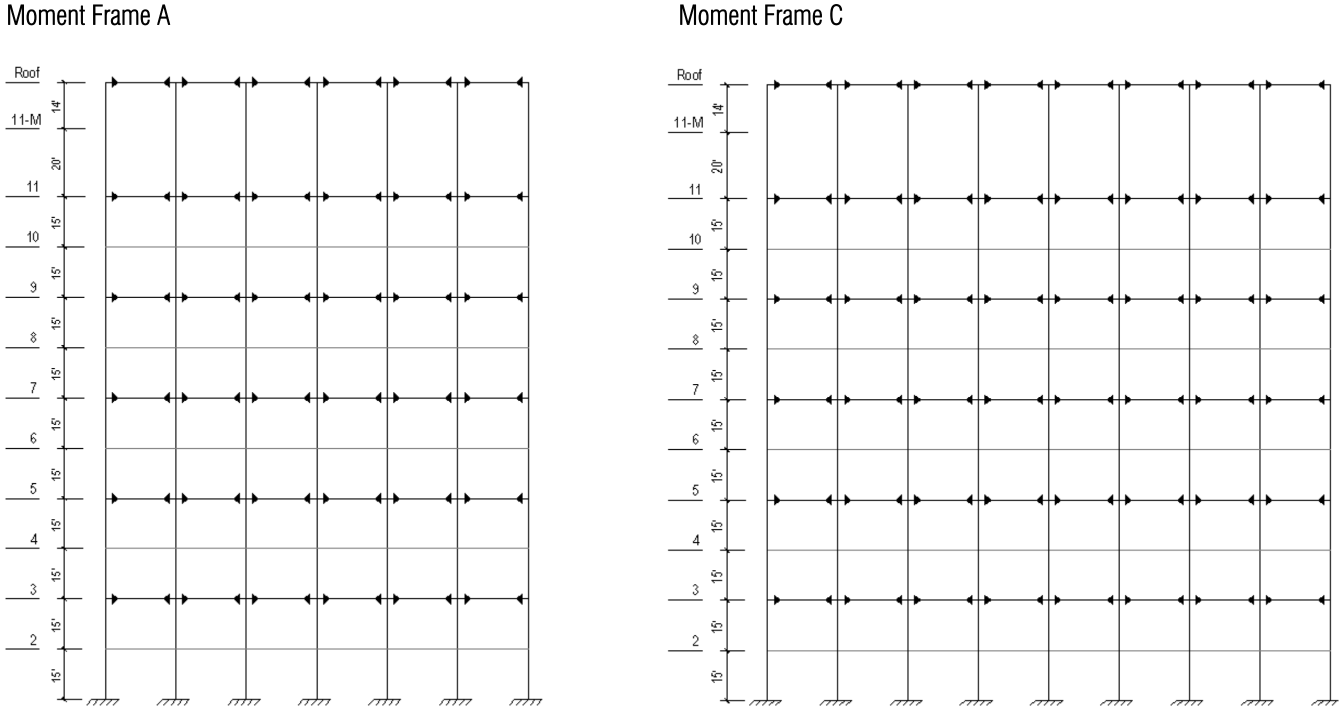


Figure 3: Braced Frames

**Moment Frames.** In both the North-South and East-West directions, remaining lateral loads are taken by a system of beam/column moment frames located at the perimeter of the building (or just inside of it, see Moment Frame D). These moment frames have been designed to use W14 or W24 column sections spaced approximately 21'-0" on center and W30 and W24 wide flange beams. What makes these frames unique is their double-heighted configuration. The first moment connections occur on the third level and then alternate levels up through the building's roof (a total of six floors with moment connections). Thus, instead of each moment frame being 15'-0" in height (as they would have been if occurring at each floor), the moment frames are actually 30'-0" in height. Shear connections occur on even-numbered levels, and spandrel breams are set back (framing into girders), thus providing no contribution to lateral resistance at these locations.

Such a double-heighted frame configuration was necessary for CSM because of architectural design. The exterior cladding is a "perforated" system, meaning that the aesthetic pattern spans the height of two floors and the framing of every other level is visible through the windows. In other words, the exterior appears to be punched, or perforated, by alternating floor levels. For this reason, moment connections had to be placed at every other level, with intermediate levels framed by spandrel beams set back from the frame. Although this is not a desirable design from a structural point of view, it seemed to be the best solution that would satisfy both the structural integrity and the aesthetic appeal of the building. The diagrams below depict moment frames with dark lines and arrow heads, while intermediate levels (without moment connections) are grayed.

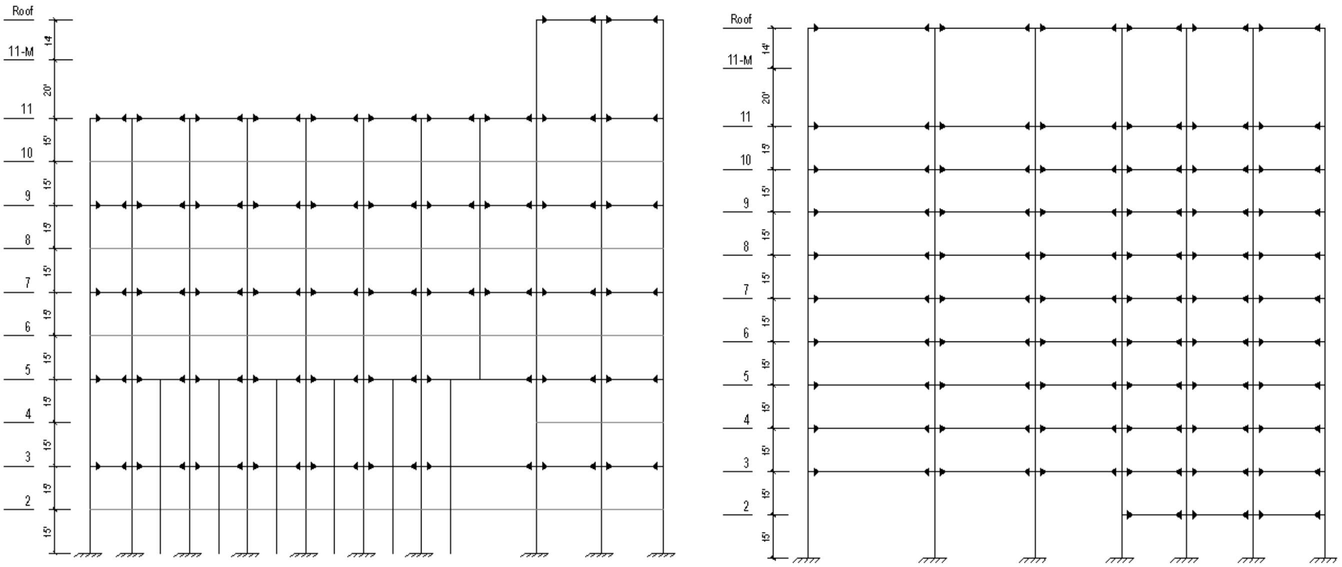
<u>East-West Direction</u>


Moment Frame A

Moment Frame C

Figure 4a: Moment Frames

## North-South Direction



Moment Frame B

Moment Frame D

Figure 4b: Moment Frames

## Roof System

The flat roof system is similar to a typical floor slab, consisting of 3" metal roof deck with 4 ¾" normal weight reinforced concrete topping and 6"x ¾" shear studs. Supporting this deck are wide flange steel beams ranging from W12x14 to W36x150 in size and spaced approximately 10'-6" on center. It is also important to note that a portion of the roof will be a green roof, but design has not progressed enough to gather significant detail at this time.

## Typical Floor Plans

**Architectural.** Below is the architectural floor plan for the first level of CSM. Colored zones indicate the functions of each area. The building footprint stays basically the same with increasing height, except for a slight decrease in area on the southwest corner beginning on the 3rd floor.

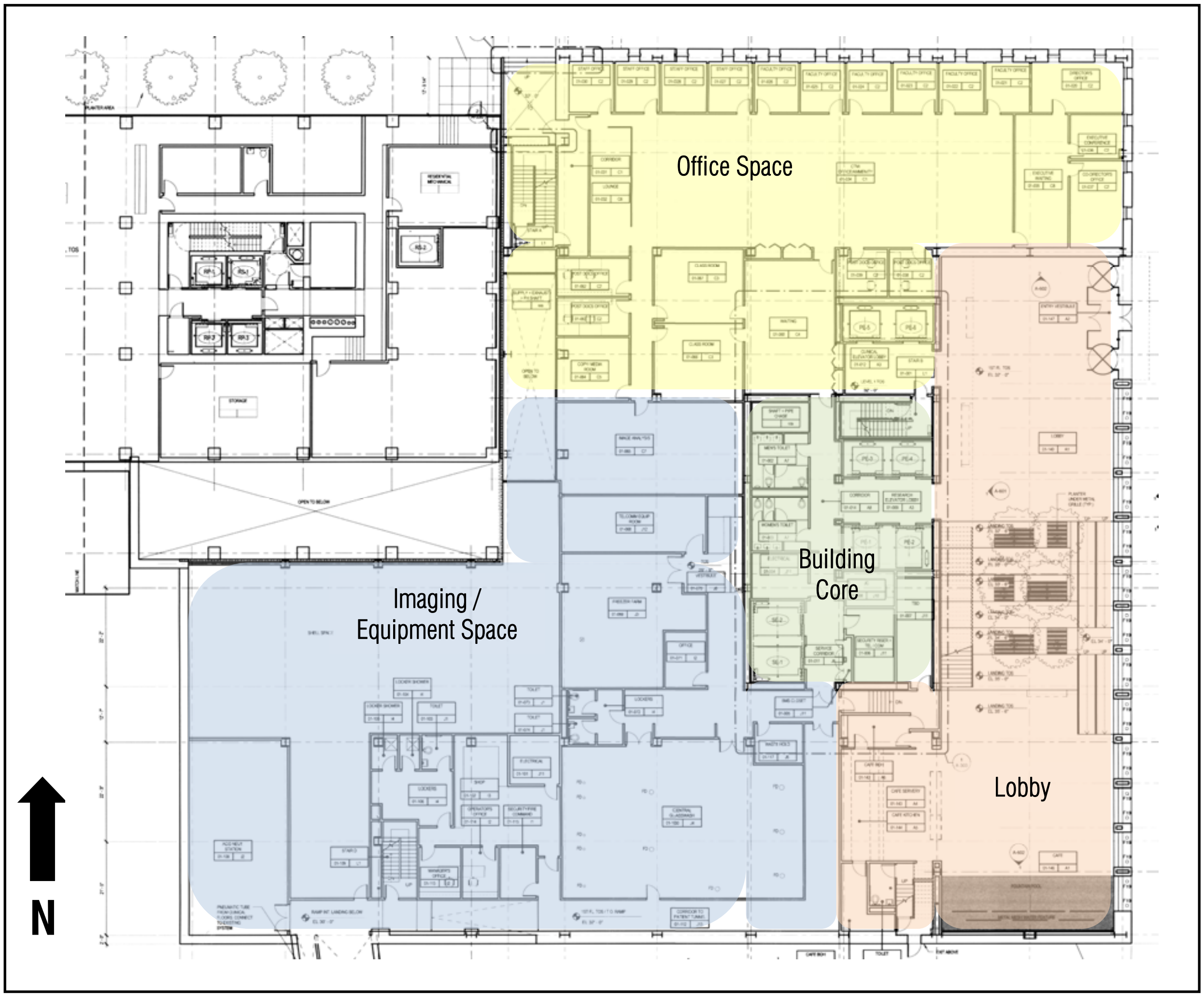


Figure 5: Level 1, Architectural Plan

**Framing.** Typical floor framing is shown in the figure below (laboratory floor). Composite metal deck spans the floor in the east-west direction in most areas and in the north-south direction above the atrium. Perimeter columns are spaced approximately 20'-0" to 22'-3" on center, and the longest span is 43'-8" (located on the north side of the building). A typical bay is noted with a dashed line and enlarged below.

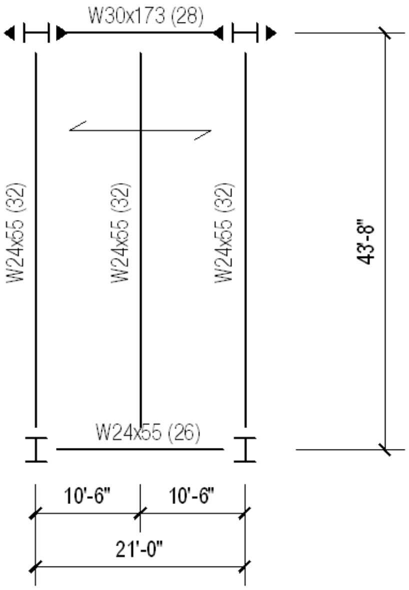


Figure 6: Typical Bay

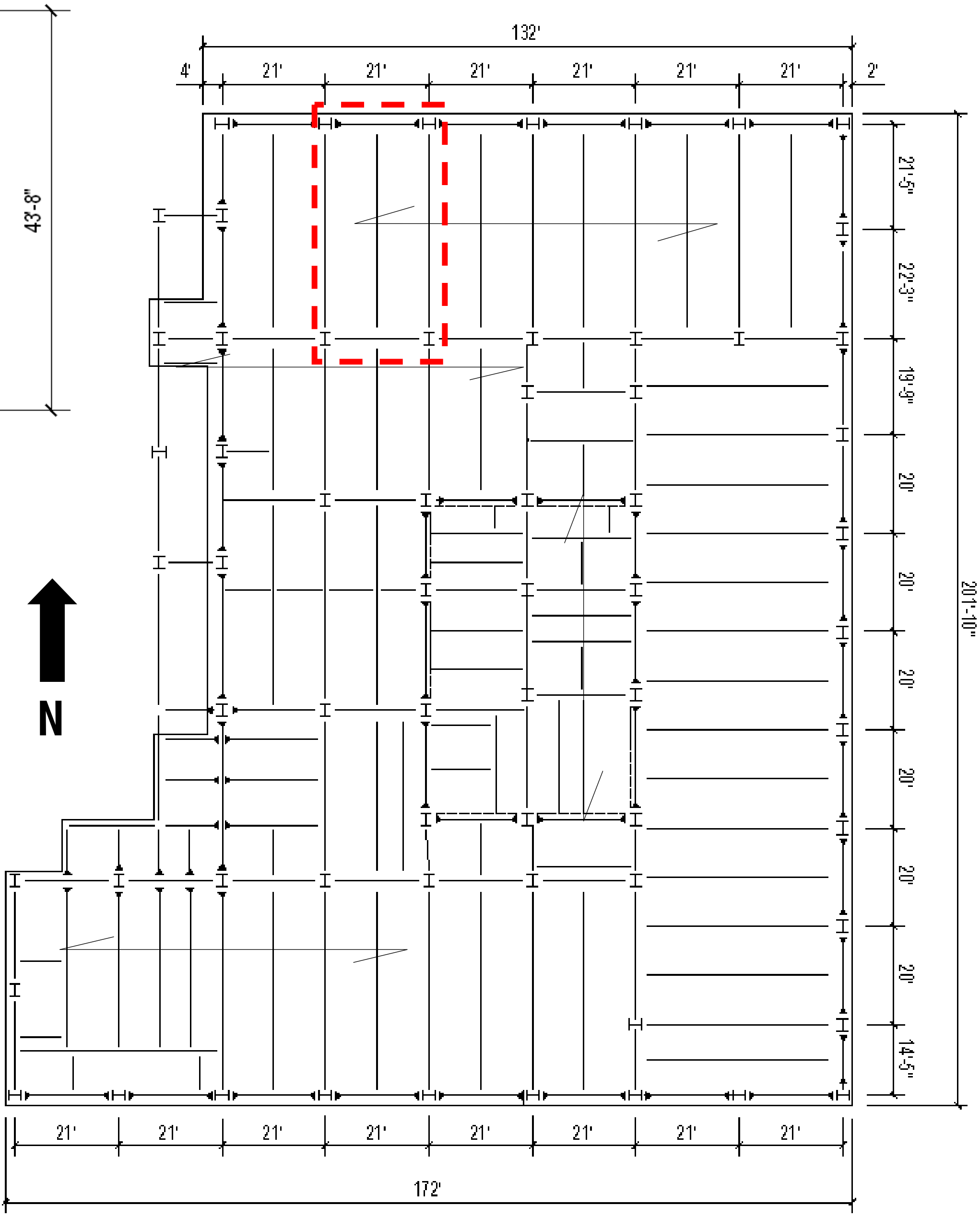


Figure 7: Level 5, Floor Framing Plan

# Proposal

## Problem Statement

In its current phase of design, the Center for Science and Medicine has been planned to utilize a combination of perimeter moment frames and core braced frames to resist lateral loads. Three of the four perimeter moment frames are two stories in height (Frames A, B, and C), due to restrictions imposed by the exterior cladding system, which makes them highly inefficient in terms of stiffness. Previous study indicates that each of these double-heighted frames resist only about 15%-20% of the lateral load in each direction, in some cases even less (Frame B, which resists 3%-8% at each level). One must question if it is even worthwhile to spend the time and money on constructing these frames, when they are not even playing a crucial role in the resistance of lateral loads. Moreover, braced frames at the core have been designed to utilize two heavy double-tee shapes for each brace. This may be difficult in terms of constructability. Braces also pose coordination issues at every level; openings are needed around the core, but awkward braces stand in the way. Thus, they must be shifted as needed, which slows the design process and increases the chance for coordination errors. Neither the braced frame system nor the moment frame system seems to be all-around ideal, and combining the two does nothing to improve their shortcomings. Therefore, an alternative system will be proposed to in an attempt to eliminate the issues outlined above.

## Proposed Solution

To improve the lateral system of the Center for Science and Medicine, a core of reinforced concrete shear walls will be proposed to replace the existing system of braced frames. Shear walls will stiffen the structure at the core in both directions, therefore eliminating the need for so many moment frames on the perimeter of the building. Also, a concrete core will alleviate coordination issues of proper brace placement, as openings can simply be punched where needed in each wall. Another expected advantage to this solution is that shear walls at the core would better resist uplift at the base of the building. Moreover, a concrete system has the potential to be more economic than a combined braced frame / moment frame system, although this is still yet to be determined. Two alternative lateral systems, both utilizing a core of shear walls, are outlined below.

### ALTERNATIVE 1: Core-only system

**Description:** The first option for a lateral system re-design is a core-only system of shear walls. The shear walls will encompass the building core, which is 64'-10" long in the North-South direction and 42'-8" long in the East-West direction. Walls may or may not surround the entire core, depending on final design. These shear walls will be designed to resist 100% of the lateral load in both directions, therefore totally eliminating the need for perimeter moment frames.

Implications: The building's effective seismic weight will likely increase due to the addition of heavy shear walls, which will consequently increase the seismic loads to be resisted. Such a design would also change the response modification factor, R, used in seismic design calculations to a value of 5 (a value of 7 had been used in previous calculations, assuming a dual system), thus increasing the seismic loads to be resisted. Finally, foundations below the core will need to be re-designed as strip footings able to carry a higher load than the original spread footings. All of this must be taken into consideration when the re-design process begins. Below are possible configurations for the new shear wall configuration at the building core.

ALTERNATIVE 2: Shear wall and moment frame combination

Description: A second system will be considered, which will use a combination of shear walls at the core and moment frames at the perimeter to resist lateral loads. While shear walls will encompass the building core as in Alternative 1, they will be thinner in this configuration. Moment frames around the perimeter will resist any load not taken by the shear walls. These moment frames will be designed with moment connections at every level, unlike the current design, to add stiffness. Instead of lining the outer perimeter, the frames will sit back a distance of one bay from the building edge. This way, the exterior cladding system will not be jeopardized. Also, these moment frames will not run the entire length of the building, as they do in the current design. With moment connections at every level, it may only be necessary to design moment frames spanning three or four bays rather than the entire building length.

Implications: Again, the use of shear walls will increase the weight of the building, therefore increasing the seismic base shear to be resisted. However, the shear walls will add less mass to the building in this alternative, since they will likely be smaller in size than in Alternative 1. Thus, seismic loads will not be as high in this design. Also, as in Alternative 1, foundations will need to be re-designed as strip footings able to carry more load than the spread footings of the current design.

## Solution Method

### ALTERNATIVE 1:

First, shear walls will be designed by hand in accordance with ACI 318-05 to resist 100% of the lateral load. The ETABS model created for the existing lateral system will then be altered to include these shear walls at the core rather than braced frames. The model will also be changed to include its four basement levels, so that actual conditions are more accurately represented by the model. Gravity and lateral loads will then be applied as determined by ASCE 7-05 and specific design criteria imposed by the designer. By comparing the two models (original and new), it will be determined if a concrete core-only system would prove to be a better alternative to the existing braced and moment frame system.

After results are obtained, a re-design of the foundation system supporting the core will be necessary. Spread footings which are currently employed in the design will be replaced with strip footings to support new shear walls. A detailed cost breakdown will be assembled using RS-Means cost data for both the proposed and original systems, and results will be compared. Finally, a schedule will be compiled outlining the lead-time and construction time for both the proposed and original designs.

### ALTERNATIVE 2:

First, shear walls will be designed by hand in accordance with ACI 318-05 to resist approximately 60-70% of the lateral load. Moment frames (with connections at every floor) will then be designed. An investigation will be necessary to determine how many bays these moment frames will span. The ETABS model created for the existing lateral system will then be altered to include the shear walls at the core and moment frames set in from the perimeter. The model will also be changed to include its four basement levels, so that actual conditions are more accurately represented by the model. Gravity and lateral loads will then be applied as determined by ASCE 7-05 and specific design criteria imposed by the designer. By comparing the two models (original and new), it will be determined if a concrete core / perimeter moment frames system would prove to be a better alternative to the existing braced and moment frame system.

After results are obtained, a re-design of the foundation system supporting the core will be necessary. Spread footings which are currently employed in the design will be replaced with strip footings to support new shear walls. A detailed cost breakdown will be assembled using RS-Means cost data for both the proposed and original systems, and results will be compared. Finally, a schedule will be compiled outlining the lead-time and construction time for both the proposed and original designs.

## Breadth Study 1: Sustainability

The Center for Science and Medicine has been designed with sustainability as a priority. Complying with the Leadership in Energy and Environmental Design - New Construction (LEED-NC) standards, the project team has set its sights on a LEED Gold rating. Such a classification requires the building and its systems to fulfill at least 39 out of a possible 69 LEED points. Since the project is still in the design development phase, only a pre-certification estimate has been performed to determine which points can be earned. The estimate indicates that 33 points are planned or have already been incorporated into the design of the building. This leaves a minimum of 6 points to still be fulfilled in order to attain LEED Gold.

In addition to the 33 points included in the CSM's current design, there are 14 credits designated by the estimate as viable options to pursue for increasing the building's overall sustainability. They are:

*Alternative Transportation,* Bicycle Storage & Changing Rooms
*Heat Island Effect,* Non-Roof
*Light Pollution Reduction*
*Enhanced Refrigerant Management*
*Green Power*
*Construction Waste Management,* Divert 75% from disposal
*Materials Re-use*, 5%
*Materials Re-use,* 10%
*Recycled Content,* 20%
*Regional Materials,* 10% Extracted, Processed, & Manufactured
*Regional Materials,* 20% Extracted, Processed, & Manufactured
*Daylight & Views,* Daylight 75% of Spaces

This breadth study will investigate these possible LEED credits and determine how, if at all, the extra points can be obtained to raise the building's credit count to that of a Gold rating. Each of the 14 possible options above will be considered, and it is hoped that at least 6 solutions will be found to increase the credit total from 33 to a minimum 39 points.

## Breadth Study 2: Construction Management & Building Information Modeling

One of the unique aspects of the Center for Science & Medicine is that it is being designed in 4-D, utilizing the latest BIM (building information modeling) technology. Since this is a relatively new design tool in an industry based on historically-rooted codes and standards, it is a question as to whether this cutting-edge design method will truly pay off. This study will consider the positive and negative effects BIM has had on the design process of CSM thus far. While problems are posed by up-front software and training costs, time spent on implementing the system within the design team, and possible tension created by the new design tool between different generations of engineers, long-term benefits will be investigated and weighed against the negative. From here, conclusions can be drawn regarding the effectiveness of building information modeling, and recommendations can be made to CSM's design team as well as the rest of the AEC community.

The following BIM-related issues will be investigated to determine the effectiveness of the technology:

- Costs: software, training, maintenance, employment of BIM coordinators, the "learning curve"
- Inter-office issues: opposition / conflict between older and younger generations of engineers
- Software issues: compatibility of software with other design programs, glitches in the programs
- Scheduling impacts: ability to meet deadlines, work faster, etc.
- Client satisfaction
- Quality of work product
- Productivity / efficiency gain within design and construction team

After interviewing several professionals in firms currently using BIM, including engineers from the design team of CSM, general conclusions can be drawn about the effectiveness of BIM and what kind of future it has in the AEC industry. These conclusions can then be applied specifically to the Center for Science & Medicine to determine specific impacts the tool has had on this particular project.

## Tasks and Tools

1. Re-Design of Lateral System: Alternatives 1& 2

   Task 1: Confirm all lateral loads and superimposed loads, according to ASCE 7-05.

   a. Double check / revise all calculations for gravity, wind, and seismic loads.
   b. Consult with structural engineer to confirm.

   Task 2: Establish trial member sizes

   a. Establish new trial member sizes for moment frames (Alternative 2), in accordance with AISC LRFD design procedures.
   b. Establish new trial sizes for shear walls (Alternatives 1 & 2) in accordance with ACI 318-05.
      1. Locate all openings needed in walls.
      2. Re-arrange floor plan if necessary.
      3. Design coupling beams where needed.
   c. Check: shear, overturning moment by hand

   Task 3: Analyze lateral systems

   a. Create ETABS models of Alternatives 1 & 2 and asses system effectiveness from analysis results
   b. Check: shear strength, overturning moment, drift, story drift, fundamental period
   c. Compare new designs with existing design

   Task 4: Consider implications of system re-design

   a. Re-design of foundation below building core
   b. Detailed cost breakdown of materials for each system
   c. Impacts on schedule for each system

2. Breadth Study 1: Sustainability

   Task 1: Research each of the 14 LEED-NC credits in question

   a. Determine basic requirements to fulfill credit
   b. Investigate means of fulfilling these requirements
   c. Asses feasibility of implementation

   Task 2: Determine which credits will be integrated into design

   Task 3: Document the proposed methods of obtaining these credits

   Task 4: Consider approximate cost of new systems and any scheduling impacts

3. Breadth Study 2: Building Information Modeling

   Task 1: Research current progress of BIM and any issues that may be associated with it

   Task 2: Compile a list of sources / references (professionals with expertise in this area)

   a. Collect professional opinion regarding BIM
   b. Collect hard data based on case studies / personal experience with the design tool

   Task 3: Research effect of BIM on the design process of CSM

   a. Gather data on cost, scheduling, coordination, etc. for this specific project
   b. Based on research from Task 2, project cost / schedule for CSM without use of BIM
   c. Compare the pro's and con's of building information modeling in specific regard to CSM

## Timetable

[redacted]