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SENIOR THESIS FINAL PROPOSAL

PENN STATE SENIOR THESES

UNIVERSITY SCIENCES BUILDING

NORTHEASTERN U.S.

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SENIOR THESIS FINAL PROPOSAL

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EXECUTIVE SUMMARY

Senior Thesis Final Proposal is intended to describe what topics will be studied at length during the spring semester. This includes four analyses topics and two breadth studied that apply directly to these main topics. The overall theme for this thesis will focus on the sustainability features of the University Sciences Building, as well as the improvement of energy efficiency and schedule efficiency for the facility.

Analysis #1: Sustainable Techniques / Energy Efficiency

The University Sciences Building is projected to achieve LEED Silver Certification upon the completion of the project. Even though this is a solid level of accreditation, some points were skipped over that might be practical and cost beneficial to implement. This analysis will focus on how to improve the sustainable features of the building while minimizing the upfront construction costs.

Analysis #2: Implementation of BIM

Turner has made the implementation of Building Informational Modeling (BIM) mandatory on all of their projects. The Turner team for the University Sciences Building petitioned against using BIM for this facility because the owner was unwilling to pay anything extra to use it. However, BIM is designed to save the construction manager and owner both time and money through upfront coordination and collaboration. This analysis will look at how the implementation of BIM could have helped this project in particular, and what the process would look like.

Analysis #3: Building Enclosure - Prefabrication

Building enclosure is critical to the start and success of the building's interior finishes work. The close-in of the building may or may not meet the 12/15/10 deadline that has been set, but it seems as though the sequencing of panels and the type of exterior façade system used could be altered to ensure interior finishes start on time. This analysis will look into the substitution of the current façade system with a prefabricated panel system. Prefabrication should save on time and help reduce congestion on-site.

Analysis #4: Simplification of Structural System

The odd structural feature for this facility is the decision to change from a precast and cast-in-place concrete system on the first five floors, to a structural steel and concrete system at the penthouse levels. This change in structural systems causes a stoppage in one process and a new learning curve for another. This analysis will look into whether it would have been more beneficial to just use one system or the other uniformly throughout.

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PROJECT BACKGROUND

The University Sciences Building is a 70 million dollar mixed use facility that will house both students and faculty of the university. It includes 39 research and teaching laboratories for bio-medical engineering, biology, chemistry, and fossil preparation. This 138,000 square foot building also houses 8 educational classrooms, a small auditorium seating 240 students, and a wing dedicated to both administrative and faculty support. There are 5 levels with a basement below and a mechanical penthouse level above.

The building footprint has a trapezoidal shape because of limited space within the city block. When referencing the plan in *Figure 1*, the classroom and lab spaces are on the left-most side, with office space on the lower right, and an auditorium on the upper right (bottom floor only). Two major city streets run parallel to the building on the bottom and left-hand portions of the building plan.

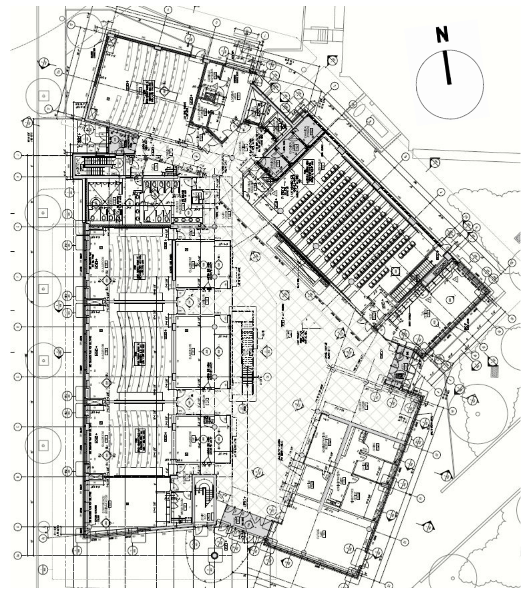

Figure 1: Building Footprint

Classrooms are located on the bottom level only. These rooms will occupy the most people and the most traffic flow within the building. Also, the floors of these classrooms will be slightly sloped for better lines of sight. All of the labs and research space will fill the remaining parts of the upper floors.

The project delivery method for the project is a Design-Bid-Build with CM at Risk, and the contract for this facility is a Lump Sum type contract.

Building Exterior

Masonry walls and concrete piers were chosen over a steel framed and thin skinned exterior so that the building exterior could act as a barrier to the outside elements. Thicker and denser walls can better block the sounds of a major city. As a result, the space within the building becomes a more private and intimate space for its occupants.

From an aesthetic standpoint, the scattered arrangement of windows and multiple building faces gives this building its character and functionality.

Figure 2: Exterior Render

Sustainability Features

Biowall

The five story biowall located in the atrium of the building will act as a natural air filter to help remove harmful VOCs and CO_2 levels from the air. As air is passed through the wall, impurities are removed by the natural photosynthesis process of the plants. A render of the biowall is shown in *Figure 3* to the right.

Figure 3: Interior Biowall Render

To feed the plants, water is pumped down the face of the wall and then collected in a basin at the bottom to be pumped back to the top of the biowall for recirculation. Nutrients will be added periodically, but this system of ventilation and air purifying requires very little amounts of maintenance.

Filigree Precast Slabs

A filigree slab is a really thin concrete precast panel with the needed reinforcement for the lower portion of the deck. It also acts as the formwork for the cast-in-place concrete on site. These slabs are first made off-site and then shipped to the jobsite for assembly and shoring. Once secured, the second layer of concrete with reinforcing is placed on top of the precast panels. This process can effectively and efficiently accelerate the construction of structures with improved physical and aesthetic properties.

Construction Sequence

The major sequence of work on this project is such that construction starts at the South-West corner of the building on the first floor and raises one floor at a time in a clockwise rotation until the penthouse is reached *(reference Figure 1 on the previous page)*.

Local Conditions / Challenges

The University Sciences Building is located in one of the largest cities in the Northeastern United States, and right in the heart of the University's campus. Turner does not have the luxury that other sites may have when it comes to things such as laydown space, material/equipment storage space, accessibility, and other challenging site logistical issues. All of these challenges are a direct result of a congested site and can alter the means or methods used to complete the project.

Limited laydown and storage space means that every delivery has to be planned out well in advance. It may have been cheaper to erect the structure using a typical crawler crane, but a tower crane made more sense for this building because it allowed for more room on-site.

ANALYSIS #1: SUSTAINABLE TECHNIQUES / ENERGY EFFICIENCY

PROBLEM IDENTIFICATION

The University Sciences Building is projected to achieve LEED Silver Certification upon the completion of the project. Even though this is a solid level of accreditation, some points were skipped over that might be practical and cost beneficial to implement. Some examples include the use of solar photovoltaic panels, wind turbines, or passive heating and cooling. Other things like the use of green roofs or gray water systems could also be beneficial to the owner.

The building looks “green” and sustainable because of the large Biowall feature in the atrium, but how sustainable is the building as a whole?

POTENTIAL SOLUTIONS

This analysis is intended to look at a variety of different sustainable and energy efficient systems to find the perfect combination of performance and life-cycle costs. The main emphasis will revolve around the feasibility of PV panels, wind turbines, and rain-water/grey-water collection systems. Other areas of focus could include solar thermal technology and energy efficient light fixtures can also affect the HVAC loads and power consumption within the building.

RESEARCH GOAL

The goal for this analysis is to learn more about natural energy storage/consumption, and how it can be applied to the University Sciences Building to save on operational costs for the university. These sustainable technologies can be a great teaching and learning tool for the students, as well as a strong marketing device for the university.

METHODOLOGY

- Research sustainable technologies and sustainable design techniques.
- Contact manufacturers for design consultation.
- Determine optimum arrangement, quantity, and sizing of the systems.
- Analyze how other building components or trades will be affected by the new systems.
- Perform a feasibility analysis on the life-cycle cost and payback period.

EXPECTED OUTCOME

The expected outcome of this analysis will be a more efficient and sustainable design for the University Sciences Building. Not only will these systems save the university money, but they will also increase the perception and credibility of the university as a whole. This analysis will provide a financial model that will show the feasibility and the energy savings of the systems mentioned above.

ANALYSIS #2: IMPLEMENTATION OF BIM IN A TRADITIONAL DELIVERY METHOD

PROBLEM IDENTIFICATION

Turner has made the implementation of Building Informational Modeling (BIM) mandatory on all of their projects. The Turner team for the University Sciences Building petitioned against using BIM for this facility because the owner was unwilling to pay anything extra to use it. No models are being used on this project for coordination or design.

Also, because this is a traditional Design-Bid-Build project, it becomes very difficult to incorporate BIM and its uses on this type of a facility. The use of BIM and technology on projects was one of the hot topics while attending Penn State's annual PACE seminar.

POTENTIAL SOLUTIONS

BIM is designed to save the construction manager and owner both time and money through upfront coordination and collaboration. It would be interesting to see how the implementation of BIM could have helped this project in particular, and what the process would look like.

BIM has a large variety of uses, not just clash detection and 4D modeling. It is important to determine first what uses of BIM would be of most value to the owner and the Turner team. Every project is unique, and you can spend as little or as much time as you want modeling and feeding information into that model. It is important to determine what level of detail is needed before the modeling and collaboration process begins.

RESEARCH GOAL

This research will focus on the development and implementation of BIM and its uses in a traditional Design-Bid-Build delivery approach. The goal for the University Sciences Building is to determine how BIM could have been used, and what benefits it has to offer. The implementation of BIM in the field will also be a key area of focus for this topic.

METHODOLOGY

- Conduct interviews with the Turner staff and the project design team.
- Survey other contractors and determine how they use BIM. Why is it valuable to them and what are its benefits? How do they bid a job that plans to utilize BIM? What potential savings do they see for both the owner and themselves?
- Develop a plan for this particular project, and determine how it relates to this type of delivery method.
- Determine what BIM uses are most valuable to this project team, and how they will be implemented.

RESOURCES & TOOLS

- Penn State's BIM Project Execution Planning Guide
- Dr. John Messner
- BIM literature
- Turner and the design team
- Other industry members

EXPECTED OUTCOME

It is expected that research will help identify what BIM used are best suited for a project of this caliber and how they can be implemented on-site. With new technology and techniques come the potential to increase the speed and efficiency of a project while maintaining the same level of quality.

ANALYSIS #3: BUILDING ENCLOSURE - PREFABRICATION

PROBLEM IDENTIFICATION

Building enclosure is critical to the start and success of the building's interior finishes work. The close-in of the building may or may not meet the 12/15/10 deadline that has been set, but it seems as though the sequencing of panels and the type of exterior façade system used could be altered to ensure interior finishes start on time. Any delays with the enclosure of the building could be a direct result of site congestion and limited material storage space on site.

The exterior walls themselves have been constructed with non-load bearing CMU's. This dead load on the building's structural system may be a little excessive, and could have been built using lighter materials that have the same thermal and acoustical properties.

POTENTIAL SOLUTIONS

The floors of the University Sciences Building were constructed using prefabricated concrete slabs, which were extremely fast and efficient to construct without any major problems or delays. Why not use prefabricated panels for the building exterior? It would clear up more space on-site, shorten the time for exterior close-in, ensure a higher quality finish, and possibly lighten the dead loads placed on the structure of the building. This would also be very beneficial for the scattered arrangement of exterior windows. The layout of these windows can be constructed faster in a controlled shop environment and with better precision then if done in the field.

RESEARCH GOAL

To propose a preliminary design for an alternate façade system, using prefabrication to improve quality, time, and coordination of the exterior skin. The goal is to learn more about prefabrication and its impact on a building of this nature.

METHODOLOGY

- Research current prefabricated panel systems and select an applicable manufacturer.
- Contact the manufacturer for details concerning the cost of fabrication, constructability & sequencing, time to manufacture & deliver the panels, and any loading requirements that should be considered.
- Design a preliminary prefabricated system for the façade of the University Sciences Building.
- Analyze impacts to schedule, cost, quality, constructability, and impact to other building systems/trades.
- Analyze site congestion and trade coordination improvements.
- Contact the Architects for feedback on any aesthetic concerns they may have.

EXPECTED OUTCOME

The use of prefabricated panels for the building's façade will reduce the time and cost of installation, while improving the coordination between the various trades on site. Prefabrication should help improve the overall quality of the façade and eliminate inefficiencies due to site congestion. While this type of a system may have a higher initial cost associated with it, the savings in labor costs and schedule durations will far exceed any extra first costs associated with the use of prefabricated panels.

ANALYSIS #4: SIMPLIFICATION OF STRUCTURAL SYSTEM

PROBLEM IDENTIFICATION

The structural system for the University Sciences Building is comprised of a variety of different systems. Steel, precast, and cast-in-place (CIP) concrete are all used throughout the building. There are no typical bays in the facility, and over 25 different steel beam sizes are used at the penthouse levels. The slabs themselves range from 10”-12” in thickness.

The odd structural feature for this facility is the decision to change from a precast and cast-in-place concrete system on the first five floors, to a structural steel and concrete system at the penthouse levels. This change in structural systems causes a stoppage in one process and a new learning curve for another. A change in the work flow of a building’s structure could cause unexpected delays and additional costs to the project.

POTENTIAL SOLUTIONS

Instead, why not use one system or the other for the entire building? For this analysis, the two types of structural systems will be compared and applied uniformly throughout. This should provide better productivity and constructability during the erection of the structure.

RESEARCH GOAL

The goal of this analysis is to determine whether there are any cost or time savings with utilizing one structural system throughout, instead of using two different systems.

METHODOLOGY

- Research the cost, durability, constructability, and quality of Filigree Slab systems. Weigh the Pros and Cons of using this type of structural element against the other elements used.
- Contact manufacturers for details concerning costs of fabrication, constructability & sequencing issues, and time to manufacture/deliver the structural elements.
- Determine the availability of material/skilled labor in the area. Are there any regional styles, preferences, or restrictions?
- Design a preliminary system for both structure types.
- Obtain craft production hours and production rates from the project team.
- Analyze the schedule, cost, and constructability impacts of each system.

EXPECTED OUTCOME

After researching and re-design of the two systems, one should prove to be more cost effective than the other, but both systems should prove to be more efficient as a single system for each when compared to the combination of the two.

ANALYSIS WEIGHT MATRIX

The Weight Matrix (shown in Table 1 below) illustrates how much time will be spent towards the four main areas of investigation for each of the analyses listed in this proposal. The percentages reflect the expected time and effort that will be allocated towards the four main areas of investigation.

DESCRIPTION	RESEARCH	VALUE ENGR.	CONST. REVIEW	SCHED. REDUCTION / ACCELERATION	TOTAL
Sustainable Tech. / Energy Eff.	**10%**	**15%**	**15%**	**----**	**40%**
Implementation of BIM	**15%**	**----**	**----**	**----**	**15%**
Building Enclosure - Prefab	**----**	**5%**	**10%**	**15%**	**30%**
Simplification of Structural Sys.	**----**	**5%**	**5%**	**5%**	**15%**
TOTAL	**25%**	**25%**	**30%**	**20%**	**100%**

CONCLUSIONS

The intent of these analyses is to provide the owner and the university with a better, more sustainable way of building the University Sciences Building. This will be accomplished through extensive research and a comprehensive review of the proposed alternatives. It is expected that these recommendations will improve the efficiency and sustainability of the facility. The implementation of BIM should allow for a smooth delivery with minimal conflicts. Furthermore, the simplification of the building enclosure and structural elements should save the owner/CM both time and money, while increasing the overall value of the project.

This proposal is expected to be a work in progress upon receiving valuable feedback from the thesis advisors.

APPENDIX A - Breadth Topics and MAE Requirements

BREADTH TOPICS

The demonstration of breadth in Architectural Engineering involves illustrating skills in at least two of the program's other option areas. These breadths should relate to a few of the previously mentioned analyses. These topics should also allot a large percentage for either Value Engineering Analysis or Constructability Review.

RENEWABLE ENERGY / ELECTRICAL BREADTH: *Contributes to Technical Analysis #**1***

The main power source for the University Sciences Building is coming from an adjacent university building at 13.2 kV on a 15 kV medium voltage cable, and then stepped down to 480/277V, (3 phase, 4 wire). For emergency power, the USB building will house a 600 kW, 480V, 3 phase diesel generator for back-up power. This generator is located on the roof of the building with a 2-hour fire rated cable.

With the integration of PV panels and more efficient lighting and controls, this breath will look into how renewable energy will be tied into the building and how much supplementary power will be needed to operate the facility. The electrical system shown in the contract documents will be changed to reflect these new systems energy demands.

A Constructability Review will be required for both suggestions, and a Value Engineering Analysis will be required for the change in systems/controls.

STRUCTURAL BREADTH: *Contributes to Technical Analysis #**3** & Technical Analysis #**4***

In analysis #3, the substitution of prefabricated panels will require some redesign to the structure and how the panels will be supported. The change in material weight can also directly affect the loading characteristics and sizing of the other structural members in the building.

In analysis #4, the change in structural components also requires some structural redesign and simplification in order to properly assess how the building could be built if only one system, either steel or concrete, was chosen for the entire structure as opposed to a hybrid of the two different systems.

This breadth will involve both a Constructability Review of the two analyses, as well as a Value Engineering Analysis. Cost, schedule, and quality will be the main factors in deciding whether or not it makes sense to use one system over the other.

MAE REQUIREMENT

The MAE requirements for this project will be met in Analyses #1 and #3. Both of which were discussed at length in Dr. Riley's course, **AE 598C**:

Sustainable Construction Project Management

This graduate level course teaches students a variety of sustainable techniques, technologies, and methodology that can be applied to buildings, especially in the early design phases.

Discussions on the benefits of PV panels and rainwater collection systems, along with other beneficial energy saving systems, can be directly applied to the first analysis that will compose of Sustainable Techniques and Energy Efficiency.

Another topic of discussion in the class was on prefabrication and its uses in the industry. This will directly relate to Analysis #3 with the prefabrication of the University Sciences Building's exterior façade.

Another way that the MAE requirement can be met is by applying the '*Rules of Credit*' learned in Dr. Thomas' course, **CE 533:**

Construction Productivity and Operations Analysis

This graduate level course looks at productivity and how it can be improved with certain activities on site. This directly relates to both Analysis #3 and Analysis #4, where studies will be performed on which type of façade/structure allows for the greatest production rates and cost savings to the owner/construction manager.

APPENDIX B - SPRING SEMESTER TIMETABLE

UNIVERSITY SCIENCES BUILDING - NORTHEASTERN U.S.

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12/10/2010

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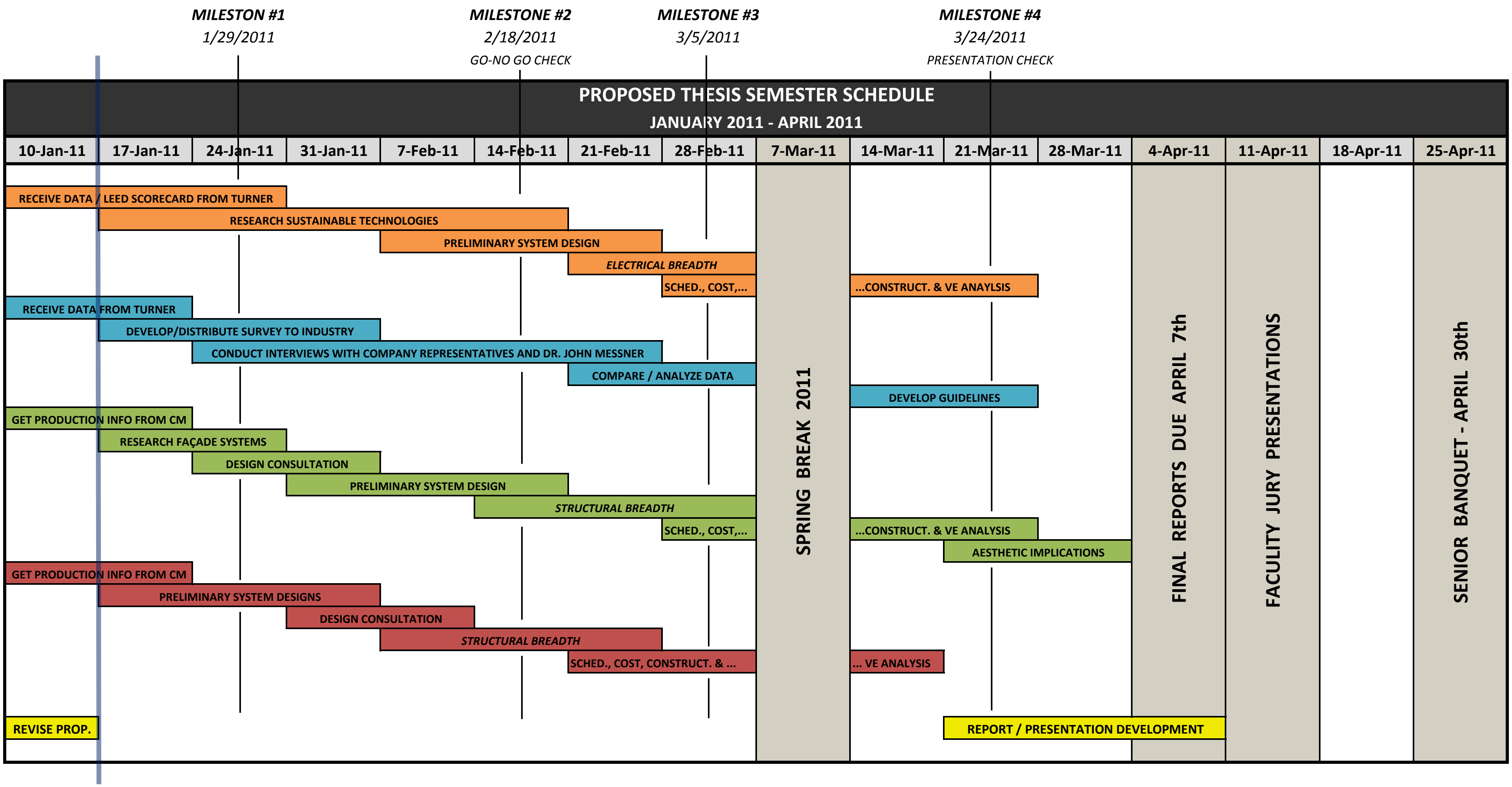

MILESTONES

1 RECEIVE ALL DATA FROM TURNER, START RESEARCH/DESIGN FOR ALL
2 COMPLETE PRELIMINARY DESIGN FOR ANALYSIS #4, RECEIVE DESIGN CONSULTATION
3 COMPLETE ALL PRELIMINARY DESIGNS, COMPLETE STRUCTURAL BREADTH FOR #4
4 COMPLETE CONSTRUCT. & VE ANALYSIS FOR #4, WRAP UP THE OTHER ANALYSES, START REPORT

ANALYSIS DESCRIPTION

- ANALYSIS #1: SUSTAINABLE TECHNIQUES / ENERGY EFFICIENCY
- ANALYSIS #2: IMPLEMENTATION OF BIM
- ANALYSIS #3: BUILDING ENCLOSURE - PREFABRICATION
- ANALYSIS #4: SIMPLIFICATION OF STRUCTURAL SYSTEM